National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Wind Cave National Park

Natural Resource Condition Assessment

Natural Resource Report NPS/WICR/NRR—2011/478

ON THE COVER
A view of the landscape at WICA.
Photograph by: NPS

Wind Cave National Park

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Natural Resource Report NPS/WICA/NRR—2011/478

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Acronyms and Abbreviations

ac - Acre

ARD - Air Resources Division

ARU - Autonomous Recording Units

BBS - Breeding Bird Survey

CBC - Christmas Bird Count

CCC - Civilian Conservation Corps

CDV - Canine distemper virus

CFU - colony-forming units

CO_2- Carbon dioxide

D - Diversity

DO - Dissolved oxygen

EA - Environmental Protection Agency

EMAP - Environmental Monitoring and Assessment Program

EPA - Environmental Protection Agency

FONSI - Finding of No Significant Impact

GLEI - Great Lakes Environmental Indicators Project

ha - Hectare

HPRCC - High Plains Regional Climate Center

LED - Light-emitting diode

NAAQS - National Ambient Air Quality Standards

NADP - National Atmospheric Deposition Program

NGP EPMT - Northern Great Plains Exotic Plant Management Team

NGPN - Northern Great Plains Inventory and Monitoring Network

NPS - National Park Service

NRCA - Natural Resource Condition Assessment

NTU - Nephelometric turbidity units

PAH - Polycyclic aromatic hydrocarbons

PIF - Partners in Flight

RMBO - Rocky Mountain Bird Observatory

SD DENR - South Dakota Department of Environment and Natural Resources

SDSMT - South Dakota School of Mines and Technology

SMCL - Secondary maximum contaminant level

SMU GSS - Saint Mary's University of Minnesota GeoSpatial Services

STORET - EPA Storage and Retrieval Data Warehouse

µg/L - Micrograms per liter

uS/cm - Micro Siemens per liter

USCB - United States Census Bureau

USFS - United Stated Forest Service

USFWS - United States Fish and Wildlife Service

USGS - United States Geological Survey

VOC - Volatile organic compounds

WICA - Wind Cave National Park

WNS - White-nose syndrome

WSDH - Washington State Department of Health

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Executive Summary

On 9 January 1903, President Theodore Roosevelt signed a bill (U.S.C., Title 16, Sec 141-146) to create Wind Cave National Park (WICA) (NPS 2011). The boundaries of WICA were extended in 1931 (U.S.C., 6th supp., title 16, sec. 141a), 1946 (16 U.S.C. §141a), 1978 (92 Stat. 3467) (P.L. 95-625), and 2005 (119 Stat. 2011) (P.L. 109-71) (NPS 2011a). Today, WICA encompasses 11,451 ha (28,295 ac) and is visited by greater than 600,000 people each year.

As a unit in the National Park System, WICA is responsible for the management and conservation of its natural resources. This mandate is supported by the National Park Service Organic Act of 1916, which directs the Park Service to:

> conserve the scenery and natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations.

In 2003, the National Park Service Water Resources Division received funding through the Natural Resource Challenge program to systematically assess watershed resource conditions in NPS units, establishing the Watershed Condition Assessment Program. This program, now titled the Natural Resource Condition Assessment (NRCA) Program, aims to provide documentation about the current conditions of important park resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. Findings from the NRCA, including the report and accompanying map products, will help WICA managers to:

- develop near-term management priorities,
- engage in watershed or landscape scale partnership and education efforts,
- conduct park planning (e.g., Resource Stewardship Strategy),
- report program performance (e.g., Department of the Interior's Strategic Plan "land health" goals, Government Performance and Results Act).

Specific project expectations and outcomes for the WICA NRCA are listed in Chapter 3.

For the purpose of this NRCA, NPS staff identified key resources that are referred to as components in the project framework and throughout the assessment. The components selected include natural resources and processes that are currently of the greatest concern to park management at WICA. The final project framework contains 20 resource components, along with measures, stressors, and reference conditions for each.

This study involved reviewing existing literature and data for each of the components in the framework, and, where appropriate, analyzing the data in order to provide summaries or to create new spatial or statistical representations. After gathering data regarding current condition of component measures, those data were compared to reference conditions, when possible, and a qualitative statement of condition was developed. The discussions in Chapter 4 represent a comprehensive summary of available information regarding the current condition of these resources. These discussions represent not only the most current published literature, but also unpublished park information and, most importantly, the perspectives of park experts.

The condition of most park resources, as indicated by the measures defined in the project framework, is of moderate or low concern. However, due to the complex relationship between grazing animals, native plant communities, and other components, any condition determined to be of significant concern warrants concern for many other components. In conclusion, due to the complexity of the relationships between park resources, it is not possible to make a definitive statement about the ecological health of WICA as a whole.

Chapter 1 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource components in national park units, hereafter "parks". For these condition analyses, they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The resources and components emphasized in the project work depend on a park's resource setting, status of resource stewardship planning and science in identifying high-priority components for that park, and availability of data and expertise to assess current conditions for the things identified on a list of potential study resources and components.

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 component frameworks[2]
- identify or develop logical reference conditions/values to compare current condition data against[3,4]
- emphasize spatial evaluation of conditions and Geographic Information Systems (GIS) products[5]
- summarize key findings by park areas[6]
- follow national NRCA guidelines and standards for study design and reporting products.

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

[1] However, 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 reporting 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.

[4] Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers").

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

[6] 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 a area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

Although current condition reporting relative to logical forms of reference conditions and values is the primary objective, NRCAs also report on trends for any study components where the underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current park resource conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, watershed, or landscape scales, though NRCAs do not judge or report on condition status per se for land areas and natural resources beyond the park's boundaries. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options is outside the project scope.

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study component where current condition or trend is reported it is important to identify critical data gaps and describe 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: 1) to assist selection of study components; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. 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 components. They can also bring in relevant non-NPS data to help evaluate current conditions for those same Vital Signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

In-depth analysis of climate change effects on park natural resources is outside the project scope. However, existing condition analyses and data sets developed by a NRCA will be useful for subsequent park-level climate change studies and planning efforts.

Important NRCA Success Factors …

Obtaining good input from park and other NPS subjective matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

NRCAs do not establish management targets for study components. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park's desired resource conditions and management targets. In the near term,

NRCA findings assist strategic park resource planning[7] and help parks report to government accountability measures[8].
Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or component, reflecting differences in our present data and knowledge bases across these varied study components.

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 credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA Program information is posted at http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm

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)***

---

[7] NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy (RSS) but study scope can be tailored to also work well as a post-RSS project.
[8] 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.

Chapter 2 Introduction and Resource Setting

Photo 1. American bison at WICA (NPS Photo).

2.1 Introduction

2.1.1 Enabling Legislation

In the late 1890s, a land ownership feud between the McDonald and Stabler families took place. The General Land Office denied the claims of both parties, and recommended the disputed land and cave itself be reserved as a public resort. In 1902, the U.S. Department of Mineral Survey conducted the first formal survey of the area. On 9 January 1903, President Theodore Roosevelt signed a bill (U.S.C., Title 16, Sec 141-146) to create Wind Cave National Park (WICA) (NPS 2011a).

> Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, that there are hereby reserved from settlement, entry, sale, or other disposal, and set apart as a public park, all those certain tracts, pieces, or parcels of land lying and being situated in the State of South Dakota and within the boundaries particularly described as follows: Beginning at the southeast corner of section thirteen, township six south, range five east, Black Hills meridian, South Dakota; thence westerly, to the southwest corner of the southeast quarter of section sixteen, said township; thence

> northerly along the quarter-section lines to the northwest corner of the northeast quarter of section four, said township; thence easterly to the southwest corner of section thirty-four, township five south, range five east; thence northerly to the northwest corner of said section; thence easterly to the northeast corner of section thirty-one, township five south, range six east; thence southerly along the section lines to the southeast corner of section seven, township six south, range six east; thence westerly to the southwest corner of said section; thence southerly to the southeast corner of section thirteen, township six south, range five east, the place of beginning: Provided, That nothing herein contained shall be construed to affect any valid rights acquired in connection with any of the lands embraced within the limits of said park. (U.S.C., Title 16, Sec. 141)
>
> SEC. 2. That said park shall be known as the "Wind Cave National Park" and shall be under the exclusive control of the Secretary of the Interior, whose duty it shall be to prescribe such rules and regulations and establish such service as he may deem necessary for the care and management of the same. (U.S.C., Title 16, Sec. 142)

The boundaries of WICA were extended in 1931 (U.S.C., 6th supp., Title 16, Sec. 141a), 1946 (16 U.S.C. §141a), 1978 (92 Stat. 3467) (P.L. 95-625), and 2005 (119 Stat. 2011) (P.L. 109-71) (NPS 2011a).

2.1.2 Geographic Setting

WICA is an 11,451-hectare (28,295-acre) park located in Custer County, South Dakota. The park is on the southeastern edge of the Black Hills in southwestern South Dakota. Custer County has a human population density of 1.81 individuals per km^2 (4.7 persons/$mile^2$), less than half the average for all of South Dakota at 3.81 individuals per km^2 (9.9 persons/$mile^2$) (US Census 2010). The Black Hills are a mountain range in western South Dakota and northeastern Wyoming that are roughly 200 km (124-mi) long by 100 km (62 mi) wide (Marriot et al. 1999). This area's name reflects the dark ponderosa pines (*Pinus ponderosa*) that cover most of the Hills (Marriot et al. 1999).

WICA is in the Mississippian-aged Madison Limestone, commonly referred to as the Pahasapa Limestone.

The southern Black Hills and WICA are warmer and drier than the rest of the Hills (Cogan et al. 2009). This area has two primary weather patterns. The first occurs when warm air travels over the Rocky Mountains and cools. As the air cools, it creates precipitation. Once the air reaches the Black Hills it is much drier, and as the air drops it becomes warmer. The second weather pattern occurs when cold air moves south from Canada. When the cold air reaches the peaks of the northern Black Hills, it deflects around and away from the park (NPS 2011b). Table 1 provides the monthly temperature normals for WICA, based on data from 1971-2000.

Table 1. Monthly temperature normals for WICA, 1971-2000 (Station 145, Wind Cave) (HPRCC 2011).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Max Temp (F)	39.4	42.2	49.8	57.9	67.7	76.5	84.9	84.4	76.6	61.8	48.4	39.8	60.8
Min Max Temp (F)	14.1	16.9	23.2	31.5	41.4	49.5	56.3	55.0	45.9	33.9	23.0	14.1	33.8
Mean Total Precip (in.)	0.48	0.59	1.09	2.31	3.31	3.57	2.61	2.19	1.43	1.40	0.54	0.39	19.90

2.1.3 Visitation Statistics

Since 2000, an average of 656,519 people visited WICA each year (NPS 2010) with the summer months being the busiest. Most WICA visitors come to participate in the cave tour. However, some utilize the 48 km (30 mi) of hiking trails at the park to watch birds, view wildflowers, or go hiking. Park staff also offer interpretive talks and various educational programs.

2.2 Natural Resources

2.2.1 Ecological Units and Watersheds

The Nature Conservancy (Hall et al. 2002) recognizes 64 terrestrial ecoregions in the U.S. (based on Bailey [1995]). “The Black Hills ecoregion is the smallest of all U.S. ecoregions, with an area of 13,263 km^2 (5,121 mi^2) or roughly 3 million acres" (Hall et al. 2002, p. 3). Compared to the surrounding Northern Great Plains Steppe ecoregion, the Black Hills is extremely different; the Black Hills receives more precipitation and temperature varies less. Within the Black Hills, the northern portions receive more precipitation than the south. Flora in the Black Hills is a unique mix of Rocky Mountain forest, grasslands, eastern deciduous forest, and northern coniferous forest (Hall et al. 2002). Some of the primary landscape-scale ecological processes in the Black Hills are fire, insect epidemics, wildlife, and flooding (Hall et al. 2002).

The Environmental Protection Agency (EPA) also defines ecoregions at multiple scales for the continental U.S. (Plate 1). WICA is in the Black Hills Foothills Level IV EPA ecoregion; the United States Geological Survey's (USGS) Northern Prairie Wildlife Research Center offers the a description of this geographic area:

> The Black Hills Plateau ecoregion is a relatively flat, elevated expanse covering the mid-elevation slopes and grasslands of the Black Hills. It includes areas of sharply tilted metamorphic rock and lower elevation granite outcrops. Competing uses, such as logging, farming and ranching, and tourist development, stress this ecosystem (USGS and EPA 2010).

WICA is within the Cheyenne River Basin, which is part of the greater Missouri River Watershed (Ohms 2009). There are three perennial streams in WICA: Beaver Creek, Cold Spring Creek, and Highland Creek (Plate 2). The boundaries of all these stream's watersheds extend beyond the park boundaries. Other drainages or canyons in the park occasionally contain water following strong storm events or wet periods, but only these three streams contain water year-round (Ohms 2009).

Beaver Creek is the main drainage of WICA and drains approximately 11,914 ha (29,440 ac); all other drainages in WICA flow into the Beaver Creek watershed. The Beaver Creek watershed starts south of Custer, SD and flows southeast into WICA before joining the Cheyenne River near Buffalo Gap, SD (Ohms 2009).

There are two major vegetation categories in WICA (dominant ponderosa pine forests and mixed-grass prairies) (Cogan et al. 1999), which form a transition zone between eastern and western biomes (NPS 2007). Historically, natural fires shaped the landscape and ponderosa pine stands were not as extensive. Today, large wild fires are rare in the Black Hills because humans suppress most fires quickly. Instead of wildfires, managers use prescribed burns to encourage mixed-age ponderosa pine stands (NPS 2008a). WICA's mixed-grass prairie is unique in that it is managed, in part, with native herbivores and fire, compared to other mixed-grass prairies under other management regimes (Burkhart, pers. comm., 2010).

Wind Cave is one of the world's longest, oldest, and most complex rectilinear maze caves in the world (Palmer 2001, NPS 2007a). It contains the world's largest collection of boxwork (a complex cave formation) (Palmer 2001) and provides visitors and researchers alike with a valuable opportunity for future exploration of cave geology and rare formations (NPS 2007a).

2.2.2 Resource Descriptions

Ponderosa pine forests cover approximately 30% of the landscape within the park and are occasionally observed with birch (*Betula* spp.), aspen (*Populus* spp.), and white spruce (*Picea glauca).* Dense ponderosa pine stands generally occur at higher elevations in WICA. Scattered groves of boxelder (*Acer negundo*), green ash (*Fraxinus pennsylvanica*), and elm (*Ulmus* spp.) typically occur near drainage areas (Cogan et al. 1999). Grasses are the main component of the mixed-grass prairie. Dominate species include western wheatgrass (*Pascopyrum smithii*), little bluestem (*Schizachyrium scoparium*), blue grama (*Bouteloua gracilis*), and a variety of forbs and shrubs are interspersed throughout the park (NPS 2005).

Common terrestrial vertebrates at the park include bison (*Bison bison*), elk (*Cervus elaphus*), pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), black-tailed prairie dogs (*Cynomys ludovicianus*), coyotes (*Canis latrans*), bobcat (*Lynx rufus*), and mountain lion *(Puma concolor*) (NPS 2005). Many species of birds are present at WICA including burrowing owl (*Athene cunicularia*), long-eared owl (*Asio otus*), golden eagle (*Aquila chrysaetos*), prairie falcon (*Falco mexicanus*), and Cooper's hawk (*Accipiter cooperii*) (NPS 2005). Chapter 4.4 provides a list of bird species in the park.

WICA was one of the earliest park areas to be designated a game preserve for the reintroduction of the American bison, and currently WICA boasts one of the most genetically diverse populations of bison in the nation (NPS 2006b).

Wind Cave contains over 193 km (120 mi) of known passages; more passages are continually being explored and described each year (Palmer 2001, NPS 2007a). The cave is the third longest cave in the United States (Alpha et al. 1997) and the fourth longest cave in the world (NPS 2007a). Boxwork appears in a criss-cross or honeycomb pattern of thin calcite fins on the cave walls and ceilings. It is found ranging in color from translucent orange-yellow to dusky brown or black (Palmer 2001). Other speleothems include calcite crystals coat the cave walls, calcite rafts, flowstone, dripstone, helictites, cave popcorn, frostwork, and moonmilk (Palmer 2001).

Photo 2. Black-tailed prairie dog town in WICA (Photo by Kevin Stark of SMU GSS, 2009)

2.2.3 Resource Issues Overview

Black-tailed prairie dogs have resided in the area of present-day WICA for thousands of years and are a crucial part of the ecosystem (NPS 2006a). There is significant concern that sylvatic plague *(Yersinia pestis)* will have an adverse effect on the prairie dogs in WICA. However, plague is not currently present nor has there been an outbreak within the park (Roddy, pers. comm., 2011). Black-tailed prairie dogs contract plague easily, and colonies experience nearly 100 percent mortality (Barnes 1993, Cully and Williams 2001).

The black-footed ferret (*Mustela nigripes*) is as an endangered species at both the federal and state level. Ferrets were extirpated from WICA in 1977, and then in 2007, 49 ferrets were reintroduced. Currently, the park estimates the population size estimated to be at least 46-52 individuals (Muenchau, pers. comm., 2011). The ferret is dependent on the prairie dog almost entirely for food and shelter (Licht et al. 2010).

Photo 3. Ponderosa pine woodlands (NPS Photo).

Invasive plant species can out-compete native plants, alter the structure and compositions of native plant communities, affect natural processes including nutrient cycling and fire regimes, and change the character of wildlife habitats. Park visitors, horses, and wildlife are some of the vectors that spread non-native plants in the park (Burkhart, pers. comm., 2010). White horehound (*Marrubium vulgare*) is a non-native, invasive plant of particular concern to park management. In WICA, this plant establishes dense populations in some prairie dog towns, causing shifts in prairie dog distribution. This plant affects all herbivores in the park because it is unpalatable and replaces palatable species (NPS 2009b).

The mountain pine beetle (*Dendroctonus ponderosae)* is a bark beetle native to western North America. Outbreaks of pine beetles occur when forests are dense, and the trees are vulnerable due to drought, old age, or root disease (NPS 2011c). In late June or July, beetles fly from infested tress to new host trees. Once the adult locates a host it tunnels beneath the bark to lay eggs. Once eggs hatch, the larvae feed on the host tree, disrupting the movement of food within the tree until the spring, when they rest for several weeks. Once larvae become adults, they emerge from the now dead host tree, and begin the cycle again. The adult beetle can also carry a blue-stain fungus, which stops movement of water within the tree (South Dakota Department of Agriculture 2009).

Climate change could have dramatic impacts on the ecosystems within WICA (Gitzen et al. 2010). Temperatures in the Northern Great Plains rose more than 2 °F over the past century and models predict an increase of 5-12 °F during this century (National Assessment Synthesis Team 2000). Currently, a climate change project is in progress for WICA, which will project future temperatures and precipitation; this research will reduce some of the uncertainty regarding future climate conditions (Burkhart pers. comm., 2010).

2.3 Resource Stewardship

2.3.1 Management Directives and Planning Guidance

WICA does not have a current General Management Plan in place. However, management plans for prairie dog, bison, elk, and cave and karst resources exist. The goal is to ensure responsible management and protections for these park resources.

The main goals for prairie dog management in WICA, from the Black-tailed Prairie Dog Management Plan (NPS 2006a), are:

- Maintain and establish a sustainable long-term minimum population and distribution that fulfills the ecological requirements;
- Identify and map all prairie dog colonies;
- Recognize existing prairie dog colonies and nearby land uses to create management zones, while retaining the native plants and their diversities;
- "Protect ethnographic and other cultural resources associated with prairie dogs colonies (NPS 2006a)";
- Discover methods for population control if needed;
- Create an emergency plan for potential disease outbreaks among the population;
- Implement a "good neighbor" policy for the boundary area.

The main goals for bison management in the park, from the Bison Management Plan (NPS 2006b), are:

- Preserve and allow natural change in population size, while utilizing 25 percent of total forage;
- Create a program to monitor and maintain the desired population count, and ensure utilization of range;
- Genetic integrity and variety of the bison herd will be preserved or increased. The herd count should not drop below 400. New bison should not be added to maintain the genetic integrity;

- "Manage the herd for health conditions resembling free ranging bison and free of nonnative diseases such as foot and mouth disease (FMD), brucellosis, tuberculosis (TB), etc., to avoid any need for de-population or the parks' ability to live ship animals (NPS 2006b)";

- Preserve the cultural resource of the bison herd;

- Allow bison to decompose as naturally as possible within the park;

The Elk Management Plan (NPS 2009a) describes many goals for management of this species in the park:

- Continue management of elk population while meeting biological objectives where wildlife health issues are present;

- Integrate relevant scientific research into management strategies as it becomes available;

- Coordinate with other responsible elk management agencies to accomplish goals and objectives;

- Establish thresholds that will prompt elk population management actions, while considering biological factors.

The overall objective defined in the Cave and Karst Resource Management Plan (NPS 2007a) is to create polices for the management and protection of non-renewable cave and karst resources. Specific objectives are to:

- Classify the current and future conditions of the cave and karst resources at WICA;

- Create techniques for examining the sustainable levels of human impacts within cave resources, and suggest suitable actions to alleviate those impacts;

- Create techniques for the protection and maintenance of natural cave and karst hydraulic processes;

- Provide a standard for cave and karst resources when conducting scientific studies and research;

- Establish procedures for comprehensive records of resources within the cave and karst system;

- "Provide educational and recreational opportunities for a broad spectrum of park visitors to discover, explore, study, respect, appreciate, and enjoy caves at their individual levels of interest and abilities (NPS 2007a);"

- “Establish park policy, guidelines, and/or permit stipulations that will ensure maximum safety of cavers and visitors while providing for the conservation of cave resources (NPS 2007a).”

2.3.2 Status of Supporting Science

The Northern Great Plains Inventory and Monitoring Network (NGPN) identifies key resources, network-wide and for each of its parks, which are used to determine the overall health of the parks. These key resources are called Vital Signs. In 2010, the NGPN completed and released a Vital Signs Monitoring Plan (Gitzen et al. 2010, Table 2).

Table 2. NGPN Vital Signs selected for monitoring in WICA (Gitzen et al. 2010). Those in bold are already monitored by the park or another NPS program.

Category	NGPN Vital Signs
Air and Climate	**Ozone, wet and dry deposition, visibility and particular matter, air contaminants, weather and climate**
Geology and Soils	Stream and river channel characteristics, cave meteorology
Water	**Groundwater dynamics, surface water dynamics,** surface water chemistry, aquatic contaminants, aquatic microorganisms and macroinvertebrates
Biological integrity	Exotic plant early detection, **forest insects and diseases,** riparian lowland plant communities, upland plant communities, land birds, **raptors**, **prairie dogs**, **ungulates, black-footed ferrets**
Human use	**Treatments of exotic infestations, visitor use**
Landscapes (ecosystem pattern and process)	**Fire and fuel dynamics,** land cover and use, extreme disturbances, soundscape

Source of Expertise

Beth Burkhart, WICA Botanist
Barb Muenchau, WICA Biological Science Technician
Dan Roddy, WICA Biologist

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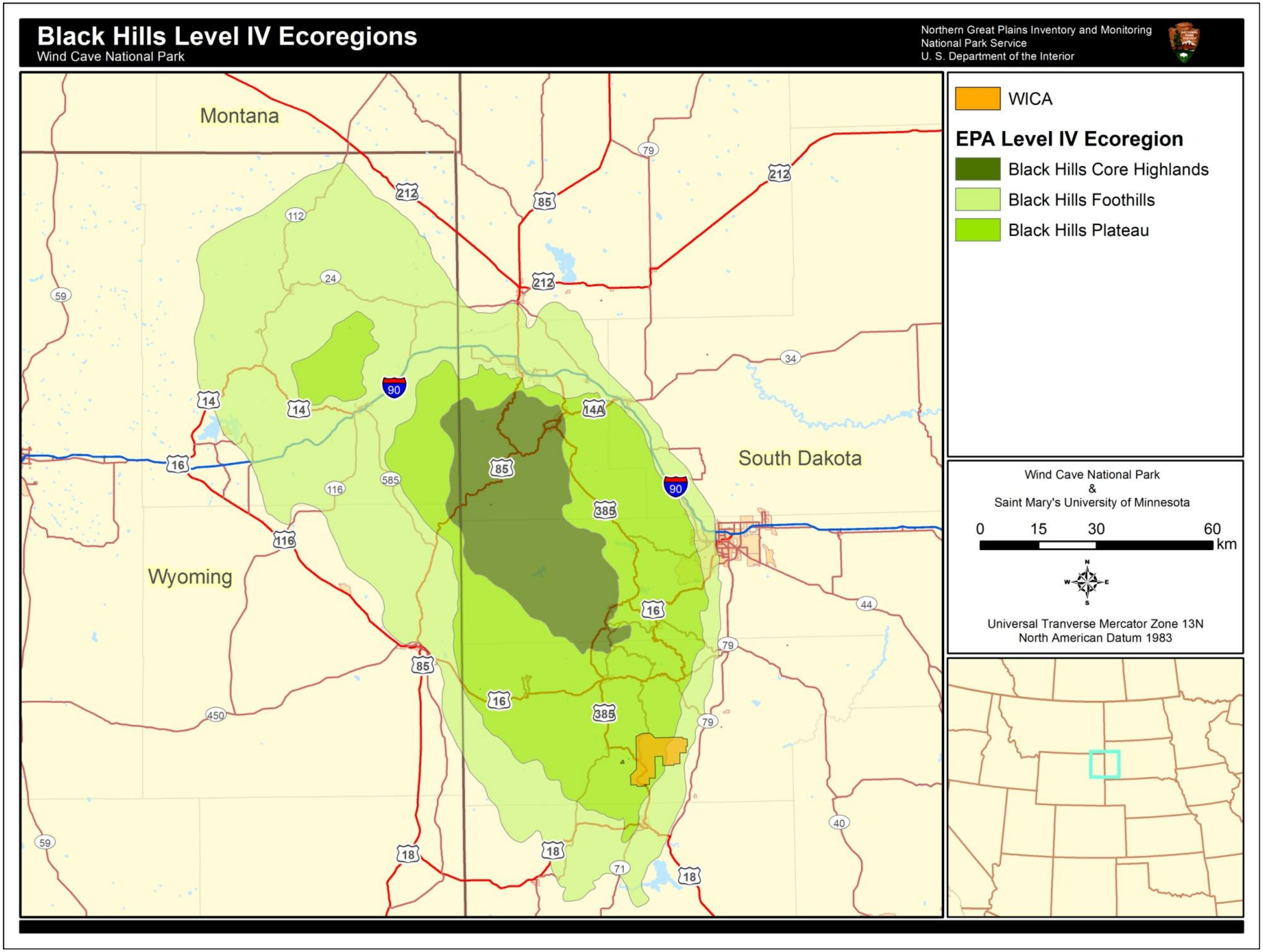

Plate 1. Regional EPA Level IV Ecoregions.

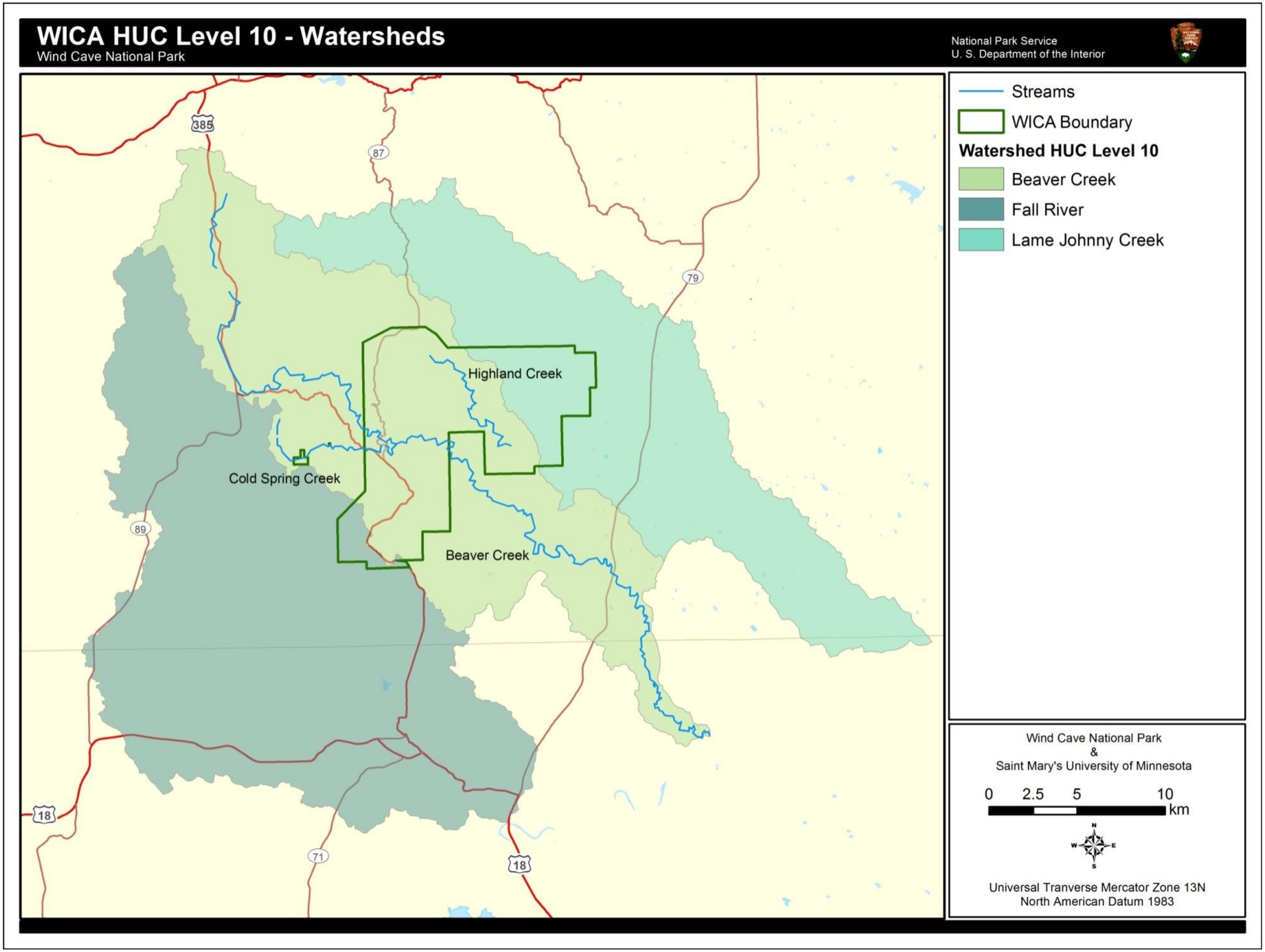

Plate 2. WICA Hydrologic Unit Code Level 10 - Watersheds.

Chapter 3 Study Scoping and Design

This NRCA was a collaborative effort between the NPS and SMU GSS. Stakeholders in this project include WICA park resource staff and the NGPN staff. Before embarking on the project, it was necessary to identify the specific roles of the NPS and SMU GSS. Preliminary scoping meetings were held, and a task agreement and a detailed scope of work document were created in cooperation with the NPS and SMU GSS.

3.1 Preliminary Scoping

A preliminary scoping meeting was held 19-20 November 2009 with SMU GSS and NPS staff. This scoping meeting determined the purpose of the WICA NRCA which is to evaluate and report on current conditions of key park resources, evaluate critical data and knowledge gaps and highlight selected existing and emerging resource condition influences of concern to WICA managers.

NPS provided specific guidance for this NRCA:

- The NRCA is conducted using existing data and information;
- Identification of data needs and gaps is driven by the framework categories;
- The analysis of natural resource conditions includes a strong geospatial component;
- Resource focus and priorities are primarily driven by WICA park resource management.

This condition assessment provides a “snapshot-in-time” evaluation of resource condition status for a select set of park natural resources, identified and agreed to by the project team. Project findings will aid WICA resource managers in the following objectives:

- Developing near-term management priorities;
- Engaging in watershed or landscape scale partnership and education efforts;
- Conducting park planning (e.g., General Management Plan, Resource Stewardship Strategy);
- Reporting program performance (e.g., Department of the Interior Strategic Plan “land health” goals).

3.1.1 NPS Involvement

Expectations for WICA staff involvement were detailed during project scoping efforts. Park staff participated in project development and planning, reviewed interim and final products, and participated in condition assessment meetings. WICA staff also assisted SMU GSS in the identification of information sources, an appropriate resource assessment structure, appropriately scaled resources, threats and stressors, and measures for these resources.

WICA park staff helped to identify other NPS personnel who could provide guidance, technical assistance, and logistical coordination for site visits and discussions with principle investigators and graduate students. Park staff collaborated with the SMU GSS Principle Investigator during data mining and status assessment to ensure that the synthesis was consistent with the project goals. Additionally, WICA natural resource staff assisted in developing recommendations for additional analyses to fulfill information needs that would aid in the assessment of park resource conditions. They also reviewed and commented on draft reports and all publishable material submitted from this project in a timely fashion. Involvement of WICA staff in this project ensured that SMU GSS efforts met the needs of the park.

The NPS was responsible for informing the GSS Principle Investigator of the specific activities required to comply with the "NPS Interim Guidance Document Governing Code of Conduct, Peer Review, and Information Quality Correction for National Park Service Cultural and Natural Resource Disciplines" or any subsequent guidance issued by the NPS Director to replace this interim document.

3.2 Study Design

3.2.1 Component Framework, Focal Study Resources and Components

<u>Selection of Resources and Measures</u>

As defined by SMU GSS in the NRCA process, a "framework" is developed for a park. This framework is a way of organizing, in a hierarchical fashion, bio-geophysical resource topics considered important in park management efforts. The primary features in the framework are key resource components, measures, stressors, and reference conditions.

Components in this process are defined as natural resources (e.g., bison), ecological processes or patterns (e.g., natural fire regime or land cover change), or specific natural features or values (e.g., geologic formation, dark night skies, or viewshed) that are considered important to current park management. Each key resource component has one or more "measures" that best define the current condition of a component being assessed in an NRCA. Measures are defined as those values or characterizations that evaluate and quantify the state of ecological health or integrity of a component. In addition to measures, current condition of components may be influenced by certain "stressors" and, thus, such "stressors" are considered during assessment. A "stressor" is defined as any agent that imposes adverse changes to a component and typically refers to anthropogenic factors that adversely affect natural ecosystems, but may also include natural processes or disturbances such as floods, fires, or predation (adapted from GLEI 2010).

During the WICA NRCA scoping process, key resource components were identified by NPS staff and are represented as components in the NRCA framework. While this list of components is not a comprehensive list of all the resources in the park, it includes resources and processes that are unique to the park in some way: of greatest concern or of highest management priority in WICA. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with WICA resource staff.

<u>Selection of Reference Conditions</u>

A reference condition is a benchmark for which to compare current values of a given component's measures to determine condition of that component. A reference condition may be a historical condition (e.g., flood frequency prior to dam construction on a river), an established ecological threshold (e.g., EPA standards for air quality), or a targeted management goal/objective (e.g., a bison herd no larger than 700 individuals) (adapted from Stoddard et al. 2006).

Reference conditions in this project were identified during the scoping process using input from NPS resource staff. In some cases, reference conditions represent a historical reference in which human activity and disturbance was not a major driver of ecological populations and processes, such as “pre-exotic invasions" or "pre-1908 establishment.” In other cases, peer-reviewed literature and ecological thresholds helped to define appropriate reference conditions.

Finalizing the Framework

An initial framework was adapted from the organizational framework outlined by the H. John Heinz III Center for Science’s “State of Our Nation’s Ecosystems 2008” framework (Heinz 2008). Key resources for the park were gleaned from the NGPN Vital Signs Monitoring Plan (draft form of Gitzen et al. 2010) and publically available informational materials from WICA. This initial framework was presented to park resource staff to stimulate meaningful dialogue about key resources that should be assessed. Significant collaboration between SMU GSS analysts and NPS staff was needed to focus the scope of the NRCA project and finalize the framework of key resource to be assessed.

The NRCA framework was finalized in April 2010 following acceptance from WICA resource staff. It contained 21 components (Table 3) and was used to drive analysis in this NRCA. This framework outlines the resources (components), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each resource to for comparison to current conditions.

Table 3. Final WICA NRCA Framework (bolded components represent assessment and management priorities).

Wind Cave National Park
Natural Resource Condition Assessment Framework

Component	*Measure*	*Stressors*	*Reference Condition*
Extent and Pattern			
Landscape Composition			
Landcover Extent	Changes to major plant communities	Timing and intensity of precipitation	Pre-global warming conditions
	Change in ponderosa pine distribution	Pine is stressor of water availability and competitor with native vegetation	Historic photo conditions
	Park management activities	Vegetation removal, developed areas, trails, Native American ceremonial areas, prescribed burns	Pre Use Condition
Fire	Forest fire frequency	Suppression and land cover changes	Natural frequency
	Forest fire severity	Increase in fuel loads & land cover changes	Natural fuel and frequency relationships
	Forest fire released contaminants and heavy metals	Ash deposits, and ash access to Wind Cave through openings or water entry routes	Historic photo conditions prior to conversion of prairie to forest
Biological Components			
Ecosystem and Community			
Native plant communities	**Change in ponderosa pine density and distribution**	**Ponderosa pine competes with other native plant communities. It affects Wind Cave moisture and humidity.**	**Pre Ponderosa Pine planting initiatives**
	Native species of special concern (rare, riparian, seeps etc.)	**Competition from native and exotic species, wildlife impacts, climate change**	**Current conditions**
	Exotic plant - distribution and density	**Fire regime, climate changes, moisture patterns, potential atmospheric nitrogen deposition, visitation, horses, transported hay (exotic stressors to native plant communities)**	**Pre-Exotic infestations**
Biotic Composition			
Birds	Species richness	Land cover change, bio-accumulation, prey base fluctuations, regional population declines, exotic bird species, climate change, predators	Breeding and healthy populations
	Species diversity		
	Species density		
Elk	**Density**	**Vegetation, chronic wasting disease, mountain lions**	**Natural and healthy population**
Bison	**Genetic conservation**	**Neighboring herd threat for integration of cattle genes and disease**	**Current population**
	Population	**Drought, change in forage composition from exotics and climate change, competition with other grazing species**	**Healthy population**
Prairie Dog	**Total colony acreage**	**White horehound, drought, sylvatic plague, predator cycles**	**1000-3000 acres of prairie dogs, as indicated in 2006 EA FONSI**
Black-footed Ferret	**Population number and distribution**	**Decrease in prairie dogs disease, or other predators**	**Current population of Prairie Dogs**
Pronghorn	**Population number and distribution**	**Prairie dog population, competition, disease**	**Breeding and healthy populations**
Porcupine	Population number and distribution	Predators, disease, loss of high value food sources	Breeding and healthy populations
Herptile Species	Population number and distribution	Human impacts, flea dusting, predators, climate change	Breeding and healthy populations
Bats	Nation-wide species of concern	Disease, predators, caving, white-nose syndrome threats, climate change	Breeding and healthy populations
Coyote	Natural behavior; non-habituation to humans	Regular interaction with humans, disease, prey base cycles	Natural and healthy population and behavior

Table 3. Final WICA NRCA Framework (bolded components represent assessment and management priorities). (continued)

	Component	*Measure*	*Stessors*	*Reference Condition*
Chemical and Physical Characteristics				
Cave Environment				
	Natural Environment	**Temperature**	**Visitors, electrical systems (control panels)**	**Beginning of historic measurement**
		Humidity	**Visitors**	
		Air flow	**Unnatural openings**	
		Cave physical processes (dissolution of rock, air-flow exchange, and Speleothems formation)	**Surface vegetation and hydrology changes, unnatural openings, changes in cave chemistry (addition of human derived chemicals), human debris and contamination (microbes, urine, lint, hairt, etc.), human-caused breakage and cave feature destruction**	
Water Quality				
	Water Quality	Mercury	Coal plants and atmospheric deposition	EPA Water Quality Criterion
		Nitrates	Airborne deposition, residential (septic) runoff, and	
		Chemicals and Heavy Metals	Change in management, fires, or urban development	
		Dissolved oxygen	High temperatures	
		Fecal coliform	Ranching activities	
		pH	Atmospheric deposition	
		Specific conductance	Suspended solids	
		Temperature		
		Turbidity	Suspended solids	
Hydrology				
	Changes in Hydrology	**Springs and surface flow**	**Climatic cycles, disappearing (karst related) streams, upstream dams and water withdrawals, soil compaction by large ungulates**	**Beginning of historic measurement**
		Groundwater (Cave Lake, water table fluctuations)	**Small and major wells, water development**	
Air Quality				
	Air Quality	Deposition of Nitrogen & Sulfur	Nearby development of coal-fired plants, vehicle exhaust, large forest fires	NPS ARD air quality standards; EPA NAAQS standards consistent with Class I Airshed
		Ozone		
		Particulate matter		
		Visibility		
Goods and Services				
Non-Consumptive				
	Soundscape	Ambient sound levels and distribution of non-natural sound character (e.g. engines and motors)	Neighboring and in-park development, roads, overflights	Undeveloped and "natural" park experience, as typified by recent biological recordings
	Viewshed	Natural viewsheds	Close neighbors, planned developments, management activities within the park	Undeveloped and "natural" park experience
	Dark Night Skies	V Magnitude	Rapid City, Visitor Center, Hot Springs, Custer, potential development	Current level of ambient light

3.2.2 Reporting Areas

Some NRCAs utilize reporting zones to divide park regions in order to accommodate resource condition reporting. Reporting zones were not used in this assessment due to the size of the park.

3.2.3 General Approach and Methods

This study involved gathering and reviewing existing literature and data relevant to each of the key resource components included in the framework. No new data were collected for this study, however, where appropriate, existing data were analyzed to provide summaries of condition for resources or to create new spatial representations. After data and literature relevant to the measures of each component were reviewed and considered, a qualitative statement of overall current condition was created and was compared to the reference condition when possible.

<u>Individual Component Assessments</u>

Data Mining

The data mining process (acquiring as much relevant data about key resources as possible) began at the first scoping meeting, at which time WICA staff provided data and literature in multiple forms, including: NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, non-governmental organizations (NGO) reports, databases, tabular data, and charts. Geographic information system (GIS) data were provided by NGPN and by WICA staff. Access was also granted to various NPS online data and literature sources, such as NatureBib and NPSpecies. Additional data and literature were also acquired through online bibliographic literature searches and inquiries on various state and federal government websites.

Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality regarding the resource components identified at the scoping meeting.

Data Development and Analysis

Data development and analysis was highly specific to each component in the framework and depended largely on the amount of information and data available on the topic and recommendations from WICA staff about analysis. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Preparation and Review of Component Rough Draft Assessments (Phase I Documents)

The process of developing draft documents for each component began with a detailed phone or conference call with an individual or several individuals considered experts on the resource component(s) under examination. These conversations allowed analysts to verify the most relevant data and literature sources to be used and to also formulate ideas about current conditions with respect to the experts' opinions. Information gained in these initial conversations was important for rough draft development. Rough drafts were developed using the data gathered through the data mining process and the insights provided by component experts. Documents were then forwarded to component experts for initial review and comments.

The preparation of rough draft assessments for each component was a highly cooperative process among SMU GSS, WICA, and NGPN staff. Though SMU GSS analysts rely heavily on peer-reviewed literature and existing data in conducting the assessment, the expertise of NPS resource staff also plays a significant and invaluable role in providing insight into the appropriate direction for analysis and assessment of each component. This step is especially important when limited data or literature exist about a resource component.

Development and Review of Final Component Assessments (Phase II Documents)
Following review of the component rough drafts (Phase I documents), analysts used the review feedback from resource experts to compile the final component assessments (Phase II documents). Consistent contact with experts was maintained throughout this process in order to adequately address questions and comments pertaining to rough draft reviews and to ensure accurate representation of WICA and NGPN staff knowledge. Once Phase II documents were completed, they were sent back to expert reviewers for a second thorough review and to provide an opportunity to add more insights. Any comments or feedback received during this second review were incorporated into the assessment document. As a result of this process, and based on the recommendations and insights provided by WICA resource staff and other experts, the final component assessments (Phase II documents) represent, for each component, the most relevant and current data available as of April 2011 and the sentiments of park resource staff and resource experts.

All resource component assessments are presented in a standard format in the final report. The format and structure of resource component assessments is described below.

<u>Format of Component Assessment Documents</u>

Description
This section describes the relevance of the resource component to the park and the context within which it occurs in the park setting. The importance of the resource component to the park and why it is important to include in this assessment is explained. For example, it may represent a unique feature of the park, may be a key process or resource in park ecology, or it may be a resource that is of high management priority in the park. Also emphasized are any interrelationships that occur among a given component and other resource components included in the broader assessment.

Measures
Resource component measures were defined in the scoping process and refined through extensive dialogue with resource experts. Those measures deemed most appropriate for assessing the current condition of a component are listed in this section, typically as bulleted items with a very brief description of metrics used in the assessment.

Reference Conditions/Values
This section explains the reference condition determined for each resource component as it is defined in the framework. Explanation is provided as to why specific reference conditions are appropriate or logical to use. Also included in this section is a discussion of any available data and literature that explain and elaborate on the designated reference conditions. If these conditions or values originated with the park experts or SMU GSS analysts, an explanation of how they were developed is provided.

Data and Methods
This section includes a discussion of the data sets used to evaluate the component and if or how these data sets were adjusted or processed as a lead-up to analysis. If adjustment or processing of data involved an extensive or highly technical process, these descriptions are included in an appendix for the reader or a GIS metadata file. Also discussed is how the data were evaluated and analyzed to determine current condition (and trend when appropriate).

Current Condition and Trend
This section presents and discusses in-depth key findings regarding the current condition of the resource component and trends (when available). The information is presented primarily with text but is often accompanied by detailed maps or plates that display different analyses, as well as graphs, charts, and/or tables that summarize relevant data or show interesting relationships. All relevant data and information for a component is presented and interpreted in this section.

Threats and Stressor Factors
This section provides a summary of the threats and stressors that may impact resource and influence to varying degrees the current condition of a resource component. Relevant stressors were described in the scoping process and are outlined in the NRCA framework. However, these are elaborated on in this section to create a summary of threats and stressors based on a combination of available data and literature, and discussions with experts and park natural resources staff.

Data Needs/Gaps
This section outlines critical data needs or gaps for the resource component. Specifically, what is discussed is how these data needs/gaps, if addressed, would provide further insight in determining the current condition of a given component in future assessments. In some cases, the data needs/gaps are significant enough to make it inappropriate or impossible to determine condition of the resource component. In these cases, stating the data needs/gaps is useful to natural resources staff who wish to prioritize monitoring or data gathering efforts.

Overall Condition
This section provides a qualitative summary statement of the current condition that was determined for the resource component. Condition is determined after thoughtful review of available literature, data, and any insights from park staff and experts, which are presented in the Current Condition and Trend section. The Overall Condition section summarizes the key findings and highlights the key elements used in determining and justifying the level of concern, if any, that analysts attribute to the condition of the resource component.

Initial designations of current condition for a component (i.e., made by the authors during component rough draft preparation) were subject to review from resource experts during the review process and amended when appropriate to provide a more accurate representation of park staff/experts' interpretation of condition. When applicable, condition designations were made with respect to the defined reference condition. At other times, when reference conditions were not available, the opinions of park staff and experts were relied on more heavily to determine condition.

Condition Graphic

This provides a graphical representation of the condition of the component (and trend when appropriate). This graphic is intended to give readers a more visual interpretation of the assessed condition. However, it does not replace the written statements of condition, which provide an in-depth discussion of and justification for the condition attributed by analysts to the resource component.

Figure 1 shows an example of the condition graphic as it is used to represent the assessed condition of a component. Colored circles are used to indicate a components condition expressed by level of concern. Red circles signify that a resource is of "significant concern" to park management. Yellow circles signify that a resource of "moderate" concern to park management. Green circles indicate the condition of a component has been currently assessed as of 'low' concern. Gray circles signify that there is currently insufficient data to make a statement about concern or condition of the component.

The arrows nested inside of the circles indicate the trend of the condition of a resource component. Arrows pointing up indicate the condition of the component is improving from reference condition. Arrows pointing to the right indicate a stable condition or trend. Arrows pointing down indicate a decline in the condition of a component from reference condition and are only used when it is appropriate to comment on the trend of condition of a component. A triple-pointed arrow indicates the trend of the component's condition is currently unknown.

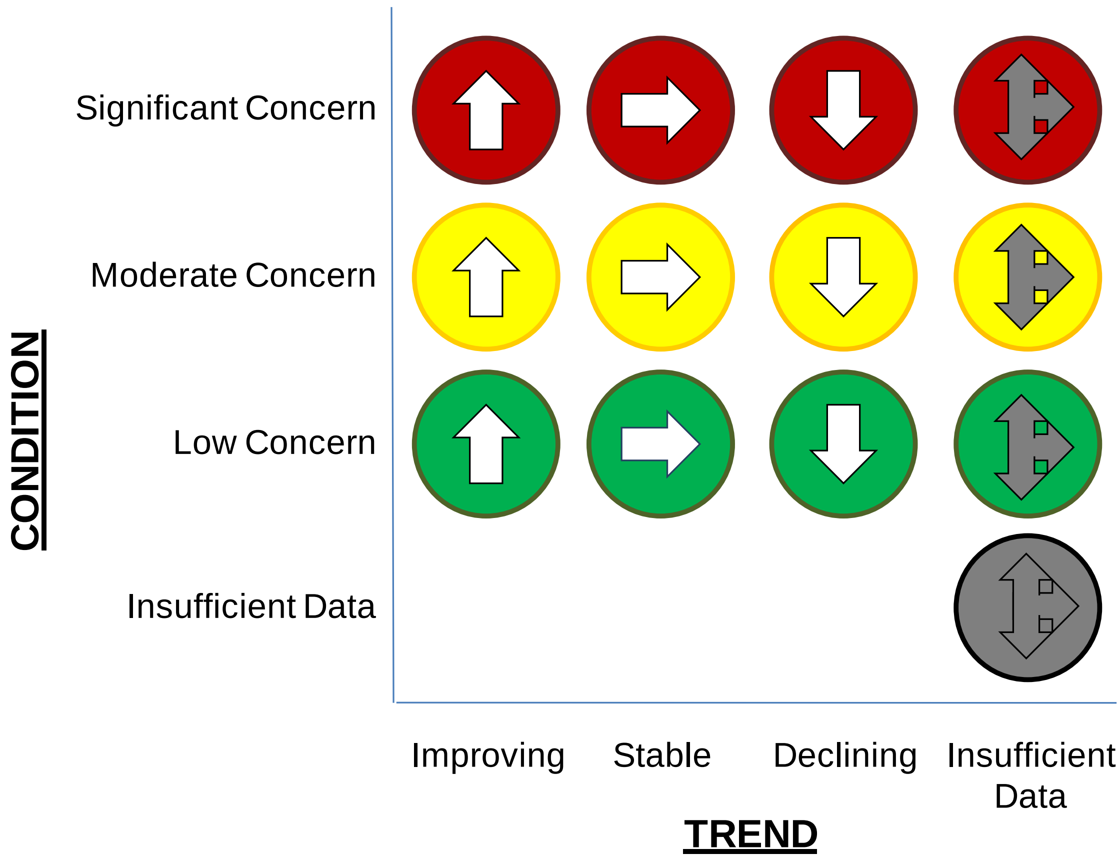

Figure 1. Graphical representation of current condition and trend of a component.

Literature Cited

This is a list of formal citations for literature or datasets used in the analysis and assessment of condition for the resource component.

3.3 Literature Cited

Gitzen, R. A., M. Wilson, J. Brumm, M. Bynum, J. Wrede, J. J. Millspaugh, and K. J. Paintner. 2010. Northern Great Plains Network Vital Signs Monitoring Plan. Natural Resource Report NPS/NGPN/NRR—2010/186. National Park Service, Fort Collins, Colorado.

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Chapter 4 Natural Resource Component Summaries

4.1 Land Cover Extent

Description

Land cover is the physical surface of the earth described using classes of vegetation and land use classifications (e.g., agriculture, developed, transportation). Land cover is portrayed in maps created through field surveys and/or analysis of remotely sensed imagery (Comber et al. 2005). The NGPN recognizes "land cover and land use", as a Vital Sign because natural disturbances, stressors, and management cause large-scale changes to the general ecosystem composition of NPS units, altering the land cover of a park. In addition, the type, amount, and arrangement of vegetative structural types in park units partially determine the composition and abundance of vertebrate and invertebrate communities in those units (Vinton and Collins 1997). The protocol for monitoring this Vital Sign will be developed over the next one to five years.

This assessment examines landcover of the park as broad vegetation classes (i.e., a coarser scale than individual native plant community types). Measures that have particular relevance to park-wide resource management include the balance of early, middle, and late seral vegetation stages; shrubland cover; riparian cover; and ponderosa pine cover. First, the balance of early, middle, and late seral vegetation stages is relevant to management decisions regarding the timing and extent of prescribed fire; wildfire management; population management of prairie dogs, elk, and bison; and invasive plant management. While the proportion of different seral stages in a landscape is dynamic over time because of natural and human-cause disturbance, a general rule of thumb is that a desirable landscape-scale balance in rangelands is roughly 10-15% early seral vegetation, 10-15% late seral vegetation, and 70-80% mid-seral vegetation (Uresk, pers. comm., 2011). There has been no investigation or determination of a more specific desirable seral stage balance for the rangelands of WICA. This particular balance may not be suited specifically to WICA because it applies to very large areas. Second, the extent of shrubland cover is relevant to management of elk populations, timing and extent of prescribed burns, and management of wildfires. Third, the extent of riparian land cover is relevant to management decisions regarding riparian area management activities, large herbivore (e.g., elk and bison) population management, and invasive plant species management. Lastly, the amount of ponderosa pine cover across the park is relevant to management decisions in several different areas, including mountain pine beetle management, pine encroachment into prairies, wild and prescribed fire management and planning, and management of fuel reduction activities (such as mechanical thinning).

Measures

- Balance of early, middle, and late seral vegetation stages
- Extent of shrubland cover
- Extent of riparian cover
- Extent of ponderosa pine forest cover

Reference Conditions/Values

The reference conditions for the extent of seral stages for shrubland, riparian, and ponderosa pine cover is not established. However, analysis of acreage of prairie dog town acres provides an example of how seral stage targets are applicable in a management context (see discussion in Balance of Seral Stages, p.32).

Major anthropogenic factors and park management activities are important in understanding the land cover conditions that exist in WICA. The following offers an historic timeline (from the late 1800s to today) of some of the major events and factors that have contributed to present-day land cover in WICA. The information below is adapted from Beth Burkhart in the Resource Ramblings 2009 edition, and includes additional information regarding the management plans of prairie dog, bison, and elk:

> **1878 to 1883**– The number of cattle in the Black Hills went from 100,000 to 500,000 on an "open range" basis (Palais 1942). It is unclear exactly how much land was affected by cattle grazing in present-day WICA, but it is clear that the park area was impacted.
>
> **1939**– Grazing permits were discontinued in Custer Recreational Demonstration Area (RDA).
>
> **1946**– There were still 284 structures in the park, 52 of which were homesteads. With an average of 7.7 ha (18.9 ac) per homestead, this means there was approximately 400 ha (988 ac) total of plowed/planted land in the park (NPS 2010b).
>
> **1951**– A complete boundary fence was created for WICA.
>
> **1956 to 1960**– A four-year re-vegetation and treatment program was created on 3,035 ha (7,500 ac) in WICA. The goals were soil stabilization and adequate forage of native grasses to support bison.
>
> **1973**– "Prior to this date, the fire management policy at WICA was total suppression of all fires in the Park. Some small experimental test burns were held to look at the effects of prescribed fire on plants and animals. Starting with small fires on one or two acres, it has expanded to thousands of acres." (NPS 2010a – Fire Management website)
>
> **2006**- Black-tailed Prairie Dog Management Plan established - established a prairie dog town acreage target of 405 to 1,214 ha (1,000 to 3,000 ac). The total area was allowed to increase from approximately 526 ha (1,300 ac) in 1999 to approximately 1133 ha (2,800 ac) in 2010. Part of the reason for the allowed increase in prairie dog town area was to support the reintroduction of black-footed ferrets, initially reintroduced in 2007. However, it was also done to increase broad ecological functioning of prairie dogs in the park. That is, prairie dogs are keystone and foundational species, with roles as prey, ecosystem engineers, and modifiers of the vegetative community (McDonald et al. 2011).
>
> **2006**- Bison Management Plan - established bison target population at 400 animals. Herd size in WICA had been maintained over the years between 350 and 500 animals.

2008- Elk Management Plan - established elk population target at 232 to 475 elk; elk populations have steadily increased from approximately 2004 to current conditions of 900 elk documented overwintering in WICA in 2009-2010 and 800 elk overwintering in WICA in 2010-2011 (Weber, pers. comm., 2010). As a start to achieving management goals, elk gates were installed in summer 2010, and use will be implemented in 2011 to reduce WICA elk numbers. Heavy forage utilization as a disturbance may cause a shift from later seral to earlier seral expression of an apparently stable plant community type (e.g., Little Bluestem – Grama Grass Herbaceous Vegetation).

2010 – Suppression of all fires regardless of cause continues today, however, prescribed fire is used to mimic natural fire-return intervals in prairie and ponderosa pine forests of WICA. The American Elk prescribed fire burned the largest area 1, 376 ha (3,400 ac) of any prescribed fire since prescribed fires began in 1973. Invasive plant species are monitored and integrated pest management techniques are employed to control infestations. The managed populations of bison, elk, and prairie dogs play important roles in driving vegetation changes in WICA.

The reference conditions for the extent of ponderosa pine, shrubland, and riparian cover are not developed (i.e., there are no specific management targets for the extent of each of these cover types).

Data and Methods
The NPS contracted the USGS – Biological Resources Division to implement a multi-year project producing vegetation maps for 235 national parks. The USGS contracted with the Bureau of Reclamation's Remote Sensing and Geographic Information Group and The Nature Conservancy to map vegetation occurring in and around WICA. The WICA mapping project was completed in 1999 and produced a detailed vegetation report, vegetation plot data, a dichotomous vegetation key, a photo-interpretation key, digital vegetation map, and accuracy assessment data/analysis (Cogan et al. 1999). One representation of this digital vegetation map (Cogan et al. 1999) is displayed in Plate 3.

Burkhart (2011b) states that WICA vegetation mapping products assist WICA resource staff in conserving plant biodiversity; managing invasive species; managing outbreaks of insects and disease; understanding wildlife/habitat relationships; and understanding wildland and prescribed fire effects. WICA vegetation mapping products provide foundational information for managing every surface resource at the park.

Plate 3 displays vegetation as broad life-form groups, however these are not equivalent to seral stages. Plant community types may occur in successional relationships (e.g., fire disturbance causing change from tree community type [late seral] to grassland community type [early seral] that eventually returns to tree community type [middle or late seral]). However, there are also early, middle, and late seral expressions for any given plant community type, related to time since last disturbance. For example, some early seral stages can be a specific plant community that is always found with recent disturbance (e.g., purple three-awn-fetida). Another example is an expression of a plant community that may generally be considered middle or late seral stage such as Weastern Wheatgrass – Needle and Thread mixed Grass Prairie that is caused by disturbance (e.g., heavy grazing). With continued heavy grazing, the determination of total area of early seral vegetation is difficult to do accurately. Published protocols to determine seral stages of both plains grassland and woody draw community types are offered by (Uresk et al. 2011).

Following completion of the 1999 WICA vegetation mapping project, WICA staff observed significant changes in some of the park's vegetation (Burkhart 2011b). Disturbances such as fire (wild and prescribed fire), lack of fire (allowing ponderosa pine regeneration and expansion into grasslands), drought, and changes in numbers and locations of wildlife species (e.g., prairie dog colonies) have contributed to these vegetation changes (Burkhart 2011b). WICA also experienced four years of below average precipitation, which also contributes to vegetation changes. Burkhart (2010b) suggests that an accurate vegetation map enables park staff to make appropriate management decisions, allowing them to better conserve plant biodiversity; manage invasive species; manage outbreaks of insects and disease; understand wildlife/habitat relationships; and understand wildland and prescribed fire effects. WICA staff is in the process of updating the 1999 vegetation map products using 2010 color infrared aerial photography. The 2010 vegetation map product will not be as rigorous as the original map due to differences in the expertise of aerial photo interpretation and available aerial photographs. In addition, accuracy assessment (ground truthing) of digitized map classes has not yet been completed.

Current Condition and Trend

According to the digital vegetation map produced by Cogan et al. (1999), the park was composed of two major vegetation types, ponderosa pine forests/woodlands and mixed grass prairies, with approximately 25 percent of the park covered by trees. Other than the ponderosa pines found primarily in the higher elevations of the park, forested areas also include scattered groves of elm, aspen, bur oak (*Quercus macrocarpa*), boxelder, and birch, generally along drainage areas (NPS 2010a). The map classes covering the most area in the park were Western Wheatgrass – Kentucky Bluegrass Complex, Little Bluestem – Grama Grass Herbaceous Vegetation, Ponderosa Pine Woodland Complex II and Ponderosa Pine/Little Bluestem Woodland respectively (Appendix A**).** Plate 3 displays the distribution of these land cover classes in WICA, grouped by major vegetative structure (e.g., shrubland, forest and woodland, herbaceous).

<u>Balance of seral stages</u>

A dynamic balance of seral stages is important for maintaining biological diversity in landscape ecology, because a variety of plants and animals rely on different forest and grassland ecosystem seral stages to meet their habitat needs (MFRP 1998). The Ministry of Forest Resource Program (MFRP), British Columbia, CA, states that ecosystems within a landscape age through time, and succession transforms the composition of forested ecosystems as biotic communities respond to and modify their environment (MFRP 1998). Seral stages also occur in mixed grass prairie ecosystems. Uresk (1990) developed a multivariate statistical analysis methodology for assessing seral stages of Great Plains' grasslands, specifically wheatgrass-grama-buffalograss (*Agropyron-Bouteloua-Buchloe*). Applications of methods to identify seral stages have been examined in Great Plains' shrublands, sagebrush shrub step habitat type (Benkobi and Uresk 1996, Benkobi et al. 2007), and in a hackberry-shrub ecological type (*Celtis occidentalis* L.) (Uresk et al. 2010). The methodology developed by Uresk (1990) recognized the need to determine range conditions and classification for better management of rangelands with the perspective of meeting livestock and wildlife needs. Uresk et al. (2010) suggest that "multivariate quantitative models of plant succession allow resource managers to easily obtain quantitative measurements and relate current condition to management effects at one-time and over long-term on a repeatable basis."

Multivariate methods could be used in WICA to determine seral stages of grasslands, but applications have yet to cover ponderosa pine classification types. In addition, WICA would still have to define the desired balance of seral stages. The D. Uresk rule of thumb may or may not be appropriate to WICA. Uresk (pers. comm., 2011) suggests that the considerations of this seral stage balance as a management tool is only applicable in large areas; the area covered by WICA may be, in itself, too small. The current or past balance of seral stages has not been determined for WICA.

Prairie dog town area can serve as an estimate for early seral vegetation since it is the largest category of, and most easily identified, early seral vegetation in the park. The continuing disturbance in prairie dog towns caused by animals burrowing and eating/clipping vegetation ensures that prairie dog town vegetation is maintained primarily as early seral as long as towns are occupied. However, grassland species composition remains in some areas within prairie dog towns. The 1999 vegetation map presents approximately 526 ha (1,300 ac) in prairie dog town (Purple three-awn Fetid Marigold Herbaceous Vegetation). WICA completed a Black-Tailed Prairie Dog Management Plan in 2006 with the chosen alternative of 405 to 1,214 ha (1,000 to 3,000 ac) of.prairie dog town area (NPS 2006). An estimation of prairie dog town area in WICA during 2010 is approximately 1,133 ha (2,800 ac) (from WICA GIS data on prairie dog towns 2009-2010). The change in vegetation from prairie dog colony expansion over the last decade is not represented in the 1999 vegetation map, supporting the need to update the vegetation mapping products. The park is at a minimum of 10% early seral vegetation based on 1,133 ha. (2,800 ac) of prairie dog towns relative to the full area of the park 11,318 ha. (28,295 ac).

A confounding factor for seral stage assessment at WICA in recent years is the non-native, invasive plant species, white horehound. It has increased from 2004 to 2008 to cover approximately 243 ha (600 ac) in WICA prairie dog towns. Horehound is replacing native early seral prairie dog town vegetation and is unpalatable to prairie dogs and other herbivores. In some cases, it is causing displacement of prairie dogs due to their increased risk of predation in areas of tall, unclipped horehound plants. At this time, it is unknown how long horehound will persist in these infestations - an invasive-dominated vegetation type of unknown seral character. Invasive species treatment is underway, but WICA is still learning about what site preparation, herbicide, and other variables are most effective in reducing horehound. Because horehound directly impacts prairie dogs and their endangered species host, the black-footed ferret, this situation is of great concern to WICA wildlife management.

Ponderosa pine forest cover

According to the vegetation map from 1999, ponderosa pines cover approximately one third of the park's surface. Mature ponderosa pine trees are generally considered fire resistant, or damaged only when fire burns 60% or more of the crown (NPS 2010a). Fire suppression has stopped the natural thinning that wildfires once provided to ponderosa pine forests and woodlands in the Black Hills. This has resulted in even-aged stands across the Black Hills. Ponderosa pine seedlings are prolific and quite shade tolerant, growing in the shade of mature trees, competing with each other and with grasses and forbs (NPS 2010a).

Before fire was widely suppressed across the landscape, wildfires thinned the forest and prevented broad-scale expansion of pine trees into adjacent prairies. After fires burned through young seedling- and sapling aged stands, only a small number of trees would survive, allowing for trees of different age classes to exist in a given stand. In addition, fires varied in their effects and in their spatial distribution, creating a mosaic of different stand ages and forest structures across the landscape of the Black Hills. This mosaic of stand ages and structures represents healthier forests than those dominated by even-aged stands.

Ponderosa pines have generally increased in density and expanded into prairies across much of the Black Hills over the last century. Photographs from 1874 compared with photographs from the early 1970s indicate dramatic increases in ponderosa pine densities and invasion into meadows (Prokulske 1974, as cited in Brown and Sieg 1996). McAdams (1995) measured increases in ponderosa pine tree densities and basal areas in the Black Hills forests, and quantified up to a five-fold increases in trees between 1-20 cm (0.4-7.9 in) in diameter from 1874 to 1995.

Brown and Sieg (1996) suggest that since "…ponderosa pine forests are not burning today nearly as often as they did in the past," they are generally increasing in density and extent across the Black Hills. In addition, According to Brown and Sieg (1996), changes in ponderosa community structure and function are directly or indirectly attributed to fire exclusion, and the authors describe the specific changes: 1) overstocked patches of saplings and pole-sized trees; 2) reduced tree growth and increased mortality, especially of the older trees in a stand; 3) stagnated nutrient cycling; 4) increased irruptions of insects and diseases; 5) higher fuel loads, including increased vertical fuel continuity ("ladder fuels"); 6) decreased stream flows; and 7) less wildlife habitat for species dependent upon herbaceous vegetation.

The cover of ponderosa pine in WICA, as observed by Brown and Sieg (1996), share a similar history to densities measured by McAdams (1995). However, the park has been conducting prescribed burns since 1973 in an attempt to restore fire as a natural process across the park. Prescribed fires and wildfires have resulted in substantial reductions in ponderosa pine cover. WICA staff have observed these reductions over the last decade. A comparison of photography from the 1990s and 2010 in the Highland Creek Wildfire perimeter (north central portion of the park) illustrates such a change (Figure 2). Other fires occurring from 2000-2009 each had impact on a significant area of ponderosa pines (as observed from comparing the 1999 vegetation map (Cogan et al. 1999) to current aerial photography). These fires include Tower prescribed burn, the southeastern portion of Bison Flat prescribed burn (2001), Campground prescribed burn (2005), Centennial prescribed burn (2006), Headquarters West prescribed burn (2009), and the recent (2010) American Elk prescribed burn. In some areas that have not experienced fire in the last decade, WICA personnel have observed increases in pine densities and encroachment of ponderosa pine into grasslands.

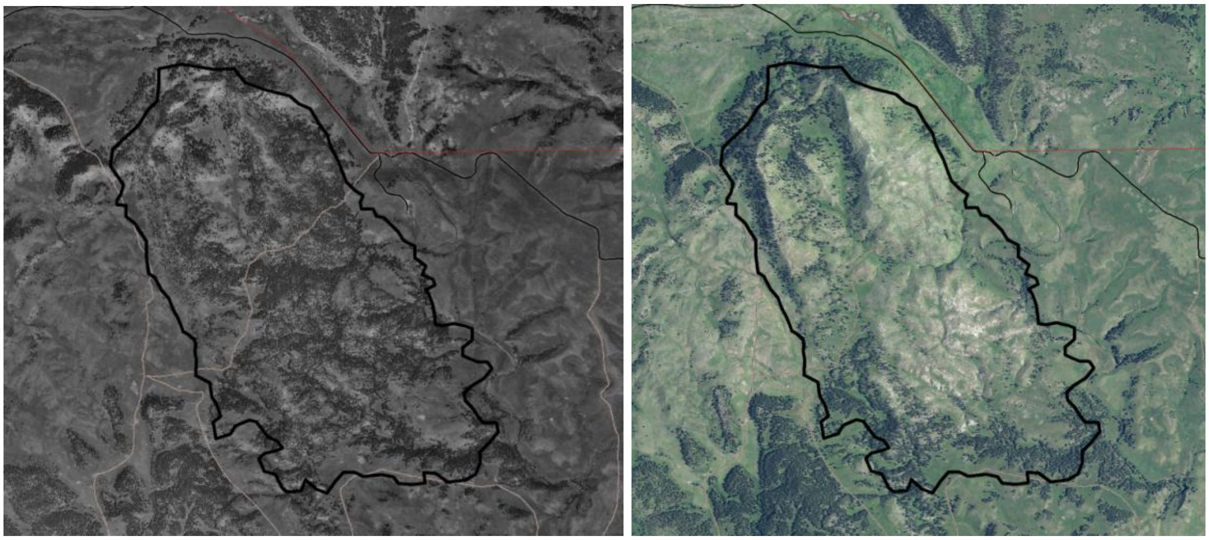

Figure 2. Perimeter of the 2000 Highland Creek Wildfire on 1990s black and white aerial photography (left) and 2010 true color aerial photography (right). Notice vegetation change from fire - substantial reduction in ponderosa pine cover (Burkhart 2011b).

WICA's fire management policy directs management to suppress all fires no matter the source of ignition. Total fire suppression is necessary because of the small size of the park; however, wildfires do occur and it is not always possible to suppress them immediately. The WICA Fire Management Plan warns that a large fire would temporarily force grazing animals onto unburned areas and that potential over-grazing could have a negative impact on the park's vegetation. Other important considerations regarding fires include the inconvenience to visitors and the potential danger to human life. The management plan also recognizes that the park needs to be aware of the effects fires may have on adjacent landowners (NPS 2010a). Finally, the plan recognizes that a higher frequency of fires could move grassland community types into earlier seral stages.

The fire management policy at WICA also specifies the use of prescribed fires to achieve a more "natural" state. Since large fires could have a variety of negative effects given the park's relatively small size, prescribed burns are set to mimic wildfires and to meet current management goals. The three primary goals of prescribed fires are to reduce accumulated fuel levels, reduce ponderosa pine encroachment on the grasslands, and eliminate non-native plants (namely invasive plant species), while increasing the diversity and health of native plant communities (NPS 2005). For more specific information regarding fire management and general status of fire in WICA, refer to the Fire Regime Section (Chapter 4.2)

<u>Shrubland cover</u>

Shrubland cover offers important habitat and forage for native fauna (e.g., deer and elk) in WICA. For example, mountain mahogany shrublands (a late seral community type on limestone bedrock substrates) are very valuable winter forage areas. The amount and condition of shrubland cover across the park's landscape is also important for understanding plant biodiversity. According to the 1999 vegetation map, the extent of shrubland cover is 854 ha. (2,110 ac) or 7.4 % of the total park area. Cogan et al. (1999) describes shrublands in the 1999 vegetation map as including: Creeping Juniper/Little Bluestem Dwarf-shrubland, Mountain

Mahogany/Sideoats Grama Shrubland I, Leadplant Shrubland, Chokecherry Shrubland, and Western Snowberry Shrubland .

The shrubland cover type of greatest extent in WICA is Western Snowberry Shrubland, followed by Chokecherry Shrubland, and Mountain Mahogany/Sideouts Grama Shrubland. Creeping Junipers/Little Bluestem Dwarf-shrubland is a rare plant community type.

Riparian cover

Riparian cover is limited in WICA and represents valuable habitat for many species of wildlife. Generally a high diversity of plants is represented in a mosaic of riparian community types. According to the 1999 vegetation map data, a total of 345 ha. (852 ac) are mapped as riparian vegetation associations, representing approximately 3% of the total park area. Mapping units included in this estimate include Emergent Wetland Complex, Western Snowberry Shrubland, and Plains Cottonwood/Western Snowberry Woodland. Cogan et al. (1999) states that riparian vegetation is diverse and occurs along the Park's streams and wet meadows. The authors also note that multiple riparian types often occur together in a mosaic of small patches. Riparian vegetation communities in the area also include the Prairie Cordgrass – Sedge Community and the Western Great Plains Streamside Vegetation Community. Cogan et al. (1999) note that the small creeks, streams, and drainages are mapped as linear wetland features, and that the primary riparian corridor in the park is along Beaver Creek.

The riparian cover type of greatest extent is Western Snowberry Shrubland. There are small areas of Emergent Wetland Herbaceous Vegetation (total of 10.5 ha. or 25.4 ac) and a very limited area of Plains Cottonwood/Western Snowberry Woodlands (total of 1.3 ha. or 3.1 ac).

Threats and Stressor Factors

NPS natural resource staff at WICA provided a list of stressors and natural factors that affect landcover for this assessment. These included fire suppression, ponderosa pine, mountain pine beetle, non-native and invasive plant species, vegetation removal, human use areas, trails, and use of Native American ceremonial areas.

Changes in ponderosa pine distribution and density due to altered fire regimes over the last century can be viewed as a stressor to overall land cover. For example, ponderosa pines could be considered a stressor to other plant communities, namely the grassland communities. Without frequent, low-intensity surface fires, pines expand into meadows and can out-compete many of the grasses and forb species. Specifically, they can reduce water availability for other plants, and shade them out as they develop into dense stands of thin trunked trees, often referred to as "dog-haired" stands (Flanderka 1995).

Mountain pine beetle

The mountain pine beetle (MPB), could contribute to reducing the overall cover and density of ponderosa pines in WICA. MPB are native to pine forest ecosystems of the Black Hills. MPB may be considered a natural stress factor to individual pine trees and forest stands, but infestations and their effects are a natural shaper of landcover. That is, MPB acts with fire to change the temporal and geographic distribution and diversity of age classes and tree densities of ponderosa pine forests and woodlands across the landscape.

Epidemic levels of MPB infestations are capable of killing millions of trees; over 1.4 million ha (3.6 million ac) were impacted in northern Colorado and southeastern Wyoming from 1996 to 2009 (USFS 2011). Such adverse impacts on forest values have long been recognized. However, it has also become apparent that MPB disturbances, in conjunction with other natural disturbance agents, play a major role in maintaining the structure and function of healthy ecosystems (Mock 2007, as cited in Burkhart 2011a). MPB were first documented in the Black Hills in the late 1890s through the early 1900s, killing approximately 1-2 billion board feet of timber. Subsequent outbreaks lasting 8 to 13 years occurred in the 1930s, 1940s, 1960s, and 1970s. Today, the USFS conducts aerial surveys of MPB infestations across many western forests. A MPB epidemic has been documented in the Black Hills for the last decade, with areas of infestations including the Harney Peak/Mount Rushmore National Memorial and nearby Custer State Park vicinity. WICA resource staff documented MPB-infested trees in the park and are currently working on a strategy to address this natural disturbance. Part of this strategy development involved the creation of an MPB risk map. A risk level is assigned to each map class in the 1999 WICA vegetation map (Cogan et al. 1999), shown in Table 4. This is based on the percent cover of ponderosa pine on each map class. If the percent cover was lacking in the map class definition, WICA botanical expert opinion was enlisted to categorize risk levels based on experience with the map classes/vegetation types. WICA staff determined four levels of risk:

No risk – vegetation types and map classes not including any component of ponderosa pine (grasslands, shrublands, and non-ponderosa pine forests/woodlands).

Low risk – vegetation types and map classes with widely spaced ponderosa pine (pine woodlands, grasslands and woodlands with burned pine).

Moderate risk – vegetation types and map classes with lower density of ponderosa pine.

High risk – vegetation types and map classes with higher density of ponderosa pine.

Table 4 displays the map classes and risk level applied to each vegetation type in WICA.

Table 4. Mountain pine beetle risk levels assigned to vegetation types for WICA mountain pine beetle risk assessment. Map classes not included in a vegetation type are listed but identified as map class (Burkhart 2011a).

Risk Level by Broad Vegetation Type	Specific Vegetation Types and Map Classes
NO RISK Sparse vegetation	Redbeds (Siltstone, Sandstone, Gypsum) Sparse Vegetation Black Hills Granite/Metamorphic Rock Outcrop Sparse Vegetation Shale Barren Slopes Sparse Vegetation White Sedimentary Rock Outcrop (map class) Recent Burn Sparse Vegetation Bison Wallows (map class)
NO RISK Graminoid and herbaceous vegetation	Northern Great Plains Little Bluestem Prairie Western Wheatgrass – Green Needlegrass Mixed grass Prairie Big Bluestem – Little Bluestem Western Great Plains Herbaceous Vegetation Kentucky Bluegrass Herbaceous Vegetation Cheatgrass Annual Grassland Introduced Weedy Graminoid Herbaceous Vegetation Needle and Thread – Blue Grama Mixed grass Prairie Prairie Dog Town Grassland Complex Prairie Cordgrass – Sedge Wet Meadow Creeping Spikerush Wet Meadow Western Great Plains Streamside Vegetation
NO RISK Shrubland vegetation	Mountain Mahogany/Side-oats Grama Shrubland Leadplant Shrubland (map class) Chokecherry Shrubland Beaked Willow Shrubland Western Snowberry Shrubland Creeping Juniper/Little Bluestem Dwarf-Shrubland
NO RISK Non-pine tree forests and woodlands	Cottonwood/Western Snowberry Floodplain Woodland Boxelder/Chokecherry Forest Green Ash-American Elm/Western Snowberry Forest Birch – Aspen Stand (map class) Bur Oak Stand (map class)
LOW RISK Widely spaced ponderosa pine	Ponderosa Pine/Sunsedge Woodland Ponderosa Pine/Little Bluestem Woodland Ponderosa Pine/Western Wheatgrass Woodland Grasslands and Shrublands with Burned Pine (map class) Ponderosa Pine Limestone Cliff Sparse Vegetation
MODERATE RISK Lower density ponderosa pine	Ponderosa Pine Complex II (15%-75% Cover) (map class) Ponderosa Pine/ Chokecherry Forest Young Ponderosa Pine Dense Cover Complex (map class)
HIGH RISK Higher density ponderosa pine	Ponderosa Pine Complex I (75%-100% pine cover) (map class) Ponderosa Pine/Common Juniper Woodland

The process of updating the 1999 vegetation map to a 2010 status began by NPS staff focusing on the major changes in forested areas (i.e., areas that have changed from forest to grassland or vice versa). A photo-interpretation exercise resulted in a preliminary 2010 map, without any field validation (Burkhart and Kovacs 2011). Prior to one of the largest prescribed fires in WICA history (the October 2010 American Elk prescribed fire), results of the MBP risk mapping exercise indicated 295 ha. (729 ac) of the park at High Risk for MPB (2.5%), 1,743 ha. (4,306 ac) at Moderate Risk (15.3%), 1,252 ha. (3,095 ac) at Low Risk (11%), and 8,135 ha. (20103 ac) at No Risk (71.2%). With some uncertainties related to photo-interpretation expertise and using true color instead of color infrared aerial photography, the map displayed in Plate 4 shows the best estimate of MPB risk levels in WICA in 2010 based on updated vegetation polygons.

Non-native plants
Non-native plant species continually encroach in native plant communities. Non-native (also referred to as exotic) plants, especially those that are invasive, threaten native plant community structure and function. If changes were to occur at a broad enough scale, they could collectively alter land cover. WICA park management employs a number of different tools and resources such as the Northern Great Plains Exotic Plant Management Team (NGP EPMT) to treat infestations of a variety of plant species using integrated pest management techniques.

Precipitation timing and intensity
The timing and intensity of precipitation is a natural factor that can drive vegetation composition and structure. Precipitation timing and intensity are components of climate, and are important in examination of potential ecological effects of climate change. Temperatures in the Northern Great Plains have risen more than 2 °F over the last century, and climate models predict continued increases of 5-12 °F, with increases in precipitation during this century (National Assessment Synthesis Team 2000). However, different climate models have different predictions relative to whether increased precipitation will be balanced with evapotranspiration, or if there will be an increase in droughts (National Assessment Synthesis Team 2000). A climate change project currently underway at WICA will provide more specific model information for the park and the Black Hills region, as changes in precipitation are highly uncertain for this specific area.

Park management activities
Park management activities such as prescribed burns, vegetation removal (both non-native invasive plant removal and removal of fire fuels), construction projects, and even wildlife population management affect landcover in WICA. While prescribed burns restore ecological processes of fire to the landscape, they can also have potentially negative results in the short-term. For example, they can provide establishment sites for early seral non-native plants. Vegetation removal from fire may cause some localized disturbances and allow for more early seral species to establish. Fuel reduction is a practice conducted in order to reduce potential for severe fires and their associated effects on vegetation recovery. However, this activity does not usually occur at a scale large enough to affect land cover type. Construction projects also may cause localized disturbances offering establishment sites to some invasive non-native plant species. Finally, large numbers of elk can be a stressor to broad land cover, and more specifically, to some plants species and communities. There are concerns that recent high elk numbers in the park are causing damage to existing native plant communities by overgrazing in some upland areas and overuse of some riparian areas.

Human use
While the vast majority of WICA's land surface is vegetated (mostly with native plants), the land cover of some areas is influenced by continued human use. Developed areas such as parking lots,

roads, park structures, trails, and Native American ceremonial areas are examples of such areas. Developed areas in the park are dominated by impervious surfaces (pavement or roofs) and some trails and ceremonial areas contain higher non-native plant species cover relative to other areas of the park due to increased disturbance that opens niches for early seral, weedy species.

Data Needs

The park's landscape has experienced varied levels of human disturbance, both prior to the land being established as a park and since park establishment (NPS 2009a). However, the level to which these collective disturbances have affected the native plant communities and the overall balance of seral stages, forest, shrub, and riparian cover and related natural processes is not well understood.

The vegetation map produced by Cogan et al. (1999) is no longer accurate because significant changes in vegetation have occurred in some areas of WICA. WICA staff are in the process of using aerial photo-interpretation and ground truthing to create an update to the vegetation mapping products. WICA staff have observed that fires, both wildfire and prescribed, have generally reduced pine cover and density in some areas, whereas the lack of fire in other areas has allowed an increase in ponderosa pine density and extent. Most non-native species are not widespread or dense enough in WICA to be a mapable scale consideration for land cover class. One exception is white horehound. Primarily occurring in the prairie dog towns, this invasive species could have serious implications to the balance of seral stages across the park. It is not yet clear what seral stage this species represents so it complicates estimation of park-wide seral stage composition and balance.

Seral stages of plant community types across the park's landscape have not been determined and therefore represent a data gap. Information regarding the seral stages could help inform the condition of land cover, in terms of its relationship with nearly all terrestrial natural resource management priorities. The dynamic nature of these seral stages must also be investigated and understood in order to inform park management.

Collecting information on all prairie dog towns to determine seral stage would be informative for park management. However, data would be temporal in nature and therefore complex. The condition, structure, and species of vegetation present in a prairie dog town are affected by the length of time prairie dogs have been present in an area. From observations, D. Uresk generalizes that a grassland type will convert to a prairie dog town vegetation type within 2 years of occupation, and can revert to grassland after ca 9 years of rest from prairie dogs (Burkhart, pers. comm., 2011). However, other factors such as precipitation, temperature, prairie dog reproductive success, vegetation use by other herbivores, and invasive plant species make every case individual.

In areas where grassland community species composition is still present within prairie dog towns, Burkhart (pers. comm., 2011) suggests that composition is dynamic. Burkhart hypothesizes that seral stage determination using Uresk's protocols would show that the grassland vegetation type is in an early seral expression/condition due to prairie dog disturbance activities. This may be a precursor to conversion of the grassland type to prairie dog town vegetation type given longer time of prairie dog occupation and development of a more mature town. This may be determined by collecting vegetation data in prairie dog towns.

Burkhart also suggests that prairie dog density may have a more significant relationship to vegetation type/seral stage than the area of prairie dog towns. For example, a large area of low-density prairie dogs might result in less disturbance to vegetation than a small area of high-density prairie dogs. Therefore, a large area of high-density prairie dogs might cause greatest disturbance to vegetation. A large area with a range of different prairie dog densities may result in variability of disturbance to vegetation. One factor that may affect prairie dog density is the age of town/occupation. Finally, Burkhart (pers. comm., 2011) also suggests that perhaps a more sophisticated pattern of vegetation type/seral stage related to prairie dog density would emerge, preferable to what appears to be a random, variable pattern between vegetation type/seral stage and prairie dog town area.

There are no specific management targets for the extent of shrubland, ponderosa pine, or riparian cover.

Overall Condition

The overall condition of land cover is unknown due to the lack of data for each measure. No data exists to determine seral stage balance in the past for reference purposes. Seral stage determinations have not been made for current WICA vegetation. In order to accomplish a landscape level investigation of seral stage balance, it would be necessary to collect or develop seral stage data at the level of the 1999 vegetation mapping products (i.e., by community type polygons). A snapshot of the amount of ponderosa pine, shrub, grassland, and riparian cover in WICA can be determined by examination of the 1999 vegetation map but seral stage cannot be simply assigned by cover type in most cases. Since WICA staff have observed substantial changes in park vegetation over the last decade, the 1999 map is not representative of current vegetation across the entire park. No management objectives exist for the composition of each of the land cover types (riparian, grassland, shrubland, and ponderosa pine).

Source of Expertise

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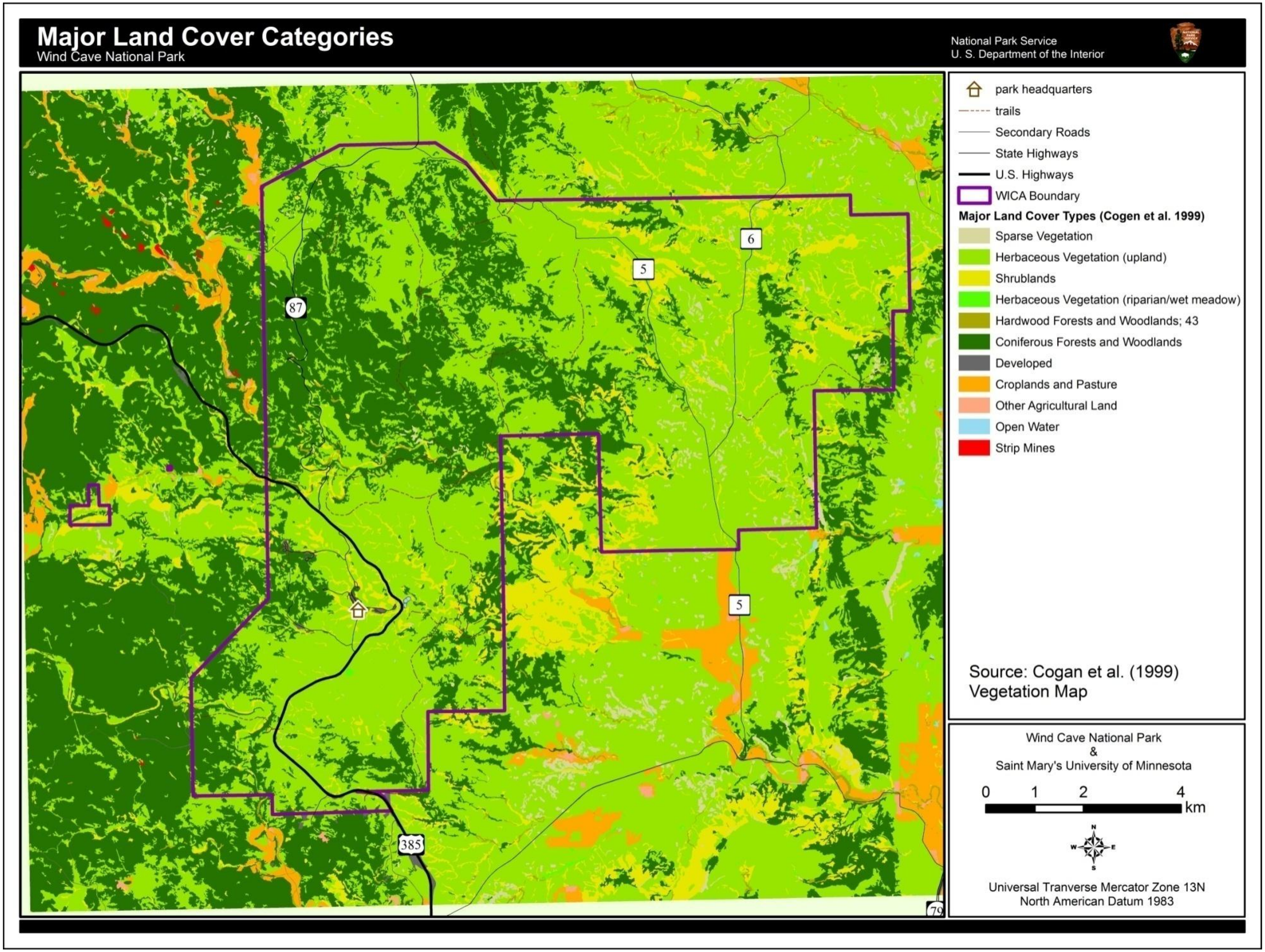

Plate 3. Major landcover categories in WICA (Cogan et al. 1999).

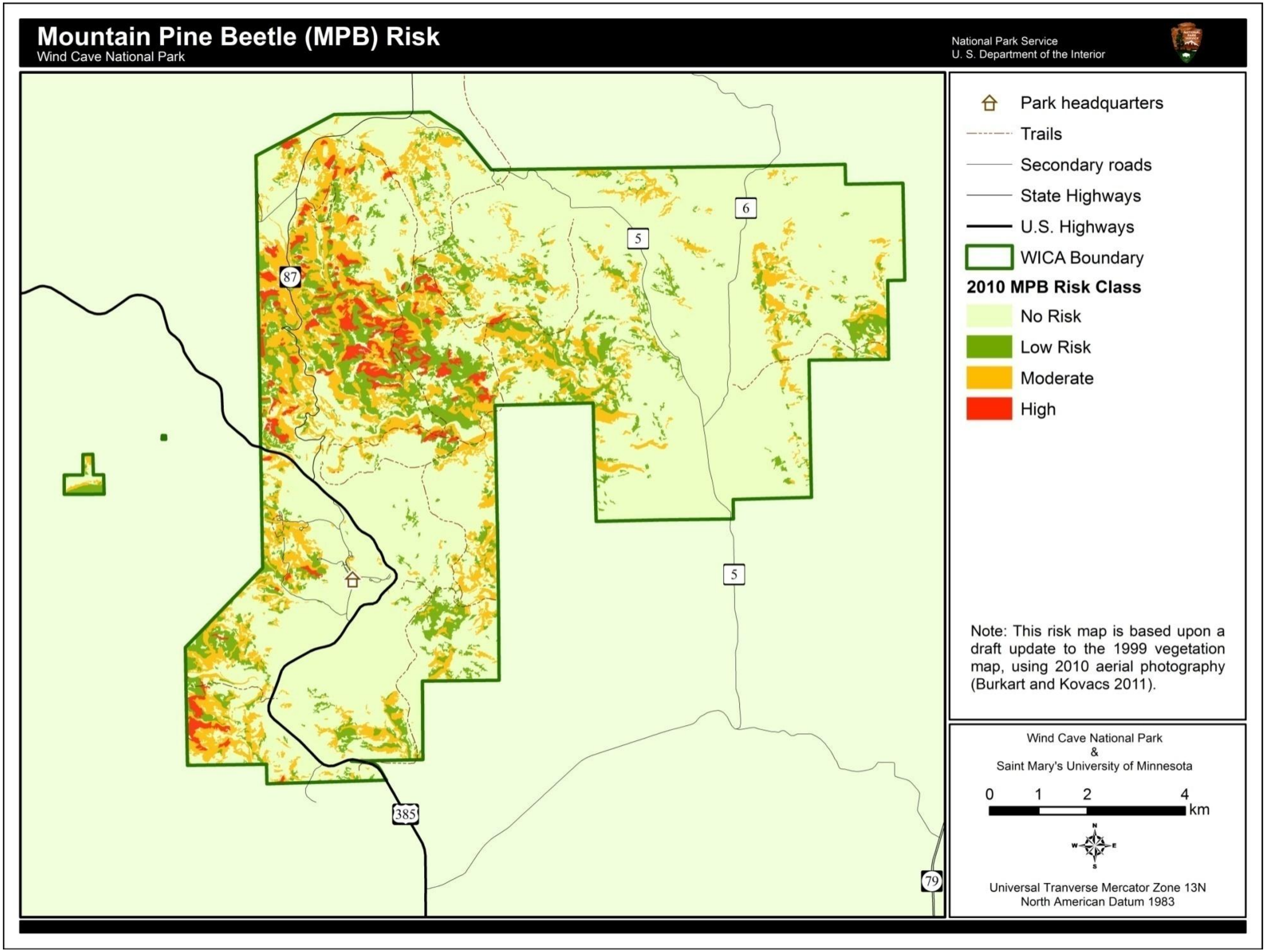

Plate 4. Mountain pine beetle risk map (draft) (Burkhart and Kovacs 2011).

4.2 Fire Regime

Photo 4. Head fire moving into a ponderosa pine stand - Headquarters West prescribed fire (NPS 2011).

Description

The NPS Fire Program defines fire regime as the combination of frequency, predictability, intensity, seasonality, and size characteristics of fire in a particular ecosystem (NPS 2010e). During pre-European settlement times, fire regime in the Black Hills was generally characterized by light and frequent surface fires (Brown and Sieg 1996, NPS 2005). Following European settlement in the late 1800s, large landscape scale fires became virtually non-existent (Brown and Sieg 1996). Typically, settlers suppressed fires and, consequently, ponderosa pines expanded into the prairie, displacing hardwood trees and increasing the density of younger, even-aged pine trees in forest stands. This created a monoculture of ponderosa pines; in some places, ponderosa pine density was such that a lack of sunlight penetration reduced forest floor vegetation (NPS 2010b).

Today, the WICA fire management plan directs that all fires be suppressed in the park regardless of the ignition source (NPS 2005). The plan identifies that suppression is necessary, even in the case of lightning-caused fires. Lightning-caused fires in larger parks may be left to burn if not threatening areas such as adjacent private property, cultural resources, or park infrastructure, but since WICA is relatively small, these fires are suppressed (NPS 2010c). Considerations must be made for the protection of human life, both employee and public; the protection of facilities, cultural resources, archeological sites, and fences; the perpetuation of natural resources and their associated processes; and the consideration of any effects of fire to the park's neighbors (NPS 2010c). Specific areas identified as fire prevention zones in WICA include the visitor center/housing zone, Elk Mountain campground zone, buffalo corrals zone, Hwy 385 and Hwy 87 Corridor Zone, and the mixing circle zone.

However, while wildfires are suppressed, one of the park's purposes is to preserve the natural processes of the mixed-grass prairie ecosystem (NPS 2005). WICA is located at the confluence of the ponderosa pine forests of the Black Hills and the mixed grass prairie (Bachelet et al. 2000). At this confluence, prairie and forest fires are natural disturbances that are essential to the maintenance of the mixed-grass prairie and ponderosa pine ecosystems (NPS 2010c). Without the effects of fire, the prairie would change and could even disappear as trees and woody shrubs would continue to establish in the grassland communities (NPS 2009b). In place of natural fire, prescribed burns were first initiated in 1973 to

> create more natural conditions at Wind Cave by preventing pine encroachment into grasslands, opening dense thickets of pine, reducing exotic plants, invigorating stagnant grasslands, controlling forest insect epidemics, increasing vegetative diversity, creating seral vegetative stages necessary for many wildlife species, improving wildlife distribution, re-establishing stream flows, and possibly controlling some wildlife populations such as black-tail prairie dogs (Lovass 1976, pg. 71).

The current Fire Management Plan defines prescribed fire as "any fire ignited by management actions to meet specific objectives" (NPS 2005, pg 4). Burns are specifically used to "reduce hazard fuels, restore the natural vitality and variability of ecosystems, remove or reduce alien species, and to conduct research into fire effects" (NPS 2005, summary pg. i). They are calculated and carefully planned events that consider elements such as wind conditions, weather, season, humidity, the amount of moisture in the dead vegetation, and the quantity and availability of fuel. The long-range fire management goal as of 2005 was to stabilize and/or establish ecosystems that approach pre-European settlement ecosystems that may have existed at WICA (NPS 2005). However, WICA's current management goal dismisses historic condition, as scientists and managers have recognized that reaching historical conditions are neither possible nor desirable.

In addition to the long-range goals, individual burns are used to accomplish a variety of specific management goals including creating fuel breaks, reducing unnatural fuel loads, and reducing fuel hazards around structures inside and adjacent to the Park and along boundary areas. The 2001 Working Group (U.S. Department of the Interior [DOI] and USFS 2001) concluded that fire exclusion, through fire suppression, has resulted in continued deterioration of the condition of fire-adapted ecosystems in the Black Hills and that fire hazard in these areas was worse than previously understood (NPS 2005). It is also important to note that in addition to prescribed burns, fuel management also includes non-fire fuel treatments such as manual, mechanical (use of feller-buncher [harvester used in logging]), and mowing to reduce fuel loads and thereby the risk of high severity fires.

Measures

- Return Interval (frequency): time in years between two successive fires in a designated area
- Severity: low, med, high, mixed severity class determined by plot samples or by satellite imagery using Normalized Difference Burn Ratio (nDBR), (pre-fire and post-fire comparisons).
- Extent: annualized burned area in WICA

Reference Conditions/Values

In the Black Hills forests, fire was one of the most prevalent natural disturbances among extreme weather, and insect and disease epidemics (Sieg and Severson 1996). In WICA, many factors contributed to the frequent fires, including: large contiguous areas; fine fuels; frequent hot, dry weather; and common lightning strikes (NPS 2005). Fires helped to limit the density and extent of ponderosa pine trees across the landscape, and resulted in distinct groups of even-aged trees with a wide range of size classes, that occurred as discontinuous stands (NPS 2005).

Fires occurring in pre-European settlement times in ponderosa pine forests were, most likely, primarily grass fires, and the introduction of livestock grazing reduced fine fuels necessary to carry fire for any distance beyond a point of ignition (Brown and Sieg 1996). Historic records indicate that fire suppression enhanced forest expansion in the Black Hills, and livestock grazing, which reduces grass biomass and fuel loads indirectly reduced fire frequency, also allowing for the expansion of forests or woodlands (Bachelet et al. 2000). While it is unclear to what extent grazing affected the landscape of present-day WICA, it is clear that there were some impacts.

Fire Return Interval

Fire return interval is defined as the time in years between two successive fires in a designated area, and is sometimes referred to as fire-free interval (Dickmann and Cleland 2010). It is often reported as mean fire return interval, the arithmetic average of all fire intervals determined, in years, in a designated area during a specified time period (Dickmann and Cleland 2010). A study in a northwestern Black Hills ponderosa pine stand found that frequent fires burned for at least 300 years before European settlement in the area, which effectively halted the natural fire regime (Wienk et al. 2004). Fisher et al. (1987) found the mean fire interval changed from 14 years from 1770 to 1900 (prior to major settlement) to 42 years from 1900 to 1987. However, WICA is located in the southern Black Hills ponderosa pine savannas, where mean fire intervals were historically shorter, approximately 10 to 12 years with ranges of 2 to 34 years in the park (Table 5) (Brown and Sieg 1999). The current fire management plan states the natural fire frequency in ponderosa pines is 10-25 years and 3-9 year for prairie areas in WICA (NPS 2005).

Table 5. Measures of fire frequency for three ponderosa pine savanna sites at WICA (GOB, PIG, and WCN). Fire intervals used in calculations are for all dates recorded on any tree at each site for the period of analysis (Brown and Sieg 1999).

Site	Period of analysis	No. of intervals	MFI (+/- SD)[1]	Range of intervals[2]	WMPI[3]	5% to 95% prob. Inter.[4]	Fire freuency[5]
WCN	1564 to 1896	27	12.3 ± 6.9	3-32	11.6	3.5-22.7	0.077
PIG	1528 to 1912	38	10.1 ± 5.8	2-23	9.3	2.3-20.3	0.100
GOB	1652 to 1910	21	12.3 ± 7.2	3-34	11.5	3.5-22.6	0.078

[1] Mean and fires standard deviation of all intervals in composite fire chronology in years.
[2] in years.
[3] Weibull median (50% exceedance) probability interval in years.
[4] Weibull 5% and 95% exceedance probability intervals in years.
[5] Slope of line of cumulative fire dates (number of fires year^{1})
Note: Gobler Ridge (GOB) is located in the southern portion of WICA, Pigtail Bridge (PIG) is located in WICA along the western boundary, and Wind Cave North (WCN) is in the Black Hills National Forest just to the north of the park boundary.

Brown and Sieg (1996) note that a study in the western Black Hills suggests frequent fire was present in ponderosa pine forests of the Black Hills and its exclusion may be at least partially responsible for historic changes seen in community structure and density. In addition, the USFS assessment of current forest conditions indicates fire is an important disturbance that has been limited during the last century due to aggressive fire suppression. This lack of fire has created an unhealthy forest with abnormal amounts of fuels that have led to the decline of many western mountain ecosystems. As a result, fire exclusion has made it more dangerous for those living in and near mountain forests as well as for those that fight fire in the forests of the Western U.S (Keane et al. 2002, as cited in Benson and Murphy 2003).

Fire Severity

For WICA, quantifiable measurements of natural fire severity or fire severity levels during pre-European settlement times are lacking. However, Lovaas (1976, citing Weaver 1967, Biswell 1972, and Biswell et al. 1973), states that during pre-European settlement times, natural low intensity fires thinned ponderosa pine forests. While a differentiation between fire intensity and fire severity was not explicit during the mid-1970s, low-intensity, as used by Lovaas (1976), likely refers to low fire severity. These low severity fires prevented accumulation of heavy fuels and resulted in open-canopied forests during the 1800s (Benson and Murphy 2003). Fire research has also revealed shorter fire return intervals during pre-European settlement times than in post-European settlement times (Brown and Sieg 1996). Anthropogenic changes in the landscape allowed for the build-up of fuel, both live and dead. This increased fire severity and continues to present risks of severe fires in WICA (NPS 2005).

Fire Extent

Pre-European settlement fire extent in the Black Hills is not well documented. However, early explorers (circa 1880) reported lightning-caused fires of large extent in the Black Hills of South Dakota (Bachelet et al. 2000 citing other authors). In addition, Shinneman and Baker (1997) proposed that large, catastrophic disturbances were a part of the natural disturbance regime in the ponderosa pine forests of the Black Hills (as cited in NPS 2005). Since the establishment of the park in 1903, fire events in WICA were of various sizes and intensities (Cogen et al. 1999).

Data and Methods
See Appendix B.

Current Condition and Trend

<u>Fire-return Interval</u>
Although fire records are incomplete from early decades of the park, records from 1910 to 2003 indicate relatively frequent fires with a total of 317 fires (an average of four fires and 96 ha or 238 ac burned annually) (NPS 2005). While this information shows that fire is present in WICA on average every year, in terms of recreating natural fire return intervals, fire should burn the entire park every 10 to 25 years in forested areas and every 3 to 9 years in prairies (NPS 2005). Recent GIS fire history data (1986 to 2009) allows for determination of recent fire-return intervals. Kevin Stark of SMU GSS conducted a GIS analysis to determine how much of the park has not burned in recent history and of that area how much is considered prairie verses forest. The methods for this analysis are available in Appendix B.

The results of the analysis show that approximately 4,969 ha (12,577 ac) or 43 % of the park's total acreage of 11,426 ha (28,233 ac) have not burned from 1980 to 2009. This represents a period of 29 years, which is outside the accepted fire return interval for grasslands (3 to 9 years) and of the forest fire return interval (10 to 25 years) identified in the WICA fire management plan. The resulting layers of this analysis provide a representation of the dates of most recent fires and unburned areas (since at least 1980) for both grasslands (Plate 5) and forests (Plate 6). Over 38 percent of the total area classified as grassland in the 1999 vegetation map and over 52 percent of the forested area, as of the 1999 vegetation map has not burned since 1980 (Table 6). Adding areas that have not burned in more than nine years (maximum fire return interval for grasslands) the total percentage rises to over 60 percent of the 1999 grassland vegetation.

Table 6. Area and date of most recent burn by grassland and forested areas in WICA, 1980-2009. Grassland and forest areas were determined from the Cogan et al. (1999) vegetation map. Burned area information is from two NPS GIS datasets combined with redundancies eliminated (NPS 2010d).

	Grassland			Forest		
Year Burned	**ha**	**ac**	**% of total grassland** [a]	**ha**	**ac**	**% of total forestland** [b]
Unburned*	2,747.8	6,790	38.7	1,740.2	4,300.1	52.5
1980	8.3	20.4	0.1	1.6	4.0	0.0
1981	0.4	1.0	0.0	0.0	0.0	0.0
1982	0.0	0.0	0.0	0.0	0.1	0.0
1983	1.4	3.4	0.0	0.1	0.2	0.0
1984	0.4	1.0	0.0	0.4	1.0	0.0
1985	58.3	144.0	0.8	7.5	18.6	0.2
1986	0.0	0.0	0.0	0.0	0.0	0.0
1987	228.6	564.9	3.2	78.3	193.5	2.4
1988	274.5	678.4	3.9	122.4	302.4	3.7
1989	0.0	0.0	0.0	0.0	0.0	0.0
1990	0.0	0.0	0.0	0.0	0.0	0.0
1991	0.2	0.5	3.9	98.8	244.0	3.0
1992	141.4	349.3	2.0	38.0	94.0	1.1
1993	73.0	180.4	1.0	2.0	4.9	0.1
1994	30.4	75.1	0.4	1.3	3.3	0.0
1995	15.3	37.8	0.2	0.9	2.2	0.0
1996	36.2	89.6	0.5	3.8	9.4	0.1
1997	217.1	536.5	3.1	289.0	714.1	8.7
1998	0.0	0.0	0.0	0.0	0.1	0.0
1999	230.8	570.4	3.3	6.1	15.1	0.2
2000	495.4	1,135.2	6.5	289.2	714.7	8.7
2001	558.5	1,380.0	7.9	99.4	245.5	3.0
2002	503.3	1,243.8	7.1	88.0	217.6	2.7
2003	4.6	11.2	0.1	13.3	33.0	0.4
2004	713.2	1,762.4	10.0	85.4	211.0	2.6
2005	277.4	685.5	3.9	175.7	434.2	5.3
2006	23.3	57.6	0.3	61.7	152.5	1.9
2007	0.0	0.0	0.0	0.1	0.2	0.0
2008	30.0	74.2	0.4	13.0	32.2	0.4
2009	147.4	364.2	2.1	100.0	247.1	3.0
total:	6,967	17,543.8	100.0	3,316.0	8,195.0	100.0

*Unburned since at least 1986 (the beginning of the fire perimeters dataset used in the analysis).

Severity

Severity and intensity are distinct terms, though they are often incorrectly used as interchangeable terms. Fire severity, or sometimes referred to as burn severity, is a measure of the physical change in an area caused by burning. Fire intensity is the energy output from a fire

(Keeley 2009). Keeley (2009) states that fire severity is dependent on intensity and residence of the burn; it is often measured by above-ground and below-ground organic matter loss. Fire intensity influences fire severity and subsequently creates ecosystem responses (e.g., erosion, vegetation recovery) and societal impacts (e.g., loss of life or property, suppression costs) (Keeley 2009). Ecosystem responses to fires are often what resource managers are interested in most, and some of these responses correlate with measures of fire severity.

Photo 5. Prescribed fire team during pre-fire briefing (NPS 2011).

WICA fire management utilizes prescribed burns to simulate the frequent, low-intensity surface fires that occurred naturally in the area. Low-intensity as used here could correlate to low-severity because the effects of a low-intensity fire would often equate to low-severity in terms of its effects on vegetation. Low-intensity fires are important for the maintenance of soil nutrients, benefiting wildlife habitat and forage quality. Kerns et al. (2006) found that high severity prescribed fires create localized gaps favorable for the spread of early seral non-native and native plant species; these findings support the use of low-intensity, low-severity fires as a management tool.

Due to the potential responses high temperature ground fuel burns could elicit on soils and, consequently water quality, high severity fires are a concern in WICA (NPS 2005). These fires could affect surface and cave water quality and quantity. In addition, severity is an important measure because fuel loading may lead to high severity fires that could threaten local plant communities. Benson and Murphy (no date) suggest that post-European settlement activities, including mining, logging, and tourism, have created a landscape carved by numerous roads and a complex intermingling of public and private land. With the potential for severe fires, Benson and Murphy (n.d.) suggest this landscape could become dangerous to the local community.

Monitoring efforts by the NGPN Fire Ecology Program include measurements of fire severity, along with fuel loading, tree mortality, and biomass/soil moisture. Predetermined monitoring plots allow for burn severity measurements for both vegetation and substrate in WICA prescribed burns. In September 2009, a relatively large prescribed fire (263 ha) achieved reductions in total fuel load (66%) and 1000 hr fuels (81%). Initial estimates indicate that seedling, pole and over-story density reduction objectives will be met (NPS 2009a).

Fire Extent

To represent trends of fire extent in WICA, the 1980 to 2004 fire perimeter dataset is combined with the 1986 to 2009 fire perimeter dataset, with redundant fires eliminated based on repeating fire names and fire dates between datasets. The result is that all recorded fires burned a total of 12,183 ha (30,104 ac) over the thirty year period. Prescribed fires have burned a combined total of 10,176 ha (25,146 ac), and wildfire and other non-prescribed fires burned a combined total of 2,006 ha (4,957 ac) in the present-day park (1980 to 2009). Note that much of the burned acreage has likely burned multiple times during this period. The area burned annually since 1980 is variable for both prescribed fires and wildfires; however, the combined area burned is relatively consistent for 5-year moving average (Figure 3).

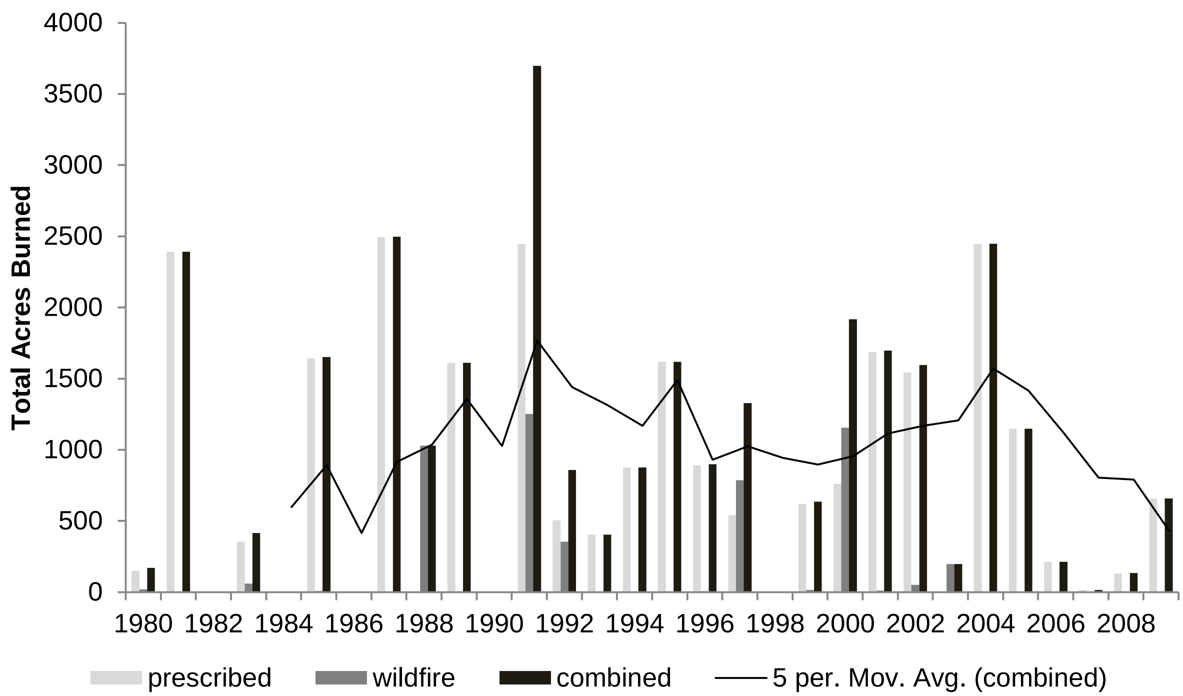

Figure 3. Annual burned area in WICA, 1980-2009. Note: area was calculated using fire perimeters clipped to current park boundaries.

From 1980 to 2009, the annual average burned area was 420 ha (1,003 ac). Taking the maximum of the range of ponderosa pine forest natural fire return interval (25 years according to the WICA fire management plan), a minimum average of 458 ha (1,132 ac) would need to burn annually in WICA to achieve this. While this annual average is significantly higher than the 96 ha (238 ac) per year average reported for from 1910 to 2003 in NPS (2005), this assumes that the majority of the landscape in WICA is ponderosa pine forests, which is not the case.

Threats and Stressor Factors

WICA staff identified many stressors regarding the three measures of fire regime. The following list describes these stressors.

Frequency

- Suppression – From 1930 to 1974, records indicate there were 79 lightning-caused fires and 33 human-caused fires suppressed in and near the park (Lovass 1976). Suppression of all unplanned fires continues as a part of the WICA Fire Management Plan, creating a situation in which the fire regime is almost completely dependent upon prescribed burning and non-fire fuel treatments.

- Changes of vegetation – Changes including invasive and exotic plant expansion into native plant communities, a potentially unnatural balance of grassland verses forest or woodland, and climate induced changes in vegetation may lead to changes in fire frequency, severity, and fuel dynamics.

- Fuel loading – Fire suppression has resulted in fuel loading. Fuel assessments are an important part of fire management planning and fire effects research. Fuel loading may prevent the use of prescribed fire due to increase fire hazards in certain areas and may require other non-fire fuel reduction methods.

- Grazing - "Overgrazing reduces fuel loads and thus fire frequency, favoring forest expansion. Vegetation can thus be affected by grazing as it prevents grasslands from dominating the landscape and promotes the expansion of shrubby woodlands until an increase in rainfall allows trees to replace them" (Bachelet et. al. 2000, pg 242). Historic cattle grazing contributed to fuel loads in WICA. Currently, only native ungulates and prairie dogs graze in the park. While the number of animals is managed by NPS, overgrazing by native undulates can still present a significant problem for certain native plant communities.

Severity

- Fuel loading – Fuel loading can result in more severe fires, which can have negative effects on soils and can increase fire hazards.

- Land cover changes –Fire cessation coupled with other impacts such as timber harvest has led to denser and more homogeneous forest structure across the Black Hills landscape (Brown and Cook 2005). While dense stands of ponderosa pines will likely always be present in future forests, what is lacking are the mosaics of open stands of variable density across the Black Hills of South Dakota (Brown and Cook 2005).

Extent

- Fuel loading - This could cause fires to burn larger areas because of increased intensity and potential for decreases in the effectiveness of fire suppression efforts.

- Suppression - This prevents the natural extent from occurring, especially in the case of large landscape scale fires.

- External/internal development – Existing and future development in and out of the park can prevent larger scale prescribed fires from being conducted. Areas identified as fire prevention zones include visitor center/housing areas zone, Elk Mountain campground zone, buffalo corrals zone, Hwy 385 and Hwy 87 Corridor Zone, and the mixing circle zone.

- Park size - "Given the potential for large-scale fires in the Black Hills, few management areas (NPS, USFS, etc) are large enough to allow for large-scale fires. Unless such areas are big enough, fire management risks burning the entire area, thereby jeopardizing recovery of both plants and animals. Large-scale fires can be patchy, mitigating this concern to some degree. Consideration could be given to using management techniques that emphasize natural values in management units adjacent to these areas" (Marriott et al. 1999).

<u>Data Needs/Gaps</u>

A three-year invasive plants research project started in 2010 is ongoing at WICA, Jewel Cave National Monument, and Devils Tower National Monument. This project is investigating the strategies for early detection of target invasive plants following prescribed burns. Fire effects research is ongoing, but there are several specific data needs. First, further research is needed to determine which fire techniques are most effective for changing vegetation composition from undesirable exotics to desirable native grasses and forbs. Second, research is needed to understand the effects of fire in hardwood shrub, woody draw areas. Third, an effort is needed in modeling the potential areas for reduction of forest extent/density and determining appropriate methods for treatment. Lastly, it would be beneficial to model potential areas suitable for hardwood expansion and to determine appropriate methods for treatment (NPS 2005). Recent monitoring results for five plots in the Kentucky bluegrass (*Poa pratensis*) monitoring type, covering three different bun units, indicate increases in native grasses and sedges of 17% and 59% respectively, while the average percent cover of non-native grasses decreased by 51%. Native forbs decreased by an average of 51%.

NGPN Fire Monitoring Program studies fire effects using different variables depending on the vegetation type (e.g., Ponderosa Pine Forest, Ponderosa Pine/Mixed-grass Savannah, Bluestem-Needlegrass Mixed-grass Prairie, Wheatgrass-Needlegrass Mixed-grass Prairie, Non-Native Perennial Grass). Variables examined include density of overstory, pole-size, and seedling ponderosa pine; cover of native and non-native species; shrub density; and total dead and down fuel load (NPS 2005). Fire Effects teams take measurements to determine if objectives are met using immediate post-burn, one, two, five, and ten-year post-burn measurements at each sampling plot.

Brown and Sieg (1996) suggest that it may be appropriate to focus as much attention on the variability of fire return intervals and their distribution across the landscape as the means of fire return intervals, when assessing impacts of disturbance dynamics in ecosystem and community function. This variability in fire frequency distribution represents a data need for further development of the parks understanding reference conditions of natural fire regime in WICA.

Overall Condition

Long-term fire suppression, initial logging, grazing, and agricultural activities altered fire regimes and have had a lasting effect on the WICA landscape. Since 1973, prescribed burning has attempted to recreate, to the extent possible, a natural fire regime.

According to fire-scarred ponderosa pines in WICA, from 1820 to 1910, the fire return interval ranged from 12 to 21 years (NPS 2005). The WICA Fire Management Plans specifies that fire-return intervals for WICA are three to nine years in prairie and ten to twenty-five years in forested areas. From 1986 to 2009, grassland fires fell outside natural fire return intervals in large sections of WICA, and a relatively large area of forest in the park is near or exceeding the maximum fire return interval of 25 years. According to fire perimeter data collected between 1980 and 2009 and a 1999 vegetation (land cover) map, nearly half of the grasslands have not burned in over nine years, and over half of the forested areas have not burned for at least twenty-three years. Although this is just outside the fire return interval range for forests, Battaglia et al. (2008) suggest that in order for successful maintenance of low densities of ponderosa pine seedlings, burns should occur every ten years, and that waiting until 20 years have passed would require more intense fires that are capable of burning more coarse woody debris.

Fire extents during pre-European settlement generally are unknown. Cogan et al. (1999) suggest that historic fires were of various size and intensities, and Shinneman and Baker (1997) suggest that catastrophic disturbances were part of the natural disturbance regime in ponderosa pine forests of the Black Hills. While large landscape fires may have occurred in the Black Hills during pre-European settlement times, current fire extents are constrained by the logistics of prescribed burns, weather, the size of the park, and the consideration for protection of particular land within the park and land adjacent to the park. The largest prescribed fire in the last 29 years burned an area of 956 ha (2,460 ac) in the park during 1987 fire season, and many others were of various smaller sizes. The American Elk prescribed burn on 20-22 October 2010, was the largest prescribed burn in WICA's history. This 3,400-acre unit consisted primarily of ponderosa pine forest, and the majority of this unit has not likely seen fire in approximately 100 years, however reliable GIS polygon data only begin in 1980. Small portions of the American Elk unit burned in the Lookout Point wildfire, Centennial prescribed fire, and the Rankin wildfires. Immediate post-burn plot monitoring indicate that most resource management objectives should be achieved including reductions in fuel loading, tree density, and encroachment of ponderosa pine regeneration at the forest-prairie ecotone (NPS 2010a).

Natural fire severity, although no park-wide documentation exists, is likely quite variable depending on a multitude of factors, including quantity of fuel available, the fuel's combustion rates, existing weather conditions, and landscape position. Current fire severity is measured on a plot-by-plot and individual fire basis, and is only measured in a small number of fires. The results of these individual fire severity measurements do not necessarily indicate the broader severity levels throughout many different prescribed fires in the park's history.

Managers, even in the best of conditions, have not been able to burn enough area to fully simulate natural fires regimes (NPS 2005). Five years since the acceptance of the WICA fire management plan, natural fire frequency and extent continue to be unmet by prescribed fire. However, over the last decade prescribed fires have burned a large portion of the land surface of the park, approximately 39 percent of the grasslands and 19 percent of the forests. In addition, recent fire effects monitoring reports that prescribed burns created moderate to low severity fires that mimicked natural, generally light surface fires. Several recent prescribed fires have proven to make strides in achieving specific goals of pine seedling density reduction and fuel reductions (NPS 2008, NPS 2009a). In addition, recent burns have decreased non-native plant species and helped native ones re-establish.

Sources of Expertise
Dan Swanson, Northern Great Plains Park Group Fire Ecologist.

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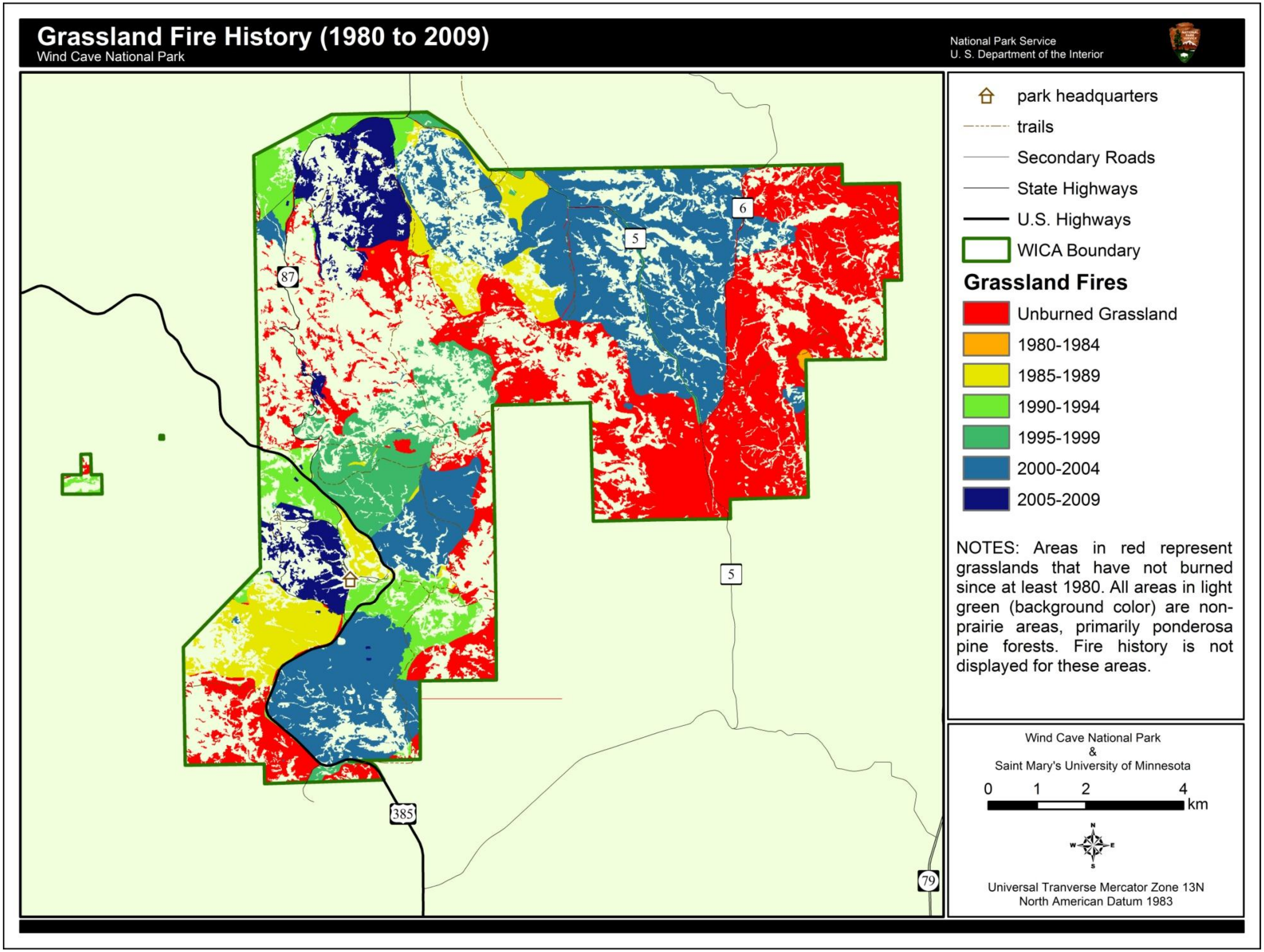

Plate 5. Grassland fire history, WICA, 1980 to 2009.

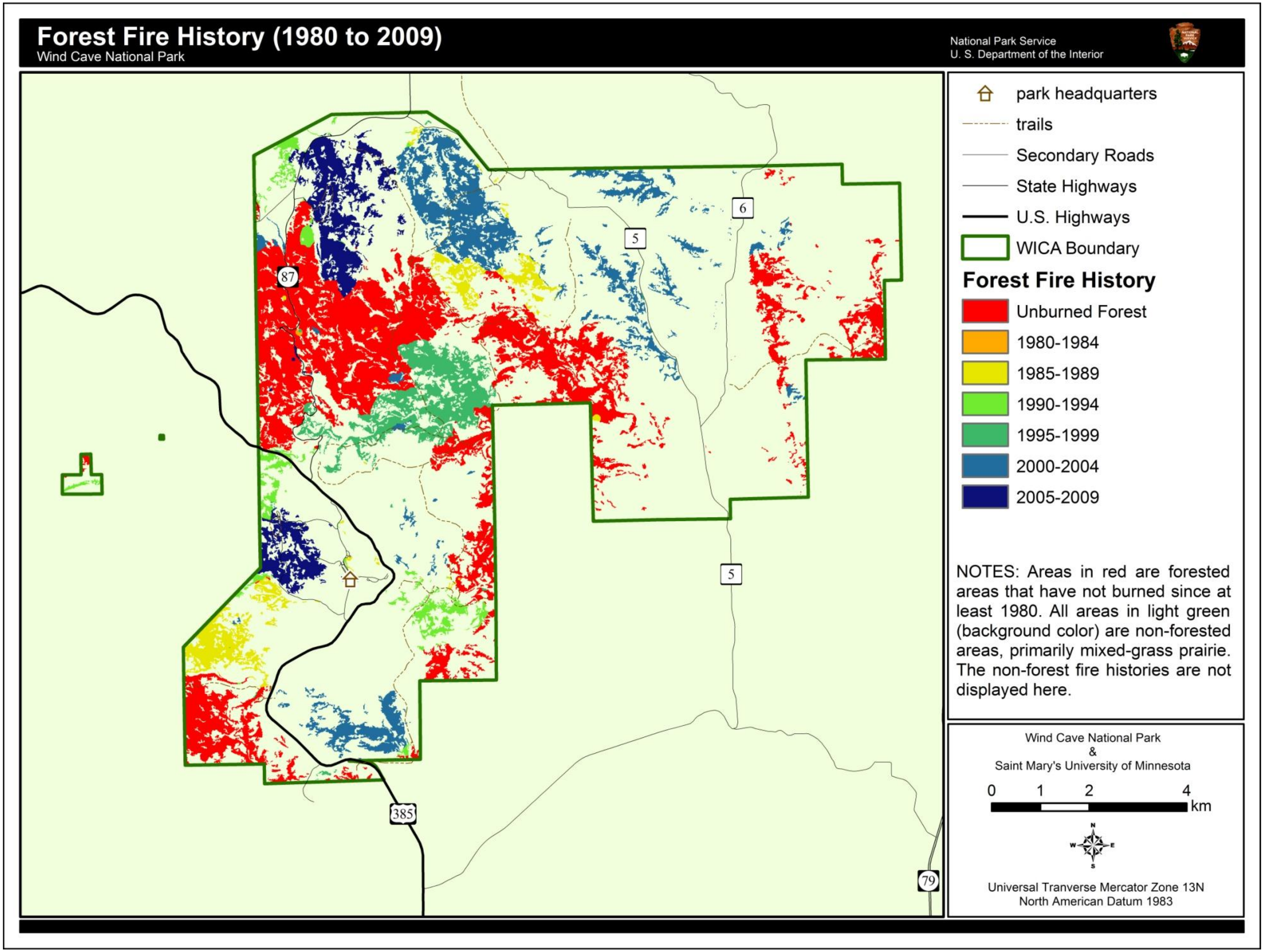

Plate 6. Forest fire history, WICA, 1980 to 2009.

4.3 Native Plant Communities

Description

Native plant communities are a significant resource in WICA; along with water, they form the ecological foundation for wildlife and many of the natural processes occurring within the park (NPS 2010b).

WICA's vegetation is not the best representation of a Northern Great Plains Prairie; rather, it represents its own unique ecotone between the Northern Great Plains and Black Hills ecoregions. The park contains 22 plant community types (Black Hills Community Inventory based on US National Vegetation Classification), nine of which are considered rare (i.e., NatureServe Global ranks of G1 to G3). Two-thirds of the park is covered by mixed-grass prairie, consisting primarily of blue grama, western wheatgrass, little bluestem, and threadleaf sedge (*Carex filifolia*). Ponderosa pines dominate the forest cover and, in some areas, ponderosa pine is found in conjunction with Rocky Mountain juniper (*Juniperus scopulorum*). Deciduous tree species in the park include paper birch (*Betula papyrifera*), plains cottonwood (*Populus deltoides*), aspen, bur oak and American elm (*Ulmus americana*) (NPS 2010b). Wooded draws and riparian vegetation represent a small proportion of the park landscape, but are integral to ecosystem function (NPS 2010b).

Native plant communities are viewed by WICA resource management staff as a significant natural resource for a number of reasons, including: 1) The park contains relatively undisturbed mixed-grass prairie area that may serve as a resource baseline; 2) the park's location at the juncture of eastern grasslands/western forest results in a diversity of species that are easily accessed by visitors and researchers; and 3) WICA provides a valuable opportunity for visitors to view a mixture of equally significant cave resources and portions of a larger prairie ecosystem and to appreciate the connections between surface and subsurface resources (NPS 2010b).

Regarding item number one above, it may not be appropriate to view WICA as a general purpose scientific baseline for mixed-grass prairies due to the wildlife priority and potential effects of large populations of herbivores (Burkhart, pers. comm., 2010). However, it may still represent an area that has been minimally disturbed [minimally disturbed defined by Stoddard et al. (2006) as containing one of the best available physical, chemical, and biological habitat conditions given the current state of the surrounding landscape].

Measures

- Ponderosa pine density and extent (stems/acre by size class)
- Native species of special concern (list and status of species)
- Native plant communities of special concern (list and status of communities)
- Non-native plant species density and extent (undefined)

Reference Conditions/Values

The reference conditions are native species, native plant communities and natural ecosystem processes.

It is important to note that a landscape without any non-native plants is not a realistic expectation for management. However, zero non-native plants acts as a baseline for comparison of current conditions and will serve as a comparison for future conditions.

Data and Methods

The methods used to develop this assessment were primarily review of available literature, synthesis of data from the park and outside researchers, and input and review by park specialists. Some additional literature was acquired via online literature databases.

Current Condition and Trend

Ponderosa pine density and extent

Ponderosa pine, a native tree in western North America, dominates coniferous forest communities in WICA and in the Black Hills. Ponderosa pine communities naturally compete with the mixed-grass prairie and other plant communities. This competition creates a naturally shifting balance between the prairie and the ponderosa pine forest. However, factors such as fire suppression, timber management, and increased precipitation have led to an expansion of ponderosa pine cover in parts of the Black Hills; even causing, in some areas, dense stands of even-aged pines and rapid expansion into grassland areas (Cogan et al. 1999).

Fire and its effects on vegetation is one of the main and possibly most influential processes or natural disturbances affecting ponderosa pine density and extent in WICA and across the Black Hills. A history of fire suppression, beginning in the late 1800s and continuing until 1973, in WICA resulted in increased density and extent of ponderosa pine stands (NPS 2005). Brown and Sieg (1996) note that a study in the western Black Hills suggests that frequent fire was present in ponderosa pine forests of the Black Hills and its exclusion (resulting from fire suppression efforts) may be at least partially responsible for historic changes seen in ponderosa pine community structure and density. The WICA Fire Management Plan recognizes that frequent fires and other disturbances, such as extreme weather, insect infestations and disease epidemics, once limited the density and extent of ponderosa pines across the landscape (NPS 2005).

In the past, natural fires prevented forest expansion in to grassland communities by killing many of the young trees that had established in open areas (NPS 2005). Prescribed fire aims to restore native grassland communities by reducing the extent of ponderosa pine forest and controlling encroachment into grasslands. The 2005 WICA Fire Management Plan describes the desired future condition of ponderosa pine stands as maintenance of open-canopy forest with over-story tree density in a range of 150 – 250 stems/ha (60-100 stems/acre) (NPS 2005). It also targets 50 to 80% of the ponderosa pine/mixed-grass community type burned within 7-15 years, depending on topography, to generate a mosaic of different aged stands across the type.

Ponderosa pine extent changed little from 2000 to 2010 (Swanson, pers. comm., 2010). The park's 1999 vegetation map (product of USGS/NPS/BOR Vegetation Mapping Project) provides an approximation of ponderosa pine current extent: approximately 3,318 ha (8,200 ac) or 29% of the park's land surface (Plate 7). While over 405 ha (1,000 ac) acres have burned in the park since 2005, only approximately 175 ha (432 ac) of this was forested area. Approximately 5% of the total forested area has been burned as of 1999 (NPS 2009d).

Current densities of ponderosa pines vary depending on the stand and the recent prescribed and wildfire history. The NPS fire effects monitoring team measures ponderosa pine over-story tree density and stand structure on a plot-by-plot and fire-by-fire basis. Typical management objectives for unburned forested burn units are to achieve at least 30% mortality in pole-size ponderosa pine (>1" and <5.9" or >2.5 and <15 cm diameter breast height [dbh]) or to achieve at least 70% mortality on seedling ponderosa pine (< 1" dbh or 2/5 cm dbh). According to monitoring plot data, recent prescribed fires in WICA achieved reductions in tree density with notable reductions in pole-sized trees and significant seedling mortality (Swanson, pers. comm., 2011).

<u>Native plant species of special concern</u>

WICA uses several different sources to determine plant species it focuses management attention on (i.e., plant species that are inventoried, monitored for persistence, and protected relative to park management activities). First, the U.S. Fish and Wildlife Service has a process of evaluation to establish Threatened and Endangered species based on a national context. There are currently no designated Threatened or Endangered plant species known to occur in South Dakota. Despite tremendous loss of habitat in the Great Plains, relatively few Great Plains species have been listed as Threatened or Endangered compared to other geographic areas of the country (Sieg et al. 1999). The relatively low number of listed species in the region may be related to the physiography and evolutionary history of the Great Plains. The lack of geographic barriers to dispersal has likely contributed to low plant endemism. Also, the Great Plains grasslands have evolved relatively recently (approximately 12,000 years ago), a short time period for endemism to develop. Lastly, it is likely that the variable climate and disturbance regime under which Great Plains ecosystems evolved has resulted in high rates of adaptability in resident species (Sieg et al. 1999). If there were threatened or endangered plant species in SD that occurred in WICA, the park would be required to consult with U.S. Fish and Wildlife Service (USFWS) regarding any actions that could impact the species and agree upon best management practices or mitigations.

Secondly, the state of South Dakota Natural Heritage Program (SDNHP) has a process of evaluation to establish plant species of concern based on a state-wide context. SDNHP tracks these species in the interest of supporting their long-term persistence in the state. There are currently 223 plant species on SDNHP state list of tracked rare plant species. Seventeen of these occur or have been reported to occur in WICA (Table 7). There are no legal requirements for managing SD rare/tracked species, but WICA's mission of preserving native vegetation unimpaired for future generations makes it a reasonable conservation choice to protect these species. The 17 state-tracked species are the object of inventory, monitoring, and protection relative to park management activities at WICA. Data on occurrences of these species are stored in park databases and in a GIS format.

Lastly, WICA recognizes plant species that are uncommon in a park-wide context. Persistence of these species of limited occurrence is important to WICA based on the park's mission to preserve native vegetation unimpaired for future generations. These 48 species of limited occurrence (Appendix C) are the object of inventory, monitoring, and protection relative to park management activities in WICA. Data on occurrences of these species are stored in park databases and spatial (GIS) format.

The lists of plant species that focus conservation attention are dynamic; changing as more information on abundance, distribution, autecology, and threats becomes known. In 1999, seven SDNHP rare/tracked species were known to occur in WICA, while eight additional species were thought to potentially occur based on available habitat (Marriott 1999). In 1998, WICA arranged with The Nature Conservancy (TNC) (H. Marriott, botanist) to undertake a focused floristic survey in the park. Before Marriott's survey project, 407 vascular plant taxa were documented in WICA. During the 1998 field season, 88 new records for the park were added, expanding the documented flora by 22%. In addition, the field investigation resulted in documentation of several locations of four SDNHP rare/tracked plant species not previously known to occur in the park. The TNC 1999 project was the first and last floristic-type survey completed at WICA. Additional floristic survey is needed in the park. It is highly likely that additional survey would provide more information on the native plant species in the park, including new locations of rare plant species. Additional floristic survey would also help provide a more robust baseline for characterization of climate change impacts over time.

Two notable species tracked by SDNHP and found in WICA are slender moonwort (*Botrychium lineare*) and Iowa moonwort *(Botrychium campestre)*. These are currently some of the species of greatest conservation concern known to occur in the park. Slender moonwort was a candidate for designation by the USFWS as a Threatened Species until 2007 when it was removed - in part because of the discovery of several large occurrences nationwide including the WICA occurrence. During 2005, Dr. Farrar, an Iowa State University botanist, found slender and Iowa moonwort in WICA as part of a Black Hills-wide moonwort survey. Dr. Farrar said,

> What is significant about this find is what it tells us about the prairie in the park. There is a very high diversity of native plants here and the discovery of the plant tells us this is a very healthy environment. This is the best native mixed-grass prairie we've seen in the Black Hills. (Tom Farrell – 2005 NPS Park News website).

Dr. Farrar continues to carry out moonwort survey throughout the United States (including the Black Hills) and will continue to produce information leading to better understanding of moonwort species distribution and abundance and a more accurate determination of their conservation status. WICA annually monitors the park's occurrence sites of slender and prairie moonwort and conducts surveys of new ground every year.

Table 7. Plant species tracked by SD Natural Heritage Database known or suspected to be in WICA (reproduced from Burkart 2010).

Scientific name/common name	*Global Conservation Rank	*State Conservation Rank	Status in WICA - reference	Habitat and Notes from SD Natural Heritage Database
Achnatherum robustum/ sleepy grass	G5	S3	Present - Curtin 2004	Uncommon in grasslands of s Black Hills
Botrychium campestre/ prairie moonwort	G3G4	S2S3	Present – Farrar 2005	Native grasslands of the BH and east SD
Botrychium lineare/ slender moonwort	GNR	S1	Present – Farrar 2005	Native grasslands of the s BH
Clematis hirsutissima/ sugarbowl	G4	S2	No voucher – Thomas 1996	Uncommon in grasslands of southwest SD
Chrysothamnus parryi/ Parry's rabbitbrush	G5	SU	Not yet verified – Curtin 2004	Reported from southwestern SD – no specimens
Cryptantha cana/ silver-mounded candleflower	G5	S2	Present – Brutvan/Klukas 1982	Regional endemic extending into southwestern SD
Cypripedium parviflorum/ yellow lady's slipper	G5	S3?	Present – Curtin 2005	Forests of BH and northeastern SD
Echinocereus viridiflorus/ Hedgehog cactus	G5	S3	Present – Marriott 1999	Native grasslands of southern Black Hills
Elymus diversiglumis/ interrupted wildrye	G3G4Q	SH	Present? – Marriott 1999	Last collected 1969 Black Hills wetlands

***Global/State Rank Definition** (applied rangewide for global rank and statewide for state rank)

G1 S1 Critically imperiled because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.

G2 S2 Imperiled because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extinction throughout its range.

G3 S3 Either very rare and local throughout its range, or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction throughout its range because of other factors; in the range of 21 of 100 occurrences.

G4 S4 Apparently secure, though it may be quite rare in parts of its range, especially at the periphery. Cause for long term concern.

G5 S5 Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery.

GU SU Possibly in peril but status uncertain, more information needed.

GH SH Historically known, may be rediscovered.

GX SX Believed extinct, historical records only.

G? S? Not yet ranked

T Rank of subspecies or variety

Table 7. Plant species tracked by SD Natural Heritage Database known or suspected to be in WICA (reproduced from Burkart 2010). (continued)

Scientific name/common name	*Global Conservation Rank	*State Conservation Rank	Status in WICA - reference	Habitat and Notes from SD Natural Heritage Database
Erigeron acris/ bitter fleabane	G5	SH	Present? – Marriott 1999	3 historical collections from wet meadows in Black Hills
Erigeron ochroleucus/ buff fleabane	G5	S4	Present – Marriott 1999	Few collections from Black Hills hogback ridge
Ipomopsis spicata/ spike gilia	G5	S4?	Voucher in question – Marriott 1999	Uncommon in western SD
Lesquerella arenosa ssp. *argillosa*/ sidesaddle bladderpod	G5T3	S3	Voucher in question – Marriott 1999	Regional endemic of badlands in southwestern SD
Phleum alpinum/ alpine timothy	G5	S2	Voucher in question – Brutvan/Klukas 1982	High elevations of central and northern Black Hills
Thelesperma megapotamicum/ hopi tea	G5	S3S4	Present – Marriott 1999	Coarse-soiled prairie of southwestern SD
Townsendia exscapa/ Easter daisy	G5	S4?	Present – Marriott 1999	Uncommon in grasslands of western SD
Townsendia hookeri/ Hooker's Easter daisy	G5	S3	Present – Marriott 1999	Sparse grassland and bare substrate of southwestern SD

***Global/State Rank Definition** (applied rangewide for global rank and statewide for state rank)

G1 S1 Critically imperiled because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.

G2 S2 Imperiled because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extinction throughout its range.

G3 S3 Either very rare and local throughout its range, or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction throughout its range because of other factors; in the range of 21 of 100 occurrences.

G4 S4 Apparently secure, though it may be quite rare in parts of its range, especially at the periphery. Cause for long term concern.

G5 S5 Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery.

GU SU Possibly in peril but status uncertain, more information needed.

GH SH Historically known, may be rediscovered.

GX SX Believed extinct, historical records only.

G? S? Not yet ranked

T Rank of subspecies or variety

Native plant communities - rare or “of concern”

Maintaining or enhancing biological diversity on the Great Plains requires identification and conservation of plant communities as well as rare plant species (Ostlie et al. 1997, Grossman et al. 1998). Plant communities do not receive as much attention as individual species due to the species-based regulatory environment of the Endangered Species Act and other policies of federal land managing agencies. However, TNC’s work in the Great Plains ecoregion provides an example of the role plant community types can play in ecoregional conservation. The Great Plains encompass approximately 405 thousand ha or nearly one million acres in interior North America (roughly 14% of the continent’s land mass), stretching from the boreal forests of Canada to northern Mexico. TNC completed a major review of the biological diversity of this ecoregion (Ostlie et al. 1997) which identified over 619 plant communities throughout the Great Plains. These are primarily grasslands, but also include forests, woodlands, and shrublands. Nearly half of these community types were considered to be endemic or near-endemic (meaning their distribution is wholly or mostly within the Great Plains). These plant communities, along with the ecological functions they support, greatly contribute to the unique character of the region. TNC’s conservation strategy for the region is based on maintaining the best examples of each of them.

Parallel to individual plant species, plant communities are given a conservation status ranking, describing their rarity and vulnerability to extinction (Faber-Landgendoen 2001). Nine of the 22 plant communities in the park are ranked as globally rare, according to Marriott et al. (1999) (Table 8) (Burkhart 2010a). Identifying and conserving intact native plant communities and their ecological processes, biotic interactions, and species (including poorly studied or understood taxa like microbes and soil invertebrates) is the path most likely to allow the park to meet its mission of conserving native vegetation resources in an unimpaired condition for future generations. Additional inventory of plant communities is needed in the park. Inventory would provide more information on rare native plant communities, including better distribution data. Monitoring rare native plant communities and documenting condition trends would provide important feedback to supporting sustainable vegetation and ecological systems while achieving wildlife management goals. Plant community monitoring information would also contribute to characterizing climate change impacts in the park over time.

Table 8. Rare native plant communities documented in WICA (reproduced from Burkart 2010a, Marriott et al. 1999).

Global common plant community name	Global code	*Global Rank	**Element Occurrence Rank
Cottonwood/Wolfberry Floodplain Woodland	CEGL000660	G2G3	B
Western Great Plains Streamside Vegetation	CEGL001583	G2G4	AB
Box Elder/ Chokecherry Forest	CEGL000628	G3	AB
Northern Great Plains Little Bluestem Prairie	CEGL001681	G3G4	A
Ponderosa Pine/Little Bluestem Woodland	CEGL000201	G3G4	A
Ponderosa Pine/Sedge Woodland	CEGL000849	G3	A
Ponderosa Pine/Western Wheatgrass Woodland	CEGL000188	G3G4	A
Prairie Cordgrass – Sedge Wet Meadow	CEGL001477	G3?	B
Western Wheatgrass – Green Needlegrass Mixedgrass Prairie	CEGL001583	G3G4	AB

***Global Rank Definition** (applied range-wide for global rank)

G1 Critically imperiled because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction.

G2 Imperiled because of rarity or because of some factor(s) making it very vulnerable to extinction throughout its range.

G3 Either very rare and local throughout its range, or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction throughout its range because of other factors.

G4 Apparently secure, though it may be quite rare in parts of its range, especially at the periphery. Cause for long term concern.

G5 Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery.

GU Possibly in peril but status uncertain, more information needed.

GH Historically known, may be rediscovered.

GX Believed extinct, historical records only.

G? Not yet ranked

**Element occurrence ranks: A=Excellent, B= Good, C=Fair, D=Poor) (Marriott et al.1999)

Riparian and Wetland Areas

Although riparian areas and wetlands do not cover a large percentage of the park's landscape, the wetland plant communities that are present contribute greatly to the plant diversity of the park (NPS 2010b). Likewise, wetlands are more important to the park ecosystem than the proportion of the landscape they cover would seem to indicate (Marriott et al. 1999, NPS 2010b). Wetlands create an area of high plant diversity and provide water sources for the fauna of WICA. Information specific to wetland plant communities in WICA are unavailable. More work beyond information collected for the Black Hills plant community inventory (Marriott and Faber-Landgendoen 2000) is needed to refine information pertaining to native vegetation on low elevation streams in the Black Hills (including in WICA).

Riparian areas contain some of most vulnerable of native plant community types in WICA, specifically the Cottonwood/Wolfberry Floodplain Woodland and the Western Great Plains Streamside Vegetation (Burkhart 2010a). Due to their vulnerability, the NPS fire management plan states that a 30-m (100-ft) buffer around riparian areas are to be excluded from non-fire fuel treatments (NPS 2005). Large populations of wildlife or intensive use can also be damaging to native vegetation in riparian areas. In WICA, several large herbivore species (elk, bison, mule deer, white-tailed deer, and antelope) are dependent on limited surface water available in park streams and springs. Wildlife must be managed wisely to maintain resilient riparian areas vegetated with native plant species.

Both vegetation communities mentioned above are considered to be globally imperiled and occur in the park along the three perennial streams as well as other drainages and canyons that occasionally contain flowing water during storm events and wet periods (Curtin 2005). Two examples are the Highland Creek riparian area, from the north park boundary downstream to where the creek dries up most years, and the Beaver Creek riparian area between the west park boundary and the High Bridge on Route 87 (Curtin 2005).

Riparian vegetation types often occur in a mosaic of small patches in WICA (Curtin 2005). It is important to note that digital and hard copy USGS 1999 vegetation maps, produced by Cogan et al. (1999), do not provide the detail necessary to capture individual stands of plant communities, specifically the small and narrow stands of riparian plant communities. To capture these stands in a vegetation map would require detailed on-the-ground reconnaissance (Curtin 2005).

Springs and Seeps

Together, seeps and springs provide needed water for relatively small but diverse plant communities in WICA. Ohms (2009) documents 94 springs within the park, with eight of them modified to provide water for animals. A GIS layer (NPS 2006) indicates locations of 70 springs, 61 locations labeled as pools. Twenty-seven are locations of some man-made structure such as a dam, spring with concrete and tank, concrete surrounded spring, or a dry or collapsed well. Most of the springs are small with low flow-rates, rarely over three gallons per minute; they are highly dependent on precipitation, and often do not contain water during dry periods (Ohms 2009). Because of development with man-made structures and use by large numbers of herbivores, springs and seeps need to be carefully managed to allow persistence of sustainable seep/spring native plant species and communities in good condition.

<u>Non-native plant species distribution and density</u>

Human disturbance, ranging from initial settlement activities (e.g., land clearing, cattle grazing, and logging) to current NPS management actions (e.g., fire suppression, wildlife management, and effects of wildlife grazing), has influenced WICA's vegetation composition and structure. These historic human disturbances provided for a long history of opportunities for non-native plant establishment, both intentional non-native species planting (e.g., plants for cultivation) and unintentional establishment. In 1946, there were approximately 284 structures in the park, 52 of which were homesteads. The average cultivated area per homestead was 7.7 ha (18.9 ac) translating to approximately 400 ha (988 ac) of total plowed/planted land in the park (NPS 2010b). In the late 1940s, the Soil Conservation Service attempted to reestablish native grasses in some of these areas. Park managers also reseeded areas in 1956, 1957 and in 1960 (NPS 2010b). Only a few non-native planted species remain in the park, including lilacs (*Syringa* spp.) near the early game preserve headquarters, apple trees (*Malus* spp.) in the homesteads of the Red Valley, and a variety of plantings near the present Visitor Center/housing/maintenance area (NPS 2010b).

While locations of non-native plants were recorded in the park since at least 1995, comprehensive park-wide inventory and mapping of non-native or invasive plant species distribution in WICA has not been undertaken (Burkhart, pers. comm., 2010). Effort has been focused on treatment and control rather than inventory and mapping. Therefore, the resulting spatial data (list of data in Appendix D), though likely very useful in planning and prioritizing control efforts and monitoring, may be misleading in its representation of park-wide non-native and invasive plant distribution or density. However, the available data indicate non-native plants distributed through many areas in the Park (Plate 9).

Comparison of the total area affected by non-native plants from year to year is also misleading since different years reflect differing levels of inventory effort. In addition, inconsistencies between spatial data collection efforts and datasets complicate the understanding of non-native and invasive plant distribution and density.

In 2009, Integrated Pest Management activities at WICA addressed over 20 species of invasive plants. 544 person-hours were expended while inventorying 212 ha (525 ac) of non-native, invasive plant species. This resulted in 28 ha (70 ac) of non-native, invasive species mapped and 39 ha (96 ac) of non-native, invasive species treated manually (i.e., hand pulled) or mechanically (i.e., mowed) (NPS 2009c).

The precise nature of the non-native and invasive plant distribution and density is difficult to understand and report based on available data. However, the number of documented non-native plant species in WICA has nearly doubled in the last decade. In 1999, there were 56 non-native plant species, five of which were specifically designated as noxious by the state of South Dakota in WICA (Marriott 1999). In 2008, there were a total 89 documented non-native species (NPS 2010a).

In the following paragraphs, Beth Burkhart provides a synopsis of non-native and invasive plant numbers, treatment efforts, and the importance of management into the future for WICA.

> Botanical evaluation regarding invasive species in Wind Cave NP in recent years indicates that numbers of invasive species in the park have increased, paralleling the increase in numbers of invasive species in the surrounding Black Hills region. The description from 1999 that some invasive species are locally common at scattered locations is still accurate, but the species and locations have changed over the last 10 years. For example, large infestations of Canada thistle (*Cirsium arvense*) (largely located on prairie dog towns, due the continual ground disturbance) have decreased as a result of repeated mowing of large occurrences on prairie dog towns since 1999. However, scattered Canada thistle in the overall

park landscape has likely increased since 1999, as it has in the general Black Hills landscape.

New invasive species have been tracked when discovered and treatment efforts applied to keep occurrences small [for example, yellow toadflax (*Linaria vulgaris*), leafy spurge (*Euphorbia esula*), and spotted knapweed (*Centaurea maculosa*]. Most treatment in recent years has been by mechanical means (e.g., mowing, hand-pulling, clipping and removing seed heads, etc.) with some biological control (for Canada thistle and leafy spurge). The park used chemical treatment (herbicide application provided by the NGP EPMT) in addition to mechanical treatment in 2005 to 2007. Concerns about proper planning and implementation of chemical treatment relative to the cave and karst resources of the park removed herbicide application from the park's treatment activities in 2008 and 2009 while an Integrated Pest Management Strategy was researched and written. In 2008, 1,454 ac of invasive species were inventoried and mapped and 107 acres were treated (NPS 2008a). In 2009 with a reduced crew, 241 ha (595 ac) of invasive species were inventoried and mapped and 39 ha (96 ac) were treated (NPS 2009c). Herbicide application designed to be protective of the park's cave and karst has been developed and herbicide application has been accomplished according to plans in 2010.

Invasive species management in Wind Cave NP is an important program and will remain important into the future. Invasive species as a whole are aggressive and successful at outcompeting native species in disturbed areas. Natural disturbances look no different to an invasive species than man-made disturbances, so areas such as prairie dog towns and wildfire areas in the park will remain vulnerable to invasive species establishment and growth. Treatment to remove one invasive species (e.g., Canada thistle) may open the door to establishment by another (e.g., horehound).

While Canada thistle remains in areas of the park, white horehound appears in locations where Canada thistle had previously been adequately controlled (NPS 2009a). Infestations of white horehound increased dramatically in WICA during 2004-2007, likely due to combined effects of drought, intense wildlife grazing, and the substantial ground disturbance that occurs with excavation and vegetation clipping by prairie dogs in their colonies (NPS 2009a). White horehound now covers the most acreage of any non-native invasive plant species in WICA (as documented in all WICA exotic plant GIS layers). March 2010 estimates of white horehound are approximately 272 ha (671 ac) in total were infested within or near many of the prairie dog colonies (towns) (Plate 10). White horehound provides a significant threat to the native plant communities that are associated with prairie dog towns because of direct replacement of native plants. The bitter taste of white horehound causes grazing animals to feed on surrounding plants, reducing competitive palatable plant species and aiding in horehound's establishment and persistence (Weiss et al. 2000).

Integrated Pest Management reports to the Custer County weed program discuss the status of horehound control efforts. Pulling has proven ineffective because of the invasive species' fibrous root system and mowing encourages plant growth and expansion (NPS 2009c). Because coverage of the plant is currently thick enough to investigate implementation of larger scale fire as a treatment method, research examining broadcast burning effects on horehound is underway. The NPS will incorporate fire, herbicide, and limited manual control in designing a white horehound treatment plan for 2010 and future years (NPS 2009c).

Threats and Stressor Factors

Stressors to the 21 native plant community types include (Burkhart, pers. comm., 2010):

1) Large numbers of browsing and grazing wildlife species, particularly elk and prairie dogs;
2) Climate change (including drought, extreme weather events including very heavy rainfall in a short period of time, more intense wildfires, etc.);
3) Non-native plant species, especially invasive species;
4) Changes in pollinator populations/dynamics; and
5) Man-made disturbances from park management activities.

In addition, ponderosa pine communities compete with other native plant communities, mainly mixed grass prairies. However, ponderosa pines are native and therefore naturally compete with other vegetation. In the absence of a natural fire regime that would tend to balance the plant communities over time, ponderosa pine density and extent both have increased for many decades. In this case the resulting increase of pines can be seen as a stress factor to other plant communities.

Since non-native plant species, especially invasives are stressors on native plant communities, it is important to mention some other factors that may affect non-native plant distribution and density in a variety of ways. These include fire regime changes, moisture patterns and climatic changes, and potential atmospheric nitrogen deposition. Also important to non-native and invasive plant species density and distribution are vectors for spread. Important vectors include park visitors, horses (transported hay can act as a potential source of non-native plant introductions), wildlife (e.g., bison, deer, and elk), and wind dispersal (an especially important mechanism for non-native grass species introduction and spread).

Data Needs/Gaps

Native plant species of concern

Adequate floristic survey of WICA has not been completed to fully document plant species in the park, including native plant species of concern. Once a floristic survey is completed, inventory can be accomplished to determine overall distribution, abundance, and condition of plant species of concern. Lastly, a park monitoring plan for plant species of concern (including protocols appropriate for each species) can be developed and implemented to track native species persistence and quality of occurrences in the park over time.

Rare native plant communities
Marriott et al. (1999) state that riparian vegetation types need to be well characterized and documented in the Black Hills; this is true in WICA as well. Adequate successional models of ponderosa pine forest and woodland development are also lacking for the Black Hills (Marriott et al. 1999). Adequate survey for and inventory of rare native plant communities in WICA has not been completed to document location, distribution, abundance, and quality of rare native plant communities. When that information is known, a park monitoring plan can be developed and implemented to track rare plant community persistence and quality over time. This information will be critical to the park meeting its commitments for monitoring and adaptive management included in recent wildlife management plans (e.g., WICA Elk Management Plan, WICA Prairie Dog Management Plan, WICA Bison Management Plan). It would also be helpful in characterizing alterations over time from climate change.

Invasive plant species
Current prioritization of invasive plant species control efforts in WICA is relatively informal and has followed the general public's lead of focusing on the high profile species with economic impacts to agriculture and range industry (e.g., Canada thistle and leafy spurge) (Burkhart, pers. comm., 2010). A formal ranking of non-native plant species invasiveness could help prioritize invasive plant efforts as it relates to the preservation of natural resource integrity. The park should take an in-depth look at the full spectrum of invasive species found in the park and invasive species that may threaten the park from surrounding lands.

Some invasive species are considered to have positive economic benefits. For example, smooth brome (*Bromus inermis*) and yellow sweet clover (*Melilotus officinalis*) have good forage value because of crude and digestible protein and therefore are desired on many private lands for livestock grazing. Burkhart suggests that species like these on the natural landscape in WICA may have the greatest potential for long-term negative impact to native plant species/communities because little to no management attention is being focused on them. A limited body of research and anecdotal information supports the hypothesis that these species result in major changes to native plant species, plant communities, and ecosystem processes. However, WICA lacks the information to support or deny any hypotheses in this regard, or to lead the park managers to prioritize invasive species management for beneficial long-term results. The following quote by a park expert exemplifies this dilemma:

> More information is needed on interactions between native and non-native species, including ways of combining invasive species removal with methods of re-vegetation to support establishment and persistence of appropriate native species over non-native invasive species. In addition, it would be helpful for management choices to be evaluated for comprehensive effects including invasive species. For example, Wind Cave Canyon may be the area of highest invasive species load in the park, based on number of species and numbers of plants. The cultural landscape currently being maintained in Wind Cave Canyon is shadier and moister than that found in any natural prairie drainage. This landscape was created by plantings by the Civilian Conservation Corps in the 1930s. Wind Cave Canyon is now a haven for numerous invasive species that find little foothold anywhere else in the park. In addition, treatment methods have been limited in the past due to cave/karst considerations, visitor use, and cultural resource values (Burkhart, pers. comm., 2010).

Finally, there currently is no formalized reporting of success in terms of non-native plant eradication or reduction. The annual NGP EPMT reports do not track and measure successfulness of treatments in a quantitative manner. A quantitative measure of success could be useful in creating not only better management and treatment actions, but could help in understanding the condition of native plant communities.

Re-vegetation
NPS (2009b) suggests that, since human disturbance is varied across the park's landscape, inventory and mapping prairie areas with high plant diversity, rich soil fungi, or other indicators could help determine areas of high quality remnant prairie that are valuable to identify as target areas for conservations priority. In addition, they would be the best sources of local genetic seed for re-vegetation projects. Low quality prairie could also be identified and monitored to determine if trends toward improved quality are occurring without intervention (NPS 2009b). Collaborations with others in the Black Hills and Northern Great Plains area is important to design and develop a native plant material program that meets re-vegetation needs of regional public lands, as well as contribute to re-vegetation on private lands.

<u>Overall Condition</u>
In 1999, TNC Black Hills Community Inventory (BHCI) project (Marriott 1999) recognized WICA as an exemplary site with respect to native vegetation. The park vegetation includes 22 plant community types based on the U.S. National Vegetation Classification (USNVC), nine of which are considered rare (i.e., NatureServe Global ranks of G1 to G3). The majority of vegetation associations examined in WICA by Marriott et al. (1999) received an element occurrence (EO) rank of A or AB and some received a B. An EO rank is a composite determination based on an evaluation of size, condition, and landscape context of each plant community in the study. An EO ranking of A is the highest on the scale of rankings given by the Marriott et al. (1999) study.

In addition, in 1999, invasive species were noted as being locally common at scattered locations, but the overall condition of the native park vegetation was still considered good (Marriott et al. 1999).This description is still accurate, but the species and locations have changed over the last 10 years (Burkhart, pers. comm., 2010). Marriott et al.'s (1999) categorization of the park's plant communities indicates that, compared with many areas outside the park, native plant communities in WICA are in good condition; however, this does not mean that plant communities at that time should be considered in pristine condition (Burkhart, pers. comm., 2010). Invasive plant species numbers and density have increased in the southern Black Hills since 1999, including in the park. However, it appears that the invasive species numbers and density in the park are still at a lower level in the park compared to the surrounding Black Hills landscape (maintaining a parallel gap to the difference between park and surrounding Black Hills landscape in 1999) (Burkhart, pers. comm., 2010).

While the scope and detail of work accomplished for the Black Hills Community Inventory has not been duplicated since that time, botanical evaluation of the park vegetation in recent years has shown that 21 of the 22 plant community types are persisting in good condition in the park (Burkhart, pers. comm., 2010). However, data collection using Multiple Indicator Monitoring of Streams and Riparian Areas protocol (Bureau of Land Management [BLM]/USFS) were collected in 2009 and 2010. Once evaluated, these data will aid in determining the conditions of

Western Great Plains Streamside Vegetation stands in the park. Like many plant communities, these community types are threatened by continued expansion of non-native invasive plants in and outside of the park; the over one hundred non-native or invasive plant species are documented in WICA.

From 2004 to present, white horehound expanded to approximately 243 to 283 ha (600 to 700 ac) in total area, distributed throughout many of the prairie dog towns/colonies in WICA. Prairie dogs are unable to clip the horehound fast enough to keep up with its growth and may be forced out of areas infested with the plant (Burkhart, pers. comm., 2010). A pattern of continued movement away from infestations would create more ongoing disturbance areas and more niches for aggressive non-native plants. Even if white horehound were successfully eradicated in the prairie dog towns, it is likely that different non-natives would establish in these areas of ongoing disturbance (Burkhart, pers. comm., 2010).

Though precise park-wide measurements of ponderosa pine density and extent do not exist, it is estimated that the size of the forested area has increased by more than one third since 1870, mainly as a result of fire suppression (NPS 1979 as cited in NPS 2005). Increases in forest size and density cause declines in the amount of herbaceous vegetation in the park. While the increase in ponderosa pine extent is a concern for management, ponderosa pine is a native species that is desirable in many areas of the park. Under natural conditions in the past, an ebb and flow in the amount of forest cover and prairie cover existed overtime (Burkhart, pers. comm., 2010). However, high pine densities, especially in the seedling and pole-sized classes, may create potential for high severity fires, which could lead to negative effects in terms of native vegetation recovery after fire. WICA uses prescribed burning in an attempt to mimic the natural fire regime, which during pre-settlement times kept forests expansion in check.

As of 2009, a total of 17 native plant species tracked by the SDNHP are known or suspected to occur in WICA (Marriott et al. 1999). WICA has information on 48 species of limited occurrence in the park (Appendix C). These species of concern require additional survey, inventory, and monitoring to detect changes in abundance, distribution, and condition. Knowledge acquired from inventory and monitoring is needed to develop best management practices and mitigations to protect these species from negative impacts of management activities and to make long-term management decisions relative to other influences such as climate change.

The level of confidence in statements regarding distribution, abundance and condition of native plant species of concern is moderate. Some survey, inventory, and informal monitoring have taken place. However, more work is needed in all areas – especially in inventory (determining distribution and abundance) and monitoring (protocols developed and implemented for plant species monitoring).

The level of confidence on the condition of native plant communities is relatively low due to a lack of thorough understanding of a myriad of complex interactions between native plant communities and processes such as native ungulate grazing, possible nitrogen deposition, native plant displacement by invasive plants, and climate-weather change effects on native plant community health and sustainability.

The level of confidence on distribution and abundance of non-native, invasive plant species is probably the highest of any vegetation category, although there is room for significant improvement as discussed earlier. The attention to invasive species is primarily the result of necessary cooperative efforts with southern Black Hills neighbors (federal, state, and private) in order to make significant impacts on invasive vegetation at a landscape scale. While this level of confidence in invasive species is desirable, it is not in balance with confidence levels on the full spectrum of vegetation in the park (from native species/communities to non-native/invasive species). Treatment and control of non-native invasive species is one angle to approach enhancing native species/communities. However, investment of effort in survey, inventory, and monitoring of native plant species/communities is also needed to support long-term persistence of good condition, native vegetation in the park.

Sources of Expertise
Burkhart, WICA Botonist.
Dan Swanson, Northern Great Plains Park Group Fire Ecologist.

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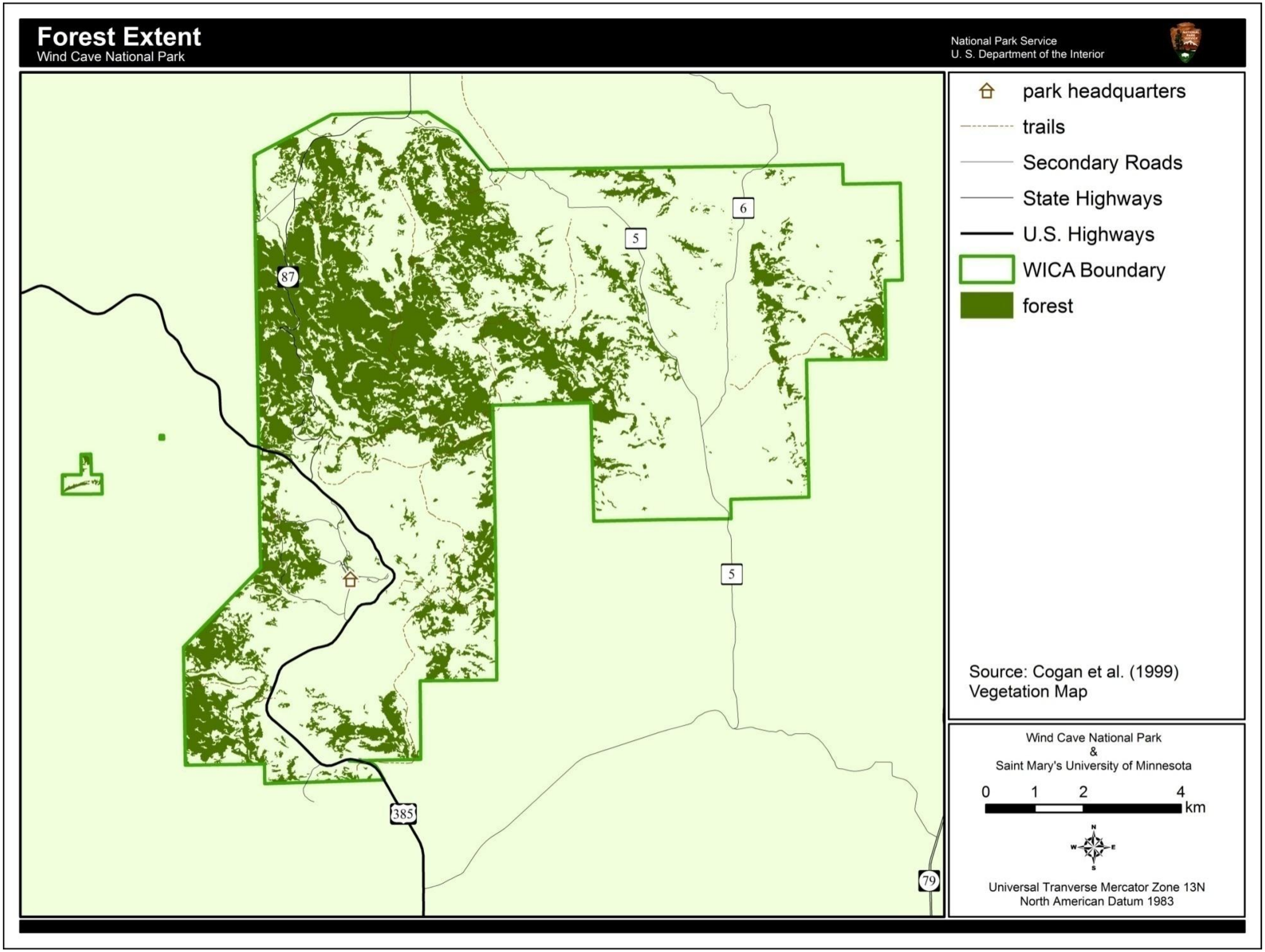

Plate 7. Forest extent in WICA.

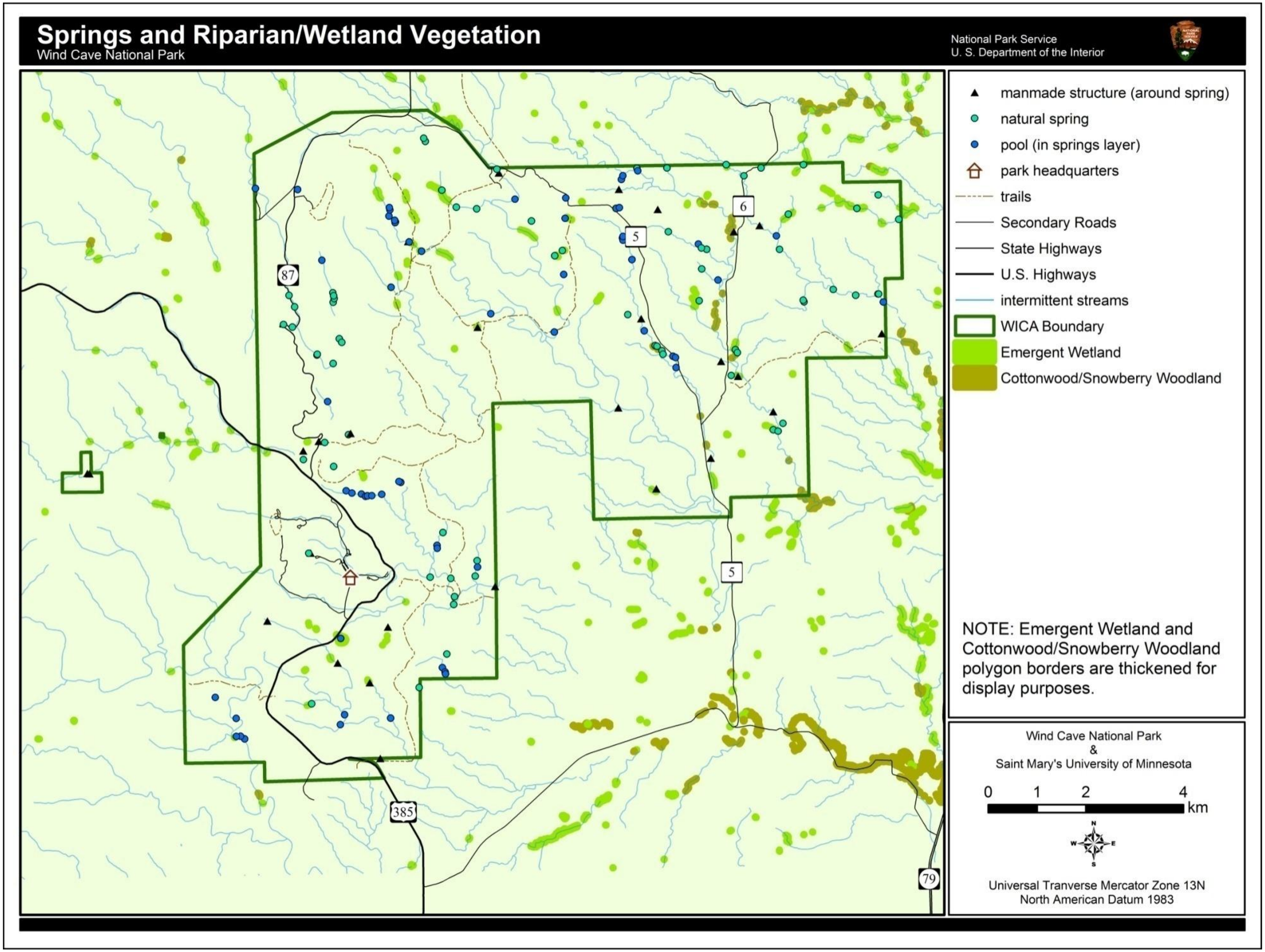

Plate 8. Springs and riparian wetland vegetation in WICA.

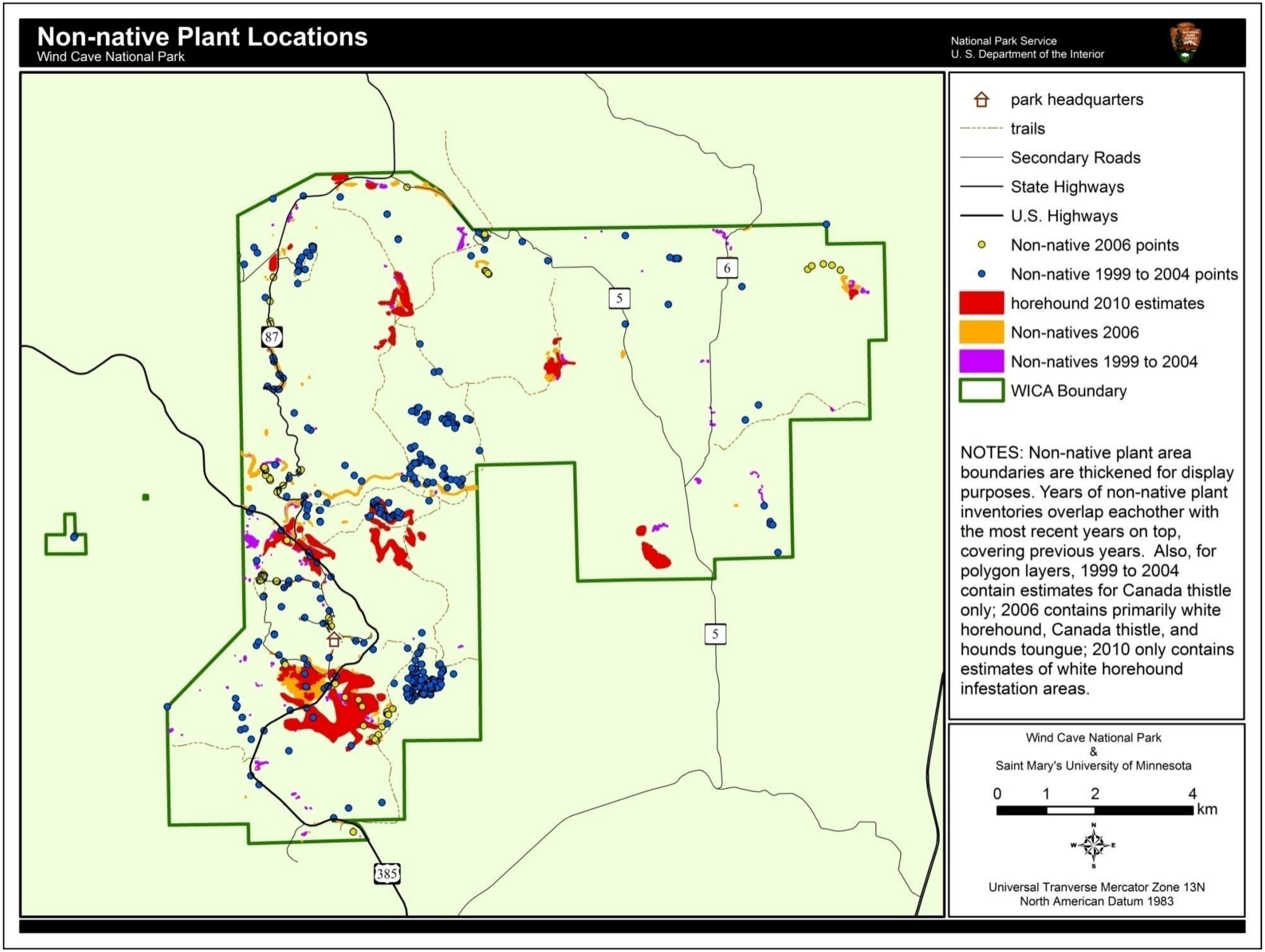

Plate 9. Documented non-native plant infestations.

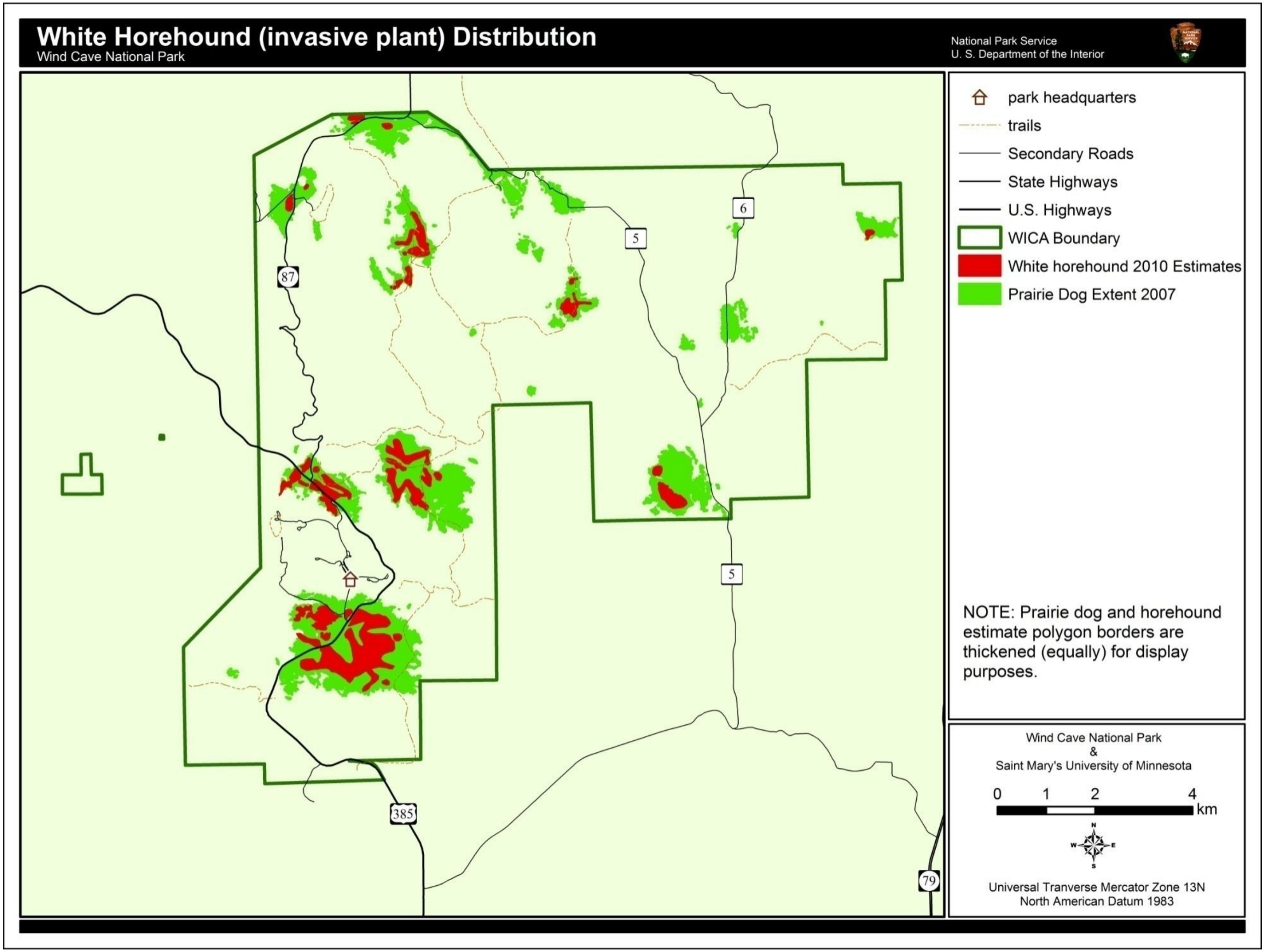

Plate 10. Non-native white horehound area estimates in associated prairie dog colonies.

4.4 Birds

Description

Bird populations often act as excellent indicators of an ecosystem's health (Morrison 1986, Hutto 1998, NABCI 2009). Birds are typically easy to observe and identify and bird communities often reflect the abundance and distribution of other organisms with which they exist (Blakesley et al. 2010). WICA is home to one of the last mixed-grass prairies in North America. A mixed-grass prairie is an ecotone characterized by a mixture of the tall grass species of the eastern tall grass prairie and the short grass species of the western high plains (NPS 2006). Mixed-grass prairies provide niches for a wide array of avian species and monitoring avian population health and diversity in these prairies will be important for detecting ecosystem change.

Measures

- Species Richness
- Species Diversity
- Species Density

Reference Conditions/Values

Reference condition for WICA birds is defined as breeding and healthy populations. Breeding and healthy populations are described as populations representative of those that would naturally occur across the southern Black Hills within suitable habitat (Muenchau, Roddy, pers. comm., 2010).

Data and Methods

Seven monitoring programs have been established to survey birds in or around WICA: 1) on-road breeding bird survey; 2) off-road breeding bird survey; 3) Christmas bird counts; 4) raptor monitoring; 5) nightjar survey; 6) sharp-tailed grouse lek monitoring; and 7) spatially balanced breeding bird community monitoring (as established by Blakesley et al. 2010). Results from these surveys were provided in Microsoft Excel format by Barbara Muenchau, WICA Biological Science Technician. The Rocky Mountain Bird Observatory (RMBO) also established two point-transect survey routes in 2002 (Panjabi 2005). RMBO surveyed these transects from 2002-2004.

<u>On-road Breeding Bird Survey</u>

The WICA breeding bird survey route is part of the large-scale North American Breeding Bird Survey (BBS), which began in 1966 and is coordinated by the USGS and the Canadian Wildlife Service. The standard BBS route is approximately 40 km (25 mi) long with survey points at every 0.8 km (0.5 mi) (Plate 11). The survey begins ½ hour before sunrise, and at each survey point the number of birds seen and heard within a quarter-mile radius during a three minute interval is recorded. Only BBS route 81911 (Wind Cave National Park Route) is within the park boundaries. This route has been surveyed annually since 1999 and data are current through 2009.

<u>Off-road Breeding Bird Survey</u>

Beginning in 1999, a system of extensive off-road point count routes was established along five hiking trails at WICA. Fifty points (10 per route) were permanently marked on the trails approximately 250 m (820 ft) apart from each other (Plate 12). The points were located in habitats not well represented by the on-road BBS. One survey is conducted each year for the five routes. Surveys begin at sunrise each morning; points are monitored for five minutes at a time, and closely follow the procedure for monitoring land birds as outlined in Ralph et al. (1993). This protocol allows comparisons between both the on-road and off-road BBS routes.

Data provided for off-road BBS routes are current through 2009. Beaver Creek was not surveyed from 2002-2004 due to its inclusion in an inventory project (Panjabi et al. 2005) being completed by the RMBO (Muenchau, pers. comm., 2010). Adjustments to the data consisted of the exclusion of data from analysis. Any birds observed between points were excluded from analysis. Records with the following labels were removed from analysis: unknown thrush, unknown woodpecker, unidentified woodpecker, unknown bird, unidentified swallows, and unidentified Buteo.

Christmas Bird Count

The WICA Christmas Bird Count is patterned after the International Christmas Bird Count (CBC), which started in 1900 and is coordinated internationally by the Audubon Society and locally by WICA resource management staff. The CBC has been conducted annually from 1995-2007 and again in 2009. Hazardous driving conditions in 2008 prevented the count from taking place. Multiple volunteers survey a 24-km (15 mi) diameter on one day, typically between 14 December and 5 January. The center point of the 24-km (15 mi) diameter is in the northwest corner of the park so that it covers the entire park (Plate 13). Unlike the BBS, the CBC is not restricted by the park boundaries and deals with overwintering resident birds that are not territorial and singing; this often results in different survey results when compared to the BBS. The number of species and the total number of survey hours are recorded each year. Data for CBC in WICA are current through 2009.

Raptor Count

As time permits, park staff attempt to conduct informal surveys for nesting raptors in the park. The number of known territories, number of active nests, and the number of fledglings are recorded. Because there is currently no comprehensive/intensive raptor monitoring program, park-wide raptor surveys are incomplete (WICA 2010). Many hard to reach backcountry areas are not surveyed on a regular basis, but they may still support raptor territories. Raptor records date back to around 1984, but in 1988 the first formal attempt was made by Lynn Hetlet (Hetlet 1988) to document nesting raptors in the park. Park records are incomplete due to lack of available staffing and changing priorities for park resource management staff.

Nightjar Survey

United States Nightjar Survey Network routes are collected nationwide by The Center for Conservation Biology of William and Mary and Virginia Commonwealth University (CCB 2004). Park staff established and surveyed two 14.5 km (9 mi) long roadside nightjar survey routes in 2009 and 2010 (WICA 2010). The objective of the surveys is to document the presence, absence, and relative abundance of common poorwills (*Phalaenoptilus nuttallii*) and common nighthawks (*Chordeiles minor*). These routes were established on top of the BBS route already conducted in the park and included 10 stops on each route approximately one mile apart. NPS conducted these surveys from late May until early July and occurred at night, under clear skies, close to the full moon period with the moon above the horizon (WICA 2010).

Spatially Balanced Breeding Bird Community Monitoring (as established by Blakesley et al. 2010)

Prior to the 2008 breeding season, Blakesley et al. (2010) developed a spatially balanced sampling design within the park. Sampling units were 750 x 750 meter grids and each grid contained nine sampling points 250 meters apart. Twenty grids were selected for sampling and three samples were conducted each year (Blakesley et al. 2010).

From 2008-2009, point counts were conducted at each survey point within the sample grids for seven minutes. Observers recorded the species, sex, detection method (i.e., call, visual, drumming), and distance from the sampling point. Specific data analysis methods and programs used are described in detail in Blakesley et al. (2010).

Current Condition and Trend

Species Richness

On/Off Road BBS

Species counts for each year and survey were calculated to estimate WICA's species richness (Figure 4). There does not appear to be an increasing or decreasing trend in species richness observed each year (Figure 4). However, there may be undetected changes in species richness of native species when compared to non-native species, or in neotropical migrants species richness compared to native species richness. Such changes would not be apparent in Figure 4.

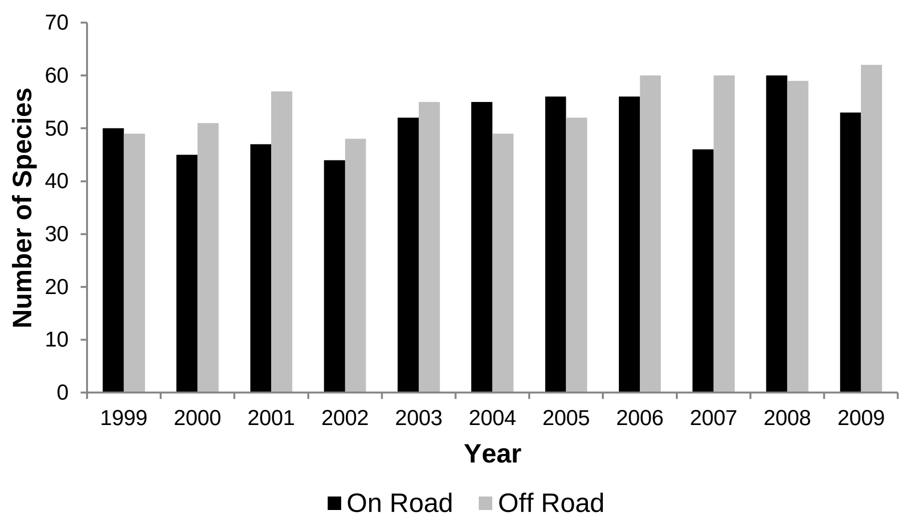

Figure 4. Number of species detected during on and off road breeding bird surveys in WICA from 1999-2009.

BBS data pose several problems when attempting to detect changes in species abundance; BBS sample sizes are usually small, relative abundance is low, and trends are imprecise (USGS 2010), thus these survey results should be interpreted carefully.

Christmas Bird Counts
Because CBC and BBS routes and methods are so different, the results of the surveys do not allow comparison between each other. For this reason, the total number of bird species identified during the WICA CBC from 1995-2009 is represented separately in Figure 5.

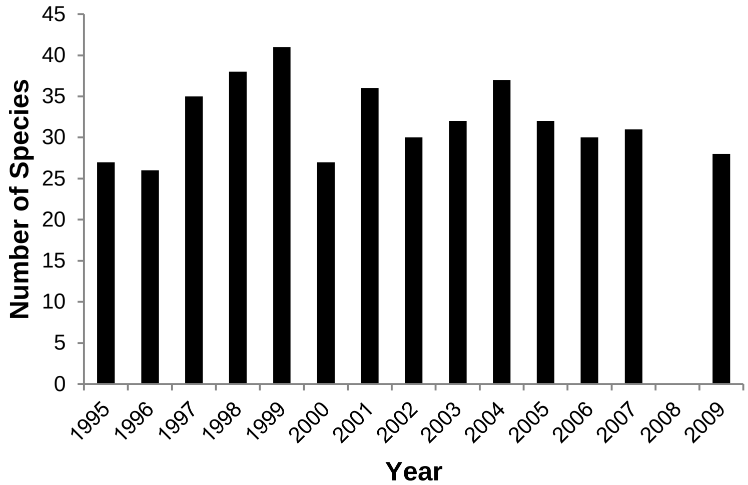

Figure 5. Number of species identified during Christmas bird counts in WICA from 1995-2009. No survey was conducted in 2008 due to inclement weather.

Similar to the on/off road BBS species richness estimates, the CBC species richness estimates presents no discernable trend. This may be indicative of a stable breeding population and consistent migration pattern though the park, however this is speculation and warrants further investigation.

Peterson (2000) Breeding Bird Inventory
Peterson (2000) conducted an inventory of the breeding birds at WICA during the summer of 1998 and the entire breeding seasons (April to mid-August) of 1999 and 2000. Among the measures performed was species richness (Figure 6). Peterson (2000) grouped the habitat of WICA into seven types of breeding bird habitat for species richness analysis and pooled data from 1998-2000 to create this estimate. Coniferous woodlands and forest exhibited the highest species richness value, while wetlands showed the lowest value (Figure 6).

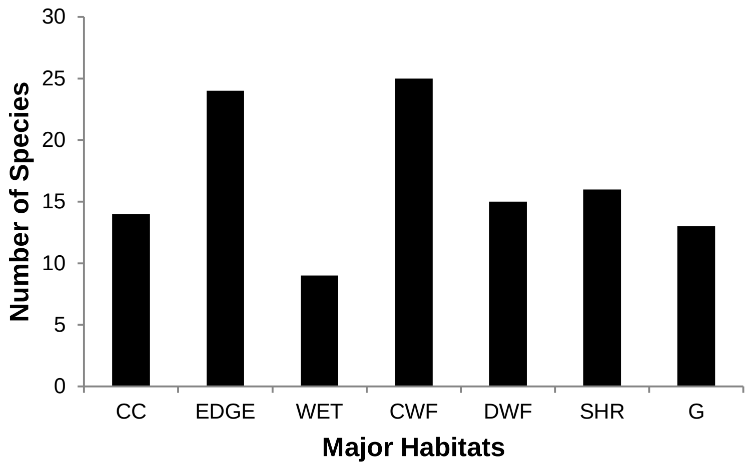

Figure 6. Total number of bird species detected in WICA from 1998-2000. Detections are distributed across seven different habitat types: CC = cliffs/caves, EDGE = Edge, WET = wetlands, CWF = coniferous woodlands and forest, DWF = deciduous woodlands and forests, SHR = all shrubs: riparian and wetlands, G = grasslands.

Species of Conservation Concern

Six species of birds listed on the level I priority bird species list for South Dakota were observed in WICA (Bakker 2005) (Table 9). The priority bird species list includes birds:

- listed on the Partners in Flight (PIF) watch list with distributions in South Dakota
- with a high proportion of their total population breeding in or wintering in South Dakota
- endangered and threatened species federally listed under the Endangered Species Act
- American Bird Conservancy green list species

Priority species are ranked in accordance with continental and state decline levels. Bakker (2005) defines the three levels of priority species:

Level I species have the highest conservation priority due to high maximum abundance of the species within its range in South Dakota, South Dakota constitutes the core of the species breeding range, and/or the species is showing population declines in South Dakota or across its range. Level II species are those with moderate conservation priority due to medium abundance scores in South Dakota or management plans are already in place (e.g., Federally listed, game species). Level III species include birds with moderate conservation priority due to low abundance scores in South Dakota or South Dakota is on the periphery of the species’ range, the species is unique to some habitats (i.e., Black Hills) in South Dakota, or wintering species.

Table 9. Species of conservation concern, their priority level (as defined by Bakker [2005]), and the survey the species were detected on for WICA, 1999-2009.

Species	Priority Level	Survey	Observed During Period of Record	Years Observed
sharp-tailed grouse (*Tympanuchus phasianellus*)	I	On-road	Yes	2003, 2005
		Off-road	Yes	2003
		Grouse Count	Yes	1999, 2004, 2007-2009
upland sandpiper (*Bartramia longicauda*)	I	On-road	Yes	1999-2009
		Off-road	Yes	2003, 2006-2009
grasshopper sparrow (*Ammodramus savannarum*)	I	On-road	Yes	1999-2009
		Off-road	Yes	2001, 2003-2005, 2007-2009
western meadowlark (*Sturnella neglecta*)	I	On-road	Yes	1999-2009
		Off-road	Yes	1999-2009
orchard oriole (*Icterus spurius*)	I	On-road	Yes	2004
		Off-road	No	-
burrowing owl (*Athene cunicularia*)	I	On-road	Yes	2003, 2005, 2006
		Off-road	No	-

In 2009, only four upland sandpipers (*Bartramia longicauda*) were reported in the park's surveys (both on/off road BBS surveys, and the CBC). This represented the lowest reported value since 2001, when only one was observed. Over the past decade, the prevalence of this species has begun to increase (Figure 7), but low observations the past two years suggest the status of the population warrants further investigation. Western meadowlark (*Sturnella neglecta*) abundance appears to be increasing since 1999, but no discernable trend is evident (Figure 7).

The grasshopper sparrow (*Ammodramus savannarum*) appeared to be steadily decreasing from 2003–2007, but in 2008, the highest number of recorded grasshopper sparrows was observed (38 individuals) (Figure 7). In 2009, the same trend was apparent as 31 grasshopper sparrows were observed on park surveys. More research and data are needed to determine if these trends in abundance are reflective of natural variability, sampling error, management practice, or are of significant concern.

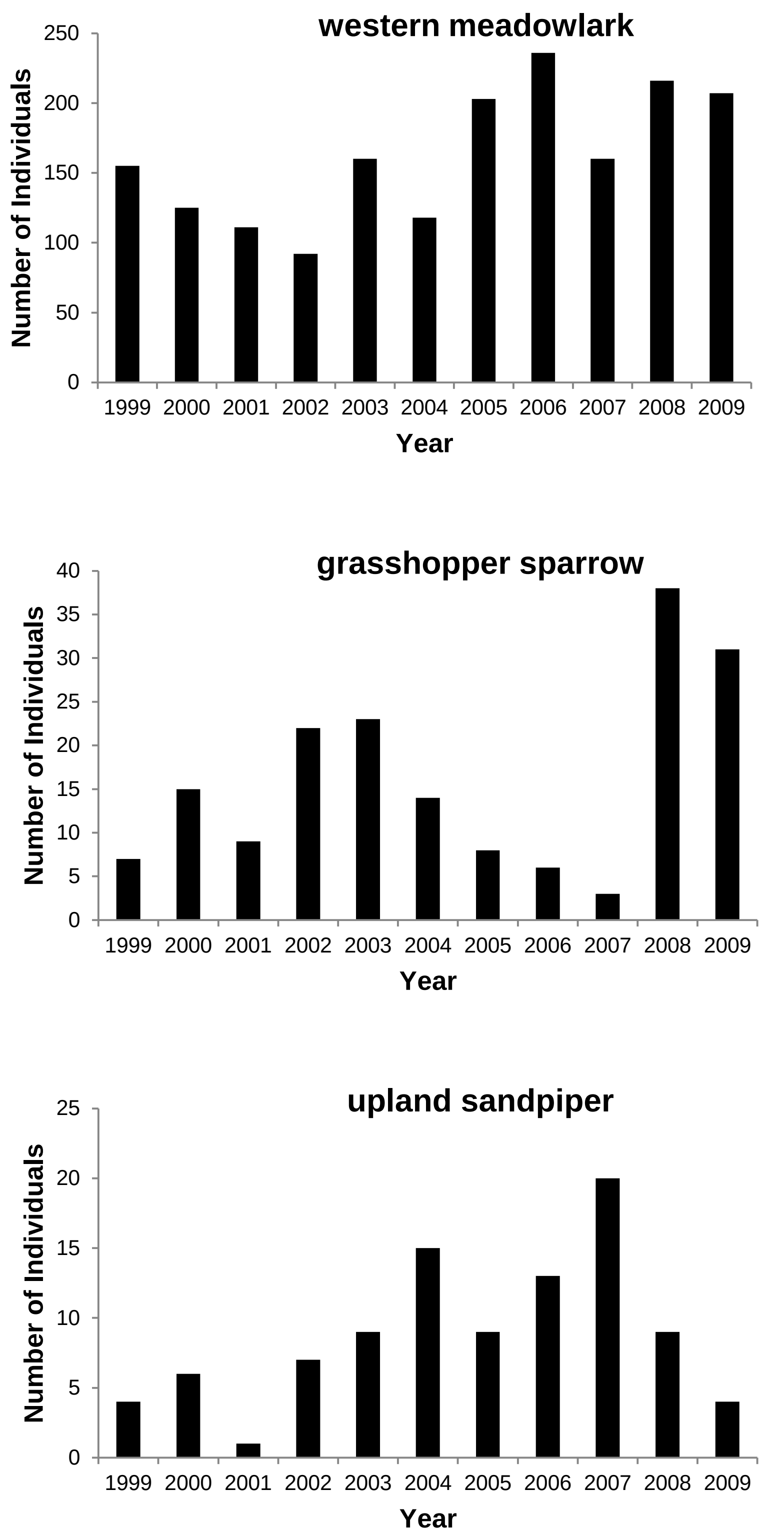

Figure 7. Change in individual bird species abundance among selected level I priority species in WICA.

Raptor Populations

In 2009, park staff visited 42 nest locations/territories of 11 different raptor species within the park. During these visits, 12 nests were confirmed as being active and one nest was deemed possibly active (WICA 2010) (Table 10). Of the 12 active nests, four belonged to burrowing owls, one to long-eared owls, one to golden eagles, and six to red-tailed hawks (*Buteo jamaicensis*). Two Turkey Vulture (*Cathartes aura*) nesting areas were reported as being active, but reproduction/nesting success was not able to be confirmed due to the inaccessibility of the nest locations (WICA 2010).

One red-tailed hawk nest was observed late into the nesting season to determine nesting success. This nest was part of a pilot project conducted by the Midwest Region's Wildlife Biologist. Park staff assisted the biologist in installing two different video surveillance systems, overlooking the nest with the objective of determining types and frequency of prey items brought to the nest during the chick-rearing period (WICA 2010). Only three prey items were able to be clearly identified and they included a prairie dog, a bird species, and a small snake.

Table 10. Species of raptors observed in WICA during 2009 monitoring efforts, the number of known territories, and the number of active nests observed for each species.

Species	Known Territories	Active Nests
great horned owl (*Bubo virginianus*)	4	0
long-eared owl (*Asio otus*)	6	1
northern saw-whet owl (*Aegolius acadicus*)	2	0
burrowing owl (*Athene cunicularia*)	2	4
turkey vulture (*Cathartes aura*)	3	2
sharp-shinned hawk (*Accipiter striatus*)	0	0
cooper's hawk (*Accipiter cooperii*)	4	0
northern goshawk (*Accipiter gentilis*)	1	0
red-tailed hawk (*Buteo Jamaicensis*)	7?	6
golden eagle (*Aquila chrysaetos*)	5	1
merlin (*Falco columbarius*)	4-6	0
prairie falcon (*Falco mexicanus*)	2	0
ferruginous hawk (*Buteo regalis)*	0	0

Sharp-tailed Grouse Population

Over the past 10 years, there have been five concerted efforts to survey all of the 13 known sharp-tailed grouse (*Tympanuchus phasianellus*) leks in the park (Table 11). The leks within the park are divided into two regions, the eastern half of the park (9 leks) and the southern end of the park (4 leks). There have not been grouse recorded at the southern leks since 2007; informal searches of these leks found little evidence of bird use other than a few droppings and an occasional sighting (WICA 2010).

Table 11. Estimated Sharp-tailed Grouse population size in WICA (1999, 2004, 2007-2009), and estimates of lek size for both the southern and eastern leks.

Year	Max # Birds	Southern End of Park	Eastern Half of Park	Comments
1999	91	37	54	Active Leks (3 southern/ 4 or 5 eastern)
2004	56	19	37	Active Leks (2 southern/ 4 eastern)
2007	57	8	49	Active Leks (1 southern/ 4 eastern)
2008	18	0	18	Active Leks (0 southern/ 2 eastern)
2009	17	0	17	Active Leks (0 southern/ 3 eastern)

Male and female sharp-tailed grouse can be difficult to differentiate during the mid March thru mid May surveys but skilled observers can accurately count the number of males and females on a lek based on the bird behavior. Over the past 10 years, the park has used numerous volunteers of various skill levels to help with these surveys. For comparison of survey results from year to year, the park has decided to use spring surveys that yield the highest number of birds (Muenchau, pers. comm., 2010). This approach should enhance the ability to distinguish between male and female grouse, although male grouse are the indicators most used by state game agencies (Roddy, pers. comm., 2011).

It is apparent that the number of sharp-tailed grouse has declined over the past decade (Figure 8). However, the data for sharp-tailed grouse in WICA are less than optimal and further investigation is necessary to see if the trend is the result of diminished survey efforts or is in fact indicative of a serious population trend/crash.

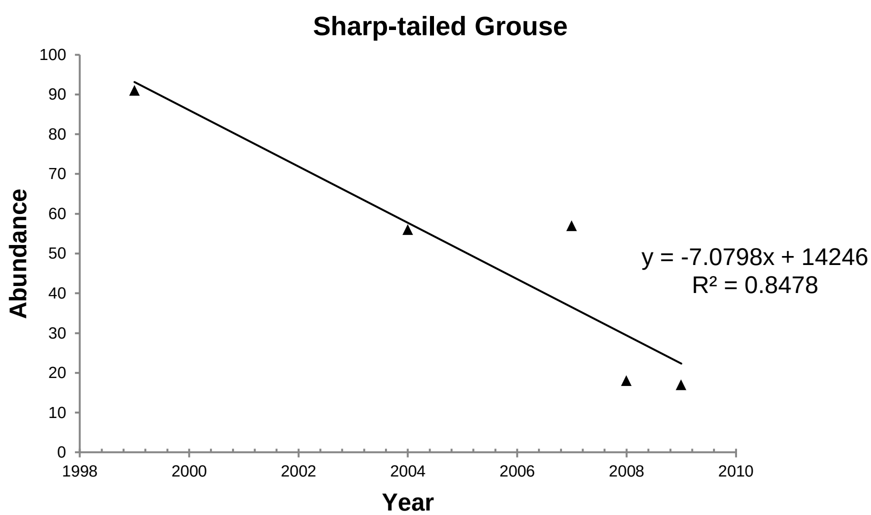

Figure 8. Estimated sharp-tailed grouse abundance as determined by WICA survey efforts from 1999, 2004, 2007-2009. Estimate includes all observed individuals from both the southern and eastern leks in the park.

Nightjar Population
Nightjar surveys were conducted for the first time in 2009. There were two surveys, the first occurring on 30 June 2009, and the second on 8 July 2009. In total, 17 common nighthawks and 16 common poorwills were observed (WICA 2010). Because this was the first survey year, trends cannot be determined.

Species Diversity
The Simpson diversity index (D) was calculated for each year and each survey (Figure 9). The Simpson diversity index represents the probability of any two individuals drawn randomly from a community belonging to the same species (Magurran 2004); this index is one of the most widely accepted measures of ecological diversity available (Gorelick 2006). The index is often reported as 1/D, this is because as D increases, diversity decreases. The value of 1/D will increase as the community becomes more even (Evenness is a measure of the relative abundance of the different species making up the richness of an area). There is no apparent trend in WICA species diversity. Off-road surveys yielded higher 1/D values than did on-road surveys (Figure 9).

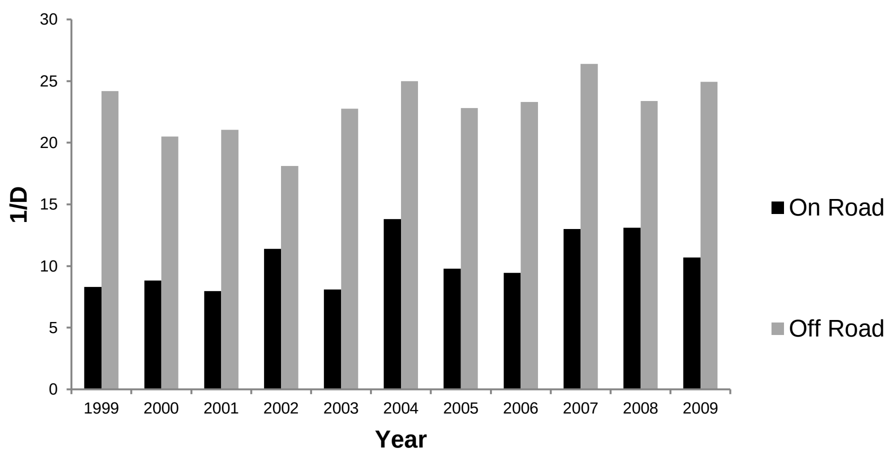

Figure 9. WICA Simpson Diversity Index (1/D) calculated from on- and off-road breeding bird surveys in WICA from 1999-2009.

Species Density
RMBO Survey Efforts, 2002-2004 (Panjabi et al. 2005)
From 2002-2004, Panjabi et al. (2005) surveyed two point transects within WICA; each transect was surveyed once each year. One transect was located in a foothill riparian habitat, while the other was located in a mixed-grass prairie. Along the foothill riparian transect, Panjabi et al. (2005) recorded between 195 and 294 individual birds of 59 species over the three year study period. The average annual density of all birds at this site decreased steadily from 8.52 birds/ha (2002), to 7.42 birds/ha (2003), to 6.46 birds/ha (2004) (Table 12). This decline was not statistically significant, but Panjabi et al. (2005) suggested that intensified monitoring may be warranted to better determine trends.

Table 12. Average annual density of all bird species detected in WICA for both the foothill riparian site and the mixed-grass prairie site as determined by Panjabi et al. (2005).

Transect	Year	Average Annual Density of All Birds
Foothill Riparian Site	2002	8.52
	2003	7.42
	2004	6.46
Mixed-grass Prairie	2002	1.53
	2003	1.85
	2004	0.69

For the mixed-grass prairie transect, Panjabi et al. (2005) recorded between 87 and 191 individual birds of 26 species. The average annual density of all birds at this transect ranged from 0.69 birds/ha (2004), to 1.85 birds/ha (2003). This decrease in density may be attributed to observer error, as the observer for that year had difficulty detecting birds at greater distances (Panjabi et al. 2005).

Blakesley et al. 2010 Breeding Bird Community Monitoring

In 2008, 4334 individuals and 89 species of birds were detected, while 3979 individuals of 82 species were detected in 2009 (103 different species detected across both years) (Blakesley et al. 2010). Survey efforts for 2008 and 2009 yielded reasonably precise density estimates for 22 species (Table 13). While trends are not discernable at this time, continued long-term monitoring will make it possible to detect increases/declines in a species population (Blakesley et al. 2010).

Table 13. Sample sizes (n) and estimated densities (Density) for 22 avian species in WICA, 2008-2009 as found in Blakesley et al. (2010).

Species	Year	n	Density
mourning dove	2008	57	14.08
	2009	41	10.17
northern flicker	2008	29	2.54
	2009	33	2.67
black-billed magpie	2008	52	1.61
	2009	10	0.09
American crow	2008	51	9.27
	2009	16	2.92
horned lark	2008	66	13.18
	2009	27	2.75
black-capped chickadee	2008	51	26.55
	2009	31	16.2
red-breasted nuthatch	2008	58	12.11
	2009	50	10.48
rock wren	2008	53	5.44
	2009	23	2.5
house wren	2008	27	1.01
	2009	49	1.85
mountain bluebird	2008	93	21.87
	2009	83	19.59
american robin	2008	58	76.27
	2009	44	58.09
yellow-rumped warbler	2008	30	2.3
	2009	32	2.46
ovenbird	2008	27	1.39
	2009	37	1.91
western tanager	2008	49	17.18
	2009	92	12.17
spotted towhee	2008	82	72.53
	2009	79	70.15
chipping sparrow	2008	158	180.06
	2009	158	180.77
vesper sparrow	2008	91	13.93
	2009	34	5.23
grasshopper sparrow	2008	87	44.57
	2009	98	110.5
dark-eyed junco	2008	41	24.2
	2009	22	13.04
western meadowlark	2008	210	84.84
	2009	179	72.6
brown-headed cowbird	2008	58	70.11
	2009	45	54.61
American goldfinch	2008	90	38.64
	2009	16	6.9

Threats and Stressor Factors

One of the major threats facing bird populations across all habitat types is land cover change (Morrison 1986). Altered habitat can compromise the reproductive success or survival rates of species adapted to that habitat. Being one of the last mixed-grass prairies remaining in North America, WICA offers refuge to several habitat specific species. A change in land cover could drastically alter the species composition of the park.

One of the driving forces of land cover change is climate change. As global temperatures change, bird species adjust by moving their home ranges north (Hitch and Leberg 2007). As this occurs, non-native species may encroach on native species' home ranges. In WICA, there are few exotic bird species (Roddy, pers. comm., 2010). European starlings (*Sturnus vulgaris*) are present but do not appear to be a serious problem by out-competing native bird species for cavity nesting spots, and house sparrows (*Passer domesticus*) do not breed in WICA. Eurasian-collared doves (*Streptopelia decaocto*) have been observed in the park but to date have not been documented as nesting in the park (Roddy, pers. comm., 2010).

Short and sparse vegetation is preferred on sharp-tailed grouse dancing grounds, but tall and dense grassland cover is required for nesting during April through June (WICA 2010). Grouse nesting success, then, is dependent upon specific climatic and land cover components at specific periods of the nesting season. Slight alteration of these could lead to range-wide decline.

Raptors face threats from a variety of sources: land cover change (loss of tree cover or prairie dog habitat), climate change, human disturbance, and prey-base fluctuations. Perhaps the most significant stressor raptors have faced in the last 100 years has been bioaccumulation. As pesticides and heavy metals are introduced into an ecosystem, the concentration at which they are present increases as they progress up the food chain. Raptors are top-level predators and are often subject to elevated levels of contaminants. Heavy metals, such as lead, mercury, cadmium, and zinc, cause reproductive stress or mortality on various raptor species (Hickey and Anderson 1968, Elliot et al. 2004, Lopez et al. 2008).

<u>Data Needs/Gaps</u>

Breeding bird surveys and Christmas bird counts provide snapshots in time of species richness in WICA; however, only one survey/visit per year yields little information in terms of population trends. Further observation could help to remedy this data gap and could potentially help the park better understand the status of breeding bird species in the park as well. WICA needs long-term trend data so that overall condition can be assigned to this component. In order to obtain these data, WICA needs to establish a long-term monitoring program for birds in the park.

Sharp-tailed grouse monitoring needs a more thorough, timely series of lek counts and male/female counts. To raise confidence in raptor nest occupancy/success, more than one visit per nest/territory should be made during the nesting season. Ideally, surveys should be conducted so the nests are visited 3 times, once in the breeding/courtship period, once in the period after egg hatch, and once during the time of chick fledging near the end of the nesting season.

<u>Overall Condition</u>

Overall condition of the birds in WICA cannot be determined at this time. While WICA BBS and CBC efforts help to provide momentary glimpses into the status of the population, they do not provide long-term trend data that are needed to accurately assess condition.

WICA has not experienced any recent, substantial increases or decreases in species richness estimates. Both BBS and CBC estimates of this measure showed no discernable trend, perhaps indicative of a stable breeding/migratory population. However, the park lacks long-term species richness data that is needed to accurately assess the condition of this measure.

Very few estimates regarding species diversity in WICA have been made. In order to have an accurate estimate of this measure, long term monitoring of the measure needs to take place.

Species diversity estimates in WICA are also limited. Panjabi (2005) and Blakesley et al. (2010) both created detailed estimates of this measure, but surveys have not persisted long enough to create trend data needed to assess the condition of WICA's species diversity. Continuation of the Blakesley et al. (2010) spatially balanced survey design will help to gather needed long-term trend data.

Sharp-tailed grouse surveys indicate that this species' population is potentially at a high risk of extirpation in the park. A consistent downward trend in population numbers has been observed since 1999. However, the data for sharp-tailed grouse in WICA are less than optimal and further investigation is necessary to see if the recent trend is the result of diminished survey efforts or is in fact indicative of a serious population trend/crash. Enhanced survey efforts are needed to determine appropriate management practices for the species to ensure the future existence of the population in the park.

Sources of Expertise

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Duane Weber, WICA Biological Science Technician
Dan Roddy, WICA Biologist

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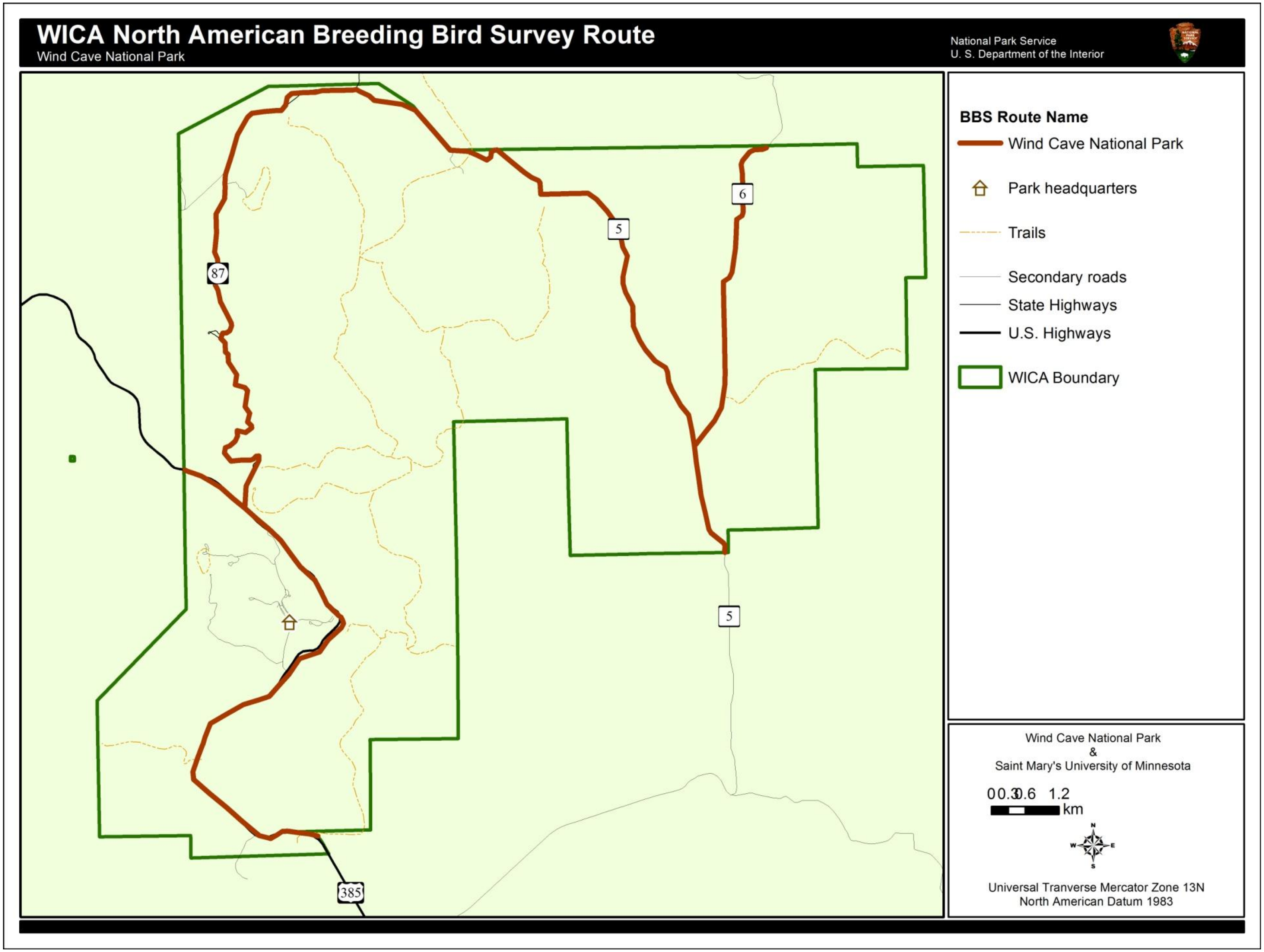

Plate 11. WICA on-road BBS Routes

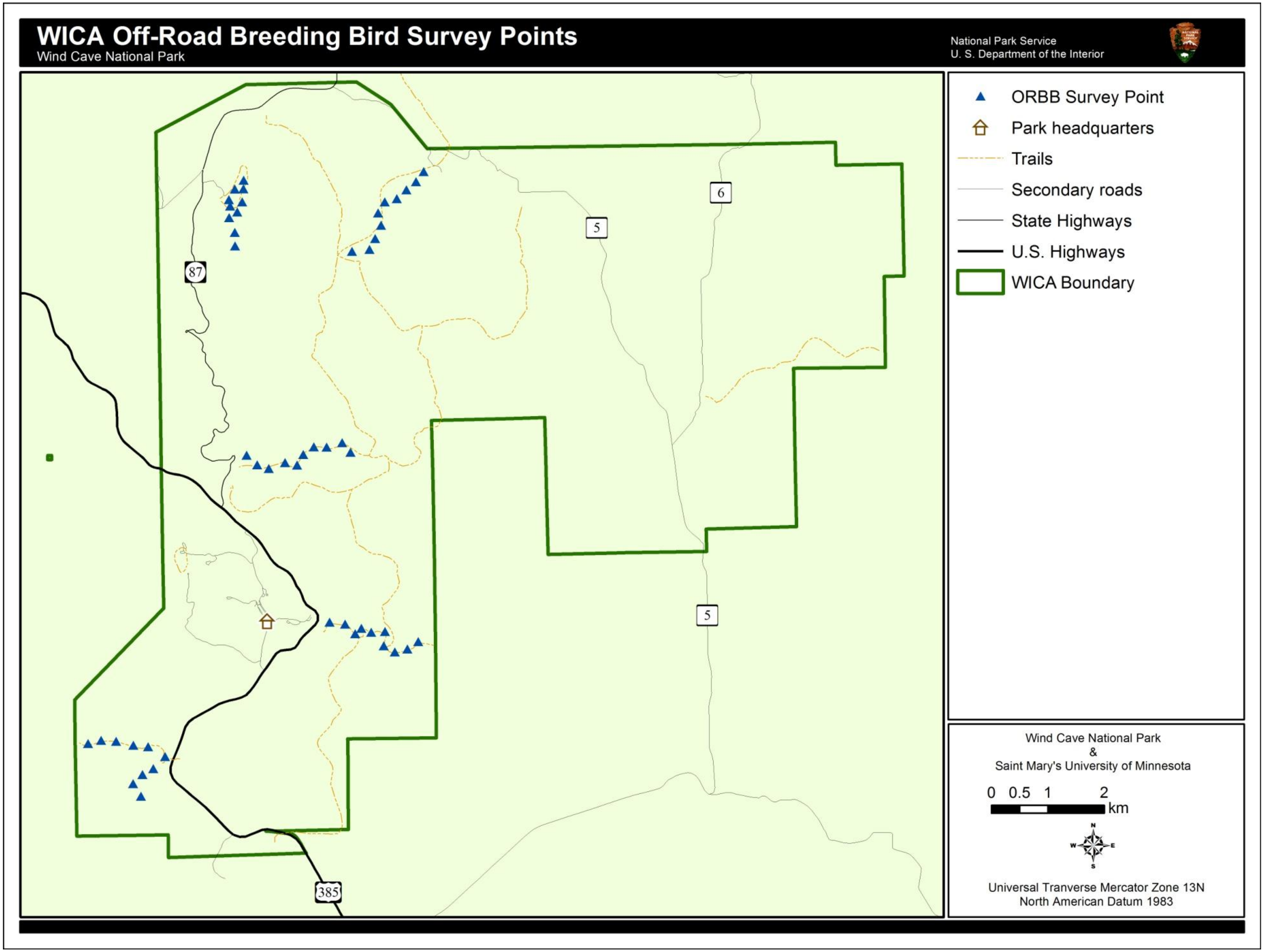

Plate 12. WICA off-road BBS routes

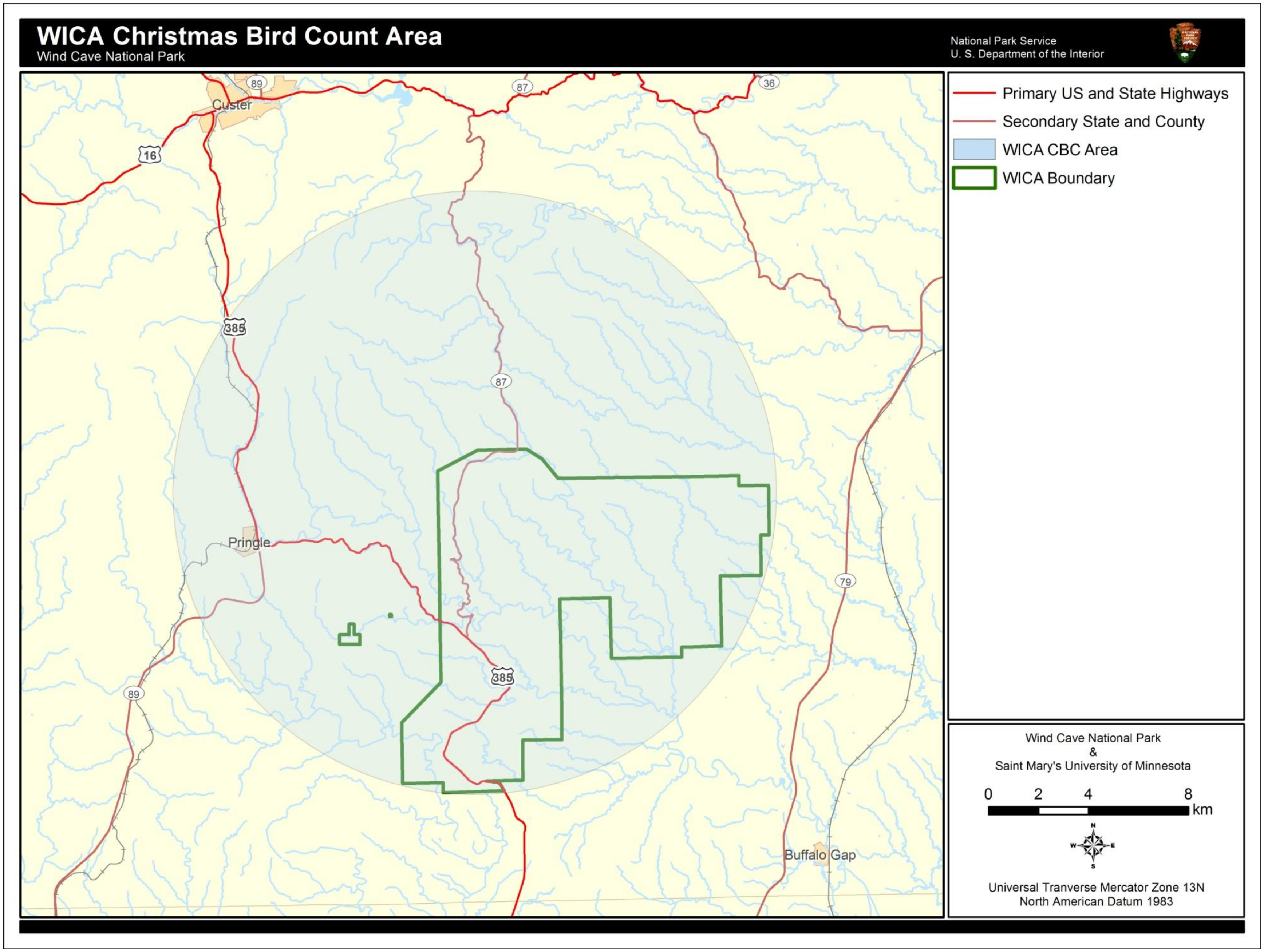

Plate 13. WICA Christmas Bird Count survey area

4.5 Elk

Description

Elkare considered a valuable natural resource to WICA as they historically existed in the region. However, careful management of populations must occur to prevent overpopulation, degradation of range resources from over-grazing, and adverse effects on neighboring private property or livestock operations. Prior to park establishment in 1903, elk were extirpated from the area. Between 1914 and 1916, elk were reintroduced to the area. The elk population increased to 1,200 - 1,500 animals before NPS began managing to prevent further population growth (Sargeant et al. 2011). Vegetation studies during this time examined range and forage conditions, and determined that they were in poor condition following the expansion of the elk population (NPS 2009a).

At high population densities, elk browsing can "have substantial localized impacts on some vegetative communities" (NPS 2009b). High elk densities can also affect landowners in the park's vicinity through increased crop degradation, the need to repair fences more frequently, and a higher prevalence of chronic wasting disease (CWD) in other cervids through transmission from elk. WICA elk management practices also affect other government organizations. South Dakota Game, Fish and Parks (SDGFP) provide funding for mitigation efforts related to crop degradation. In 2005, SDGFP spent approximately $87,000 in these efforts, double what was spent in 1999 (SDGFP Elk Depredation Summary, Elk Units 403 and 404, 1998-2003 as cited in NPS 2009a).

Measures

- Population density: The number of elk in park, expressed as total number of elk per km^2.
- Sex and Age Composition: The ratio of bulls and calves per 100 cows. Bull to cow ratios are not entirely reliable though, because bulls and cows are not equally observable during surveys (Sargeant, pers. comm., 2010).
- Distribution and Movements: This measure includes the proportion of elk that reside entirely within the park and the proportion of time elk spend inside and outside the park.
- Reproduction: pregnancy rates of adult and sub-adult cows

Reference Conditions/Values

The reference condition "Natural and Healthy Populations," specified by park staff, is unknown. Historical data that speak to elk population characteristics prior to park establishment are unavailable. Since the reference condition does not provide metrics for measure comparison, measures will be discussed relative to goals in the elk management plan and those that are outlined in the current condition and trend section of this document.

Data and Methods

The 2009 Final Elk Management Plan and Environmental Impact Statement (EMP) is the principal source of data for this assessment. Additional literature was obtained from the literature cited section of the EMP.

Current Condition and Trend

Population Density

The Science Team, comprised of WICA staff and other experts (NPS 2009a), established the current elk population goal in the park as 232-475 (mid-range 374) animals. This corresponds to a density of 2.03-4.16 elk/km^2 (5.1-10.8 elk/mi^2) (Table 14). In 2009, the over-winter elk population in WICA was estimated to be 850-900 animals, corresponding to 7.5-7.9 elk/km^2 (19.3-20.5 elk/mi^2), well above the established management goal. Sargeant et al. (2011) examined mortality rates, pregnancy rates, and age ratios of the WICA elk herd. They found evidence of substantial perinatal mortality. During 2005-2010, vital rates were indicative of a stable population: sampling variation and changes in methodology are therefore likely explanations for variation in population estimates of Table 14.

Table 14. Estimated winter elk population size, WICA, 1995-2009 (NPS 2009a).

Survey Year	Estimated Population Size
1995	250-300
1996	300
1997	443
1998	250-300
1999	-
2000	-
2001	350
2002	-
2003	650
2004	657-700
2005	800-850
2006	525-550
2007	600-650
2008	650-700
2009	850-900

Sex and Age Composition

From 2005-2009, recruitment to three months of age averaged 28 calves per 100 cows, substantially less than reported by Wydeven (50-64:100; 1977) and Bauman (51-55:100; 1998) (Sargeant et al. 2011). Reduced calf:cow ratios have resulted from combined effects of relatively low pregnancy and juvenile survival rates (Sargeant et al. 2011). The most recent estimates that are available suggest a sex ratio of approximately 55 bulls per 100 cows (NPS 2006). Because recruitment rates are relatively low, and many elk that reside within WICA are protected from hunting, average ages of elk within WICA probably are greater than those of elk outside the park (Sargeant, pers. comm., 2010).

Distribution and Movements

In the past, some of the elk that wintered in WICA would jump the lowered fence segment in the southwest corner of the park in spring and summer. In the fall, many of these animals would return to the park. Most of the animals that exit the park are those that are typically found in the

Gobbler Knob and central region of the park. Sargeant et al. (2008) observed the movements of radio-collared elk in the park and found that two of the 31 eastern-most females and one of the 18 eastern-most males exited the park, whereas 23 of 61 total females and 14 of 38 total males exited the park at some point over the course of the study. For animals that frequent the southwest portion of the park, 17 of 20 females observed and six of six males observed exited the park.

Photo 6. Elk in WICA. (NPS Photo)

During the summer of 2010, NPS modified 6.4 kilometers of 1.2-meter to 1.5-meter high boundary fence in the Southwest corner of the park raising it to 2.1 meters, consistent with the rest of the park boundary. 3.0-meter to 3.7-meter wide, 0.3-meter high (in the open position) elk jump gates were installed to provide easy access for elk to exit the park in the spring. Similar gates will be installed along the rest of the west boundary during the summer 2011. The gates will be closed in late summer/fall, to a height of 2.1 meters, to inhibit the return of elk to the park. Currently, USGS and NPS are beginning a study to determine the responses of elk to changes in fencing (Sargeant, pers. comm., 2010).

Reproduction

Elk are polygamous; mature bulls (greater than age 3.5) will gather harems of cows in the fall. Bulls will bugle during the breeding season to both ward off other males and attract females (NPS 2009a). Sargeant et al. (2011) found that two of 21 subadult females (9.5%) and 80 of 104 adult females (76.9%) sampled between 2005 and 2009 were pregnant. They also found that from 2005-2009 there was an average of 0.28 calves surviving to three months of age per adult female. The pregnancy rate of elk at WICA is low compared to the rest of the region, likely indicating resource limitation (Sargeant et al. 2011). For comparison, the elk herd at Theodore Roosevelt National Park (THRO) experienced a subadult pregnancy rate of 54.1% (n = 85) and an adult pregnancy rate of 96.8% (n = 288) for female elk sampled in 1993, 2000, 2001, and 2003-2006 (Sargeant and Oehler 2007). Sargeant and Oehler (2007) indicate that the pregnancy rates of the elk herd at THRO represent the upper end of the regional potential.

Threats and Stressor Factors

CWD is a neurological disease that has a 100% mortality rate and affects North American cervids, including white-tailed deer, mule deer and elk. This disease is a transmissible spongiform encephalopathy (TSE), resulting from the accumulation of misfolded proteins called prions. Other TSEs include mad-cow disease (which affects cattle) and Creutzfeldt-Jacob disease (which affects humans). Infected cervids experience behavioral and anatomical changes, including altered social interaction, loss of fear, and progressive weight loss (USGS 2007). CWD testing by SDGFP has shown prevalence in the greater Black Hills area to be <0.007 (n = 1,867) (Sargeant et al. 2011) The WICA herd is experiencing a 3.4% annual loss to CWD, suggesting rapid spread of the disease in the high density herd (Sargeant et al. 2011).

Vegetation is a driving factor of management goals regarding the three primary grazing species in WICA: elk, bison, and prairie dogs. The maximum number of elk the park can support without negative effects on native vegetative communities varies with bison and prairie dog population size and forage productivity/precipitation. WICA aims to "have a variety of seral stages for habitat and a number of species in the park" (NPS 2006, p. 6). Consequently, management goals for any species changes with altered vegetation production.

The mountain lion population in the Black Hills has expanded rapidly since the early 1990s when few animals were present. As of 2010, SDGFP estimates there are 223 mountain lions in the Black Hills region of South Dakota, but SDGFP acknowledges that additional population monitoring is needed to verify this estimate (SDGFP 2010). Mountain lion predation is a stressor that accounts for 2.9% of the yearly elk mortality at WICA (Sargeant et al. 2011). Effects of mountain lion predation at WICA from 2005-2009 were largely additive and likely had the most effect on juvenile elk mortality rates (Sargeant et al. 2011).

Photo 7. Elk in WICA (Photo by Kevin Stark of SMU GSS, 2009).

<u>Data Needs/Gaps</u>
Monitoring seasonal elk movement to and from the park has always been a priority of park management and even more so now that NPS has modified WICA's boundary fence. The fence

was modified in order to encourage elk movement out of the park in spring and reduce their return rate in late summer and fall. This was one of the provisions defined in the EMP in hopes of reducing the number of wintering elk in the park.

The NPS also uses uncorrected counts from aerial surveys to index elk abundance in the park. This is cause for concern because aerial counts often overlook substantial portions of elk populations, causing inconsistency that result in variation of annual estimates that does not accurately match the population (Sargeant, pers. comm., 2010). Increasing the accuracy of the elk population estimates at the park would benefit future management decisions.

Sargeant (pers. comm., 2010) noted that body condition scores for elk in the park could also be beneficial to park management.

<u>Overall Condition</u>
The elk population in WICA exceeds the management goal of 232-475 individuals. The most recent population estimate (850-900 individuals in 2009) is nearly three times larger than the mid-range of the goal. A large elk population could affect populations of other species in the Park, including bison, prairie dogs, and the reintroduced black-footed ferret. In addition, native vegetative communities could experience negative effects if the elk population continues to increase or the herd is not brought down to the management goal in the near future. Hoof action from elk herds, sometimes numbering 200-300 in a group, can result in streambank erosion as well as ground disturbances conducive for introduction of non-native plant species (Roddy, pers. comm., 2010). Overall, a population size that exceeds EMP goals and low pregnancy rates in the park, possibly indicative of resource limitation, make the condition of elk at WICA of significant concern.

Sources of Expertise
Dan Roddy, WICA Biologist
Glen Sargeant, USGS Research Wildlife Biologist
Duane Weber, WICA Biological Science Technician

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4.6 Bison

Description

For almost 10,000 years, plains bison were a keystone element of the Great Plains, providing food and materials for aboriginals and the European settlers that arrived later (NPS 2006). No one is certain how many bison were present in North America prior to European settlement, but estimates are in the millions (NPS 2009). Today, there are a few remnant wild populations in North America, with most populations occurring in parks, preserves, or private ranches.

WICA's enabling legislation directs the park to maintain herds of large ungulates (NPS 2006). In addition, "Bison are an essential component of the Park because they contribute to the biological, ecological, cultural, and aesthetic purpose of the Park" (NPS 2006). The WICA bison population is also of great value because of high levels of genetic variation, the absence of brucellosis, and no evidence of cattle gene introgression (the influx of cattle genes into a genome) (NPS 2006).

Measures

- Genetic Conservation: degree of cattle gene introgression in herd and genetic diversity
- Population: number of individuals in the herd

Reference Conditions/Values

The reference condition for the WICA bison herd is the current population. According to the literature, the WICA bison population shows no evidence of cattle gene introgression or brucellosis (Halbert and Derr 2006). Currently the park manages to maintain an in-park herd with a minimum of 400 individuals (NPS 2006). Gross and Wang (2005) examined the effects of different management strategies on genetic heterozygosity, allele retention, and sex and age structure of NPS herds. They found that a herd size of approximately 1,000 animals is "necessary to meet a long-term goal of achieving a 90% probability of retaining 90% of allelic diversity for 200 years." and that "bison herds with fewer than about 400 animals are unlikely to meet a long-term goal of achieving a 90% probability of retaining 90% of genetic heterozygosity for 200 years." Even though the current bison population at WICA is less than 400 individuals, there are management actions that can reduce genetic diversity loss (Gross and Wang 2005). These include removing young animals from the herd to increase generation time, and developing satellite herds to increase the effective population size. The park is in the process of establishing satellite herds.

Data and Methods

WICA staff provided all data and most literature. Additional literature was acquired via online literature databases. Data provided by the park were not altered.

Current Condition and Trend

<u>Genetic Conservation</u>

"Genetic introgression, especially from interspecies hybridization, is a significant threat to species conservation worldwide (Halbert and Derr 2006)." Halbert and Derr (2006) examined 11 US Federal bison populations for domestic cattle gene introgression. Through blood, hair, and tissue samples, they examined introgression in mitochondrial and nuclear DNA. Federal employees collected 3301 samples from 1999-2001, of which 352 were from the WICA bison population. Of the 11 populations examined by Halbert and Derr (2006), only one displayed evidence of domestic cattle mitochondrial DNA introgression: the National Bison Range in northwest Montana. Four populations did not exhibit evidence of mitochondrial or nuclear introgression: Grand Teton National Park, Sully's Hill National Game Preserve, WICA, and Yellowstone National Park. Of these, only the WICA and Yellowstone populations had adequate sample sizes to allow for 95% confidence in the results (Halbert and Derr 2006).

Halbert and Derr (2008) examined the patterns of genetic variation within 11 federal bison herds. They identified three herds as critical sources of genetic resources: WICA, Yellowstone, and the National Bison Range. WICA and Yellowstone are of particular importance because these herds are not cattle gene introgressed. The authors stated that, "The creation of satellite herds from these sources therefore should be a conservation priority for this species to mitigate the effects of genetic drift and protect against the catastrophic loss of critical germplasm [genetic resources]."

<u>Population</u>

In 1913, the American Bison Association donated 14 bison to WICA, in an effort to establish a new federal bison herd and six additional bison were brought from Yellowstone in 1916. By 1950, the herd had grown to over 300 individuals. Since then, the herd has typically ranged from 300-400 individuals (NPS 2010a). In 2009, NPS estimated that the bison herd consisted of 300-325 individuals (Roddy et al. 201). Bison are captured nearly every October to remove mainly yearling animals to bring the herd back to a manageable number that coincides with the amount of forage available in the park. Today, the bison herd functions naturally as possible, given they are in a restricted environment (Roddy, pers. comm., 2010). WICA staff does not provide supplemental feeding or watering. Because of this, there are times individuals may not appear as vigorous as those in other federal herds. Rather, variations in weather, vegetation, available water, etc. may determine the herd's characteristics.

Photo 8. American bison (NPS Photo).

In the 1960s, WICA and the Natural Resource Conservation Service (NRCS) established a population goal of 350-500 bison for the WICA herd. They developed this goal using forage allocation models that accounted for the needs of the various herbivores in the park, including bison, elk, pronghorn, mule deer and black-tailed prairie dogs. The bison population varied during the years following goal establishment, but was always within the range.

In 2004, WICA repeated the forage allocation study to verify bison and elk management goals and to establish new goals for other species (e.g., black-tailed prairie dog). At that time, WICA also took into consideration the fact that bison in the park were of particular conservation concern because there was no evidence of cattle gene introgression and the herd had a high level of genetic diversity. Experts concluded that in order to maintain the herd's genetic diversity a minimum of 400 individuals was needed in the population. However, current population goals are derived from Gross and Wang (2005) as mentioned in the reference condition of this document. The final forage management strategy allocated 25% of available forage for large mammals (bison and elk), 25% for other wildlife habitat and plant damage compensation, and 50% to ensure plant health and vigor (NPS 2006). The black-tailed prairie dog is another wildlife species that has an effect on available forage in the park. The prairie dog is accounted for in the grazing model by placing all prairie dog town area in a low, less productive seral stage, thereby lowering the production potential for other wildlife species in the park.

Threats and Stressor Factors

Brucellosis

Brucellosis is a contagious disease that primarily affects cattle, bison, swine, and occasionally humans. The causative agents come from the bacterial genus *Brucella*. The species *B. abortus* is the chief affecter of cattle and bison. In bison and cattle, the disease centralizes in the reproductive tract and/or the udder, causing abortion, delayed conception, and occasionally arthritis. The disease spreads through direct contact with infected individuals, aborted fetuses, placental membranes or fluids, or other vaginal discharges present following the abortion or calving of an infected animal (USDA 2010).

Management for brucellosis in the WICA bison herd began in 1945. At that time, 60 bison were tested for brucellosis. Thirty-three WICA bison were confirmed to have brucellosis and 18 others were suspect cases of brucellosis; WICA staff dispatched all bison confirmed or suspected of having the disease. In 1949, brucellosis vaccination efforts ceased and did not resume until 1960. In the early 1960s, WICA and neighboring Custer State Park resumed vaccination efforts and began eradicating infected individuals. In November of 1982, the State of South Dakota placed the WICA herd under quarantine because of brucellosis. From 1960 to 1986, when the quarantine ceased, NPS tested 3,197 bison for brucellosis of which 243 were confirmed or suspected to have the disease. In total, NPS removed 1,332 bison during the eradication process. Since the quarantine release in 1986, WICA has tested approximately 4,104 bison for brucellosis; zero animals tested positive (Muenchau, pers. comm., 2010). In addition, the park stopped administering brucellosis vaccination to heifers in 1998 (Muenchau, pers. comm., 2010).

Cattle gene introgression

Cattle gene introgression and a suite of other factors threaten the diversity and integrity of the bison genome (Freese et al. 2007). Today, few bison are free of cattle gene introgression (Halbert et al. 2005, Halbert and Derr 2006). In the United States and Canada, all but six significant bison herds exhibit cattle gene introgression (Freese et al. 2007). The WICA bison herd is one of these herds and is one of two herds that have an adequate sample size to achieve 95% confidence in this claim, with the Yellowstone National Park herd being the other (Halbert and Derr 2006). A potential vector for cattle gene introgression into the WICA bison herd is the Custer State Park bison herd (a neighboring herd that is "cattle-gene-introgressed") (Freese et al. 2007). Only a fence separates the WICA and Custer State Park herds and bison from the Custer State Park herd have crossed the fence into WICA (Freese et al. 2007).

Data Needs/Gaps

The data needs for the WICA bison herd are dependent on a few factors. If NPS supports the Single Nucleotide Polymorphism (SNP) method for detecting cattle gene introgression, then the herd will need to be tested using the new methodology. However, there is a possibility that the Chinese Government will be funding a project to map the bison genome. If the bison genome was known, NPS would most likely test all of the bison in the WICA herd to compare their genome to that of a true American bison. There is a possibility that no bison are truly 100% free of cattle genes. Regardless, a standard monitoring procedure to count calves in late July/early August, when most cows are in large herds, is a necessity (Roddy, pers. comm., 2010).

Overall Condition

The WICA bison herd is a unique resource and is in good condition, genetically and physically. Regarding their genetic make-up, there is no or little evidence of cattle genes within the herd, making it an important source for reestablishing other bison herds. The population has been stable in recent history, ranging from 302 to 459 individuals in the fall following the capture. Potential threats to the population, brucellosis, and cattle gene introgression, do not appear to be affecting the current population. Finally, Roddy (pers. comm.) noted that the herd functions as naturally as possible given the constraints of the park.

Sources of Expertise

Dan Roddy, WICA Biologist
Barbara Muenchau, WICA Biological Science Technician
Duane Weber, WICA Biological Science Technician

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4.7 Prairie Dogs

Description
The black-tailed prairie dog, hereafter prairie dog, is a keystone species. Prairie dogs have resided in present-day WICA for thousands of years (NPS 2006a). Early in park history, prairie dogs were considered a nuisance and many different methods of removal were employed. Today, the value of prairie dogs is better understood, realizing that prairie dogs provide habitat or food for badgers (*Taxidea taxus*), burrowing owls, tiger salamanders (*Ambystoma tigrinum*), prairie rattlesnakes (*Crotalus viridis*), black-footed ferrets, and many other species (NPS 2006a, NPS 2009).

Measures

- Active area and distribution

Reference Conditions/Values
According to the NPS 2006(b) Environmental Assessment (EA) Finding of No Significant Impact (FONSI), 405 to 1,214 ha (1,000 to 3,000 ac) of prairie dog colonies in WICA allows for long-term viability of the prairie dog population and the availability of forage and habitat for other species in the park. Specifically, the FONSI expressed that prairie dog populations should allow adequate and sustainable forage conditions for bison and elk, the main grazers in the park.

Data and Methods
WICA staff provided data and some literature. Additional literature was acquired via online database searches.

Current Condition and Trend

<u>Active area</u>
WICA staff use active prairie dog colony acreage as an index for population size. Many prairie dog colonies in WICA have had historic acreage estimates from aerial photo interpretation, ground surveys, or remote sensing (NPS 2010a). These estimates tell what prairie dog colony distribution was prior to 2000, when intensive control of prairie dogs was more prevalent.

Since 2000, total prairie dog acreage has increased but also remained within the management range (Figure 10). Currently, prairie dog colonies occupy an estimated 1,093 ha (2,700 ac) in WICA (NPS 2010a). When populations increase above the defined management goal, some control may be necessary to prevent possible negative effects on other park species. Limited control may also be needed to control prairie dogs that are near adjacent private lands if landowner complaints dealing with prairie dog encroachment are received.

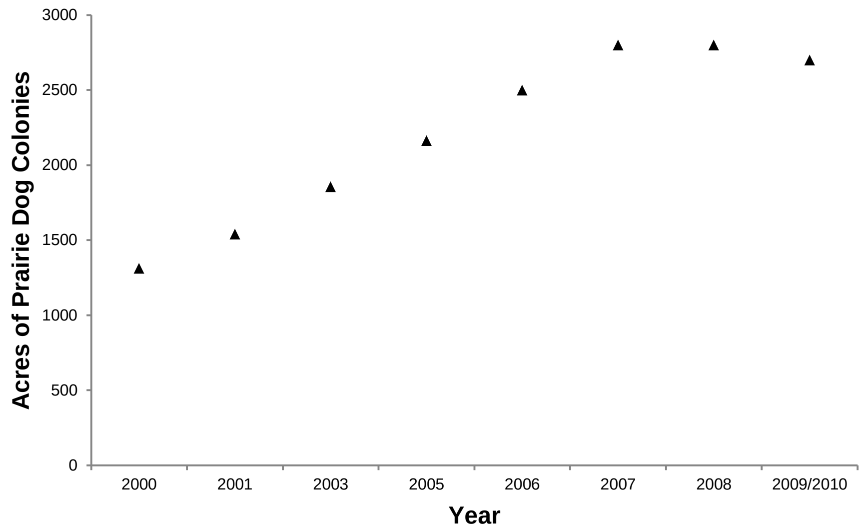

Figure 10. Estimated prairie dog colony acreage, WICA, 2000-2010.

Distribution

The largest prairie dogs colonies in WICA, Bison Flats and Research Reserve, are in the southwestern portion of the park. Throughout the rest of the park, colonies are scattered. Ten out of the 22 colonies are viewable from the roads that traverse the park (Plate 14).

Threats and stressor factors

Sylvatic plague, caused by the bacterium *Yersinia pestis*, is the most well known stressor to prairie dog populations and the primary cause for the rangewide decline in prairie dog distribution and abundance (Pauli et al. 2006). Sylvatic plague is the only major factor that limits prairie dog abundance, which is beyond human control (Cully and Williams 2001). Black-tailed prairie dogs are highly susceptible to plague, exhibiting near 100 percent mortality, compared to approximately 85 percent mortality in white-tailed prairie dogs (*Cynomys leucurus*) (Barnes 1993, Cully and Williams 2001). Additionally, plague results in smaller and more isolated prairie dog colonies, which reduce genetic variability through inbreeding and genetic drift (Trudeau et al. 2004). A plague outbreak has never occurred in WICA, but it is a major concern since it has been detected within 32 km (20 mi) of the park boundary (Roddy, pers. comm., 2010).

Photo 9. Black-tailed prairie dog (Kevin Stark, SMU GSS, 2009).

White horehound is a persistent, exotic invasive plant that is unpalatable to grazing animals because of its bitterness. In 2006, there were 41 ha (100 ac) of horehound in the Bison Flats dog town (NPS 2009). In 2010, there were 271 ha (670 ac) of horehound mapped in or near nine of the 22 recognized prairie dog colonies (NPS 2010, Plate 15). Prairie dogs avoid dense areas of horehound. The combination of native plant and prairie dog displacement makes horehound a significant concern to park management. When prairie dogs are removed or displaced from an area, it also has effects on the endangered black-footed ferret that relies heavily on prairie dogs for food and its burrows for survival as well as for raising its young.

Human interaction also plays a role in the health and behavior of prairie dog populations (Magle et al. 2005, Johnson and Collinge 2004, and Antolin et al. 2002). Prairie dogs in WICA are subject to human interaction on a regular basis because so many of the colonies are easily accessible by park roads. A study in Boulder, Colorado found that black-tailed prairie dogs exhibited increased responsiveness in concealment behavior, returning to burrows faster, with repeated human disturbances (Magle et al. 2005). The same study found that repeated human disturbance led to prairie dogs barking with less frequency as part of their avoidance response (Magle et al. 2005). Magle et al. (2005) speculate that the loss of barking behavior could reduce a prairie dog colony's ability to protect themselves from predators, such as humans, pets, and native carnivores. In addition, many visitors feed the prairie dogs at WICA, attracting them to the road and making them more susceptible to road kills (Muenchau, pers. comm., 2010).

<u>Data Needs/Gaps</u>
Park staff (pers. comm., 2010) mentioned many data needs that if fulfilled would assist WICA prairie dog management. Delineating active and inactive areas of prairie dog towns would provide added insight regarding changes in distribution. Successful methods for stopping white horehound spread need to be realized to alleviate this stressor. Continued monitoring of flea loads and analysis of fleas for plague evidence is a priority.

<u>Overall Condition</u>
Since 2000, prairie dog extent has been increasing and is near the upper limit of the management goal of 405 to 1,214 ha (1,000 to 3,000 ac) established in the 2006 EA FONSI. Currently, prairie dogs occupy approximately 1,093 ha (2,700 ac) in WICA. However, sylvatic plague and horehound are a cause for concern. Plague has decimated prairie dogs range wide and has been detected within 24-32 km (15-20 mi). White horehound, an exotic invasive and persistent plant, is also a concern because it displaces prairie dogs, alters native plant communities, and has expanded to cover 243 to 283ha (600 to 700 ac) in WICA (Muenchau, pers. comm., 2010). Based on the population being near the upper limit of the management goal and the potential for threats and stressors the prairie dog population at WICA is of moderate concern.

Sources of Expertise
Dan Roddy, WICA Biologist
Barbara Muenchau, WICA Biological Science Technician

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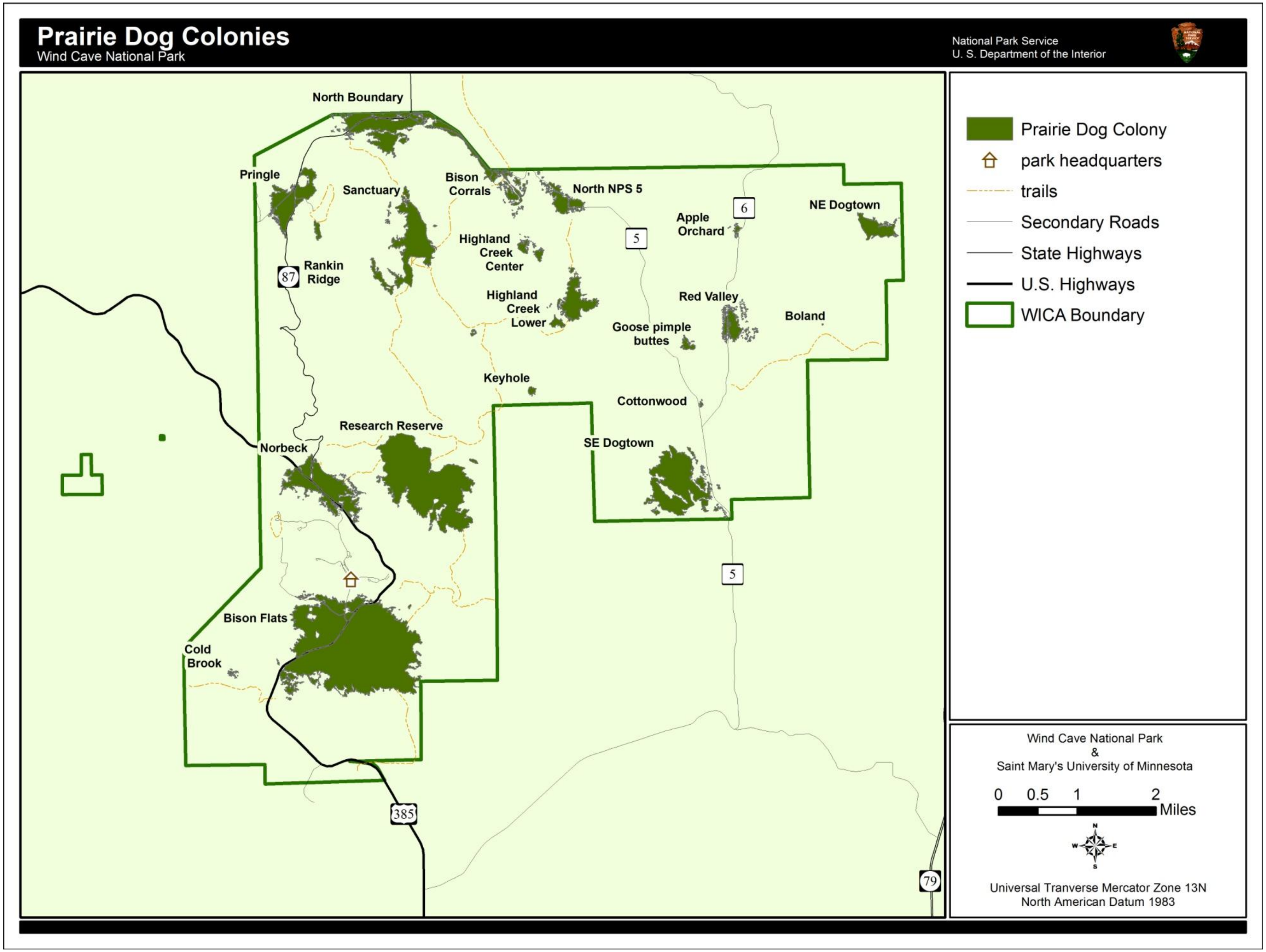

Plate 14. Prairie dog colonies, 2007 (NPS 2007).

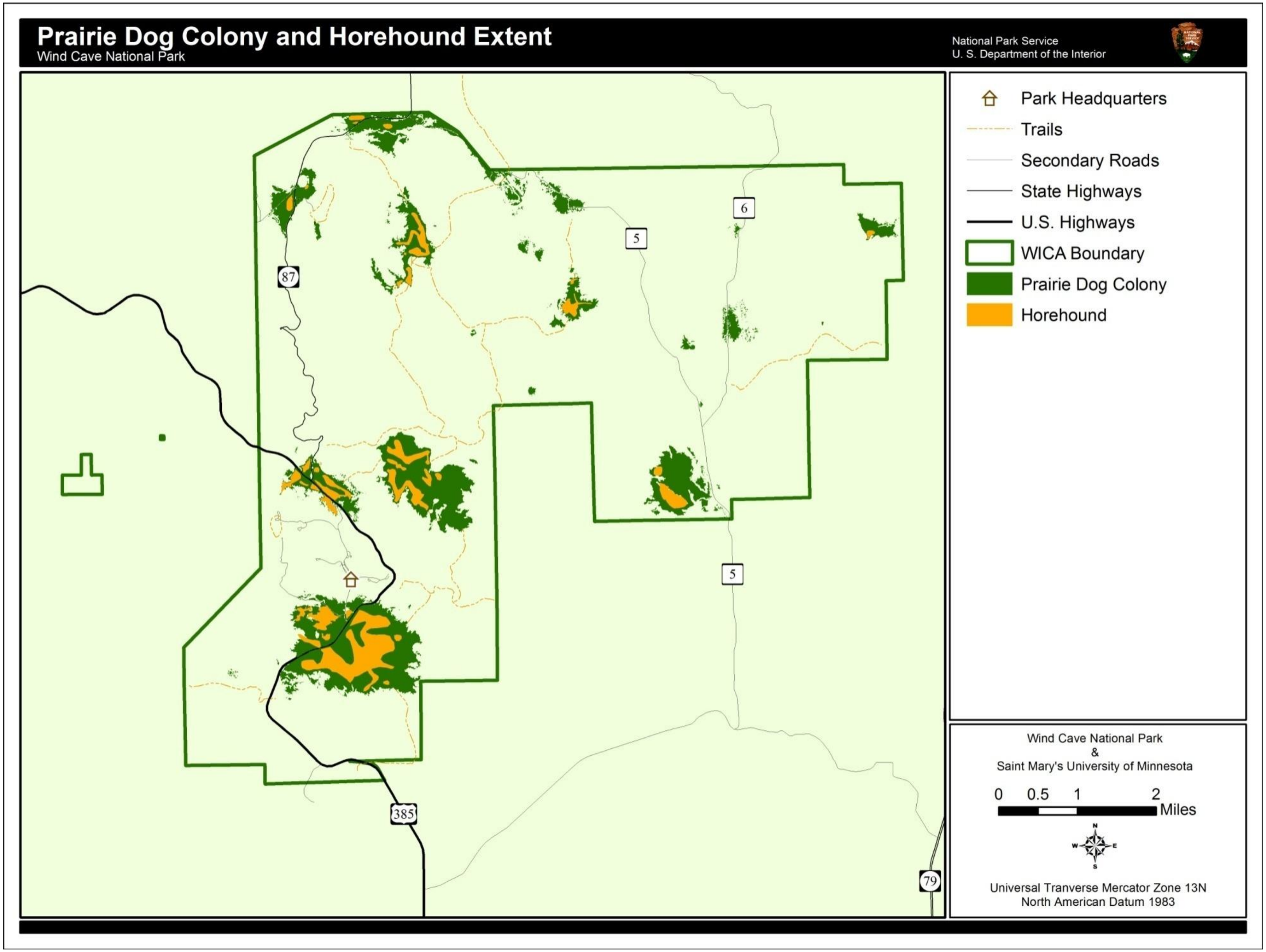

Plate 15. Prairie dog colony and horehound extent (NPS 2007, 2010a).

4.8 Black-footed Ferret

Description

The black-footed ferret, hereafter ferret, once ranged from the "Great Plains of Canada to intermontane regions of the interior Rocky Mountains and southwestern United States" (Anderson et al. 1986). Ferrets depend on prairie dogs for both food and shelter. The range-wide population of this species declined significantly throughout the 1900s because of the widespread decline of prairie dogs. The ferret is currently classified as an endangered species at both the state and federal level. WICA is only one of two National Parks that host a ferret population. It is also the only National Park where the ferret was introduced as an endangered species. The other park, Badlands National Park, introduced its population as a non-essential, experimental population.

The last time a ferret was observed within WICA was in 1977. In 2007, after a 30 year absence, NPS, in cooperation with USFWS, reintroduced 49 ferrets (25 male and 24 female) to WICA. These organizations defined many goals for this reintroduction project (NPS 2006a):

- *Test* the viability of using a reintroduction site with less than 2,023 ha (5,000 ac) of prairie dog complexes;
- *Establish* a self-sustaining population of black-footed ferrets;
- *Provide* surplus wild-born ferret kits for translocations to other sites;
- *Meet* NPS policy by reintroducing an extirpated species;
- *Support* the NPS mission in keeping with NPS policies;
- *Collaborate* with park partners on the project;
- *Educate* the public about black-footed ferret restoration and conservation; and
- *Avoid or minimize* adverse effects on local economies, life styles, and the natural environment.

Measures

- Population Number and Distribution

Reference Conditions/Values

The reference condition for ferrets at WICA is the current extent of prairie dogs in the park. Plague is a major concern to park staff, because of the potential for catastrophic prairie dog losses as well as direct losses of ferrets. A severe decline in the prairie dog population would cause the ferret reintroduction efforts to fail.

Data and Methods

NPS staff provided data for this assessment.

Current Condition and Trend

<u>Population Number and Distribution</u>

Survey Efforts
Barbara Muenchau and Dan Roddy provided the following documentation of ferret survey methods and results at WICA. They provided both unpublished manuscripts and information via telephone and email.

Photo 10. Black-footed ferret (NPS Photo).

WICA staff attempts to perform three ferret surveys a year, along with recording incidental observations. There are two spotlight surveys each year (spring and fall) and snow tracking in the winter. During the summer months, staff lead nighttime walks that give park visitors the opportunity to observe and learn about ferrets.

Spotlight surveys are the primary method used to determine the presence of ferrets. These are nighttime surveys that should take place over three consecutive nights. During spotlight surveys, surveyors walk over a designated area within a prairie dog colony from sundown to sunup, using battery operated spotlights while traversing the landscape searching for the emerald green eye-shine of a ferret. Once a ferret is observed, surveyors will mark the burrow the ferret went into with a colored reflector, take a GPS location, and either place a transponder reader over the opening of the burrow (spring surveys) to identify the ferret as it leaves the burrow, or a ferret trap into the burrow (fall survey) to capture and collect data as well as mark the ferret if no microchip is present.

It is extremely difficult to capture 100% of the ferrets so not all of them within the park have a transponder chip in the back of their neck between the shoulder blades. The chip provides an individual identification number so that the number can be read by the transponder reader when the ferret comes through the opening of the burrow or a hand held scanner if they are trapped in the fall. The unique number can be cross referenced to obtain the sex and age of the ferret.

Spring spotlight surveys are conducted in March and April to estimate the number of ferrets that survived the winter going into the breeding season. Since spring surveys are conducted during the breeding season, biologists want to disturb the ferrets as little as possible so a passive transponder reader is placed at the burrow entrance rather than a trap. When the ferret sticks its head out of the burrow the reader records the number from the microchip (if the ferret has one) located under the skin on its upper back between the shoulder blades.

Fall surveys are conducted in September/October primarily to capture kits and insert transponder chips as well as vaccinate for canine distemper, plague, etc. During this time, a specially made live trap is placed into the burrow where the ferret was last observed. The trap is covered with cloth material and acts as an extension of the burrow, and as the ferret attempts to leave the burrow, it is captured. Surveyors check traps roughly every hour, and once a ferret is captured, it is then transferred to a round tube for ease of transport and safety to the ferret. The ferret is then transported to a trailer, anesthetized, examined, vaccinated, and a transponder chip inserted. The ferret (after it awakes from anesthesia) is then returned to the burrow it was captured from.

Snow tracking is done opportunistically and informally at WICA with the best results attained when snow cover is continuous and undisturbed for several days. This type of survey takes place during daylight hours, is inexpensive, and is least likely to have an adverse affect on ferrets, but it is also dependent on weather conditions (Biggins et al. 2006). Good tracking conditions occur only sporadically in WICA. Snow tracking involves searching the ground for tracks and other ferret sign (especially digging, or "trenching"). Ferrets make a typical mustelid "twin track" pattern (hind feet placed in same spot as front feet) and typically go from burrow to burrow. Surveyors attempt to follow ferret tracks from origin burrow to terminus burrow (Biggins et al. 2006). Lack of tracks does not mean a ferret is not present since research indicates ferrets can be inactive up to six nights and days. Snow tracking is an excellent tool for checking areas that were not surveyed previously, or areas where ferrets are believed to be present but were not found in previous surveys.

2008 Surveys

During 2008 snow tracking surveys, participants observed five to seven individual sets of tracks. Tracks were so prolific in some areas of the prairie dog towns that it was difficult to distinguish between individuals. Following this survey, park staff concluded that the minimum number of ferrets were 12-17 individuals.

WICA staff performed the 2008 spring spotlight survey for three nights in April, totaling 144 person-hours. They located five to six different ferrets, but were only able to identify two of them. Following the survey, they concluded that the minimum number of ferrets in the population was 14 to 19. This estimate was derived from snow tracking and spring spotlight survey data.

The 2008 fall spotlight survey was more intense than the spring spotlight survey. WICA staff surveyed for four nights, for a total of 380 person-hours. They captured 14 kits and 4 adults (identified from microchip reading) and located eight to 11 other ferrets that were observed but not captured. They determined the minimum ferret population to be 26 to 29 individuals.

2009 Surveys

WICA staff dedicated 40.5 person-hours to snow tracking in 2009. Conditions were poor for tracking; surveyors only surveyed one prairie dog colony. Three to six sets of ferret tracks were observed, resulting in a minimum population estimate of three to six individuals.

There were 11 participants in the 2009 spring spotlight survey, resulting in 140 person-hours. Surveyors spotted five ferrets during this survey period, but only three were identified. Based on snow tracking and this survey, WICA staff concluded there was a minimum of four to seven ferrets in the population.

In 2009, there were three incidental ferret observations; one was during a staff-lead night hike, another during a salamander survey, and the third was by NPS biologists Dan Roddy and Dan Licht. All three ferrets were identified.

There were 15 participants during the 2009 fall spotlight survey, expending 362 person-hours. They found five kits, identified two adults, and observed nine to 11 other individuals. Following this survey, the minimum number of ferrets was determined to be 16 to 18.

2010 Surveys and Monitoring Efforts

In 2010, WICA staff spent 23 hours snow tracking ferrets and found a total of five to eight different sets of tracks. They found two to three sets in the Norbeck prairie dog colony, one to two sets in the North Boundary colony, one to two sets in the Research Reserve colony, and one in Bison flats colony. They also sampled the Pringle and Southeast colonies, but did not observe any tracks.

WICA staff led three spring spotlight surveys in late March and early April of 2010. Eleven people participated in these efforts, accounting for 177.5 person hours. They identified seven ferrets using the PIT reader, three females and four males, and one additional ferret came through the reader that did not have a tag. There were a number of other observations without readings. In total, 13 to 19 ferrets were observed.

There were three incidental black-footed ferret sightings at WICA in 2010. One ferret was observed at the Norbeck prairie dog colony in March; a passive integrated transponder (PIT) reader was placed near the observation but no identification was obtained. In September, two ferrets were observed in the southeast portion of the Bison Flats prairie dog colony, neither was identified.

WICA completed two different surveys in the fall of 2010, one from September 20 to 24, and the other from October 18 to 21. Both times, the participants surveyed Bison Flats, Norbeck, and the North Boundary prairie dog colonies. The first survey at Bison Flats colony yielded 19 to 23 ferrets and the second yielded 20 to 23 ferrets. At Norbeck, one adult male was captured in September but not in October. This was a different male than the one the park got a reading on in March 2010. At the North Boundary colony, the survey group observed seven to ten ferrets during the first survey and 13 to 15 during the second survey.

In addition to the above mentioned population estimates, 12 ferrets were released near the South East and Red Valley prairie dog colonies. Taking into account all observations, captures, and new releases, the current ferret population size at WICA, at minimum, is 46-52 individuals (Muenchau, pers. comm., 2010).

<u>Threats and Stressor Factors</u>

Disease and loss of habitat have caused a drastic decline of ferrets in their historical range, and continue to be the main threats to ferrets within the park. Predators may also be considered a threat/stressor.

Sylvatic plague is a major threat to ferrets both directly and indirectly. Ferrets are highly susceptible to the effects of plague directly though fatal infection, and indirectly because plague kills prairie dogs which are the prey on which they depend (Gasper et al. 2001). Plague has the potential to decimate an entire prairie dog population (Barnes 1993, Cully and Williams 2001) and the bacteria can be maintained in animal tissues within burrow systems for up to 2 months (Godbey et al. 2006). No evidence of active plague has been seen within the park, but analysis of a small percentage of fleas collected in several prairie dog colonies has shown the presence of *Y. pestis* DNA. Active plague has been documented within 24 - 32 kilometers (15-20 mi) of the park.

Canine distemper (CDV) is a highly infectious viral disease in which ferrets are also susceptible. Few, if any individual ferrets exposed to the disease, recover (Williams et al. 1988). The disease is spread by animals that frequent prairie dog colonies such as coyotes, badgers and skunks (*Mephitis mephitis*). Domestic dogs (*Canis lupus familiaris*) also carry the disease and are believed to be largely responsible for introducing CDV to wildlife. Canine distemper was the main cause of the catastrophic losses of ferrets in northwestern Wyoming in 1985 and 1986. Most of the ferrets within the park have been vaccinated against CDV, but it is important the park continue to be vigilant in keeping domestic animals out of all areas of park, especially the prairie dog colonies and backcountry to prevent disease transmission to wildlife.

Ferrets are also susceptible to rabies, tularemia and human influenza, but those diseases are not considered a serious threat.

Loss of habitat is another serious threat to ferrets within the park. Ferrets depend on prairie dogs for food and shelter, making threats to prairie dogs, such as sylvatic plague and the invasive, non-native white horehound, important aspects of managing for ferrets. White horehound is of major concern due to its aggressive growth habits within prairie dog colonies. It takes over bare ground, sometime forcing prairie dogs to move from the area thereby reducing habitat for ferrets. The recent increase in horehound within the park has led to an estimated loss of 162 ha (400 ac) of prairie dog habitat.

Habitat may also be lost as a result of management decisions to reduce prairie dog acres through poisoning. The park currently shares a prairie dog colony with the State of SD where part of the park’s ferret population occurs. This is a colony that has previously been poisoned and was scheduled for removal by the State. Loss of this prairie dog colony would have a detrimental effect on the park’s ferret population. In addition, the current prairie dog management plan for the park prescribes a range of 405 to 1,214 ha (1,000 to 3,000 ac) of prairie dogs (NPS 2006b). A management decision made to reduce the prairie dogs to the lower end of the range would have a detrimental effect on the park’s ferret population.

Predators, such as coyotes, badger, Great Horned Owls (*Bubo virginianus*), eagles and other raptors have been known to have a serious impact on some reintroduced and free ranging ferret populations (Breck et al. 2006). The USFWS does give ferret allocation priority to those reintroduction sites that develop proactive, effective predator management programs, especially those that include predation monitoring and rapid response capabilities. Other research indicates that lethal control, specifically with coyotes, is not only ineffective in the long run, but may actually have the opposite effect of what is intended with predator reduction. Indiscriminate killing of coyotes may actually increase predation pressure on ferrets by producing larger coyote litters (Blejaws et al. 2002). In addition, the killing of resident predators allows transient animals to move in that may be a vector for disease transmission. WICA staff made the decision that no park-wide predator control measures would be used but the park does reserve the right to take or relocate under exigent circumstances (NPS Management Policies, section 4.4.2 [NPS 2006a]) an individual predator that appears to be actively focusing on the ferrets. At the time of the initial ferret reintroduction in July of 2007, the coyote densities appear to have declined, attributed to a sarcoptic mange epizootic (Chronert et al. 2007).

<u>Data Needs/Gaps</u>
Chiefly, disease monitoring, especially for plague, needs to increase. The park needs to receive flea test results in a timely manner so they can be proactive with flea dusting efforts in areas where fleas known to carry plague are located. In addition, a small mammal survey, specific to the prairie dog colonies, would identify other species that are potentially plague hosts. Finally, the effects of deltamethrin (agent used to eliminate fleas) on insects, reptiles, and amphibians in the prairie dog colonies should be researched.

A formal survey of all prairie dog colonies to determine ferret occupancy would assist future management decisions. This information would allow park staff to make sound decisions when relocating ferrets from colonies that are already saturated with ferrets.

Dan Licht noted (pers. comm., 2010) that predator effects on black-footed ferrets in WICA are unknown. When the ferret population was reestablished at WICA, coyotes were experiencing mange, as the coyote population rebounds there could be adverse effects on the ferret population. Another predator of concern is the Great Horned Owl, which has caused severe problems with other ferret reintroduction efforts.

<u>Overall Condition</u>
The black-footed ferret population at WICA is roughly equal to the number of animals released in 2007. It appears that the population decreased during the first year following release, as is typical of most reintroductions, but has rebounded recently (Licht, pers. comm., 2010). The success of the black-footed ferret at WICA is dependent on the health of the prairie dog colonies. The prairie dog population within the Park has shown a steady increase from 1997 – 2007, with a slight decline over the past 3 years. There is additional potential habitat for prairie dog and ferret growth within the park, but disease and white horehound are a present threat.

Sources of Expertise
Dan Roddy, WICA Biologist
Dan Licht, NPS Midwest Region Wildlife Biologist
Barbara Muenchau, WICA Biological Science Technician

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4.9 Pronghorn

Description

NPS, with the help of the Boone and Crocket Club, reintroduced 13 pronghorn in 1914. The same year, 14 bison and 21 elk were reintroduced. Elk and bison thrived in WICA following reintroduction, whereas pronghorn did not. Managers believed that predators held the pronghorn population at low numbers, but at that time, little was known about pronghorn biology. WICA implemented a strict predator control program to stimulate the pronghorn population, which was unsuccessful until WICA removed interior fences and acquired additional land. The increased park size allowed pronghorn to move and forage in a more natural way (Muenchau, pers. comm., 2010). By 1960, the pronghorn population exceeded 300 animals (NPS 2008).

"Pronghorn, bison, and prairie dogs form a grazing association on the northern United States mixed-grass prairie" (Krueger 1986). In addition, WICA is home to two other large grazing species: mule deer and elk. Typically, pronghorn and bison graze on sites dominated by cool-season grasses while elk and mule deer graze on sites dominated by warm-season grasses (Wydeven and Dahlgren 1985). NPS manages these large ungulates closely to ensure the prolonged success of both the ungulate and native plant communities.

Measures

- Population number and distribution

Reference Conditions/Values

The reference condition for pronghorn in WICA is a breeding and healthy population.

Data and Methods

WICA staff provided data and the initial body of literature for this assessment. Online journal database searches provided supplemental literature.

Photo 11. Pronghorn (NPS Photo).

Current Condition and Trend

<u>Population number and distribution</u>

The size of the pronghorn herd in WICA has been variable (Figure 11). Between 1914 (initial introduction of WICA pronghorn) and the late 1930s, WICA pronghorn numbers were held in check by the size of the park, interior fences, and predators. Following removal of interior fences and predators in the 1920s, the herd grew to a maximum of 350 individuals in 1965. From 1965 to 1980, the herd declined steadily, followed by a period in which the herd ranged between 50 and 100 animals. Part of this decline was attributed to NPS relocating animals into Custer State Park. Sievers (2004) concluded that the neonate survival contributed to the low density of the herd in the late 1990s. On two occasions several pronghorn (125 and 16) have walked across frozen or snow-packed cattle guards and were not able to find their way back into the park. Since so many variables affected the pronghorn population from the 1950s to the late 1990s, determining the cause of the WICA pronghorn population decline is difficult (Roddy, pers. comm., 2010).

In the early 2000s, when the pronghorn population was at an all-time low (~21 individuals), the effects of mange reduced the coyote population in the area (Roddy, pers. comm., 2010). During this period of low numbers of coyotes, the pronghorn numbers rebounded and then leveled off at 100-110 individuals in 2007. The most recent park survey of pronghorn was in the fall of 2010, 124 animals were observed (NPS unpub. data).

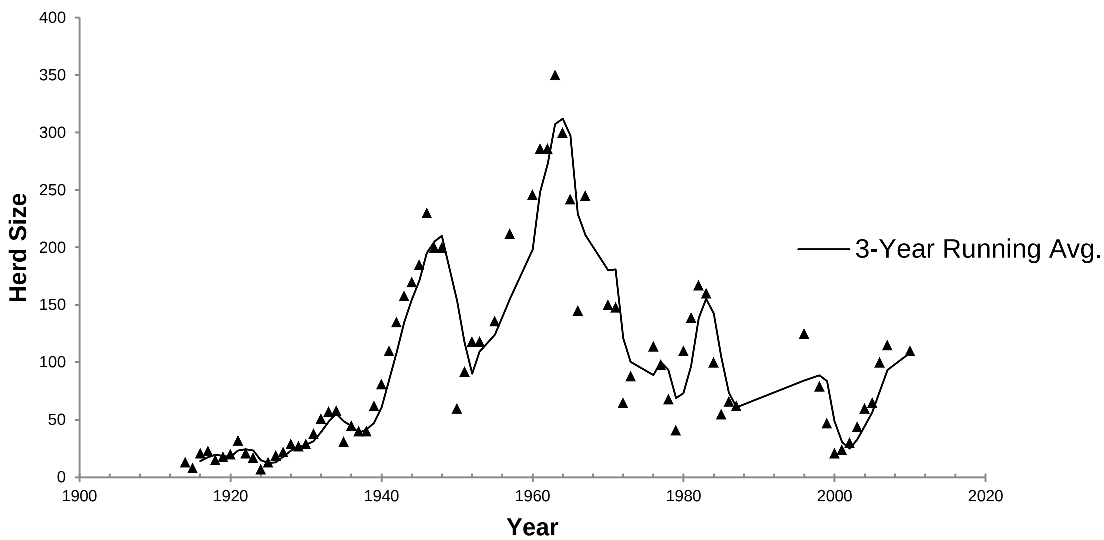

Figure 11. Estimated pronghorn population, WICA, 1914-2010 (NPS 2010).

Jacques et al. (2005) examined the survival of pronghorns in western South Dakota. They documented that coyotes were the primary cause of neonate (<1 month of age) pronghorn death. Specific to WICA, they confirmed that the pronghorn population grew quickly following a coyote population decline in the early 2000s.

Sievers (2004) also concluded that forage composition could limit the growth of the WICA pronghorn herd. Jacques (2006) examined this claim and found that the annual diets of pronghorn at WICA consisted of 41.5% grasses, 31.1% shrubs, and 27.4% forbs. At the time of the study, the total forage production in the park was 72% grass, 4% shrub, and 23% forbs. Jacques (2006) concluded that there was strong dietary selection toward shrubs. In conclusion, the authors hypothesized that the "reduced distribution and diversity of optimal forage (i.e., habitat quality)" which was influenced by long-term drought contributed to the population decline of the herd in the late 1990s.

Threats and Stressor Factors

Pronghorn prefer to graze on areas occupied by prairie dogs. Because of this, stressors to prairie dogs (e.g., plague, white horehound, and drought) could indirectly affect the pronghorn population at WICA. An in-depth discussion of prairie dog stressors is located in Chapter 4.7 of this document.

Photo 12. Pronghorn in a field infested with white horehound (NPS Photo).

Predation is a primary stressor of the WICA pronghorn population. It is expected that coyotes, Golden Eagles, and mountain lions are having an impact on young pronghorn survival. Park staff observations suggest that mountain lions also predate on adult pronghorn. Vegetation is a key component of pronghorn predation. When vegetation is sparse, high fawn predation occurs because of the lack of cover. Currently, park habitat appears suitable for young survival (Roddy, pers. comm., 2010).

Other potential stressors are disease and competition with other grazing animals; these are not currently an issue.

Data Needs/Gaps

Jacques (2006) examined pronghorn forage composition during a long-term drought. They indicated that examining foraging behavior during a year with normal precipitation could be helpful for management.

Overall Condition

The WICA pronghorn herd is in good condition. The population fluctuates naturally in response to precipitation and predators, as well as un-natural events such as driving them into Custer State Park or pronghorn walking across frozen-over cattle guards. The population has increased over the last ten years since being at all-time low numbers during the severe drought and high predator populations of the mid to late 1990s.

Sources of Expertise

Dan Roddy, WICA Biologist

Barbara Muenchau, WICA Biological Science Technician

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4.10 Porcupine

Description

The common porcupine (*Erethizon dorsatum*) is the second largest rodent in North America, outsized only by the beaver (*Castor canadensis*). Individuals range in length from 600 to 900 mm and can weigh up to 14 kg (Roze 1989). An adult porcupine is covered with anywhere from 15,000-30,000 specially adapted quills. These quills extend from the rear of the head to the tip of the tail on the porcupine's dorsal surface (Roze 1989). When confronted with a predator, the porcupine will erect its quills as a defense mechanism. If a predator comes into physical contact with the porcupine, the quills will be released instantly (NPS 2007). Unlike many common myths about porcupines, the quills cannot be shot or propelled from the porcupine's body – they are only released upon contact.

The diet of the porcupine is generalized, but shows a marked difference between summer and winter; winter diet typically consists of bark and cambium layers of trees, while summer diet consists of roots, stems, berries, and grasses (Linzey et al. 2008). Porcupines often feed heavily on a single tree, causing extensive damage or even death to that tree (Linzey et al. 2008).

In the southern Black Hills, porcupines appear to have nearly vanished from the landscape, including WICA. It is a rarity to see a porcupine in the vicinity of the visitor center, park housing, picnic grounds, roadways, or back country where they seemed to be relatively common 5-10 years ago (Roddy and Muenchau, pers. comm., 2010). A decrease in anecdotal observations (i.e., road kill carcasses and sightings by park staff members that spend a lot of time in the backcountry of the park and surrounding National Forest) also indicates very low numbers of porcupines (Roddy, pers. comm., 2010). Outside of the Black Hills, where mountain lions are few and far between, porcupines appear to be holding their own (Muenchau and Roddy, pers. comm., 2010). Determining the population size and distribution of porcupines in WICA will be important in determining the status and threats facing the porcupine population. It is uncertain if the apparently low numbers are within the normal range of variation for this wildlife species, or whether the high number of mountain lions currently occupying the Black Hills has impacted the local porcupine population. There may also be other unknown factors taking place in the environment that have caused the decline of the porcupine.

Measures

- Population number
- Distribution

Reference Conditions/Values

The reference condition for porcupines in WICA is described as breeding and healthy populations. Breeding and healthy populations are described as populations representative of those that would naturally occur across the southern Black Hills within suitable habitats and particular seasons of the year (Muenchau and Roddy, pers. comm., 2010).

Data and Methods

There has been no porcupine monitoring or reports conducted within WICA.

Current Condition and Trend
The current condition of porcupines in WICA is unknown. There are no annual surveys of porcupines in the park and an estimate of the population size and distribution is unknown.

<u>Threats and Stressor Factors</u>
WICA staff identified three potential stressors to porcupines in the park: predators, loss of high value food sources, and disease.


Photo 13. Porcupine (NPS Photo).

Known predators of porcupines include fishers (*Martes pennanti*), mountain lions, lynx, bobcats, coyotes, gray wolves (*Canis lupus*), wolverines (*Gulo gulo*), and Great Horned Owls (Weber and Myers 2004). Of these species, mountain lions (occasional in park), bobcats (resident animals observed occasionally in the park), coyotes (common in park), and Great Horned Owls (common in park) have been reported in WICA and could potentially be predators of porcupines.

Predators tend to hunt and kill porcupines mostly in open habitats, as porcupines are adept climbers and will first attempt to climb a nearby tree before using its quills as a defense mechanism (Weber and Myers 2004). Mountain lions have been reported as making no attempt to avoid the quills of porcupines; instead they attack at will and later deal with the consequences of the embedded quills (Sweitzer and Berger 1992, Sweitzer et al. 1997 as quoted in Weber and Myers 2004).

Another potential threat for porcupines is the loss of high value food sources. Nitrogen is the most important nutritional resource for porcupines (Weber and Myers 2004). In order to maximize their nutritional uptake, porcupines will feed at night. At night, plant and leaf chemistry changes and porcupines take advantage of the added nutrients made available during the nighttime metabolic processes of plants (Roze 1989).

Porcupine diets are continually changing with the seasons. In the spring months, porcupines will feed on young buds of trees. However, as the leaves of these trees flush out, porcupines must change their diet as many tree leaves contain high levels of tannins, which are a toxic chemical to porcupines (Weber and Meyers 2004). Porcupines will focus the rest of their forage efforts for the summer months on ash and aspen cambium layers. Porcupines will also opportunistically feed on raspberry stems, grasses, nuts, and flowering herbs (Roze 1989). The diet of porcupines in WICA and the Black Hills is uncertain; approximately 98% of the tree cover is ponderosa pine, which is a species not frequently utilized by porcupines.

In the winter months, porcupines must feed on bark, twigs, and evergreen needles. These are poor sources of nitrogen, and during the winter months porcupines slowly move towards starvation and lose weight throughout the winter (Weber and Myers 2004).

Presently, not much is known about the diseases that affect porcupines and whether disease is actually a factor in the apparently low numbers in the park or Black Hills – this is reflected by the limited number of disease descriptions in published literature (Barigye et al. 2007). Rabies in rodents is very rare; in the eastern United States, raccoon variant rabies occasionally spills over into large rodents, especially woodchucks (WSDH 2010). It may be possible for porcupines to be exposed to rabies or to be a reservoir of the disease, but it appears very unlikely. Overall, disease does not appear to be a major stressor of porcupine populations in WICA. With limited knowledge of porcupine diseases, however, the threat cannot be entirely dismissed.

<u>Overall Condition</u>
Because there have been no porcupine surveys or estimates or population size or distribution, condition cannot be assessed at this time.

<u>Data Needs/Gaps</u>
Monitoring of porcupine populations is needed to assess the size and distribution of porcupines in WICA.

Sources of Expertise
Dan Roddy, WICA Biologist
Barbara Muenchau, WICA Biological Science Technician
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4.11 Herptile Species

Description
Herptile species (reptiles and amphibians) are an important component of the ecosystem in WICA. Reptiles are an important predator of many different abundant animals in the park – prairie rattlesnakes are predators of prairie dogs and other rodents, bullsnakes (*Pituophis catenifer sayi*) are predators of small birds, and smooth green snakes (*Liochlorophis vernalis)* are predators of insects (NPS 2006). Amphibians act as key indicator species as they are especially susceptible to ecological changes, largely due to their permeable skin (Smith 2007). In addition, amphibians are often prey species, so the toxins absorbed through their skin can quickly spread throughout an entire food web (Smith and Keinath 2007). The importance of both reptiles and amphibians makes monitoring their populations and distributions in WICA important.

Measures
- Population number and distribution

Reference Conditions/Values
Breeding and healthy populations

Data and Methods
Smith (1996) conducted a herpetological survey of WICA in 1996 using a variety of techniques, including drift fences, sampling along transects, visual encounter surveys, turtle trapping, road cruises, and surveys of springs and precipitation catchment ponds. The efficiency of these different techniques and recommendations for a future monitoring protocol in WICA are discussed at length in Smith (1996).

WICA was included in the sampling units as part of the Black Hills region in a herpetological inventory of the larger Black Hills region in 2004 (Smith et al. 2005). Smith et al. (2005) used GIS coverages and Environmental Monitoring and Assessment Program (EMAP) hexagons to determine sampling units in the Black Hills. The authors then assigned values to these EMAP hexagons to determine priority of each sampling unit. Once the sampling units were determined, three types of surveys were used: call surveys, visual encounter surveys, and road surveys (Smith et al. 2005).

In an effort to determine effects of deltamethrin on tiger salamander populations, NPS staff performed spotlight surveys for tiger salamanders in the Bison Flats Prairie Dog Town during June, 2009. Deltamethrin is an insecticide sprayed into prairie dog burrows to reduce flea abundance in an attempt to prevent plague epizootics (NPS 2009).

NGPN loaned WICA two Autonomous Recording Units (ARU) to record bioacoustical vocalizations in 2009. WICA was specifically interested in the presence and breeding status of northern leopard frogs (*Lithobates pipiens*) in the park (NPS 2009). Thousands of hours of recordings were made from March 6th – June 21st near Beaver Creek and the “Herp Hole” in Cold Brook Canyon in the southwestern part of WICA. Interpretations of these recordings have not yet been completed.

Current Condition and Trend

Population number and distribution

Smith (1996) documented a variety of herptile species in WICA including one species of salamander, one species of turtle, four species of frogs and toads, and six species of snakes (Table 15). Three additional species of snakes, one species of frog, and one species of turtle have been observed in WICA since the Smith (1996) survey (Smith et al. 2005; Roddy, pers. comm., 2010). No lizards were found during this survey, and none have ever been reported in the park (Smith 1996). However, it is possible that lizards exist in the park, as WICA is within the range of many lizard species (NPS 2006). Table 15 includes a complete list of herptiles documented by WICA staff as well as Smith (1996) and Smith et al. (2005).

Table 15. Reptiles and Amphibians Documented in WICA.

Scientific Name	Common Name	Confirmation
Ambystoma mavortium melanostictum	blotched tiger salamander	Smith 1996
Anaxyrus cognatus	Great Plains toad	Smith 1996
Anaxyrus woodhousii woodhousii	woodhouse's toad	Smith 1996
Pseudacris maculata	boreal chorus frog	Smith 1996
Lithobates pipiens	northern leopard frog	Muenchau, Roddy[1]
Spea bombifrons	plains spadefoot toad	Smith 1996
Coluber constrictor flaviventris	eastern yellowbelly racer	Smith 1996
Crotalus viridis viridis	prairie rattlesnake	Smith 1996
Heterodon nasicus nasicus	plains hognose snake	Kobza, Muenchau[2]
Lampropeltis triangulum multistriata	pale milk snake	Smith 1996
Liochlorophis vernalis	smooth green snake	Kobza, Weber[3]
Pituophis catenifer sayi	bullsnake	Smith 1996
Thamnophis elegans vagrans	wandering garter snake	Lawson, Muenchau[4]
Thamnophis radix	plains garter snake	Smith 1996
Thamnophis sirtalis parietalis	red-sided garter snake	Smith 1996
Chelydra serpentina serpentina	common snapping turtle	Smith 1996
Chrysemys picta bellii	western painted turtle	Smith et al. 2005

[1] Observed numerous times by Barbara Muenchau (Biological Science Technician) and Dan Roddy (Biologist) with photo documentation

[2] Observed on two separate occasions by Bob Kobza (Fire Monitor) and Barabara Muenchau in 1998 and 2000

[3] Observed on two separate occasions by Bob Kobza and Barbara Muenchau with photo documentation on 10/6/2004

[4] Observed by Tamara Lawson (researcher) and Barbara Muenchau on 5/22/1998

All reptiles in Table 15 can be found throughout WICA because of the relatively small size of the park (Smith, pers. comm., 2011). It is also possible that the Black Hills red-bellied snake (*Storeria occipitomaculata pahasapae*) is in WICA, but it has not been documented to date (Muenchau, pers. comm., 2011). Amphibian distribution is more ambiguous due to the lack of permanent water throughout WICA. Specific population numbers and distribution for individual herptile species are not known.

The smooth green snake is of particular interest because it is denoted as rare by NPS and the state of South Dakota (NPS 2006, South Dakota Games, Fish and Parks). Smooth green snakes were observed on two separate occasions by fire monitor Bob Kobza and biological technician Duane Weber, with photo documentation by Weber on October 6, 2004 (Roddy, pers. comm., 2011).

Photo 14. Western painted turtle (*Chrysemys picta bellii*) (Courtesy of Gary Stoltz, U.S. Fish and Wildlife Service).

Smith (1996) declared tiger salamanders to be a common species in WICA, although they were difficult to locate. Adult tiger salamanders were generally documented in prairie dog towns during the night (Smith 1996). A large number of larval salamanders were found living in the sewage treatment ponds east of the visitor center and many larvae were also found in Bison Flats Pond. This pond dried up within a month of discovering larvae, and it is not likely that the larvae reached maturity before the pond dried up (Smith 1996).

Although Smith (1996) found tiger salamanders throughout WICA, the NPS (2009) survey resulted in only 62 salamander observations with 4% of inspected burrows occupied. The small number of observations makes statistical analysis for population estimates inappropriate (NPS 2009). Though few tiger salamanders were found in this survey, previous surveys (including a black-footed ferret survey in April of 2009) found tiger salamanders to be prevalent. It is hard to draw a conclusion on the effects of deltamethrin on tiger salamanders because of the low observation rates. The weak evidence suggests that if the deltamethrin does have an effect, it is not catastrophic in terms of population abundance (NPS 2009). However, more work remains to be completed, especially looking at long-term effects of bioaccumulation within this local population (Roddy, pers. comm., 2011). Currently (2011) a graduate student is working in the park collecting data on salamanders and deltamethrin.

The northern leopard frog is common throughout the Black Hills region but is declining or extinct throughout other portions of its range (Smith et al. 2005). In 2009, the northern leopard frog was a candidate to be listed as a threatened species under the Endangered Species Act of 1973 (USFWS 2009). In the regional inventory performed by Smith et al. (2005), northern leopard frogs were found along the edges of larger lakes and along creeks. However, no northern leopard frogs were found within WICA in 1996 due to a lack of suitable habitat, although specimens have been documented in Custer State Park, just to the north of WICA (Smith 2003). Although Smith (1996, 2003) did not document any northern leopard frogs in the park, WICA staff has recorded numerous sightings (visual, not vocal, observations) over the past 5-10 years along Beaver and Highland Creeks in the park (Roddy, pers. comm., 2011).

The ARU's used in the 2009 NPS survey have thousands of hours of recordings that still need to be interpreted. According to what has been interpreted thus far, there appears to be evidence of northern leopard frogs at both locations (Beaver Creek and "Herp Hole" in Cold Brook Canyon), but this has not been confirmed by the park (NPS 2009).

Threats and Stressor Factors

Identified threats and stressors identified by WICA include human impacts, flea dusting, predators, and climate change. According to Smith (pers. comm., 2011), the biggest concern for the park should be flea dusting. Since adult tiger salamanders are known to live in prairie dog burrows, flea dusting of prairie dog burrows or other control efforts could negatively impact salamanders. Weak evidence from the NPS (2009) survey suggests that flea dusting does not have a significant effect on tiger salamander populations, but additional research is needed to determine the possible long-term effects.

Roddy (pers. comm., 2011) suggests that stressors to the northern leopard frog appear to be cyclic. During the wetter years they seem to be observed frequently along stream courses that have tall vegetation for them to rest and conceal themselves. During dryer times they seem to be rare with very few observations. Stressors include lack of available water for breeding (during drought periods) as well as less height and density of plants for concealment and resting. In addition, streambank erosion and trampling from over-utilization by elk and bison in riparian areas can have negative effects on northern leopard frogs.

Smith (pers. comm., 2011) suggests that most visitors come to WICA to explore the cave and most do not explore the trails throughout WICA. Though introduction of non-native herptiles by humans is possible, human disturbance should not be of significant concern.

Data Needs/Gaps

An examination of prairie dog burrows around Bison Flats Pond to determine if the tiger salamanders congregate at Bison Flats Pond on a yearly basis would help increase the understanding of tiger salamander habitat use in WICA (Smith 1996). Since the Bison Flats Pond is a popular breeding location for amphibian species on the southern end of the park, it would also be beneficial to study the trends of the Bison Flats Pond to observe its pattern for drying up in the summer months (Smith, pers. comm., 2011).

Information regarding the possible negative impact flea dusting can have on tiger salamanders would be beneficial. This would help the Park have a better understanding of the potential impacts to salamanders and other organisms from plague prevention activities that occur in prairie dog colonies. More observations of tiger salamanders are needed in future studies in order to conduct statistical analysis.

Audio interpretation of the ARU recordings from 2009 is needed to confirm the presence and breeding status of northern leopard frogs in WICA.

Overall Condition

The reference condition of herptile species in WICA is described as a breeding and healthy population. In WICA, there have been surveys and inventories to identify present herptile species (Table 15). Unfortunately, there is little data collected on specific herptile populations and distributions. It is therefore not possible to assign a condition to WICA herptile species at this time.

Sources of Expertise

Barbara Muenchau, WICA Biological Science Technician
Duane Weber, WICA Biological Science Technician
Dan Roddy, WICA Biologist
Dr. Brian Smith, Biologist, Black Hills State University

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4.12 Bats

Description

Bat populations decline for a number of reasons: roost destruction, habitat modification, diseases, and anthropogenic disturbances (Mattson 1994). Many species of bats in the United States form their largest aggregations during winter months when they hibernate in caves and mine tunnels (Barbour and Davis 1969). During these winter months, bat aggregations can number as high as 100,000 bats in a hibernaculum. At WICA, there are typically three to 15 individuals in a hibernating site. Bats are susceptible to population declines for a number of reasons:

- Bats typically exhibit low reproductive rates (females typically have one young per year) (Mattson 1994).

- Many species aggregate in large colonies, increasing their vulnerability to natural or anthropogenic disturbances while in their roost colonies (O'Shea et al 2003).

- Bats exhibit high natal fidelity. This is of particular concern if the natal colony is in a highly disturbed area.

Bat populations are critically important indicators of an ecosystem's overall health. Bats contribute to an ecosystem's overall biodiversity, they possess ecological and economic value as ecosystem components, and they are exceptionally vulnerable to rapid population declines (O'Shea et al. 2003). These traits make monitoring trends in bat populations a much needed aspect of an ecosystem's management plan.

Measures

- Nation-wide Species of Concern

Reference Conditions/Values

The reference condition for bats in WICA is described as breeding and healthy bat populations. Breeding and healthy populations are described as populations representative of those that would naturally occur across the southern Black Hills within suitable habitats and particular seasons of the year (Muenchau, M. Ohms, and Roddy, pers. comm., 2010).

Data and Methods

Data were provided by WICA staff, NGPN reports, and online journal database searches. No transformations were made to any of the data.

Current Condition and Trend

<u>2004 WICA Survey</u>

A survey of bats in WICA was conducted in August, 2004. The survey sampled water sources in WICA to estimate bat use of water sources in the park. Sample locations were quiet pools in flowing streams (Beaver Creek and Reeve's Gulch), and an isolated pond (Herp Pond) (Schmidt et al. 2004). Survey methods utilized mist nets and Anabat acoustic monitoring survey systems.

Mist net trapping resulted in the capture of nine species of bats (Table 16). There was a confirmed, independent capture of a Townsend's big-eared bat (*Corynorhinus townsendi*) at a cave in the north-central section of WICA. A maternity roost with as many of 50 Townsend's big-eared bats has also been documented in the park (Ohms, pers. comm., 2010). With the confirmation of the Townsend's big-eared bat maternity roost, all bat species on WICA's expected bat species list (Table 17) have been officially documented within the park (Schmidt et al. 2004).

Table 16. Species captured during mist net survey in August 2004 (Schmidt et al. 2004).

Species		Abundance
little brown myotis	*Myotis lucifugus*	Common in Park
western small-footed myotis	*Myotis ciliolabrum*	Rare in Park
long-legged myotis	*Myotis volans*	Uncommon in Park
northern long-eared myotis	*Myotis septentrionalis*	Uncommon in Park
fringed myotis	*Myotis thysanodes*	Uncommon in Park
eastern red bat	*Lasiurus borealis*	Rare in Park
hoary bat	*Lasiurus cinereus*	Uncommon in Park
silver-haired bat	*Lasionycteris noctivarans*	Uncommon in Park
big brown bat	*Eptesicus fuscus*	Uncommon in Park

Table 17. WICA expected bat species list, USFWS service identifies bold species of concern (NPS 2008).

Species		Abundance
little brown myotis	*Myotis lucifugus*	Common in Park
western small-footed myotis	***Myotis ciliolabrum***	Rare in Park
long-legged myotis	***Myotis volans***	Uncommon in Park
northern long-eared myotis	*Myotis septentrionalis*	Uncommon in Park
long-eared myotis	***Myotis evotis***	Rare in Park
fringed myotis	***Myotis thysanodes***	Uncommon in Park
Townsend's big-eared bat	***Corynorhinus townsendii***	Uncommon in Park
eastern red bat	*Lasiurus borealis*	Rare in Park
hoary bat	*Lasiurus cinereus*	Uncommon in Park
silver-haired bat	*Lasionycteris noctivagans*	Uncommon in Park
big brown bat	*Eptesicus fuscus*	Uncommon in Park

USFWS 'Species of Concern'

Under the Endangered Species Act (ESA), several additional species were identified as 'Category 2' species for future listing under the ESA (USFWS 1994 as cited in O'Shea et al. 2003). Category 2 species are defined as

> taxa for which information…indicates that proposing to list as endangered or threatened is possibly appropriate, but for which persuasive data on biological vulnerability and threat are not currently available to support proposed rules (USFWS 1994 as cited in O'Shea et al. 2003).

In 1996, the USFWS discontinued the use of the term Category 2, and instead the term ”species of concern” was used to describe species that were on the list. Nineteen mainland bat species in the United States are listed as species of concern, and five of these species occur in WICA (Table 17).

Bats as indicator species and ‘species of concern’

There are other agencies that produce levels of concern, or species of concern lists. For instance, in a NPS bat survey, Schmidt et al. (2004) recognized all species of bats occurring at WICA as species of concern. Dr. Cheryl Schmidt, Research Associate for the Department of Forest, Rangeland, and Watershed Stewardship at Colorado State University, has made similar statements for the other parks as well (Schmidt et al. 2004). These statements on “species of concern” are made in documents under the section “Recommendation to Park Management.” These statements are essentially saying that parks should consider all bat species (and certain mammals) as species of concern due to the restricted habitat requirements and sensitivity to anthropogenic disturbance. Dr. Schmidt mentions bats are often considered “indicator species; other states (such as California) have suggested that all bat species be recognized as “species of concern” (Muenchau, pers. comm., 2010). Bats are excellent indicator species as not only do bats have restricted habitat requirements and sensitivity to disturbance, but they also face the following threats: they are insectivores and insecticides are widely used; the threat of White-nose Syndrome (WNS); public perception regarding rabies; and wind farms (Ohms and Muenchau, pers. comm., 2010).

Threats and Stressor Factors

WNS is the most significant threat to bat populations in the United States. WNS was first discovered in four caves in Albany, New York in the winter of 2006-2007. Colonies of bats in these caves were well studied before the WNS outbreak and after the outbreak; colonies of hibernating bats in these caves lost 81-97 percent of their population (USGS 2010). Bats are adapted to high rates of survival and produce few offspring; it is unlikely that the species of bats affected will quickly recover (USGS 2009).

Photo 15. Little brown myotis (*Myotis lucifugus*) showing WNS symptoms (U.S. Fish and Wildlife Service).

Initially, scientists could not determine what was affecting bats in these cave colonies. In the summer of 2009, however, scientists identified a previously unknown species of cold-thriving fungus (*Geomyces destructans*). This fungus thrives in low temperatures (5-14°C) and high levels of humidity (> 90%), conditions that are characteristic of the bodies of hibernating bats and the caves in which they hibernate. Although WNS was named for the obvious symptom of white noses on infected bats, the most vulnerable parts of the bats that are often infected are the wings (USGS 2010). Healthy wing membranes are vital to bats; wings make up about 85% of a bat's total body surface area. Wings help to regulate body temperature, water balance, and flight (USGS 2010).

When infected with WNS, bats experience a disturbance in their hibernation arousal patterns. Typically, bats will store large amounts of fat prior to hibernation, and most of the energy that is stored is -used up during natural arousals during the winter. During these natural arousals, bats will consume up to 90% of their stored fat to warm up their body, urinate, drink, mate, re-stimulate their immune system, and relocate their roost within the colony (USGS 2010). When WNS irritates bats enough to bring them out of torpor, bats can run out of stored body fat and starve.

White-nose syndrome has not reached South Dakota. However, as of May 2010, WNS has been found in New York, New Hampshire, Vermont, Rhode Island, Massachusetts, Pennsylvania, Connecticut, New Jersey, Maryland, West Virginia, Virginia, and Quebec, CA (NPS 2010). There are also unconfirmed reports of WNS in Missouri and Oklahoma (NPS 2010). Among the species hardest hit by WNS are little brown bats (*Myotis lucifugus*) and northern long-eared bats (*Myotis septentrionalis*), both of which are present in WICA. The sudden and widespread mortality associated with WNS is unprecedented for hibernating bats, among which widespread disease outbreaks have not been previously documented (USGS 2009).

Human entry into bat roosts may also present a threat to bats. Chronic disturbances in hibernacula are known to cause irregular arousal patterns in hibernating bats (USGS 2010). These irregular patterns can often lead to increased rates of winter mortality in cave dwelling bat species.

Often, hibernating bats will avoid disturbances by locating areas within a cave that are inaccessible to humans. These locations, aside from being free from disturbances, have a specific range of cool temperatures and humidity that allow the bats to enter hibernation safely and successfully. If humans happen upon hibernating bats and create a disturbance, an energetically expensive arousal results. Bats can burn fat equivalent to 67 days of torpor during such events (Thomas et al. 1990). Frequent disturbances at a roost colony often result in the bats relocating. While relocation reduces the threat of disturbance, the bats typically hibernate at an alternate location that has a less than optimal temperature range and hence a higher risk of not surviving the winter (Tuttle 2003).

Natural predators of bats often include skunks, raccoons (*Procyon lotor*), snakes, feral cats (*Felis catus*) and dogs, and some raptor species (particularly owls). Most predators feed opportunistically on bats, rather than specialize on bats as a primary prey species. However, nearby Jewel Cave has had severe predation of bats by feral cats (Ohms, pers. comm., 2010). When present in an area, feral cats present a huge risk to hibernating bat populations.

<u>Overall Condition</u>

The reference condition of bats in WICA is described as a breeding and healthy population. Unfortunately, with little data collected on bat populations across the continental U.S., condition is difficult to describe. In WICA, there have been few studies of bat populations (see Schmidt et al. 2004). It is therefore impossible to assign a condition to WICA bats at this time. With the spread of WNS across the continent, the bat population of WICA could be described as 'at risk'.

This characterization would hold true for most bat populations across the United States, not just WICA.

<u>Data Needs/Gaps</u>
Long-term bat population monitoring is needed at WICA. WICA is beginning to fill this void beginning in the winter of 2010-11 by completing hibernation surveys. This survey should help WICA to have a better understanding of the bat population in the park. Also, WNS has been hypothesized as potentially being spread by humans as they move from cave to cave on explorations and visits (USGS 2009). WICA does have a WNS plan in place to prevent the spread of the fungus, but with visitors of the park frequently visiting the cave, monitoring for the presence of WNS will be important.

Sources of Expertise
Dan Roddy, WICA Biologist
Marc Ohms, WICA Physical Science Technician
Barbara Muenchau, WICA Biological Science Technician

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4.13 Coyote

Description

Coyotes are common in mixed-grass prairies, such as those found at WICA (Chronert 2007). They are the dominant species of mammalian carnivores found in the southern Black Hills region (Taylor 1991). Coyotes are the primary cause of pronghorn neonatal death and they also predate black-footed ferrets and prairie dogs (details on this relationship can be found in Chapter 4.9) (Chronert 2007). Coyotes also carry diseases that can be fatal to black-footed ferrets and prairie dogs.

Measures

- Natural Behavior
- Non-habituation to humans

Reference Conditions/Values

The reference condition for coyotes in WICA is natural behavior and healthy populations.

Data and Methods

WICA staff provided the only accounts of coyote behavior in WICA.

Current Condition and Trend

<u>Natural Behavior and Non-habituation to Humans</u>

Coyote behavior and habituation to humans is an increasing concern across much of North America, especially in urban settings where habituated coyotes may pose a threat to the safety of humans and domesticated animals (Timm et al. 2004, White and Gehrt 2009, Graham et al. 2005). Coyote habituation occurs in Nationals Parks in the United States and Canada, and coyotes have become accustomed to feeding by tourists on a few occasions (Young and Jackson 1951, Parker 1995, as cited in Timm et al. 2004). In WICA, coyotes exhibit natural behavior, not showing signs of habituation to humans (Roddy, pers. comm., 2010).

Photo 16. Coyote at WICA (NPS Photo).

<u>Threats and Stressor Factors</u>

WICA staff identified three stressors to coyotes in the park: regular interaction with humans, prey base cycles, and disease. According to WICA staff, human interaction is minimal

(Roddy, pers. comm., 2010).

Coyotes are the primary predator of pronghorn and can significantly affect their population (Jacques et al. 2005). The pronghorn section of this document discusses the relationship between pronghorn and coyotes in detail.

Chronert (2007) examined the prevalence of four diseases in WICA coyotes: canine distemper virus, plague, tularemia (*Francisella tularensis*), and sarcoptic mange. Canine distemper is a viral disease transmitted by aerosol or direct contact with body fluids. Symptoms of this disease include loss of energy, high body temperatures, discharge from orifices, and increased thirst. Canine distemper is usually not fatal, except to pups. Coyotes that survive a bout with canine distemper are likely immune to subsequent infection (Williams 2001). Canine distemper can also decimate a ferret population, making it especially important for monitoring at WICA (Muenchau, pers. comm., 2010).

Sarcoptic mange is a contagious mite infection of the skin of mammals. Mites burrow into the skin, cutting in with their mouths and hooks on their legs. Hosts develop a rash and intense urge to scratch infected areas, resulting in the loss of hair and eventually death (Pence and Ueckermann 2002). In the late 1990s and early 2000s, a mange epizootic severely reduced the population of coyotes in the WICA area (Chronert et al. 2007, Roddy, pers. comm., 2010). There still appears to be low levels of mange in the local coyote population, evident by occasional sightings of coyotes with patches of hair missing on their tails or body (Muenchau, pers. comm., 2010)

Coyotes are excellent sentinels for plague (Thomas and Hughes 1992, Gage et al. 1994). Coyotes rarely exhibit clinical signs of the disease (Von Reyn et al. 1976), but serological testing of coyotes across a landscape can help define the extent of plague in rodent-prey populations more efficiently than testing rodents themselves (Willeberg et al. 1979). This could be of great importance in WICA, especially because of the effects plague exhibits on prairie dogs and black footed ferrets (these effects are outlined 4.7 and 4.8).

Tularemia is a plague-like disease transmitted directly from prey to predator and through ticks and biting flies (Friend 2006). Like plague, rodents and lagomorphs are most susceptible to the disease. In some laboratory experiments, coyotes have exhibited clinical signs of the disease but not in others (Friend 2006). Because they usually do not develop a bacteremia, they do not transfer the disease to ticks. However, they may help maintain infected tick populations (Friend 2006).

Chronert (2007) captured 26 coyotes in WICA, of which 17 (65%) were in good health, seven (27%) had sarcoptic mange, and two (8%) were dead in the trapping device (snare). Serological samples were retrieved from 16 of the 26 coyotes. All 16 were negative for plague, 13 were positive for canine distemper serum antibodies, and one was positive for tularemia.

<u>Data Needs/Gaps</u>
An accurate estimate of the coyote population in the park would help explain effects of predation on pronghorn and other species in the park. In addition, periodic disease testing would be

beneficial because coyotes act as sentinels for diseases that affect black-footed ferrets and prairie dogs.

Overall Condition

Coyotes in WICA appear to be in good condition in respect to the defined measures; there is no evidence of coyotes exhibiting unnatural behavior or habituation to humans (Roddy, pers. comm., 2010).

Sources of Expertise

Dan Roddy, WICA Biologist
Barbara Muenchau, WICA Biological Science Technician

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4.14 Natural Cave Environment

Description

Wind Cave is one of the longest and most complex caves in the world, with approximately 219 km (136 mi) of surveyed passage and up to five levels at any given point (NPS 2007; Horrocks, pers. comm., 2011). Wind Cave has more boxwork (thin veins of calcite that protrude from the walls in boxlike patterns) than any other cave in the world and contains many rare features, such as helictite bushes, gypsum ropes, and quartz formations (NPS 2007). The microbial diversity in the cave is significant, with twelve divisions and subdivisions of bacteria and two divisions of microbes from the kingdom of Archaea (Chelius and Moore 2004). In addition to Wind Cave, WICA also contains 42 known backcountry caves (NPS 2007). While these are relatively un-impacted, the natural environment of Wind Cave has been significantly altered by human activities, primarily along the tour routes and to a lesser extent along the flagged off-trail routes (NPS 2007). Changes in temperature, humidity, air flow, and physical processes have all been influenced by humans and have also had an impact on the overall cave environment (NPS 2007).

Measures

- Temperature
- Humidity
- Air flow
- Cave physical processes (natural CO_2 levels, cave feature formations)

Reference Conditions/Values

The reference condition for the condition assessment of this component is the state of the environment at the beginning of historic measurement in the cave. Early reports from 1920 indicate that Wind Cave's average temperature ranged from 42 - 47 degrees Fahrenheit (NPS 2007). However, the cave had already been significantly altered by the addition of a walk-in entrance and passage enlargements (Ohms, pers. comm., 2011). Regular measurements of humidity, air flow, and cave physical processes began in the late 1980s, after human impacts were already apparent (Ohms, pers. comm., 2011).

While this assessment uses a specific timeframe to assess the current condition of the cave, WICA has chosen to use a different management approach: to maintain natural processes in the whole ecosystem. This means that WICA will make management decisions not based on the how the condition of the cave compares to previous conditions, but rather based on how the cave processes compare to the natural processes.

Data and Methods

Information regarding the cave environment at WICA is derived from the Cave and Karst Resource Management Plan (NPS 2007), as well as many other studies (Ohms 2003, 2004a, 2004b, 2005, Nepstad 1985, 1996, Pflitsch 2002, Conn 1966, Palmer 2007, Chelius et al. 2009, Moore et al. 1996). Personal communications with WICA Physical Science Specialist, Rodney Horrocks and WICA Physical Science Technician, Marc Ohms were also main sources of information for this component.

Current Condition and Trend

<u>Temperature</u>

Nepstad (1985) and Ohms (2003, 2004a, 2004b) found significant air temperature differences between on-trail and off-trail areas of the cave. Ohms (2004a) found that the temperature along tour routes increased by a maximum of two degrees Fahrenheit after tours passed through an area, and did not return to normal until two hours after the last tour. At two interpretive stops (The Fairgrounds and Assembly Room), the temperature remained elevated midway through the summer, and did not return to normal levels until after the summer tourist season ended (Ohms, pers. comm., 2011). The findings of Ohms (2004a, 2004b) indicate that the presence of humans in the cave can have measureable impacts on cave temperature.

Ohms (2003) found that the incandescent lighting systems along tour routes created “hot spots,” raising local temperatures by 0.7 - 2.0 degrees Fahrenheit. These “hot spots” caused an increase in algae growth along tour routes when water was present (Ohms 2003, 2004a). Ohms (2004b) concluded that artificial lighting raised the temperature only in the immediate vicinity of the fixtures. Pflitsch (2002) had similar findings and determined that long-term impacts on the Natural Entrance Tour Route do not extend beyond about 152 m (500 ft) from the Walk-In Entrance in Wind Cave. Cave temperatures are not affected in backcountry caves because they have little to no human traffic and no lighting systems.

<u>Humidity</u>

Nepstad (1985) examined humidity along the Natural Entrance Tour Route and near the walk-in entrance. This study showed that unnatural airflow through the open walk-in entrance caused temperature fluctuations and humidity changes up to 183 m (600 ft) into the cave. Natural cave humidity would generally be about 95-100%, but during air inflows, humidity can drop to as low as 60% (Nepstad 1985). Before the revolving door was installed, air exchange could remove more than 100,000 gallons of water from the cave air per day when the air was blowing out, significantly impacting natural humidity levels (Nepstad 1985).

<u>Air flow</u>

Conn (1966) determined that winds at the entrances of Wind Cave originate from barometric changes on the surface. When barometric pressure rises outside the cave, air rushes into the cave to equalize the pressure, conversely when the barometric pressure drops outside the cave, air rushes out (Conn 1966). During Conn’s (1966) study, air exchange in Wind Cave occurred on average four times per day.

A study by Pflitsch (2002) demonstrated that the airflow in Wind Cave has a stable inward flow velocity in the summer and a higher inward flow velocity during the winter. However, the average outward flow velocity is almost always higher than the inward velocity year-round (Pflitsch 2002). Airflow speeds have been documented to reach nearly 80 km/hr (50 mph) through the Natural Entrance and have been known to blow in the same direction in excess of 81 hours (NPS 2007). Revolving doors were installed at the Walk-In Entrance in 1992 to regulate unnatural air flow. These doors were able to reduce the amount of freezing and thawing, as well as the subsequent ceiling collapses on the entrance stairs. However, Pflitzch (2002) determined that the revolving doors can allow up to the same amount of air to pass through as the amount that passes through the Natural Entrance, making them only partially effective.

Natural air flow patterns have been significantly altered by blasting (NPS 2007). Blasting was a process used in the 1890s and 1930s to enlarge passages and tour routes, as well as to open new entrances (NPS 2007). Blankets were used in 1890 to protect the cave from flying rocks and debris (NPS 2007). Nevertheless, the enlarged passages have allowed more air to move through these areas and have changed natural airflow patterns (NPS 2007). In addition, blast rubble has been placed in side passages and pits, which further alters and restricts natural airflow patterns through these areas (NPS 2007).

Cave physical processes

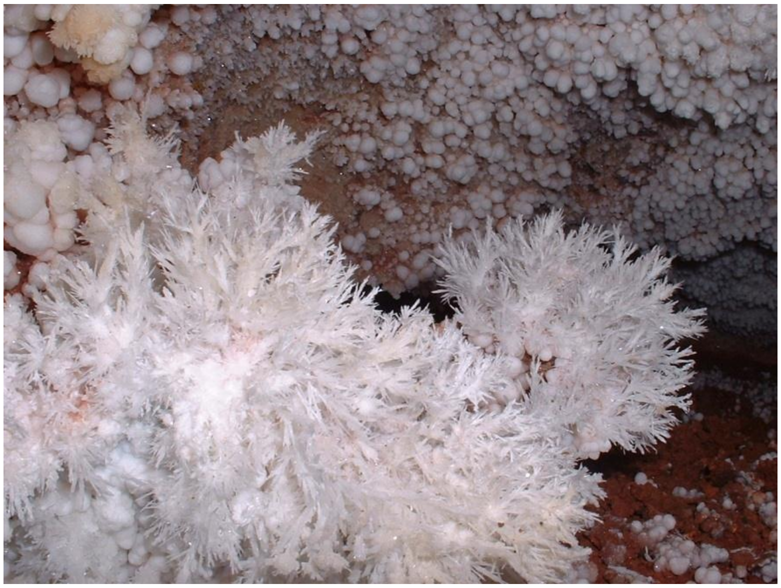

Photo 17. Cave frostwork and popcorn formations (NPS Photo).

As groundwater enters the upper levels of the cave, CO_2 escapes into the cave air and dissolved calcite is deposited (Horrocks, pers. comm., 2011). However, if the water has first infiltrated mostly insoluble rock, such as the overlying Minnelusa Formation, only small amounts of calcite is picked up in solution (Horrocks, pers. comm., 2011). When the saturated water finally enters an open cave, (or one that contains water from another source with a large CO_2 content) the infiltrating water absorbs CO_2 from the cave air or water and becomes aggressive again (Palmer 2007). This saturated water can dissolve much more carbonate rock than it already contains (Palmer 2007). It is unknown if the CO_2 expelled from visitors breath alters the deposition rate of calcite along the tour routes or changes the dissolution rate of under-saturated water entering the cave.

Wind Cave is known for its rare and unusual variety of minerals and speleothems such as helictite bushes, quartz formations, frostwork clusters, and fragile gypsum growths (NPS 2007). There is still a debate on how helictite bushes are formed and the precise conditions required. Regardless of the conditions that were required in past years, Horrocks (pers. comm., 2011) believes that those conditions are not present today.

Threats and Stressor Factors

Visitor actions, whether intentional or unintentional, have extensive impacts on the cave ecosystem (NPS 2007). Some of these intentional actions include breakage, graffiti, off-trail traffic, littering, and urinating in the cave (NPS 2007). Unintentional visitor impacts include unnatural dust accumulations along tour routes and flagged off-trail routes, lint and hair deposition, wax drippings from candlelight tours, and increased temperatures from tour groups and electrical lights (NPS 2007).

Several experiments have been performed in Wind Cave to examine how visitors are intentionally altering the cave ecosystem through stealing and breaking of cave features (NPS 2007). In early summer 1980, numerous small geodes were placed along tour routes to examine the prevalence of geode theft by WICA visitors (NPS 2007). All of the geodes were stolen by the end of the summer (NPS 2007). A similar study in 1989 planted a six and a ten pound geode in The Oven, which is a passage located on the Natural Entrance Tour Route (NPS 2007). Both of these geodes were stolen within two weeks (NPS 2007). Though these geodes were not natural features of Wind Cave, they are indicative of the likelihood of theft within the cave.

Multiple studies confirm that visitation and the infrastructure required to accommodate tours increases temperature and biota growth and can also lead to degradation of cave resources along tour routes (Ohms 2003, 2004b, Nepstad 1985, as cited in NPS 2007). WICA accommodates over 100,000 visitors every year, with approximately 90,000 to 100,000 of those visitors going on cave tours (NPS 2007). Chelius et al. (2008) reports that cave expansion and added trails and electrical systems for the large amount of visitors contribute to a significantly altered climate in Wind Cave. Cave climate change can affect the population density of resident biota and species composition of the Cave (Chelius et al. 2008). Biotic composition along tour routes can be further altered through increased levels of carbon, nitrogen, and dust as well as from the introduction of foreign microbes from humans (Ohms 2005, Moore et al. 1996). These increased levels of carbon and nitrogen are partially due to hair and skin cells, as well as lint from visitor's clothing, which introduce natural and synthetic fibers into the cave ecosystem (NPS 2007). Lint also contributes to degradation of natural cave materials, because water condenses on the fibers and dissolves cave surfaces and minerals (Jablonsky et al. 1994, as cited in NPS 2007).

NPS conducted an environmental assessment for lighting replacement due to safety reasons, out-dated lighting, and algal growth on cave surfaces promoted by the old incandescent lighting system. A new lighting system was installed in 2009, and it illuminates approximately one mile of paved tour routes in Wind Cave. The new lighting system uses LED lights, which exert very little heat and use approximately 30% of the power the incandescent lights previously used (Horrocks, pers. comm., 2011).

In 1996, airlock structures were added to each elevator landing in an attempt to reduce the unnatural air exchange through the elevator shaft and to allow the elevator doors to open and close during days with strong airflow (NPS 2007). Though the revolving door on the Walk-In Entrance and the airlocks on the elevator landings did block some of the unnatural airflow, it did not eliminate the exchange (NPS 2007, Horrocks, pers. comm., 2011).

Land use above the cave has also had a significant impact on the cave's ecosystem (NPS 2007). The Civilian Conservation Corps (CCC) planted hundreds of ponderosa pines above the cave in the mid 1930s (NPS 2007). Mature ponderosa pines can evapotranspirate up to 400 gallons of water per day, if it is available (NPS 2007). Wildfire suppression has allowed ponderosa pines to flourish, reducing the amount of water able to reach the cave, which means less input of carbon and nitrogen from meteoric waters to the ecosystem in the cave (Horrocks, pers. comm., 2011). This reduction in water also causes secondary cave formations to dry out and desiccate as calcite deposition ceases (Horrocks, pers. comm., 2011). Historic evidence of surface land use issues include high nitrate levels and hydrocarbons in cave drip waters and parking lot area water appearing at upper Minnehaha Falls in Wind Cave within six hours (Nepstad 1996, as cited in

NPS 2007). The parking lot water was identified in the cave through a dye tracing project. The parking lot has now been changed from asphalt to concrete, with runoff being captured and run through an oil and grease separation system (Horrocks, pers. comm., 2011).

In 2001, Marc Ohms examined off-trail cave excursions by monitoring foot prints and found them to be extensive (NPS 2007). This is of particular concern because the impacts humans have already had on tour routes could be brought to other parts of the cave. Off-trail excursions in Wind Cave by wandering tourists have led to some vandalism incidents (Ohms, pers. comm., 2011).

Data Needs/Gaps

Palmer (2007) has studied how water saturated with calcite absorbs CO_2 from the air. However, it is unknown if the CO_2 expelled from visitors breath alters the deposition rate of calcite along the tour routes or changes the dissolution rate of under-saturated water entering the cave.

The airlock structures that were added to elevator landings still allow unnatural air exchange to occur. Measurements of the amount of air exchange allowed by these structures would be beneficial for future improvement of these structures.

Overall Condition

The condition of the cave around the tour routes is of significant concern, as the natural cave environment has been significantly impacted by human activities. NPS (2007) defines areas with the presence of any of the following as an impacted area: artificial entrances, concrete paving, asphalt from previous trail surfacing, discarded wood from past construction, wax drippings, artificial roof supports, electrical systems, handrails, foreign debris from visitors, blasted sections, displaced sediment and rock, blocked side passages, rubble filled pits, or dust-covered walls. Most of the impacts of human activities appear to be localized around tour routes, as well as along flagged off-trail routes. Developed corridors include the Natural Entrance, Garden of Eden, Fairgrounds, Blue Grotto, Candlelight and Wild Cave tour routes. Temperature, humidity, biotic composition, and airflow differences between touring and non-touring locations are apparent.

While the condition of the natural cave environment around the tour routes is of significant concern, there is less potential for impacts in off-trail areas and backcountry caves. Nitrate runoff and contaminants from the infrastructure and parking lots that are built directly above the cave may potentially affect the off-trail portions of the cave (Nepstad 1996, as cited in NPS 2007). Water loss due to wildfire suppression and the continued growth of the ponderosa pines that were planted by the CCC are another threat to the cave's ecosystem (Pace-Graczyk and Ohms 2006, Horrocks pers. comm.). Though there are some documented negative anthropogenic impacts on off-trail areas and backcountry caves, major changes to the cave environment are not as extensive as the main tour routes in Wind Cave.

Sources of Expertise

Rod Horrocks, WICA Physical Science Specialist
Marc Ohms, WICA Physical Science Technician

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4.15 Water Quality

Description

The primary water quality parameters identified by WICA staff include mercury, nitrates, chemicals and heavy metals. Additional water quality parameters such as dissolved oxygen (DO), pH, specific conductance, temperature, turbidity, and fecal coliform were also examined. The major water resources in WICA include three perennial streams (Beaver Creek, Cold Spring Creek, and Highland Creek), several ephemeral streams, groundwater (including cave lakes), springs, and pools.

Mercury contamination is caused by airborne deposition originating from coal combustion, waste incineration, mining, and natural sources (EPA 2010a). In water, mercury is converted to methylmercury, a neurotoxin that is biomagnified in the aquatic food web (EPA 2010a). Atmospheric deposition from coal-fired power plants is considered the primary source of mercury pollution in WICA.

Nitrates can cause a host of water quality related problems when present in high concentrations including, but not limited to, excessive plant and algae growth and depleted dissolved oxygen available to aquatic organisms (USGS 2007). Nitrogen occurs naturally in soils and thus in surface waters, but is increased by human inputs such as sewage, fertilizers, and livestock waste (NPS 2009).

Chemicals and heavy metals are an extremely broad category of potential pollutants at WICA. A number of anthropogenic chemicals, including pentachlorophenol, polycyclic aromatic hydrocarbons, dioxins, and furans have been documented from the Pringle Post and Pole site upstream from the park. Several wastewater compounds have been detected in water samples, including bromoform, phenol, caffeine, and cholesterol. While arsenic is the primary heavy metal of concern for WICA, other metals found in WICA waters include copper, lead, chromium, nickel, and iron. Toxic metals can accumulate in the food chain, causing damage to organisms (USGS 2011, EPA 2011d).

Dissolved oxygen is critical for aquatic organisms. Fish and zooplankton filter out or “breathe” dissolved oxygen from the water to survive (USGS 2010, EPA 2010c). Oxygen enters water from the atmosphere or through ground water discharge. As the amount of DO drops, it becomes more difficult for aquatic organisms to survive (USGS 2010). The concentration of DO in a water body is closely related to water temperature; cold water holds more DO than does warm water (USGS 2010). Thus, DO concentrations are subject to seasonal fluctuations as low temperatures in the winter and spring allow water to hold more oxygen, and warmer temperatures in the summer and fall allow water to hold less oxygen (USGS 2010).

Fecal coliform is a measure used to assess the level of fecal contamination by homeothermic (warm-blooded) animals in water (USGS 2009). Fecal contamination can originate from several sources, including septic system leaks, untreated wastewater, animal waste, and livestock operations (NPS 2009). Septic system leaks have been identified as a threat to water quality in WICA.

pH is a measure of the level of acidity or alkalinity of water and is measured on a scale from 0 to 14, with 7 being neutral (USGS 2010). Water with a pH of less than 7.0 indicates acidity, whereas water with a pH greater than 7.0 indicates alkalinity. Aquatic organisms have a preferred pH range that is ideal for growth and survival (USGS 2010). Chemicals in water can change the pH and harm animals and plants living in the water; thus, monitoring pH can be useful for detecting natural and human-caused changes in water chemistry (USGS 2010).

Specific conductance is a measure of the ability of water to conduct electrical current, which depends largely on the amount of dissolved solids in the water (USGS 2010). Water with low amounts of dissolved solids (such as purified or distilled water) will have a low specific conductance, while water with high amounts of dissolved solids such as sea water will have a much higher specific conductance (USGS 2010). Specific conductance is an important water-quality parameter to monitor because high levels can indicate that water is unsuitable for drinking or aquatic life (USGS 2010).

Water temperature greatly influences water chemistry and the organisms that live in aquatic systems. Not only can it affect the ability of water to hold oxygen, water temperature also affects biological activity and growth within water systems (USGS 2010). All aquatic organisms have a preferred temperature range for existence (USGS 2010). As water temperatures increase or decrease past this range, the population declines. In addition, higher temperatures allow some compounds or pollutants to dissolve more easily in water and can be more toxic to aquatic life (USGS 2010).

Turbidity assesses the amount of fine particle matter such as clay, silt, or microscopic organisms that are suspended in water by measuring the scattering effect solids have on light that passes through water (USGS 2010). For instance, the more light that is scattered, the higher the turbidity measurement will be. The suspended materials that make water turbid can absorb heat from sunlight, increasing the water temperature and reducing the concentration of dissolved oxygen in the water (USGS 2010). The scattering of sunlight decreases photosynthesis by plants and algae, which contributes to decreased DO concentrations in the water (USGS 2010). Suspended particles can also clog the gill structures of many fish or amphibians, making it difficult to thrive (USGS 2010).

Measures

- Mercury
- Nitrates
- Chemicals and heavy metals
- Dissolved oxygen
- Fecal coliform
- pH
- Specific conductance
- Temperature
- Turbidity

Reference Conditions/Values

The reference condition for WICA's water quality was the EPA's water quality criterion for surface waters. Water quality parameters without an EPA standard were measured against South Dakota water quality standards. Table 18 displays water quality parameter standards set by the EPA and state of South Dakota.

Table 18. EPA and South Dakota water quality standards (EPA 2010b, Heakin 2004, South Dakota Legislature 2011, and SD DENR 2010).

Parameter	EPA standard	South Dakota standard
Mercury	1.4/0.77 µg/L[1] (freshwater)	1.4/0.77 µg/L[1] (freshwater aquatic life)
Nitrates	10 mg/L (drinking water)	10 mg/L (domestic water supply)
Copper	Varies based on water body characterics[4]	13/9 µg/L[1] (freshwater aquatic life)
Arsenic	7.24 µg/g (stream sediments), 340/150 µg/L[1](freshwater)	340/150 µg/L[1] (freshwater aquatic life)
Dissolved oxygen	-	≥5.0 mg/L (immersion recreational waters)
Fecal coliform	-	400/200[5] CFU/100 ml (immersion recreational waters), 2000/1000[5] CFU/100 ml (limited contact recreational waters)
pH	$\geq$ 6.5 – $\leq$9.0 (freshwater, chronic exposure)	$\geq$ 6.0 - $\leq$ 9.5 (fish and wildlife propagation, recreation, and stock watering waters)
Specific conductance	-	<2500 µS/cm [2] / <4375 µS/cm [3] (irrigation waters), 4000[2]/7000[3] µS/cm (Fish, wildlife, propagation, recreation and stock watering; others)
Temperature	-	$\leq$65°F (coldwater permanent fish life propagation waters)
Turbidity	-	-

[1] Acute exposure/ chronic exposure
[2] 30-day average
[3] Daily maximum
[4] Copper standards vary based upon the Biotic Ligand Model, which accounts hardness and pH levels in water bodies (see EPA 2007)
[5] Single sample/mean

Data and Methods

NPS (1998) analyzed water quality data from WICA and the surrounding area between 1963 and 1998. The study used six of the EPA national databases to acquire data: Storage and Retrieval (STORET) water quality database management system, River Reach File (RF3), Industrial Facilities Discharge (IFD), Drinking Water Supplies (DRINKS), Water Gages (GAGES), and Water Impoundments (DAMS). Water quality monitoring stations in WICA are primarily either one-time or intensive single-year sampling events.

Heakin (2004) performed a water quality characterization study on WICA's three perennial streams (Beaver Creek, Highland Creek, and Cold Spring Creek) during 2002 and 2003. The study also looked at the potential influence of parking lot runoff on drip sites in Wind Cave by simulating various runoff events.

Rust (2006) collected water quality samples for several parameters from Beaver Creek, Cold Spring Creek, and Highland Creek in 2004-2005, along with data regarding macroinvertebrates for National Parks in the NGPN.

SMU GSS calculated the mean specific conductance for the Elk Mountain Spring between 2006 and 2007 using unpublished data provided by WICA.

Current Condition and Trend

<u>Mercury</u>
Two dissolved mercury observations were taken in 1991 at different stations along Beaver Creek. Both measurements had a concentration of 0.05 µg/L (NPS 1998). Table 19 displays mercury data collected during the 2002-03 USGS study. The EPA freshwater standard for dissolved mercury is 0.77 µg/L for chronic exposure and 1.4 µg/L for acute exposure (EPA 2010b). Thus, the mercury concentrations found in WICA's perennial streams during the USGS study were well below the EPA threshold.

Table 19. Mercury concentrations (µg/L) for WICA perennial streams, 2002-2003 (Heakin 2004).

	Cold Spring Creek (site 1) 2002-03	Cold Spring Creek (site 2) 2002-03	Beaver Creek (site 3) 2002-03	Beaver Creek (site 4) 2002-03	Highland Creek (site 7) 2002-03
Mean	0.008	0.05	0.007	0.007	0.008
Minimum	0.008	0.05	0.005	0.005	0.005
Maximum	0.01	0.05	0.01	0.01	0.01
# of samples	5	3	4	4	3

The National Atmospheric Deposition Program (NADP) collects data on total mercury wet deposition across the United States. Although no NADP mercury monitoring sites are established in South Dakota, NADP was able to extrapolate mercury deposition values for the area based on the nearest monitoring sites; these estimations are available beginning in 2009. The area including WICA received between 6 and 8 µg/m^2 of mercury in 2009 (NADP 2009). This deposition range is towards the lower end of values across the United States, though one year of data is insufficient to make any conclusions on the level of mercury deposition. However, it may be prudent to monitor mercury deposition in the region to serve as an indicator of whether mercury contamination in water systems should be monitored.

The South Dakota School of Mines and Technology (SDSMT) collected mercury deposition and precipitation data for WICA between 2008 and 2010. WICA had an average mercury deposition of 5.26 µg/m^2/yr over this time (SDSMT 2011). Figure 12 displays precipitation and mercury deposition values at WICA collected during the study.

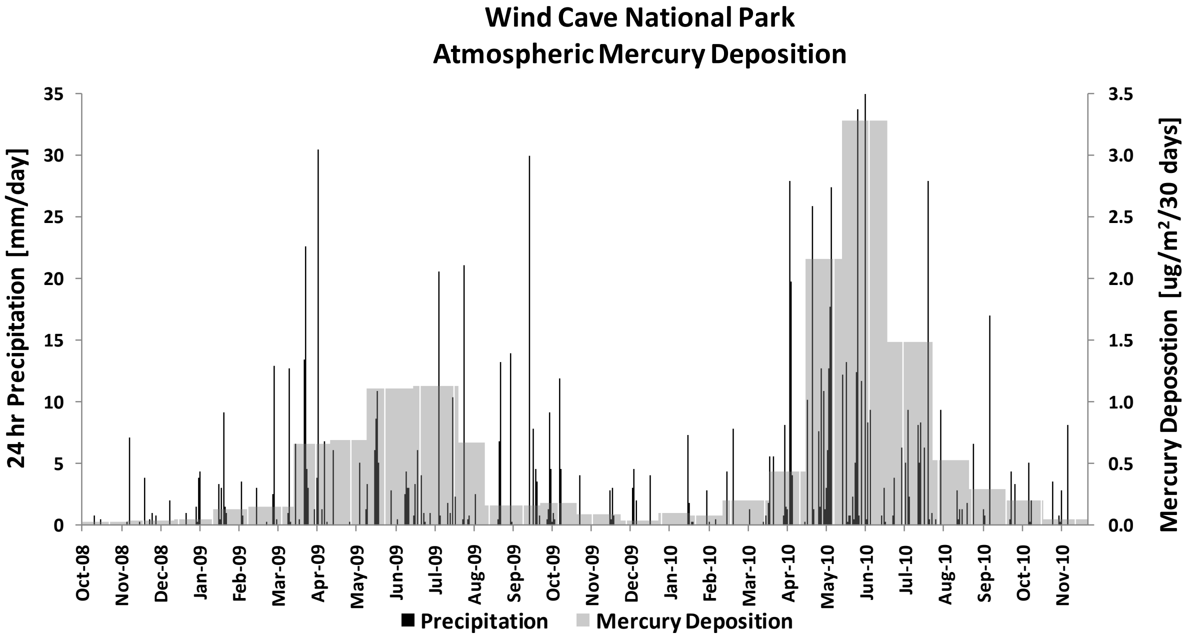

Figure 12. WICA atmospheric mercury deposition, 2008–2010 (SDSMT, unpublished data).

<u>Nitrates</u>

Alexander et al. (1989) conducted water quality analyses at drip sites within Wind Cave between 1985 and 1988. Nitrate levels were generally below 1.2 parts per million (ppm) at sites within the cave. Concentrations above 1.4 ppm were considered to be potentially impacted by human development in this study. The Near Fairy Palace site had a nitrate concentration of 3.1 ppm, and Silent Lake concentrations varied between 2 and 7 ppm. The Methodist Church site had the highest and most variable nitrate concentrations during this study, ranging between 2 and 4 ppm on average but occasionally reaching concentrations of ~10 ppm. Near Fairy Palace, Silent Lake, and Methodist Church were all above the human impact level of 1.4 ppm during this study.

There were no nutrient observations which exceeded EPA water quality standards during the 2002-2003 USGS study, although Heakin (2004) noted the highest nitrate levels in WICA were found in Highland Creek (mean concentrations of 0.4 mg/L in 1985, 0.38 mg/L in 1993-1994, 0.38 mg/L in 2002-2003; values reported as nitrite plus nitrate, as nitrogen dissolved). The EPA drinking water standard for nitrates is 10 mg/L (EPA 2011c).

Rust (2006) collected six nitrate samples from Beaver Creek, Cold Spring Creek, and Highland creek. Concentrations were less than 0.1 mg/L in Beaver Creek and Cold Spring Creek, while Highland Creek had a mean concentration of 0.13 mg/L and a maximum of 0.20 mg/L (Rust 2006). These values show a slight decrease from the measurements collected in the Heakin (2004) study.

<u>Chemicals and Heavy Metals</u>

Davis (1992) demonstrated the capacity for metals to enter cave water via infiltration at WICA. Water was allowed to pass through three-foot columns of soil and associated bedrock from several sites above Wind Cave. Water accumulated up to 80 parts per billion (ppb) of lead and contained significant concentrations of chromium and titanium. This research indicated that infiltration can transmit heavy metals from the soil and bedrock of the Minnelusa formation into groundwater within the cave (Davis 1992).

The South Dakota freshwater criterion is 9 μg/L for chronic exposure and 13 μg/L for acute exposure. NPS (1998) reported on the analysis of water samples for copper concentrations. Samples were collected between 1979 and 1994, and eight samples from six water stations exceeded the limit for copper concentrations. However, it is important to note that the current standard for copper is more stringent than when these samples were taken. These observations occurred at Wind Cave, Cold Spring Creek, and Highland Creek, with the highest concentration (70 μg/L) measured at Fairy Palace inside Wind Cave. Heakin (2004) found that chromium, nickel, and iron concentrations were higher in Beaver Creek than in other park streams during the 2002-2003 USGS study.

Several wastewater compounds were detected in Cold Spring Creek during the 2002-2003 USGS study. Bromoform, phenol, caffeine, and cholesterol were present in samples which indicated that septic system wastewater was influencing water quality in the creek (Heakin 2004). The highest bromoform concentrations in each perennial stream was <0.5 μg/L (Heakin 2004). Phenol was measured at 1.2 μg/L in Cold Spring Creek (site 1), and as high as 0.9 μg/L in Beaver Creek μg/L (site 3) (Heakin 2004).

Pentachlorophenol (PCP) is a chemical used to treat wood, which was utilized by Pringle Post and Pole approximately eight km (five mi) upstream of WICA between the 1940s and mid-1990s (Ohms 2009). Soil testing at the site in 1992 and 1994 showed the presence of PCP, polycyclic aromatic hydrocarbons (PAHs), dioxins, furans, arsenic, chromium, copper, and zinc, and soil and water testing conducted downstream from the site in 2001 found elevated levels of dioxins and furans (Ohms 2009).

Arsenic is a naturally occurring metalloid that is of concern in many areas. This metalloid can also be produced and released into the environment through certain industrial or manufacturing processes. Arsenic is a human health concern because it can contribute to skin, bladder, and other cancers (National Research Council 1999). Arsenic has been found at high concentrations in Wind Cave and the park well (Ohms, pers. comm., 2011). It is possible that arsenic concentrations were elevated in the park due to industrial activity occurring upstream, such as the Pringle Post and Pole manufacturing site or it may originate naturally from the Minnelusa Formation. Sediment samples taken from Cold Spring Creek and Beaver Creek had arsenic concentrations of 9.4 and 9.5 μg /g respectively, exceeding the EPA threshold guidelines for stream sediments (7.24μg/g) (Heakin 2004).

Dissolved Oxygen

The EPA considers dissolved oxygen levels greater than or equal to 6 mg/L to be protective of freshwater aquatic life in coldwater permanent fisheries and greater than or equal to 5 mg/L for coldwater marginal fisheries (Heakin 2004). Dissolved oxygen in WICA’s three perennial streams varied between 8.5 and 12.2 mg/L during sampling in 2002-2003 (Heakin 2004). The lowest DO measurement was in Beaver Creek at 7.5 mg/L, which is still high enough to support a permanent spawning coldwater fishery (NPS 2009).

Rust (2006) collected DO measurements from Beaver Creek, Cold Spring Creek, and Highland Creek. Ninety measurements were collected in Beaver Creek, with a mean value of 9.9 mg/L; 87 measurements were taken in Cold Spring Creek, with a mean value of 9.3 mg/L; and 60 measurements were collected in Highland Creek, with a mean value of 8.5 mg/L (Rust 2006). These DO concentrations were well above EPA and state standards for supporting coldwater fisheries.

Fecal Coliform

NPS (1998) included 91 measurements of fecal coliform at three monitoring stations between 1984 and 1997. Thirteen of these samples ranged between 210 and 820 colony-forming units (CFU), exceeding the South Dakota immersion recreation waters criterion of 200 CFU for a single sample; however, these levels are well within the state standard for limited contact recreational waters (NPS 1998).

The upland stretch of Beaver Creek (site 3) had the highest levels of fecal coliform in the 2002-2003 USGS study, ranging from 32 to 220 colony-forming units per 100 milliliters (CFU/100 mL). Cold Spring Creek and Highland Creek had lower levels of fecal coliform during this study. This range generally falls below all state water quality standards, with a few individual samples that exceeded immersion recreation standards (SD DENR 2010, Heakin 2004).

Rust (2006) found higher levels of fecal coliform in WICA's three perennial streams in 2004-2005. Six samples were collected from each of the streams; Beaver Creek had a mean concentration of 547 CFU, Cold Spring Creek had a mean of 304 CFU, and Highland Creek averaged 192 CFU (Rust 2006). While Beaver Creek and Cold Spring Creek exceeded the state standard for fecal coliform in this study, more samples collected over a longer period of time would be needed to show that this is an ongoing problem.

pH

The EPA freshwater standard for pH is 6.5 – 9.0 for domestic water supplies (EPA 2010b). Several samples collected from 2002-2003 in Beaver and Highland Creeks exceeded the upper end of the more stringent secondary maximum contaminant level (SMCL) for pH (8.5; SMCL range for pH is 6.5-8.5) (Heakin 2004, EPA 2011b). Beaver Creek (site 4) had a maximum pH measurement of 8.6 during the 2002-03 study (Heakin 2004). Highland Creek (site 7) had a maximum pH of 8.8 measured in 1993-94 by NPS, and a maximum of 8.7 during the 2002-03 study (Heakin 2004). The stretch of Highland Creek inside WICA is listed as impaired for pH under section 303(d) of the Clean Water Act (SD DENR 2010).

Rust (2006) measured pH levels in WICA's three perennial streams. Beaver Creek was measured 90 times, with a median value of 8.5 and a maximum of 9.7; Cold Spring Creek was measured 87 times, with a median of 8.1 and a maximum of 8.7; and Highland Creek was measured 60 times, with a median value of 8.7 and a maximum of 9.0 (Rust 2006). pH values in Beaver Creek occasionally exceeded the EPA domestic water standard; and Highland Creek exceeded the EPA SMCL standard for pH.

Specific Conductance

NPS (1998) included six specific conductance readings from Highland Creek between 1993-1994, with a mean of 263.2 µS/cm @ 25° C. Six additional readings were taken in 1995-1996, with a mean specific conductance of 256.8 µS/cm @ 25° C.

Heakin (2004) looked at specific conductance measurements in Beaver Creek taken between 1991 and 2003, finding that values remained fairly steady between about 500 to 600 microsiemens (µS/cm). The state standard for specific conductance is 2500 µS/cm for the 30-day average and 4375 µS/cm for a daily maximum.

Elk Mountain Spring had an average specific conductance of 596.29 µS/cm between 2006-2007 based on seven samples (NPS 2011).

Temperature

Highland Creek is listed as an impaired water body for temperature on the EPA's 303(d) list (EPA 2011a, SD DENR 2010). The cause of temperature impairment is considered to be natural in origin. In the 2002-2003 USGS study (Heakin 2004), several temperature readings exceeded the coldwater permanent fisheries criterion (18.3° C) in all three perennial streams, and two samples from Highland Creek exceeded the coldwater marginal fisheries criterion (24.0° C) (Heakin 2004). However, all of these readings occurred during the month of July indicating that warm air temperature and low flow may have influenced the temperatures.

Rust (2006) measured temperature in WICA's three perennial streams. Ninety measurements were collected on Beaver Creek, with a mean of 16.7° C and a maximum of 23.5° C; Cold Spring Creek was measured 87 times, with a mean of 15.0° C and a maximum of 20.1° C; and Highland Creek was measured 60 times with a mean of 20.0° C and a maximum of 26.7° C (Rust 2006). Some of the measurements from Highland Creek exceeded the marginal fisheries criterion.

Turbidity

Heakin (2004) noted that the mean turbidity value was higher at the upstream Beaver Creek site (7.3 nephelometric turbidity units [NTU]) than the downstream site (1.9 NTU). The upstream site for Beaver Creek had a higher mean turbidity than either Cold Spring Creek (2.3 NTU at site one and 2.8 NTU at site two) or Highland Creek (2.4 NTU).

Rust (2006) collected six turbidity samples from each of WICA's three perennial streams. Beaver Creek had a mean turbidity of 17 NTU, Cold Spring Creek had a mean of 8 NTU, and Highland Creek averaged 4 NTU (Rust 2006). These values are higher than values reported by Heakin (2004); however they are still quite low.

Threats and Stressor Factors

Mercury contamination is due primarily to atmospheric deposition from coal power plant combustion and other fossil fuel burning. The mercury concentrations measured during the 2002-03 water quality study were far below the EPA drinking water standard. Deposition data became available for the region in 2009.

Nitrates enter the aquatic environment through airborne deposition and residential (septic system) runoff. Septic system leaching represents a known threat to WICA's water quality, and a potential source of nitrate contamination. Population growth in the Black Hills region will magnify the threat posed by septic systems as the number of units increase. Groundwater contamination by nitrates is also a concern at WICA.

Chemicals and heavy metal contamination could occur due to management changes, fire, or urban development. Pesticide contamination is a threat to Wind Cave water quality if chemical application occurs above cave passages. Use of pesticides was halted in the 1990s in WICA due to the potential negative impacts to water resources, but resumed for exotic plant treatments in 2005 (Ohms 2009). WICA established three management zones for pesticide use in 2006, the spray zone, the limited spray zone, and the restricted spray zone. These zones indicate the potential for water resource contamination, and a Pesticide Water Monitoring Plan (Ohms 2009) was also developed to monitor potential water quality impacts from pesticide use.

The Pringle Post and Pole site upstream from WICA was a known threat to the park's water quality in the past (now closed), and could still potentially have an impact due to historic contamination of the soil (Ohms 2009). The presence of several chemicals and metals has been confirmed by soil and water samples on-site and from downstream samples.

Data Needs/Gaps

Additional long-term water quality monitoring is needed for WICA's perennial streams in order to determine possible trends. Surface water monitoring efforts in the park have been sporadic and generally have assessed water quantity more than water quality. Data regarding cave drip site water quality have not been extensively collected since the late 1980s; however data from two drip sites have been gathered in recent years but have not yet been published. Broader sampling from additional drip sites could give a better picture of the overall water quality condition in the cave.

Overall Condition

It is difficult to assign a condition to WICA's water quality without more consistent, long-term monitoring. Data are intermittent for nearly all water bodies in the park, making it difficult to determine any trends in water quality over time. Highland Creek is listed on the EPA's 303(d) list for pH and temperature impairment. Cold Spring Creek and Beaver Creek have exceeded the EPA standard for arsenic concentrations in stream sediments in some samples. Other water quality parameters are within EPA and/or state standards; therefore WICA's water quality was in good condition at the time of the Heakin (2004) study. Water quality is of low concern in WICA.

Sources of Expertise

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Barbara Rowe, USGS South Dakota Water Science Center

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4.16 Changes in Hydrology

Description

WICA is located in the Cheyenne River Basin within the greater Missouri River watershed. Three perennial streams form sub-watersheds in WICA: Beaver Creek, Highland Creek, and Cold Spring Creek. Springs and pools are other surface water resources in WICA. Surface hydrology can change greatly in the park depending on the amount of precipitation that occurs annually. Groundwater is held in several aquifers, with the primary aquifers being the Deadwood, Madison, and Minnelusa. The Madison Aquifer can be physically accessed at a number of lakes within Wind Cave. There are many threats to the natural hydrology of the park including changing climatic cycles, disappearing streams, upstream dams and water withdrawals, soil compaction by ungulates, wells, and water development (Ohms 2009).

Measures

- Springs and surface flow: spring discharge is measured in gallons per minute (gpm) and surface flow is measured in cubic feet per second (cfs).
- Groundwater is quantified by water level as measured at cave lake sites within Wind Cave.

Reference Conditions/Values

The reference condition for hydrology is the beginning of historic measurements at WICA.

Data and Methods

A report by Ohms (2009) on WICA's hydrology and water resources was the primary source of information for this component.

SMU GSS calculated the mean flow rate for Elk Mountain Spring using unpublished data from WICA.

Current Condition and Trend

<u>Springs and Surface Flow</u>

There are 94 small springs located within WICA. Springs depend on precipitation for recharge and generally do not flow during dry periods. The springs are primarily derived from flow within the soil zone or alluvium, with little or no bedrock flow. Eight of the springs have been modified to supply water for animals in the park (Ohms 2009). Flow rate is measured at Elk Mountain Spring, which had a mean flow of 0.428 gpm between 2006 and 2010 (NPS 2011, unpublished data).

Beaver Creek is the major drainage of WICA, but the park receives additional water flow from Cold Spring Creek and Highland Creek. The Highland Creek drainage flows into the Beaver Creek drainage to the east of park boundaries. Beaver creek originates outside of the park near the city of Custer, South Dakota, and flow rarely leaves the park as most of the water is lost to outcrops of the Madison Limestone formation (Ohms 2009). In 1998, stream gauges measured flow at 5.67 cfs above the cave and 1.99 cfs below it. Figure 13 shows the flow rate of Beaver Creek between 1990 and 2005. On average, 2.4 million gallons of water enters the aquifer every day (Ohms and Allison 1998, as cited in Ohms 2009).

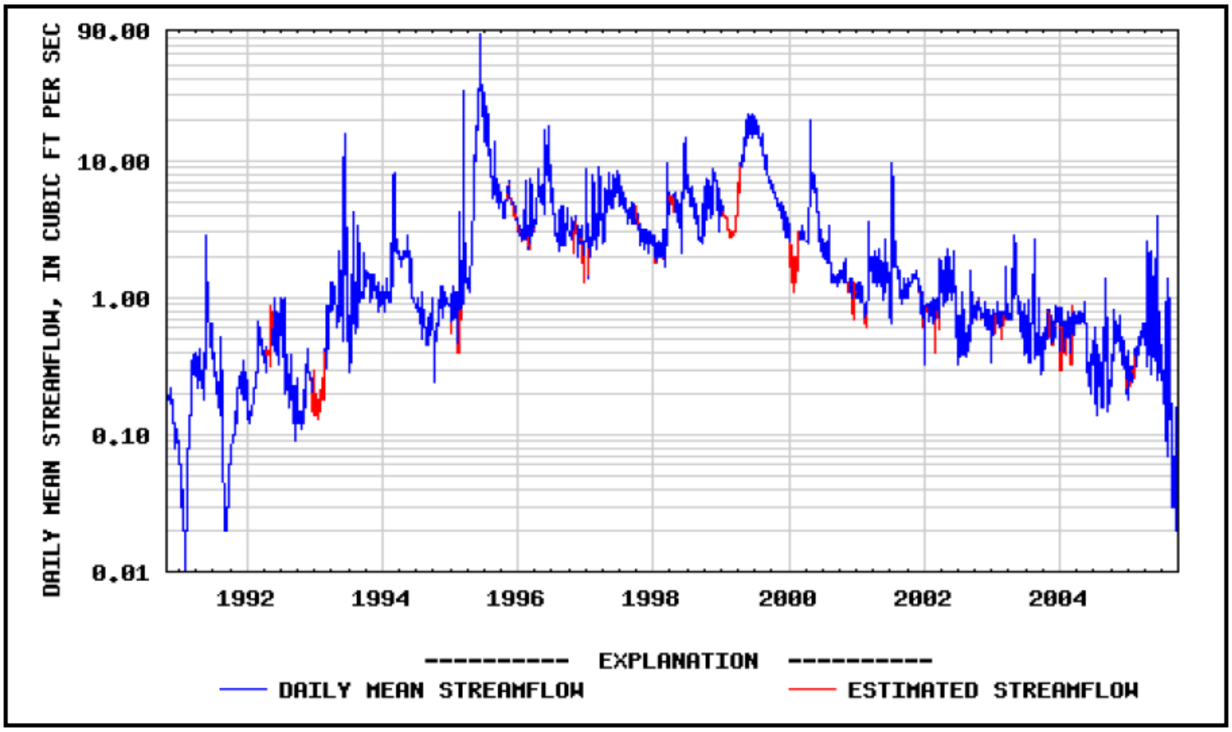

Figure 13. Stream flow of Beaver Creek, 1990-2005 (Ohms 2009).

Cold Spring Creek enters WICA on the western boundary and is the smallest of the perennial streams in the park with regard to flow and drainage. Flow in this creek is largely derived through a network of pipes from the Water Supply Springs, a small outlying unit that lies 3.2 km (2 mi) west of the park. The springs once served as the water supply for the park and overflow was directed into the Cold Spring drainage. The creek also receives some runoff from the surrounding landscape, but the pipes provide the only water during dry periods. The pipe system is no longer maintained by WICA. When the system eventually fails, the hydrology of the creek may be significantly altered if no maintenance of the pipes is performed (Ohms 2009).

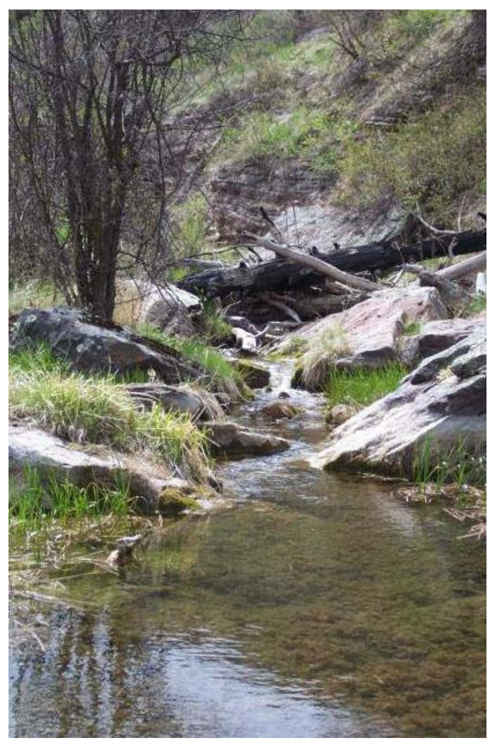

Photo 18. Cold Spring Creek in 1999 (Ohms 2009).

Highland Creek is primarily fed by springs originating in Custer State Park, located immediately to the north of WICA. The creek loses a substantial amount of water to the Madison Limestone beginning 0.4 km (0.25 mi) from the park's northern boundary. During times of greater flow, the remaining water is lost to the Minnelusa Formation within 3.2 km (2 mi) of the park's boundary (Ohms 2009).

Sixty surface pools have been identified in WICA, which are mostly small depressions on the landscape that hold standing water after a rainfall or snowmelt event. These pools are ephemeral, but are an important water source for wildlife when they are present. A series of pools exist in Wind Cave Canyon that tend to hold water even during dry periods. These particular pools are likely the result of a shallow perched aquifer lying above an impermeable layer of the Minnelusa (Ohms 2009).

Groundwater

WICA lies in the recharge zone for the regionally significant Madison Aquifer, which is part of the Pahasapa Limestone. A large portion of groundwater recharge is provided by stream flow loss as the water intersects karstic limestone outcrops (Ohms 2009). Beaver and Highland Creeks lose the vast majority of their flow to the bedrock aquifers in WICA. Groundwater levels respond quickly to significant recharge events in the area. The Madison Aquifer supplies drinking water to WICA and the local area, including the community of Hot Springs, South Dakota (Ohms 2009).

Two other aquifers exist in WICA, the Minnelusa and Deadwood Aquifers. The Minnelusa Aquifer lies above the Madison Aquifer, and the two are generally separated by an impermeable layer in the Minnelusa Formation, although some mixing does occur via fractures. The Deadwood Aquifer lies below the Madison Aquifer and within the Deadwood Formation which outcrops along Cold Spring and Beaver Creeks, providing the aquifer with recharge (Ohms 2009).

Portions of Wind Cave intersect the water table of the Madison Aquifer and form a series of groundwater lakes within the cave. Water levels are monitored at three locations: Windy City, Calcite, and What the Hell Lakes. Fluctuations in the water table, which affect cave lake levels, have been natural events to date (Ohms, pers. comm., 2011). Figure 14 shows lake level measurements since 1986 and illustrates the significant variation over time.

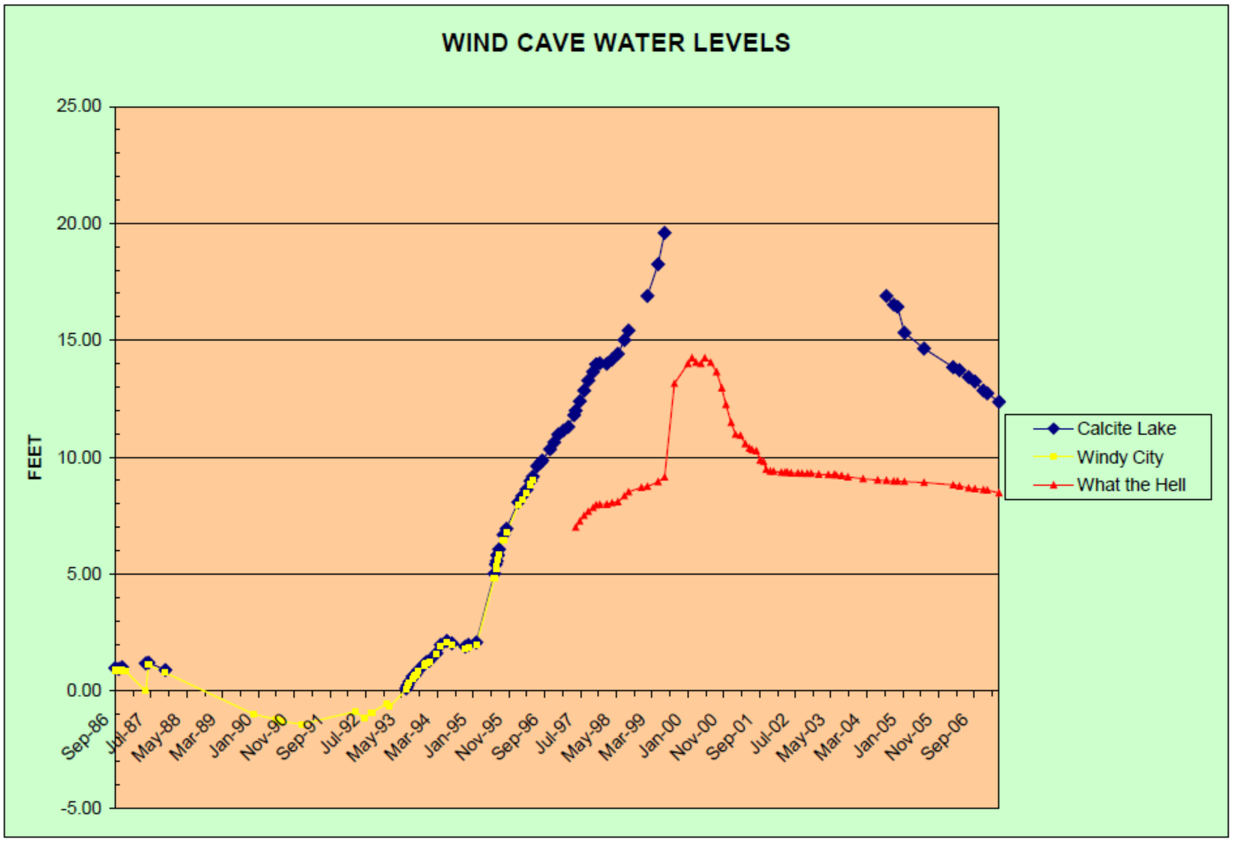

Figure 14. Water levels for the three lakes in Wind Cave - September 1986 to 2008 (Ohms 2009).

<u>Threats and Stressor Factors</u>

Climatic cycles pose a potential threat to WICA's hydrology. A multi-year drought throughout much of the 2000's caused groundwater levels to decline due to lack of precipitation. Climate change may lead to future droughts in the area (Ohms 2009).

In the future, water loss due to factors other than karst processes, such as irrigation, cattle watering, and unregulated building of stock dams, may cause additional stream flow loss, leaving little surface water available for aquatic organisms and wildlife. It is conceivable that water may need to be hauled into the park if surface water is unavailable for bison and elk (Roddy, pers. comm., 2011).

Water withdrawals are a significant threat to the natural hydrology of WICA, potentially altering surface flow, groundwater levels, and cave lakes. Thirty dams have been constructed by private landowners on Beaver Creek upstream of WICA as of 2011, creating small pools which increase evaporation and reduce surface flow in the park (Ohms 2009; Ohms, pers. comm., 2011). Reduced surface water availability in streams could negatively impact wildlife. Water temperatures have risen in the creek as a result of the dams, lowering oxygen levels which could threaten fish and other aquatic organisms (Ohms 2009). Fourteen dams have been constructed inside the park to hold water for wildlife; however, only a few function properly. None of these dams exist on the major perennial streams. These dams alter the natural hydrology of WICA by impeding runoff and infiltration and may artificially increase or decrease groundwater recharge where they exist (Ohms 2009).

There are 12 documented wells inside WICA boundaries; six of these wells were drilled while the rest are simply hand-dug. One of the drilled wells in Wind Cave Canyon serves as the park's sole water supply and a second serves as a backup. A third drilled well in that same canyon is used for monitoring. Population growth in the Black Hills region will place increased demand for water on the region's aquifers as the number of wells increase. Housing developments have been built recently in the Beaver Creek watershed, with continued growth expected in the area. In 2006, the Southern Black Hills Water System filed a Future Use Water Permit application (No. 2580-2) to appropriate 1,474 acre-ft annually of groundwater from four well sites in the Madison aquifer in Custer and Fall River Counties. They also filed Water Permit Application 2585-2 to appropriate 1,600 acre-ft annually of groundwater from one well site in the Madison aquifer in Custer County (Back 2011). This rural water system will be temporarily using the Streeter Well, which is located within one mile of park boundaries, until a second well, located within 0.4 km (0.25 mi) of park boundaries is drilled in Fuson Canyon. This project is currently under construction and will be operational by 2012. The project could have a significant impact on the Madison Aquifer and could have the potential of eliminating Wind Cave's lakes by lowering the water table. In a worst-case scenario it was estimated by using the Theis Solution that groundwater levels in the vicinity of Wind Cave could decline by 13.7 m (45 ft) within 10 years if continuous pumping was focused on the Streeter Well (Cuttilo 2006).

Large ungulates could increase the impermeability of soils through compaction, leading to additional runoff. Several native ungulates are present in WICA, including bison, elk, white-tailed deer, mule deer, and pronghorn (Muenchau 2002).

Data Needs/Gaps

Surface and groundwater resources in WICA are well documented and have been studied extensively. Monitoring of water resources should continue into the future in order to document any changes to the park's hydrology.

Overall Condition

The condition of WICA's hydrology has been significantly altered from its natural state, particularly surface streams by dam construction. However, level and flow measurements have not been significantly impacted to date. There is concern that ongoing water development in the Black Hills region could have more serious impacts on groundwater and stream levels in the future. Both the flow of surface water and springs as well as groundwater levels are of moderate concern in WICA.

Sources of Expertise

Marc Ohms, WICA Physical Science Technician
Dan Roddy, Biologist, WICA.

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4.17 Air Quality

Description

Air pollution can significantly affect natural resources and their associated ecological processes. In particular, air pollution can influence water quality and soil pH, compromise plant health and distribution, accelerate the decay of geologic or cultural features, and impair the visibility and breathable air within parks (NPS 2007a). Consequently, air quality in parks and wilderness areas is protected and regulated through the 1916 Organic Act and the Clean Air Act of 1977 (CAA) and its subsequent amendments (NPS 2004). In particular, the prevention of significant deterioration (PSD) title of the CAA outlines specific authority in protecting the natural and cultural resources of parks (EPA 2008). This title defines two distinct categories of protection for natural areas, Class I and Class II air sheds, into which all lands managed by the Department of Interior in 1977 were classified. Class I air sheds receive the highest level of air quality protection as offered through the CAA; only a small amount of additional air pollution is permitted in the air shed above baseline levels. Parks designated as Class I and II air sheds typically use the EPA National Ambient Air Quality Standards (NAAQS) for criteria air pollutants as the ceiling standards for allowable levels of air pollution. EPA believes that these standards, if not exceeded, protect human health and the health of natural resources (EPA 2008). The CAA also establishes that current visibility impairment in these areas must be remedied and future impairment prevented (EPA 2008). However, EPA acknowledges that the NAAQS are not necessarily protective of ecosystems and is currently developing secondary NAAQS for ozone and nitrogen and sulfur compounds to protect sensitive plants, lakes, streams, and soils (EPA 2010a, EPA 2010b). To comply with CAA mandates, the NPS established a monitoring program that measures air quality trends in park units for key air quality indicators, including atmospheric deposition, which affects ecological health through acidification and fertilization; ozone, which affects native plant communities and human health; and visibility, which affects how well and how far visitors can see park landscapes (NPS 2009).

The CAA designates WICA as a Class I air shed, and though it is located in a rural part of the country, there are several sources of air pollution that threaten the park's air quality. These include oil and gas development in northwest Wyoming; smoke from wood and pellet stoves, campfires, wildland fires and prescribed burning; visitor and NPS vehicle emissions; generators, space and water heating equipment and fuel storage containers within the park, and nearby operations and development of coal-fired power plants (NPS 2006a, Peterson et al. 1998, EA Engineering, Science and Technology 2003). Air pollutants of particular concern to managers at WICA include wet deposition of sulfur (S), nitrogen (N) and ammonium (NH_4^+) compounds in particular, as well as concentration of ground-level ozone (O_3) and concentration of suspended particulate matter ($PM_{2.5}$ and PM_{10}) (Ohms, pers. comm., 2010).

Measures

Criteria pollutants consistent with the maintenance of Class I air sheds, including deposition of nitrogen (N), sulfur (S), and ammonium (NH_4^+) compounds; concentrations of ground-level ozone (O_3) and suspended particulate matter ($PM_{2.5}$ and PM_{10}). Visibility across the park is measured in terms of Haze Index (deciviews [dv]).

Atmospheric deposition

Atmospheric deposition of sulfur and nitrogen can have significant effects on ecosystems through altered water quality, soils and vegetation (NPS 2005). Sulfur and nitrogen emissions form compounds that acidify water and soil systems with low buffering capacities, and excess nitrogen deposition, which acts as a fertilizer, can disrupt nutrient cycling and influence plant species composition (NPS 2005). The species diversity in grassland ecosystems is particularly vulnerable to excess nitrogen deposition, as native plants that have adapted to nitrogen-poor conditions are displaced by species that prefer high levels of nitrogen (typically nonnative grasses and other exotics) (NPS 2005, Pohlman and Maniero 2005). Over time, this shift in nutrients can result in ecosystem-wide changes including shifts in species composition (both plants and animals), increased occurrence or likelihood of insect and disease outbreaks, and disruption of natural fire regimes (NPS 2007a).

Ozone

Ozone occurs naturally throughout the earth's atmosphere. In the upper atmosphere, it protects the earth's surface against ultraviolet radiation (NPS 2005). However, it also occurs at the ground level (i.e., ground-level ozone) where, at high concentration, it is harmful to plants and human health (NPS 2005). Ground-level ozone is created by a chemical reaction between nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of heat and sunlight. Some major sources of ozone-forming chemicals include motor vehicle exhaust and industrial emissions, gasoline vapors, and chemical solvents (NPS 2005, Pohlman and Maniero 2005). Breathing air containing ozone can aggravate asthma, reduce lung function, inflame lung tissue, cause acute respiratory problems, or impair the body's immune system (NPS 2005). At high concentrations, ozone has been linked to increased susceptibility to respiratory infections in humans (EPA 2010c). This would be of particular concern for anyone engaging in strenuous aerobic activity, such as hiking in natural areas (Pohlman and Maniero 2005, EPA 2010c). Ozone is also one of the most widespread pollutants affecting vegetation in the U.S. (NPS 2005). Research has indicated that some plant species are more sensitive to ozone than humans, with some species sustaining effects or injury at concentrations that are well below the current EPA standard (NPS 2005, Pohlman and Maniero 2005). Long-term exposures can result in increased vulnerability to insects and diseases and shifts in species composition (NPS 2005).

Particulate Matter (PM) and Visibility

Particulate matter (PM is a complex mixture of extremely small particles and liquid droplets that become suspended in the atmosphere. It is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles (EPA 2009a). The EPA groups particle pollution into two categories: fine particles ($PM_{2.5}$), which are 2.5 micrometers in diameter or smaller; and inhalable coarse particles (PM_{10}), which are smaller than 10 micrometers (the width of a single human hair) (EPA 2009a). The size of particles is directly linked to their potential for causing human health and landscape visibility problems. PM_{10} and $PM_{2.5}$ are a concern to human health as these particles can easily pass through the throat and nose and enter the lungs (EPA 2009a, EPA 2010d). Short-term exposure to these particles can cause shortness of breath, fatigue, and lung irritation, while long-term exposure can cause more serious health effects, including heart and lung diseases (EPS 2009a).

Fine particles are also the major cause of reduced visibility (haze) in many parts of the United States, including many national parks and wildernesses (EPA 2010b). $PM_{2.5}$ can be directly emitted from sources such as forest fires or they can form when gases emitted from power plants, industry and/or vehicles react with air (EPA 2009a, EPA 2010d). Sources of coarse particles (PM_{10}) include grinding or crushing operations, and windblown or stirred up dust from dirt surfaces (e.g., roads, agricultural fields). These particles either absorb or scatter light. As a result, the clarity, color and distance seen by humans decreases, especially during humid conditions when additional moisture is present in the air (EPA 2010d).

Reference Conditions/Values

Park resource managers have indicated Class I air shed standards and ecosystem thresholds to be the reference condition for air quality in WICA. The NPS Air Resources Division (ARD) has developed an approach for rating air quality conditions in national parks, which is based on the current NAAQS, ecosystem thresholds, and visibility improvement goals (Table 20) (NPS 2010a). Assessment of current condition of atmospheric deposition of nitrogen and sulfur compounds are based on wet deposition, primarily because many parks do not collect dry deposition data. The ozone standard established by the EPA, which was revised in 2008 to be more protective of human health, is used as the benchmark for rating current ozone condition in parks. Visibility conditions are rated in terms of a Haze Index, a measure of visibility derived from calculated light extinction (NPS 2010a). The NAAQS standard for PM_{10} is 150 $\mu g/m^3$ over a 24-hour period; this level may not be exceeded more than once per year on average over three years (EPA 2010d). The standard for $PM_{2.5}$ is 15.0 $\mu g/m^3$ weighted annual mean or 35 $\mu g/m^3$ in a 24-hour period over an average of three years (EPA 2010d).

Table 20. National Park Service Air Resources Division air quality index values (NPS 2010a).

Condition	Ozone concentration (ppb)	Wet Deposition of N or S (kg/ha/yr)	Current Group 50 – Estimated Group 50 Natural (dv)
Significant Concern	≥ 76	> 3	> 8
Moderate	61-75	1-3	2-8
Good	≤ 60	< 1	< 2

Data and Methods

Many sources may be used to access air quality data specific to parks and natural areas in the United States. The Clean Air Status and Trends Network (CASTNet) database was searched for summary charts of sulfur and nitrogen deposition for WICA. The National Atmospheric Deposition Program–National Trends Network (NADP-NTN) database was searched for summary concentration and deposition maps of sulfate, nitrate, ammonium, and deposition maps of total inorganic nitrogen from nitrate and ammonium beginning in 1985. The Interagency Monitoring of Protected Visual Environments (IMPROVE) database was searched for summary concentrations of fine particulate matter in WICA. The EPA Air and Radiation Air Data network was searched for air quality parameters for 2003 through 2008 for Custer County, SD, where WICA is located. The NPS Explore Air website was used to obtain park specific summaries of the most current interpolated air quality data for WICA as well as tables of air quality estimates for 1999-2003. None of the datasets were adjusted or processed in any way.

Current Condition and Trend

Air quality is well-monitored within the NGPN. The CASTNet and NGPN networks monitor ozone, sulfur dioxide, dry deposition, and other meteorological parameters, while NADP/NTN monitors wet deposition. Visibility within the network is monitored through IMPROVE. Specific to WICA, there are on-site monitoring stations for wet deposition (NADP/NTN site installed in 2002), dry deposition (CASTNet site) and visibility conditions (IMPROVE site installed in 1999) within the park (Pohlman and Maneiro 2005, NPS 2006a). A ground-level ozone monitor was established in late 2004, with in-park monitoring beginning in 2005.

Atmospheric Deposition

In an assessment of air pollutant data from 1984-1995 in parks located in the Northern Great Plains, Peterson et al. (1998) found that overall deposition of hydrogen ions was low, indicating that acidity of wet deposition is not of great concern in the region. Specific to WICA, the authors also determined that deposition of sulfur and nitrogen, when combined with wet deposition of hydrogen and other ions, suggest that the park is a relatively clean site regarding deposition of pollutants (Peterson et al. 1998). Based on the most current data at the time, the authors determined there was no apparent threat to the natural resources from acidic deposition. However, at the time of the assessment, there was no NADP site located at WICA to monitor wet deposition; results were extrapolated to the WICA locale using data collected from a NADP/NTN site some 130 km northeast of WICA (Peterson et al. 1998).

Currently, WICA hosts monitoring stations for atmospheric deposition of nitrates and sulfates as well as a number of other cations and anions that influence soil and water systems. Five-year averages are used to estimate the condition of most air quality parameters; this offsets annual variations in meteorological conditions, such as heavy precipitation one year versus drought conditions in another. The most recent 5-year average for air quality parameter estimates (2004-2008) show total wet deposition of nitrogen in WICA to be 2.9 kg/ha/yr, while total wet deposition of sulfur was found to be 1.1 kg/ha/yr. Relative to the NPS ratings for air quality conditions (see Table 20 for ratings values), the amount of atmospheric deposition of nitrogen in WICA falls in the upper end of the *Moderate Concern* category and the amount of sulfur deposition in the lower end of the *Moderate Concern* category. However, several factors are considered when rating deposition condition, including natural background deposition estimates and effects of deposition on different ecosystems (NPS 2010a). The estimate for natural background wet deposition in the West is roughly equivalent to 0.13 kg/ha/yr each for sulfur and nitrogen (NPS 2010a), which means there is always a small amount of deposition present regardless of air quality in the region. Nevertheless, based on the NPS process for rating air quality conditions in parks, scores for parks with ecosystems that are potentially sensitive to nitrogen or sulfur deposition are typically adjusted up one condition category. In general, native grasslands can be quite sensitive to increased levels of nitrogen and sulfur, as these shifts in nutrients can cause shifts in species composition (Pohlman and Maniero 2005, Peterson et al. 1998). WICA supports an extensive native grassland ecosystem, which may be at risk from excess nitrogen deposition in particular. Overall, deposition of both nitrogen and sulfur is elevated above natural background. Thus, the condition for deposition of nitrogen and sulfur in WICA may be considered to be of *Significant Concern*.

The NPS has guidelines for rating the air quality parameters of most concern to ecosystems, including wet deposition of sulfur and nitrogen, ozone concentration, and visibility. An NADP monitor was installed in WICA in late 2002 and began collecting deposition data in 2003. Prior to 2003, deposition data specific to WICA was extrapolated from nearby monitors. Table 21 shows the average yearly deposition data from 2003-2008 for sulfate, nitrate, and ammonium that, when deposited in large quantities, are believed to affect ecosystems Table 21 displays the trends in deposition for each compound from 2004-2008. For all compounds, data show that deposition has been increasing on average since 2004. Deposition can vary greatly depending on the amount of precipitation that falls in any given year. It can be useful then to look at concentrations of pollutants, as opposed to deposition, because variation introduced by precipitation amounts is factored out. When looking at concentrations of nitrate, sulfate, and ammonium in the WICA region between 1985 and 2005, data show that sulfate concentrations have been decreasing overall, nitrate concentrations have remained stable, and ammonium concentrations have increased (NADP 2009).

Table 21. Annual summary of air quality deposition for WICA, 2004-2008 (NADP 2010).

	Average Annual Deposition (kg/ha/yr)				
Ambient Measure	**2004**	**2005**	**2006**	**2007**	**2008**
Ammonium (NH_4^+)	1.39	1.83	1.295	2.12	3.13
Nitrate (NO^{3-})	3.87	4.69	3.516	4.608	6.10
Sulfate (SO_4^{2-})	2.41	2.93	1.953	2.74	4.47

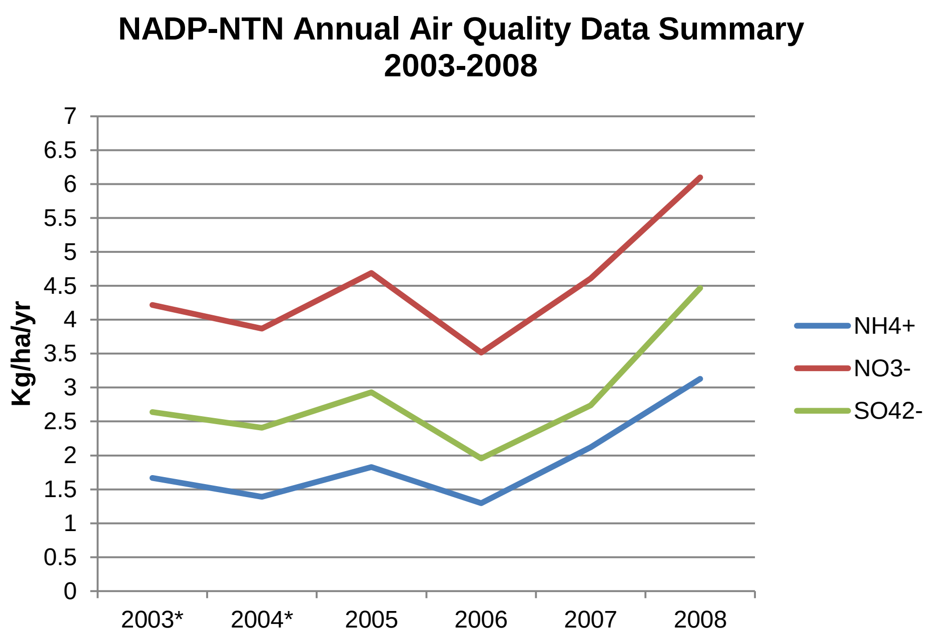

Figure 15. Trend in air quality deposition for WICA, 2003-2008 (NADP 2010). *Data do not meet NADP-NTN Completeness Criteria for this period.

<u>Ground-level ozone:</u>

Data for ground-level ozone concentrations have been recorded in WICA since 2005. Prior to 2005, ozone concentrations were recorded at nearby sites and values were extrapolated to the park. NPS air quality condition assessment protocol uses the NAAQS for ground-level ozone as the benchmark for rating current ozone conditions within park units, as it is a standard believed to be protective of human health. Current conditions of ozone concentrations in NPS park units are determined by calculating the 5-year average of the fourth-highest daily maximum of 8-hour average ozone concentrations measured at each monitor within an area over each year (NPS

2010a). From 1999-2003, the five-year average for ozone concentration in WICA was 70.4 ppb (NPS 2010b), and from 2003-2008, the five-year average was 63.9 ppb (NPS 2010c). Both concentrations fall under the *Moderate Concern* category for current ozone condition based on the NPS guidelines, though it seems ozone concentrations in WICA are declining. The most current measurements from 2008 indicate ground-level ozone concentrations in WICA to be 59.0 ppb (NPS 2009c). Figure 16 shows the declining trend for ozone concentrations (in ppm) since the start of monitoring within WICA. This would suggest that air quality in WICA is improving with regard to ozone concentration.

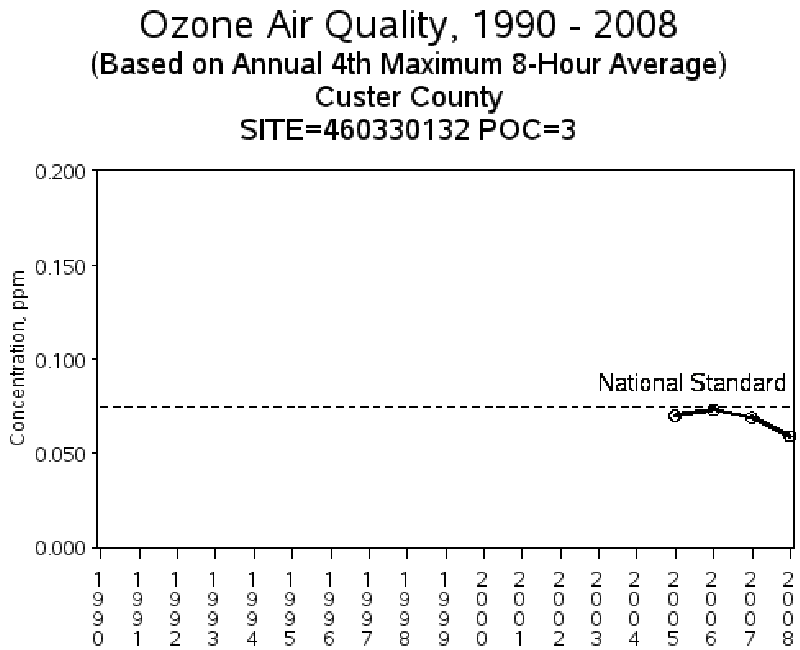

Figure 16. Average ozone (O3) air quality for WICA, 1990-2008 (Source: EPA 2009c). Note: Site 460330132 is the monitor located at WICA. Note: Ozone data collection in WICA did not begin until 2005.

In 2005, Pohlman and Maniero (2005) completed an air quality monitoring considerations assessment for the NGPN of National Park units. Part of this assessment focused on ozone concentrations in parks and the risk of injury to plant species that are sensitive to sustained ozone exposure. Analyzing ozone data from 1995-1999, Pohlman and Maniero (2005) found that ozone concentrations in WICA frequently exceeded 60-80 ppb for a few hours each year and sometimes, though very rarely, exceeded 100 ppb. Sensitive plant species begin to experience foliar injury when exposed to ozone concentrations of 80-120 ppb/hour for extended periods of time (8 hours or more) (Pohlman and Maniero 2005). The authors determined periodic peaks in concentration to be intermittent and occasional; thus, overall risk of injury to sensitive vegetation is quite low. However, if ozone concentrations should increase in the future, the authors suggested an on-site monitoring program that assesses foliar injury and growth progress would likely be necessary. Currently, there is no monitoring in place to track ozone injury of sensitive plants species in WICA (NPS 2006a). Pohlman and Maniero (2005) and Peterson et al. (1998) noted there are several plant species in WICA that are sensitive to excessive or extended concentrations of ozone, some of which could be considered bioindicators for sustained presence of unhealthy levels of ozone. A detailed list of plant species that are sensitive to ozone is included in the data needs and gaps section.

Particulate Matter ($PM_{2.5}$ and PM_{10}) and Visibility

Concentrations of particulate matter ($PM_{2.5}$ and PM_{10}) have been recorded in WICA since 2005. The NAAQS standard for PM_{10} is 150 µg/m^3 over a 24-hour period; this level may not be exceeded more than once per year on average over 3 years (EPA 2010d). The standard for $PM_{2.5}$ is a weighted annual mean of 15.0 µg/m^3 or 35 µg/m^3 in a 24-hour period over an average of three years (EPA 2010d). $PM_{2.5}$ concentrations have remained stable around 5 µg/m^3 from 2005-2008 (Figure 17). The most current available measurement (2008) for $PM_{2.5}$ in WICA is 3.8 µg/m^3. Concentrations of PM_{10} from 2005 through 2008 show an increasing trend (Figure 18). The most current available measurement (2008) for PM_{10} in WICA is 50 µg/m^3. It is not clear what is the cause of the increase in coarse particulate matter in 2007 and 2008; however, these values, and those for fine particulate matter, are well within the EPA standards for levels that are protective of human health and visibility.

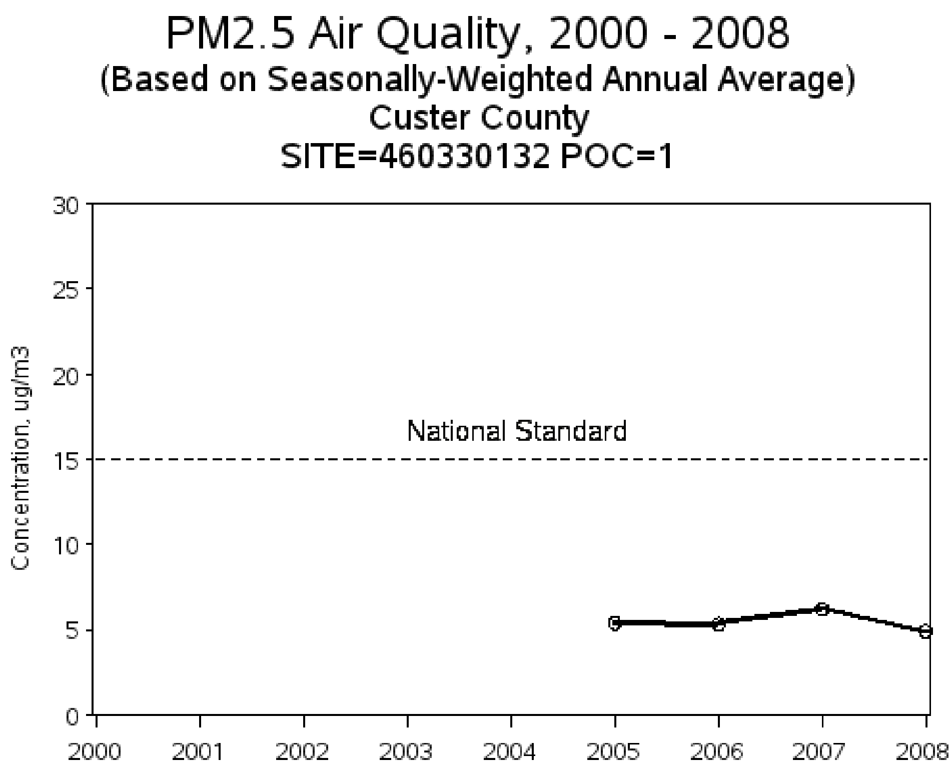

Figure 17. Trends in particulate matter ($PM_{2.5}$) in WICA, 2005-2008 (EPA 2009b). Note: PM data collection in WICA did not begin until 2005.

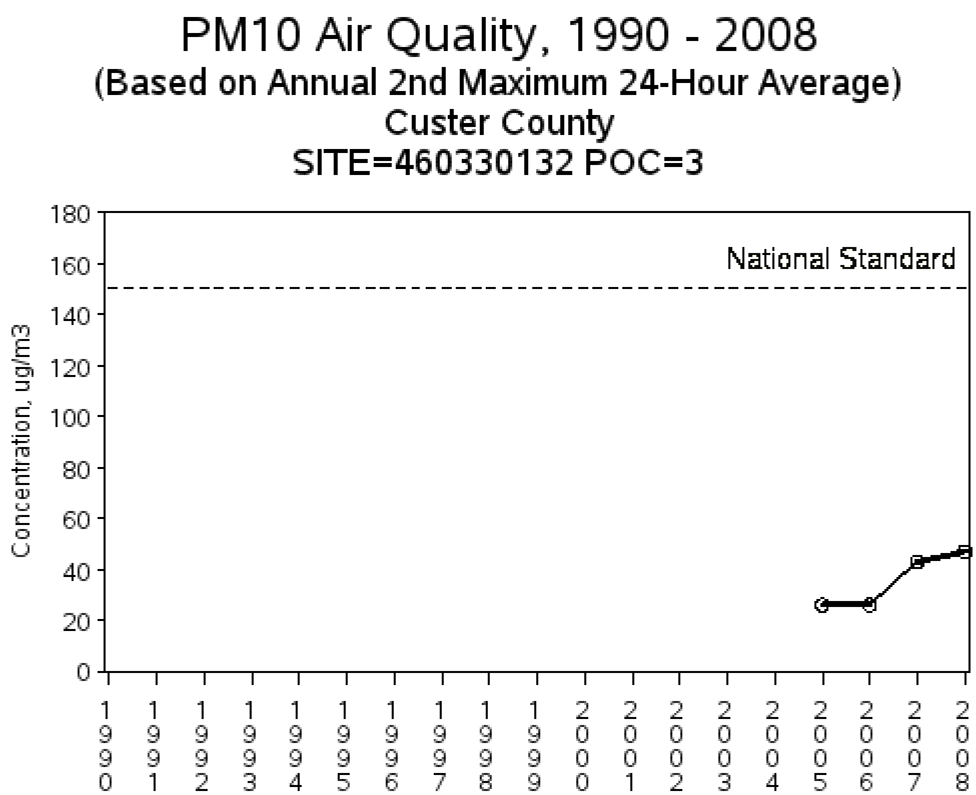

Figure 18. Trends in particulate matter (PM_{10}) in WICA, 2005-2008 (EPA 2009b). Note: PM data collection in WICA did not begin until 2005.

In response to the mandates of the CAA of 1977, Federal and regional organizations established IMPROVE in 1985 to aid in monitoring of visibility conditions in Class I air sheds (Pohlman and Maniero 2005). The goals of the program are to 1) establish current visibility conditions in Class I air sheds; 2) identify pollutants and emission sources causing the existing visibility problems; and 3) document long-term trends in visibility (NPS 2009a). Based on aerosol data collected in Badlands National Park from 1996-1998, Pohlman and Maniero (2005) indicate that the primary sources of visibility impairment in the Northern Great Plains region are sulfates from coal combustion and oil refineries, organics from vehicle emissions and chemical manufacturing, soils (e.g., windblown dusts), light absorbing particulates (likely from wood smoke and fires), and nitrates from coal and natural gas combustion as well as vehicle emissions. These particles and gases impair visibility when they scatter or absorb light; the net effect is called “light extinction”: a reduction in the amount of light from a scene that is returned to an observer (EPA 2003). The NPS examines clearest days and haziest days in each park to measure visibility conditions, in which the clearest days are defined as the clearest 20% of days each year in a park for which visibility data are available, and the haziest days are the haziest 20% in each park (NPS 2009b). Longer-term data from 1998 to 2007 suggest that visibility in WICA is improving slightly on the 20% clearest days and is remaining stable (not declining) on the 20% haziest days (NPS 2009c). NPS air quality estimates from 2004-2008 show that visibility in WICA on average is 5.7 deciviews (dv) (this is an estimate above the estimated natural conditions), which falls into the *Moderate Concern* category for NPS air quality condition assessment (NPS 2010c, NPS 2009c). Figure 19 depicts visibility (in dv) on the 20% best and 20% worst days in WICA, as well as the default natural conditions for both.

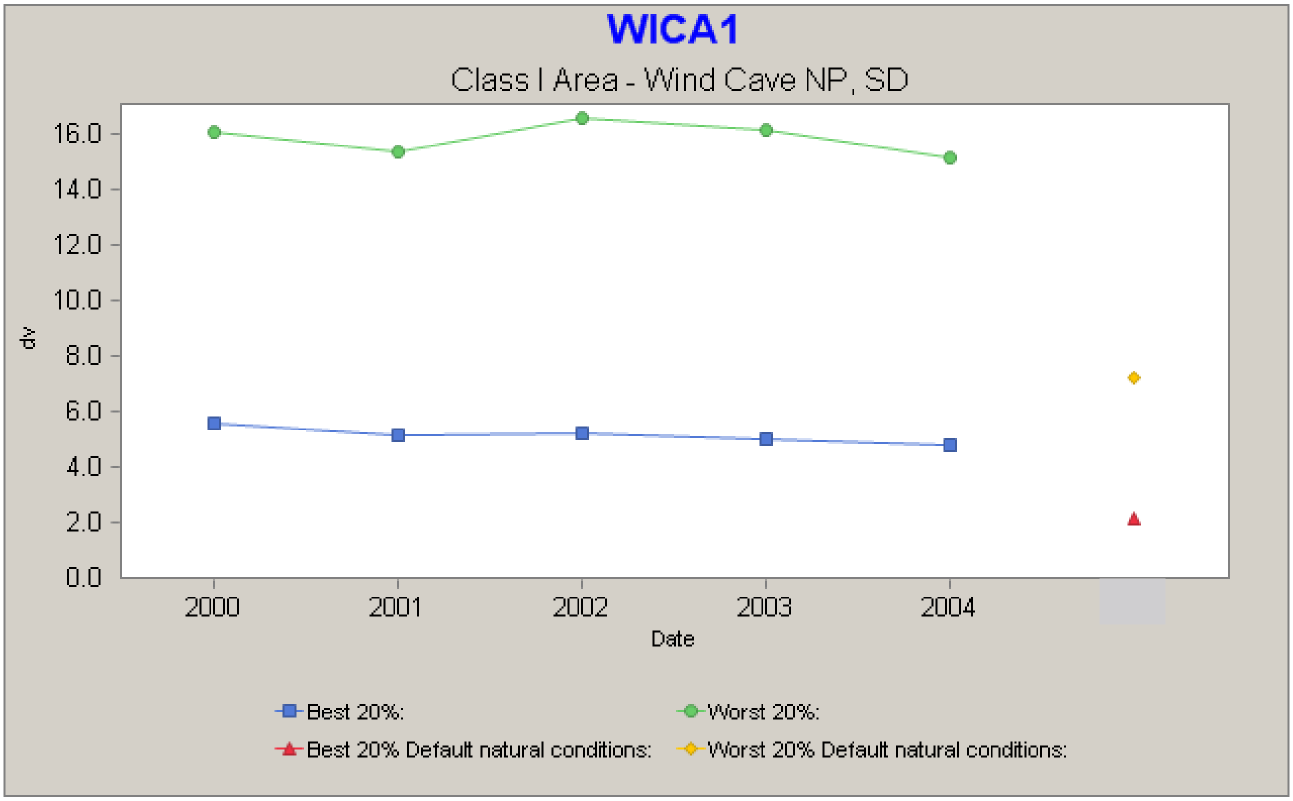

Figure 19. Annual visibility in WICA, 2000-2004 (VIEWS 2010).

<u>Threats and Stressor Factors</u>
Locally, threats to air quality in WICA come from a variety of sources: sawmills in the nearby Pringle and Custer areas; rock crushing operations and quarries in Hot Springs, SD; mineral mining operations in nearby Custer; and vehicle emissions and wood stove smoke from residences in the Hot Springs, SD area (Peterson et al. 1998). The urban area closest to WICA is Rapid City, SD where industrial operations are light. It is likely that only small quantities of pollutants from these sources actually reach WICA (Peterson et al. 1998). Posing a greater risk to air quality are the emissions sources that exist at the regional scale. Several coal-fired power plants, located primarily to the west of WICA in southeastern Wyoming, where emissions of nitrates are high (Peterson et al. 1998). These sources may pose a particular threat to WICA air quality as prevailing westerly winds carry nitrates, sulfates and volatile organic compounds eastward toward southwestern South Dakota. These produce ozone during the summer months when it is sunny, warm, and there are higher levels of moisture in the air (Peterson et al. 1998). Development of additional power plants in this part of Wyoming would certainly increase the emissions transported to WICA. Coal-fired power plants are also the major source of sulfate and nitrate emissions in South Dakota; however, the majority of these plants are located in the far eastern part of the state, which is downwind and far from WICA.

The smoke produced by forest and prairie fires has long been a part of the natural landscape in the Great Plains region. Though fires are not considered a long-term source of pollution for

WICA, if severe and substantial in extent, they may result in periods of decreased visibility and increased concentrations of particulate matter (Peterson et al. 1998). In a 2000 inventory of air emissions in WICA, EA Engineering, Science and Technology (2003) documented that the majority of air emissions in the park resulted from area campfires and prescribed burning events. Table 22 shows the estimated annual emissions from identified sources in WICA. Overall, the authors concluded that emissions from sources in and around the park are minor in comparison to the state and other NPS units (EA Engineering, Science and Technology 2003). Prescribed burning events make up the majority of total emissions in and around the park. Though prescribed burning is technically anthropogenic in nature, it is used as a land treatment process that mimics a natural fire regime in order to accomplish natural resource management objectives, including reducing the potential for catastrophic fires, eliminating excess fuel buildup, controlling disease and insect infestations, stimulating natural succession in fire dependent plant communities, and improving wildlife habitat (EA Engineering, Science and Technology 2003). As a result, prescribed burning emissions are viewed to be natural to the landscape.

Table 22. Estimated annual emissions from identified sources in WICA (EA Engineering, Science and Technology, Inc 2003).

Source	**PM** (tons/yr)	**SO_2** (tons/yr)	**NO_x** (tons/yr)	**CO** (tons/yr)	**VOCs** (tons/yr)
Point sources					
Heating equipment	0.02	0.21	0.16	0.13	<0.01
Generators	0.01	<0.01	0.07	0.02	0.01
Gasoline storage tanks	--	--	--	--	0.27
Area sources					
Campfires	0.06	<0.01	<0.01	0.46	0.42
Prescribed burning	39.15	--	--	417.95	19.55
Mobile sources					
Road vehicles	2.23	--	11.06	38.61	2.15
Off-road vehicles	0.11	--	0.17	0.16	0.67
Total	**41.47**	**0.21**	**11.46**	**457.33**	**23.06**

Data Needs/Gaps

Though monitoring of air quality parameters is quite thorough in WICA, very little emphasis has been placed on tracking the plant and animal species that are sensitive to increases in certain pollutants. Peterson et al. (1998) indicate there are no current air pollution threats to WICA vegetation, but nitrate, sulfate and ammonium deposition and ozone could become more of a concern in the future if new point and area sources of pollution emerge and increase ambient pollution levels. If air pollution increases in the future, plant and trees species can be monitored to track air pollution impacts. An on-going study conducted by scientists from Colorado State University and the USGS is focusing on plant community and ecosystem responses to nitrogen deposition in WICA (Ohms, pers. comm., 2010). Efforts will focus on mixed grass prairie communities on stony hilltops and valley bottoms; widespread vegetation types in the northern Great Plains. Results are expected sometime in 2013.

WICA has a number of species that are quite sensitive to increases in ozone and sulfates (Peterson et al. 1998 provide a detailed list). Several of these species could be used as bioindicators to track potential increases in certain criteria air pollutants as well as long-term health of the ecosystem. Table 23 summarizes the plant and tree species that have known sensitivities, either medium or high, to sulfates and ozone. While it is impractical to monitor all sensitive plant species, park staff may identify key species to use as bioindicators. Peterson et al. (1998) recommend using ponderosa pine and quaking aspen (*Populus tremuloides*) as bioindicators for ozone and quaking aspen for sulfate deposition within WICA.

Table 23. Plant and tree species of WICA with high or moderate sensitivities to sulfates and ozone (Adapted from Peterson et al. 1995; NPS 2006b).

Scientific Name	Common Name	SO_2 Sensitivity[1]	O_3 Sensitivity
Acer negundo	box elder	M	M
Agoseris glauca	pale agoseris	M	
Agropyron smithii	western wheatgrass	M	
Amelanchier alnifolia	Saskatoon serviceberry	H	M
Apocynum androsaemifolium	spreading dogbane		X
Apocynum cannabinum	dogbane; Indian Hemp		X
Artemisia ludoviciana	white sagebrush	M	
Asclepias incarnate	swamp milkweed		X
Asclepias syriaca	common milkweed		X
Betula papyrifera	paper birch	H	
Bromus tectorum	cheat grass		M
Cirsium undulatum	wavy-leafed thistle	M	
Convolvulus arvensis	field bindweed	H	
Fragaria virginiana	Virginia strawberry		H
Fraxinus pennsylvanica	green ash	M	H
Geranium richardsonii	Richardson's geranium	M	M
Helianthus maximiliana	Maximilian's sunflower	H	
Koeleria nitida	prairie junegrass	H	
Oryzopsis hymendoides	indian rice grass	M	
Parthenocissus quinquefolia	Virginia creeper		X
Pinus ponderosa	ponderosa pine	M	H
Poa pratensis	Kentucky bluegrass	H	M
Populus angustifolia	narrowleaf cottonwood	M	
Populus deltoids	eastern cottonwood	M	
Populus tremuloides	quaking aspen	H	H
Prunus virginiana	chokecherry	M	H
Rhus trilobata	three-leaf sumac		X
Rosa woodsii	Wood's rose	M	
Rubus idaeus	raspberry	H	
Rudbeckia laciniata	cutleaf coneflower		X
Sambucus racemosa	red elderberry		X
Solidago canadensis	Canada goldenrod	H	
Symphoricarpos albus	common snowberry		X
Tragopogon dubius	yellow salsify	M	
Ulmus Americana	American elm	M	

[1]Sensitivity: M=medium; H=high; X=general ozone sensitivity

In an effort to quantify harmful pollution levels and set goals for resource protection on federal lands, natural resources managers are increasingly using a "critical loads" approach for tracking and monitoring a variety of pollutants, in particular nitrogen and sulfur compounds (Porter et al. 2005). Critical loads are defined as "the quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge" (Nilsson and Grennfelt 1988, as cited in Porter et al. 2005). Essentially, critical loads describe the amount of pollution that stimulates negative impacts or harmful changes in sensitive ecosystems (Porter et al. 2005, NPS 2007a). Porter et al. (2005) developed an approach for determining critical loads for nitrogen and sulfur using two National Parks as case studies, and research is underway in other park units to aid in communicating resource condition. Their methodology can be tailored to fit most National Park lands, depending on the baseline information that is available. Since there are a variety of plant species found in WICA that are sensitive to increases in air pollutants and because grasslands are particularly vulnerable to excess deposition of nitrogen (Peterson et al. 1998), park managers at WICA may be able to develop and implement a critical load approach for managing air pollutants and to set goals for resource protection within the park.

Overall Condition

Based on NPS condition assessment protocol for air quality, the overall condition for air quality in WICA is of *Moderate Concern*. Nitrogen deposition in WICA falls into the moderate concern category. However, trend data from 1985 to 2005 indicate that concentrations of nitrogen in the region have remained relatively stable over time. However, because of the sensitivity of native grasslands to increased levels of nitrogen, WICA falls into the significant concern category. This suggests that, although deposition levels are not yet serious, steps should be taken to prevent significant impact to resources that are sensitive to increased levels of nitrogen. Sulfur deposition is of moderate concern based on NPS guidelines. Trend data indicate that concentrations of sulfate in the WICA region have actually decreased from 1985 to 2005. Similarly, annual deposition data suggest that deposition of sulfate compounds has decreased considerably between 2004 and 2008. This may lead to decreased concern over impacts to natural resources. Conversely, concentrations of ammonium have increased substantially from 1985-2005; however, there are no NPS guidelines for condition regarding ammonium deposition. Ground-level ozone concentrations are of moderate concern based on NPS guidelines, but data suggest that ozone concentrations in WICA are declining on average. Concentrations of both $PM_{2.5}$ and PM_{10} are well within EPA standards for allowable levels that are protective of human health; however, PM_{10} concentrations have experienced an increase over the last several years. Visibility in WICA is of moderate concern, but the park has experienced a slight improvement in the 20% clearest days and has remained stable for the 20% haziest days. This suggests that visibility in WICA is improving slightly on average. Although many of the designations for air quality parameters indicate a moderate concern for air quality in the park, nearly all of the parameters are experiencing declines in concentrations or deposition. Overall, this suggests air quality in WICA is demonstrating improvement.

Sources of Expertise

Marc Ohms, WICA Physical Science Technician
Ellen Porter, NPS-Air Resources Division, Air Resource Scientist.

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4.18 Soundscape

Description

Soundscape in a national park is the total ambient sound level of the park, comprised of both natural ambient sound and anthropogenic sounds (NPS 2000). The National Park Service's mission is to preserve natural resources, including the natural soundscape associated with the national park units. According to a system-wide survey conducted by the NPS, many visitors come to national parks to enjoy, equally, the natural soundscape and natural scenery (NPS 2000). Based on a survey conducted at 32 NPS units, Gramann (1999) found that intrusive sounds are of concern to park visitors, as they "detract from their natural and cultural resource experiences." While this assessment only examines soundscape as an important value to park visitors, it is important to acknowledge that anthropogenic sounds can cause major changes in wildlife breeding and behavior, as well as species success (Rabin et al. 2006).

Measures

- Ambient sound level: ambient sounds measured in A-weighted decibels (dBA). In an A-weighted decibel scale, every day sounds range from 30 dBA (very quiet) to 90 dBA (very loud) (BridgeNet 2005).
- Distribution of non-natural sounds: where any sound that is not part of the natural soundscape can be heard (e.g., vehicles, airplanes/helicopters, and other human activities).

Reference Conditions/Values

The reference condition for soundscape in Wind Cave is a "natural" experience, or a soundscape not influenced by anthropogenic sounds.

Data and Methods

No quantitative data have been collected by NPS in WICA related to soundscape (above ground or within the cave). However, Gitzen et al. (2010) explains that soundscape protocols will be developed over the next five years (this will not include the cave). This protocol will include selecting locations for each park to determine the soundscape status over one to ten years. The protocol will also include various metrics involving natural ambient sound levels, time above ambient levels, natural sound frequencies, and source of sounds.

Current Condition and Trend

<u>Ambient Sound Level</u>

No ambient sound level data have been collected in WICA to date. However, in 2010, Dr. Margaret Bruchez conducted an experiment to test low noise at seismic frequencies (between 5 Hz and 20 Hz) using microphones inside Wind Cave. In the future, Bruchez hopes to document natural underground sounds, or the measureable lack thereof. She also hopes to capture audible earthquake sounds and to measure future impact and changes to the underground aural environment (Bruchez 2010). No tests were completed above ground.

While no quantitative natural soundscape data are available, Dan Roddy describes the soundscape as quiet most of the time, with the occasional elk bugling in September, coyote howling during the day or night or prairie dogs barking during the day (Roddy, pers. comm., 2011).

Distribution of Non-Natural Sounds

No distribution data of non-natural sound in WICA have been collected to date. However, anthropogenic sounds (cars, park maintenance, etc.) most likely to occur at WICA can be heard near the park office or near roads that are found within the park (Roddy, pers. comm., 2011). The concentration of people in these areas makes it more likely that non-natural and anthropogenic sounds will occur.

Threats and Stressor Factors

WICA staff report neighboring and in-park development, roads, and overflights as contributing soundscape stress factors. There are occasional non-natural sounds coming from backhoes, leaf blowers, and operation of miscellaneous equipment. There is also traffic noise from the four-lane highway (Highway 79) approximately 6.4 km (4 mi) east of the park boundary, as well as on Highway 385, which goes through the southwestern corner of the park (Roddy, pers. comm., 2011). Roddy (pers. comm., 2011) also spoke of cattle grates in the roadways that can be heard for miles when automobiles drive over them.

Data Needs/Gaps

There is no baseline soundscape data available for WICA. The establishment of a long-term monitoring effort would ensure that condition of soundscape is quantitatively measured and assessed in the future. It would also be beneficial to study where the anthropogenic sounds are coming from, where they can be heard from and determine if the park can do anything to mitigate the impacts from the noise such as quieting the noise made when vehicles drive over the cattle grates.

Overall Condition

Due to the lack of quantitative data regarding WICA's soundscape, assessing condition is not possible. Anthropogenic sounds include park maintenance, cars, cattle grates, and overflights.

Sources of Expertise

Dan Roddy, WICA Biologist

Rod Horrocks, WICA Physical Science Specialist

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4.19 Viewshed

Description

A viewshed is the area that that is visible from a particular location. The National Park Service Organic Act (16 U.S.C. l) implies the need to protect the viewsheds of National Parks, Monuments, and Reservations. Viewsheds can be determined using GIS; specifically, a digital elevation model (DEM) is used in conjunction with a point or line to determine the visible area from that point or line. The points and lines used to calculate viewsheds often represent areas of high visitor use. The resulting viewshed layers are analyzed in order to determine the predominant visible characteristics within a viewshed. Important aspects to analyze relate to what management or patrons of the park consider valuable. Often, non-natural features (e.g., agriculture land, buildings, and roads) are considered detrimental to a viewshed in a National Park.

Measures

- Natural, undeveloped viewsheds

Reference Conditions/Values

The reference condition for the viewsheds in WICA, as defined in the framework, is an "undeveloped and natural park experience".

Data and Methods

A visibility layer was developed using ArcGIS 9.3.1 Viewshed Tool for this assessment. Plate 16 displays the visibility layer along with the roads polyline that was used to derive the viewshed. The DEMs used to develop the visibility layer were obtained from USGS (2009).

Current Condition and Trend

<u>Park Viewsheds</u>

WICA, like most NPS Units, offers spectacular views (Photo 19 and Photo 20). To maintain these views within the park, management needs to minimize development. However, views across the landscape surrounding the park are significantly different from the reference condition.

Land ownership influences WICA's viewsheds. Private individuals, often with different land management strategies than NPS, own much of the land that neighbors the park (Plate 17). This has resulted in variable viewsheds when looking out from the park. However, WICA is open to partnerships with neighboring landowners.

Viewshed analysis through a GIS determines areas visible from selected points or lines. For NPS Units, these points and lines are typically places of high visitor use, such as trails, visitor centers, or park roads. These areas are often of high management concern because of the potential impact development may have on the visitor’s park appreciation. Plate 16 displays a layer developed through a GIS viewshed analysis which displays the percent time a given cell (1/3 arc-second by 1/3 arc-second [~3 m by 3 m] area on the landscape) is visible from WICA's roads. Development in areas that are visible from a higher percentage of the roads could negatively affect visitor appreciation. Viewshed layers are valuable when overlaid with layers that explain development or disturbance in a given area.

Photo 19. A view of the landscape at WICA (NPS Photo).

Photo 20. Bison (*Bison bison*) at WICA (NPS Photo).

Threats and Stressor Factors
Human development (e.g., cell phone towers, transmission lines, housing development) appears to pose the greatest threat to viewshed quality near the park. Viewshed analysis is an important tool for recognizing areas that are the most crucial to protect. Particulate matter pollution can also deteriorate viewshed quality; a discussion of particulate matter pollution is located in the air quality section of this document (Chapter 4.17).

Data Needs/Gaps
An in-depth viewshed analysis could help determine areas in and around the park where development or possible resource extraction could deteriorate park viewshed quality. Specific analyses could utilize land cover and land use change data within different park viewsheds or fixed photopoint sites to help monitor change from a visitor's perspective.

Overall Condition
The quality of WICA's viewsheds is deteriorated in certain areas and future development is a concern. Because one of the primary reasons for park visitation is to observe the wildlife and surrounding landscape, continued monitoring of development is an important aspect of WICA management. Overall, the condition of viewsheds in WICA is of moderate concern.

Sources of Expertise
Dan Roddy, WICA Biologist
Kevin Kovacs, WICA Biological Technician

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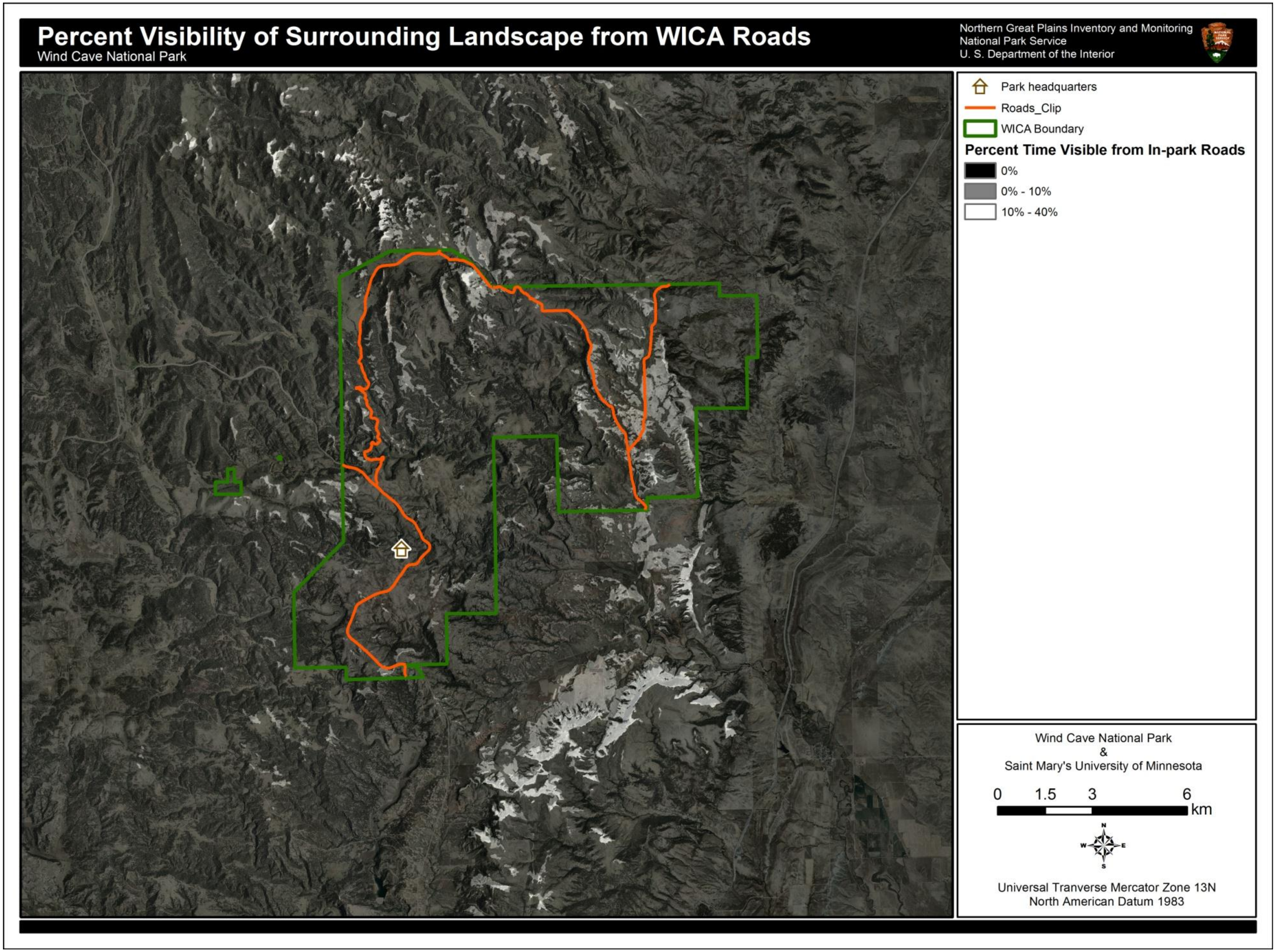

Plate 16. Percent visibility of landscape surrounding WICA from in-park roads (GeoSpatial Services 2011).

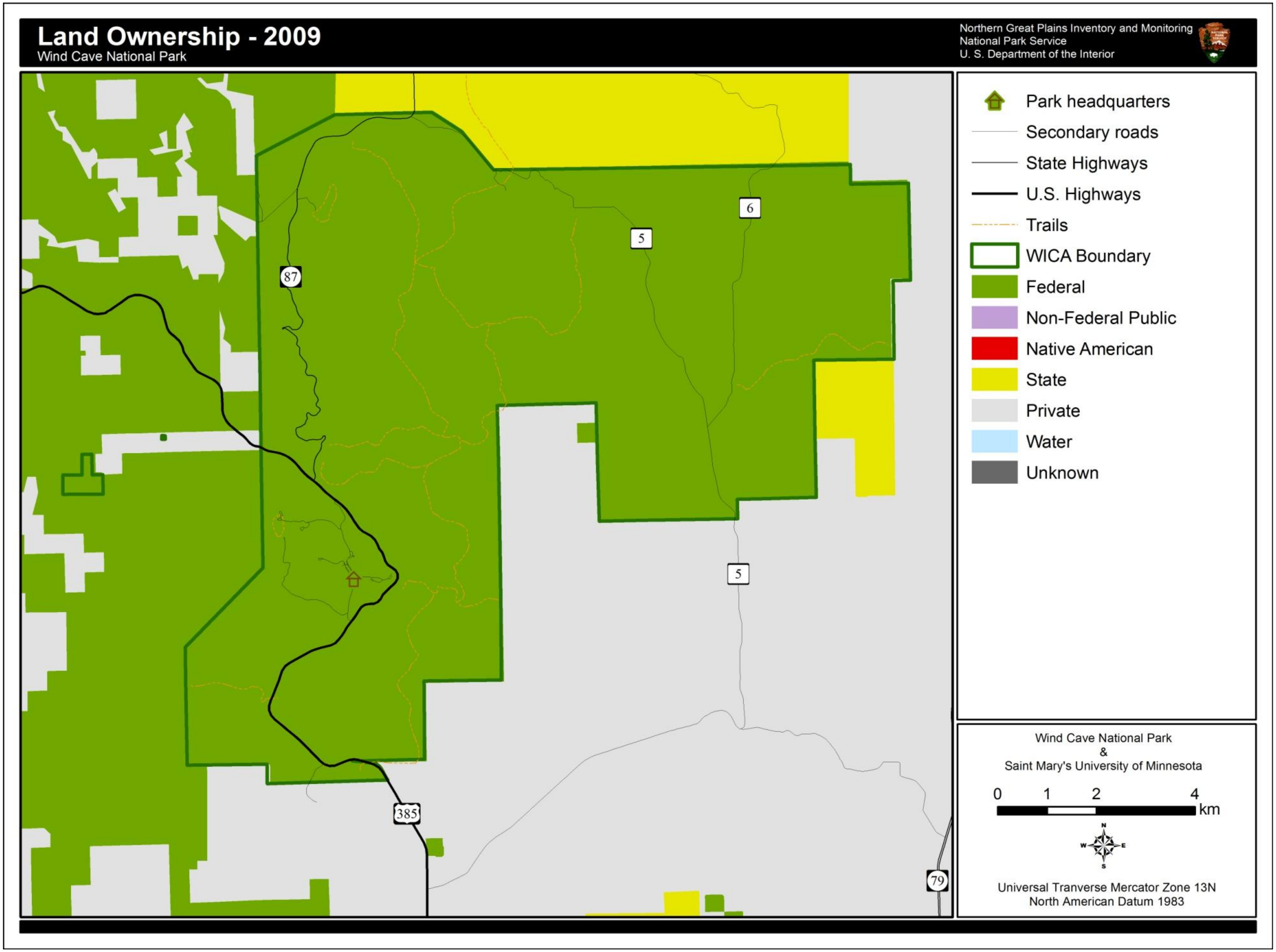

Plate 17. Land ownership, WICA, 2009 (NPS 2009).

4.20 Dark Night Skies

Description

A lightscape is a place or environment characterized by the natural rhythm of the sun and moon cycles, clean air, and of dark nights unperturbed by artificial light (NPS 2007). The NPS directs each of its units to preserve, to the greatest extent possible, these natural lightscapes (NPS 2006). Natural cycles of dark and light periods during the course of a day affect the evolution of species and other natural resource processes such as plant phenology (NPS 2006, 2007). Several species require darkness to hunt, hide their location, navigate, or reproduce (NPS 2007). In addition to the ecological importance of dark night skies, park visitors expect skies to be free of light pollution and allow for star observation.

Measures

- Night Sky Program standard- V Magnitude
- Schaff Scale Score

Reference Conditions/Values

The reference condition for WICA is the current level of ambient light. Pristine night skies exhibit minimal levels of anthropogenic ambient light, which is in accordance with National Park Service management policies.

Data and Methods

The night sky monitoring team visited the park in 2005 and 2006 and collected baseline data regarding the condition of WICA night skies. Significantly more data were collected in 2006 as three locations in the park were photographed during the monitoring team's visit (Ohms, pers. comm., 2011). Albers and Duriscoe (2001) assigned a Schaff scale score to the park, but data used in this assignment were not collected in the Park.

Current Condition and Trend

<u>Darkness – V Magnitude</u>

The National Park Service uses a charged coupled device (CCD) digital camera connected to a robotic mount and laptop computer to conduct night sky assessments and to determine darkness of park nightscapes (NPS 2007). A mosaic image of the entire night sky is created by stitching together multiple short exposure images (NPS 2007). The images are filtered using a green filter to approximate human night vision sensitivity, and the data are calibrated using the known brightness of certain stars. The resulting data are reported in units of V magnitude, which is an astronomical brightness system (NPS 2007). Weather conditions and phases of the moon limit the number of suitable nights for measuring V magnitude (NPS 2007). An initial night skies visit took place at WICA in 2005.

<u>Schaff Scale Scores</u>

Albers and Duriscoe (2001) developed a GIS that evaluated the nighttime visibility of NPS units. This model used the Schaaf scale, a 1 through 7 scale with 1 representing extreme light pollution and 7 representing pristine skies. Albers and Duriscoe (2001) overlaid Schaff scale score maps with park boundaries and then extracted the mean Schaff score for the entire area of a given park. WICA received a Schaaf score of 6.81 out of 7.00 (Albers and Duriscoe 2001). This value must be interpreted with caution though, as the original Schaff scale score maps were from 1991 and no park-specific data were used in the calculation.

Threats and Stressor Factors
Light pollution is defined by the NPS as "the illumination of the night sky caused by artificial light sources, decreasing the visibility of stars and other natural sky phenomena" (NPS 2007). Light pollution is highest in areas with high human densities and can include glare, the use of light or intrusion of light in areas not requiring lighting, and any other disturbance of the natural nighttime lightscape (NPS 2007). In addition to human sources of light, airborne particulates can also affect night sky brightness (NPS 2007).

Several sources of anthropogenic light exist near WICA and are primarily related to areas of residential use. Of those sources, the closest in proximity to the park are the cities of Custer, SD (13km); Hot Springs, SD (7km); and Rapid City, SD (90 km). Additionally, park facilities such as the WICA visitor center contribute point source light pollution. Potential 'ranchette' development of the land surrounding WICA may also contribute point source light pollution in the future.

Overall Condition
Due to the lack of data, a quantitative assessment of dark night skies cannot be completed at this time. However, an assessment may be possible once the results of the NPS night sky team's visits become available to park managers.

Because of the park's relatively close proximity to residential sites, the quality of WICA's night skies is influenced by anthropogenic light sources. Albers and Duriscoe (2001) rated the night skies in the park as 6.81 out of 7.00 which is the only quantitative estimate of dark night skies for WICA.

Data Needs/Gaps
Results of the NPS Night Sky Team's 2005 and 2006 visits should help to establish a baseline for night sky conditions in WICA. Until these data is made available, there is no baseline data regarding dark night skies at WICA.

Sources of Expertise
Marc Ohms, WICA Physical Science Technician
Chad Moore, NPS Night Sky Program Manager
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Chapter 5 Discussion

5.1 Component Data Gaps

The identification of key data and information gaps is an important objective of NRCAs. Data gaps or needs are those pieces of information that are currently unavailable, but would help to inform the status of the overall condition of a key resource component. Data gaps/needs exist for all key resource components assessed in this NRCA. Some data gaps, if addressed, would assist management of multiple components in the project framework. The data gaps regarding land cover, fire regime, and native plant communities primarily focus on increased inventory efforts regarding native species of concern and increased knowledge of the effects of different management activities and natural disturbance regimes. Table 24 describes the key data gaps for each component assessed in this NRCA in detail.

Data gaps for many wildlife components relate to developing methods for and performing population surveys, or increasing the accuracy of current survey methods. A data gap that relates to multiple park resources is the effects of deltamethrin (the pesticide used to control fleas that could be carriers of the plague bacteria) on other insects, reptiles, and amphibians. Continued monitoring of the foraging habits of elk, bison, pronghorn, and other grazing animals in the park is a priority.

For chemical and physical components (i.e., water quality, air quality, hydrology, and natural cave environment), the data gaps relate to developing more accurate methods for collecting data in the future. Regarding the cave environment component, both data gaps relate to anthropogenic changes to the cave environment. Overall, there are fewer data gaps for the environmental quality components then most components in the framework.

There are three components in the framework designated as 'goods and services' components: soundscape, viewshed, and dark night skies. Data explaining the soundscape and viewshed in the park is minimal, hence the inability to define condition for these components. For viewshed, a quantitative GIS analysis could be beneficial to management and help define the condition of this resource in the future. In order for a viewshed analysis to have value though, parameters need to be agreed upon that speak to the desired characteristics of viewsheds in the park.

Table 24. Data gaps for WICA NRCA components.

Component	Data Gaps
Land Cover Extent	- The effects of different disturbances on native plant communities and overall balance of seral stages, forest, shrub, and riparian cover. - An updated vegetation map, current map is from 1999. - Defined seral stages for plant community types within the park.
Fire Regime	- Further research to determine which prescribed fire techniques are most effective for a variety of management goals (in progress). - Research to understand the effects of fire in hardwood shrub, woody draws. - Modeling to determine the potential areas for forest reduction.
Native Plant Communities	- A floristic inventory to provide full documentation of plant species in the park, including native species of concern. - Characterization and documentation of riparian vegetation types in the Black Hills and WICA. - A formal ranking system for the invasiveness of non-native to enable prioritization of removal efforts. - More information regarding the interactions between native and non-native species, including the interactions with fire
Birds	- Additional breeding bird surveys and Christmas bird counts - More thorough monitoring of sharp-tailed grouse leks.
Elk	- Continued monitoring of season elk movement to and from the park. - Increased accuracy of elk population estimates. - Body condition scores for elk in the park.
Bison	- A standard monitoring procedure to count calves in late July/early August. - Continued monitoring of herd genetics as new methodologies are realized.
Prairie Dogs	- Accurate delineation of active and inactive areas within prairie dog towns. - Development of successful methods to alleviate the effects of white horehound. - Continued monitoring of flea loads and plague.
Black-footed Ferret	- Increased plague monitoring efforts. - A small mammal survey, specific to prairie dog colonies. - Research regarding the effects of deltamethrin on insects, reptiles, and amphibians. - A formal survey of all prairie dog colonies to determine ferret occupancy. - Research regarding predator effects on black-footed ferrets.
Pronghorn	- Research regarding foraging behavior during years with normal precipitation.
Porcupine	- Monitoring of porcupine populations to assess the size and distribution of those populations in WICA.
Herptile Species	- Determination of tiger salamander occupancy in prairie dog colonies. - Research regarding the effects of flea dusting on tiger salamanders and other species that utilize prairie dog burrows. - Monitoring to determine the presence/absence of northern leopard frogs.

Table 24. Data gaps for WICA NRCA components. (continued)

Component	Data Gaps
Bats	- Long-term bat population monitoring. - Continued monitoring looking for presence of white nose syndrome.
Coyote	- An accurate estimate of the coyote population in the park.
Natural Cave Environment	- The effects of visitors on the deposition rate of calcite along tour routes. - Determination of the air exchange allowed by airlock structures at elevator landings.
Water Quality	- Long-term monitoring of perennial stream water quality. - Monitoring of water quality at cave drip sites.
Changes in Hydrology	- Continued monitoring of surface and groundwater resources. - Long-term monitoring of cave lake levels.
Air Quality	- Tracking of plant and animal species that are sensitive to increases in certain pollutants. - Potentially, implement a critical load approach for developing resource protection goals regarding air quality.
Soundscape	- Baseline soundscape data for the park. - Determine point sources of anthropogenic sounds.
Viewshed	- An in-depth viewshed analysis to determine areas within and outside of park boundaries that are valuable from a visitor perspective.
Dark Night Skies	- Results from NPS Night Sky Team's 2005 and 2006 visits to the park, in order to establish baseline night sky conditions.

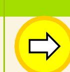
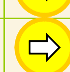
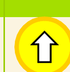
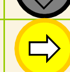
5.2 Component Condition Designations

Chapter 5 provides an opportunity to bring together and discuss the common threads in findings regarding the featured components. Table 25 displays the condition graphics assigned to each resource component presented in Chapter 4. It is important to remember that the graphics represented are merely symbols for the overall condition and trend assigned to each of the measures. It is necessary to refer to the overall condition section for each component for an in-depth account and explanation of the assigned condition, as the assignment of condition for most components is based on multiple factors. Definitions of condition graphics are located on p. 27 of Chapter 3.

Table 25. Component Condition Designations.

Components	*Measures*	*Reference Condition*	*Condition*
Extent and Pattern			
Landscape Composition			
Landcover Extent	Balance of early, middle, and late seral vegetation statges	10-15% early, 10-15% middle, 70-80% late seral stage balance	
	Extent of shrubland cover	undetermined	
	Extent of riparian cover	undetermined	
	Extent of ponderosa pine forest cover	undetermined	
Fire	Fire return interval	Natural frequency	
	Forest fire severity	Natural fuel and frequency relationships	
	Fire extent	Historic photo conditions prior to conversion of prairie to forest	
Biological Components			
Ecosystem and Community			
Native Plant Communities	Change in ponderosa pine density and distribution	Native species, native plant communities and natural ecosystem processes	
	Native species of special concern (rare, riparian, seeps, etc.)		
	Exotic plant distribution and density		
Biotic Composition			
Birds	Species richness	Breeding and healthy populations	
	Species diversity	Breeding and healthy populations	
	Species density	Breeding and healthy populations	
Elk	Density	Natural and healthy population	
Bison	Genetic conservation	Current population	
	Population	Healthy population	
Prairie Dog	Total colony acreage	1000-3000 acres of prairie dogs, as indicated in 2006 EA FONSI	
Black-footed ferret	Population number and distribution	Current population of prairie dogs	
Pronghorn	Population number and distribution	Breeding and healthy populations	
Porcupine	Population number and distribution	Breeding and healthy populations	
Herptile species	Population number and distribution	Breeding and healthy populations	
Bats	Nation-wide species of concern	Breeding and healthy populations	
Coyote	Natural behavior; non-habituation to humans	Natural and healthy population and behavior	

Table 25. Component Condition Designations. (continued)

	Components	*Measures*	*Reference Condition*	*Condition*
Chemical and Physical Characteristics				
Cave Environment				
	Natural cave environment	Temperature	Beginning of historic measurement	
		Humidity	Beginning of historic measurement	
		Air flow	Beginning of historic measurement	
		Cave physical processes (dissolution of rock, air-flow exchange, and Speleothem formation)	Beginning of historic measurement	
Water Quality				
	Water quality	Mercury	EPA water quality criterion	
		Nitrates	EPA water quality criterion	
		Chemicals and heavy metals	EPA water quality criterion	
		Dissolved Oxygen	EPA/South Dakota water quality criterion	
		Fecal Coliform	South Dakota/WRD water quality criterion	
		pH	EPA water quality criterion	
		Specific conductance	EPA water quality criterion	
		Temperature	EPA water quality criterion	
		Turbidity	EPA water quality criterion	
Hydrology				
	Hydrology	Springs and surface flow	Beginning of historic measurement	
		Groundwater (Cave lake, water table fluctuations)	Beginning of historic measurement	
Air Quality				
	Air quality	Class 1 standards	Current conditions	
Goods and Services				
Non-Consumptive				
	Soundscape	Decibel levels and distribution of non-natural sound character	Undeveloped and "natural" park experience	
	Viewshed	Natural viewsheds	Undeveloped and "natural" park experience	
	Dark night skies	V magnitude	Current level of ambient light	

The assigned condition for component measures in the project framework was variable. Data are unavailable or insufficient for many component measures and because of this condition is unknown. Many condition designations rely on expert knowledge from park staff, NGPN resource experts, or non-NPS researchers. In other instances, data regarding reference condition(s) are unavailable making quantitative comparison invalid.

For land cover, fire, and native plant community components, the condition appears to be of moderate concern. Native plant communities represent a broad resource topic that exists in the context of a complex set of interactions such as those between climate, natural disturbance regimes, and influences from stressors such as non-native plant infestations and grazing pressure. Primary concerns related to the condition of native plant communities are the influx of non-native plant species, grazing pressure, and generally the lasting effects of fire suppression, livestock grazing, and human disturbance across the landscape. Fire return intervals and fire extents are relatively simple to report and they provide an indication of the general status of fire in the park. Fire severity, depends on factors such as fire season, weather patterns, and fuel dynamics. Therefore, fire severity can be highly variable, both temporily and spatially. Generally, the goals for prescribed fires are to create low intensity and low severity burns. The available data do not categorize fire severity across all fires in the park only on a plot by plot basis and therefore not enough is known about fire severity to assign an individual condition to this measure. The condition of landcover is unknown, because of an unquantified current condition in the case of seral stage balance, and because of an undefined reference condition for the extent of shrubland cover, riparian cover, and ponderosa pine cover.

The condition of biological components assessed is quite variable. For birds, the condition of the three measures (species richness, species diversity, and species density) cannot be determined due to a lack of long-term trend data. The condition of most grazing animals in the park is of low concern. However, the condition of elk is of significant concern, due to a population that exceeds management goals. The condition of prairie dogs is of moderate concern, due to an increasing population near the upper limit of the established acreage goals of colonies. The condition of black-footed ferrets is of moderate concern, however it has improved over recent years. The condition of porcupines, herptile species, and bats in the park is unknown.

For chemical and physical components, all measures indicate condition is of low or moderate concern with the exception of measures explaining the natural cave environment. The temperature and air flow in the cave are of significant concern and condition is undefined for the physical cave processes measure. Air quality is currently of moderate concern. However, its condition has been improving.

5.3 Park-wide Condition Observations

The natural resources supported at WICA are diverse and complex. Currently, the most concerning issue appears to be the park’s elk population, which is greater than 900 animals, far greater than the accepted management goal of 232-475 animals. This large population is a cause of concern for other components analyzed in this assessment. The high elk numbers add stress to the native plant communities in the park, which could deteriorate the available habitat for other grazing species, such as bison, prairie dogs, and pronghorn. High numbers of elk also cause greater streambank erosion and ground disturbance conducive to the introduction or spread of non-native plant species.

Prairie dog colonies are expanding in the park. Currently, the acreage of these colonies is near the upper threshold of the established management goal. This, along with the establishment and expansion of invasive white horehound causes a significant concern for the condition of resources in the future. White horehound displaces prairie dogs from habitat and changes the utilization of park resources by grazing animals. Plague represents a serious threat to prairie dogs. With this continued threat, the populations of prairie dogs and black-footed ferrets, which depend on prairie dogs as prey and for shelter, are of concern.

The relationship between the grazing animal populations and native plant communities in the park is a key aspect of WICA's resource landscape. WICA defines management goals for park resources according to research regarding this relationship. As mentioned earlier, many data needs for grazing animals focus on developing new methods for or increasing the accuracy of grazing animal population estimates, a key part of understanding this relationship. For plant communities in the park, the data needs focus on accurate inventory efforts, a better understanding of seral stages, and the continued advancement in effective integrated pest management techniques for the control of non-native species. Most of these data needs are being addressed through WICA and NGPN inventory and monitoring protocol development.

The condition of most park resources, as indicated by the measures defined in the project framework, is of moderate or low concern. However, due to the complex relationship between grazing animals, native plant communities, and other components, any condition determined to be of significant concern warrants concern for many other components. In conclusion, due to the complexity of the relationships between park resources, it is not possible to make a definitive statement about the ecological health of WICA as a whole.

Appendices

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Appendix A. Community occurrence rankings (adapted from Marriott et al. 1999).

Community Type	EO Rank
Black Hills Granit/Metamorphic Rock Outcrop (CEGL002295)	B
Box Elder / Chokecherry Forest (CEGL000628)	AB
Chokecherry Shrubland (CEGL001108)	AB
Cottonwood / Wolfberry Floodplain Woodland (CEGL000660)	B
Creeping Juniper / Little Bluestem Dwarf-shrubland (CEGL001394)	AB
Creeping Spikerush Wet Meadow (CEGL001833)	B
Mountain Mahogany / Side-oats Grama Shrubland (CEGL001086)	A
Needle-and-Thread - Blue Grama Mixedgrass Prairie (CEGL002037)	AB
Northern Great Plains Little Bluestem Prairie (CEGL001681)	A
Ponderosa Pine / Chokecherry Forest (CEGL000192)	A
Ponderosa Pine / Common Juniper Woodland (CEGL000859)	AB
Ponderosa Pine / Little Bluestem Woodland (CEGL000201)	A
Ponderosa Pine / Sedge Woodland (CEGL000849)	A
Ponderosa Pine / Western Wheatgrass Woodland 9CEGL000188)	A
Ponderosa Pine Limestone Cliff (CEGL002005)	A
Prairie Dog Town Grassland Complex (CECX002003)	AB
Prairie Cordgrass - Sedge Wet Meadow (CEGL001477)	B
Redbeds (Silstone) Rock outcrop (CEGL005261)	A
Western Great Plains Streamside Vegetation (CEGL005263)	A
Western Snowberry Shrubland (CEGL001131)	AB
Western Wheatgrass - Green Needlegrass Mixedgrass Prairie (CEGL001583)	AB
Wheatgrass - Needle-and-Thread Mixedgrass Prairie (GEGL002034)	A

*Element Occurrence (from A, excellent, to D, poor). AB is between A and B.

Appendix B. Fire return interval analyses in WICA.

Initial Data:

wica_allfire_1980-2009.shp
A polygon shapefile from from Dan Swanson, NPS Northern Great Plains Fire Ecologist, NPS, representing an update to fire perimeter data from 1980 through 2009.

forest.shp
A selection of all forest vegetation types from Cogen et al. (1999) vegetation map.

grassland.shp
A selection of al grassland vegetation types from Cogen et al. (1999) vegetation map (refer to Chapter 4.2 for the full citation).

GIS processing steps for fire analysis:

1) Clip the wica_allfire_1986_2009.shp to the park boundary file.
2) Edit the resulting fire perimtershapefie. Select all 2009 fires and clip. This eliminates areas that that overlap with other fire years. This operation is repeated for each fire year in reverse order to create a new fire perimieter dataset representing only the most recent fires in the Park.
3) Convert *forest.shp*, *grassland.shp*, and *wica_allfire_1986_2009.shp* (edited version) datasets to rasters with a ten meter cell size.

   Results: *allfire.tif*, *forest.tif*, and *grass.tif*.
   The raster, allfire.tif, represents the most recent year of fire in a given cell. For example, if a given area in WICA has overlapping fire perimeter polygons (representing multiple fire years), then only the most recent year of fire remains in the resulting raster dataset. The values in each cell are either a date (e.g., 1987) or "0" which means a fire was not recorded in that location during the period of record (1980 to 2009). Rasters, *forest.tif* and *grass.tif* represent areas of forest and grasslands respectively. For *forest.tif*, a "1" value represents forest and a "0" value represents non-forest, and for *grass.tif*, a "1" value represents grassland and a "0" value represents non-grassland.

4) Multiply ("times" ArgGIS Spatial Analyst tool) *allfire.img* and *forest.img*, and allfire.img with *grassland.img*.

   Results: *forest_fire.grd, grass_fire.grd*.
   These rasters represent fire history in forests and grasslands of WICA respectively.

Summarizing fires from 1980 to 2009:

Two fire perimeter GIS datasets were available, wica_allfire_1980-2004.shp and wica_allfire_1986_2009polygon.shp. The 1980 to 2004 data were redundant with the 1986 to 2009 data through 2004. However, after eliminating redundancies the data were combined and used for the fire analysis and to report total area.

Appendix C. List of plant species with limited occurrences in WICA.

Amelanchier alnifolia	*Cypripedium parviflorum*	*Polanisia jamesii*
Amelanchier humilis	*Echinocystis lobata*	*Populus angustifolia*
Amorpha fruticosa	*Engelmannia pinnatifida*	*Populus deltoides*
Aquilegia brevistyla	*Evolvulus nuttallianus*	*Populus tremuloides*
Artemisia cana	*Fraxinus pennsylvanica*	*Prunella vulgaris*
Artemisia tridentata	*Glandularia bipinnatifida*	*Prunus serotina*
Botrychium campestre	*Gnaphalium viscosum*	*Quercus macrocarpa*
Botrychium lineare	*Platanthera aquilonis*	*Rhus glabra*
Carex rossii	*Lesquerella arenosa* var. *argillosa*	*Rudbeckia laciniata*
Celtis occidentalis	*Lupinus argenteus*	*Salix amygdaloides*
Celastrus scandens	*Lysimachia ciliata*	*Salix bebbiana*
Cirsium ochrocentrum	*Mentzelia nudicaulis*	*Salix lutea*
Cleome serrulata	*Mentzelia oligosperma*	*Shepherdia argentea*
Corydalis aurea	*Orobanche ludoviciana*	*Triodanis leptocarpa*
Cornus sericea	*Physocarpus monogynus*	*Viburnum lentago*
Crataegus chrysocarpa	*Populus xacuminata*	*Zigadenus elegans*

Appendix D. Spatial data related to native plant communities of WICA.

Name	Type	Metadata	Description (SMU GSS created)
bkf_veg08.shp	polygon shapefile	yes	R2Veg - 2003 geodatabase design was created called R2Veg for migration from either of the Regions two vegetation polygon systems CVU RMRIS
wica_veg.shp	polygon shapefile	yes	vegetation land cover and land use for WICA and surrounding areas USGS/NPS Veg Mapping Program
forest.shp	polygon shapefile	yes	definition type = 'forest', subset of wica_veg?
grassland.shp	polygon shapefile	yes	definition type = 'grassland', subset of wica_veg?
shrubland.shp	polygon shapefile	yes	definition type = 'shrubland', subset of wica_veg?
Exotics2006Poly.shp	polygon shapefile	yes	compilation of GPS files collected during 2006 in WICA.
Exotics2006Points.shp	point shapefile	yes	compilation of GPS files collected during 2006 in WICA.
Thistle_2001	Polygon coverage	Yes	Thistle locations in WICA 2001 field season
Exotics95to04point.shp	Point shapefile	No	Exotic plant locations
Exotics95to04poly.shp	Polygon shapefile	No	Exotic plant locations
HH_Complete.shp	Point shapefile	No	Horehound estimate
Highland Creek horehound estimate_032310.shp	Polygon Shapefile	No	Horehound estimate
Norbeck horehound estimate+032210.shp	Polygon shapefile	No	Horehound estimate
Northeast horehound estimate 032310	Polygon shapefile	No	Horehound estimate
Pringle horehound estimate_032210	Polygon shapefile	No	Horehound estimate
Research Reserve horehound estimate_032310.shp	Polygon shapefile	No	Horehound estimate
Sancutary horehound estimate_032210.shp	Polygon shapefile	No	Horehound estimate
Southeast horehound estimate_032210.shp	Polygon shapefile	No	Horehound estimate
Horehound_estimates_2010	Polygon feature class	Yes	This is appended version (created by GSS) of all the NPS horehound estimate shapefiles
Limited_Species.shp	Polygon shapefile	No	

Appendix E. Non-native plants of WICA (NPS 2010a).

Common Name	Scientific Name	Family	Life Form	Growth	Origin
alfalfa	*Medicago sativa*	Fabaceae (Bean)	Forb	Perennial	Eurasia
alyssum (desert madwort)	*Alyssum desertorum*	Brassicaceae (Mustard)	Forb	Annual	Europe
alyssum, pale (pale madwort)	*Alyssum alyssoides*	Brassicaceae (Mustard)	Forb	Annual	Europe
apple, crab	*Pyrus ioensis*	Rosaceae (Rose)	Tree	Perennial	
asparagus, garden	*Asparagus officinalis*	Liliaceae (Lily)	Forb	Perennial	
barnyardgrass	*Echinochloa crusgalli*	Poaceae (Grass)	Grass	Annual	Eurasia
black medic	*Medicago lupulina*	Fabaceae (Bean)	Forb	Annual	Eurasia
bluegrass, Canadian	*Poa compressa*	Poaceae (Grass)	Grass	Annual	Europe
bluegrass, Kentucky	*Poa pratensis*	Poaceae (Grass)	Grass	Perennial	Europe
bouncing bet	*Saponaria officinalis*	Caryophyllaceae (Pink)	Forb	Perennial	Europe
brome, downy	*Bromus tectorum*	Poaceae (Grass)	Grass	Annual	Europe
cheatgrass	Poaceae (Grass)	Poaceae (Grass)			Mediterranean
brome, Japanese	*Bromus japonicas*	Poaceae (Grass)	Grass	Annual	Europe
brome, meadow	*Bromus commutatus* Poaceae (Grass)	Poaceae (Grass)	Grass	Annual	Europe
brome, smooth	*Bromus inermis* Poaceae (Grass)	Poaceae (Grass)	Grass	Annual	Europe
bindweed, field	*Convolvulus arvensis*	Convolvulaceae *(*Morning glory*)*	Forb	Perennial	Europe
buckthorn, common	*Rhamnus cathartica*	Rhamnaceae (Buckthorn)	Forb	Perennial	Europe
buckwheat, wild (climbing)	*Polygonum convolvulus*	Polygonaceae (Buckwheat)	Forb	Annual	Europe
burdock	*Arctium minus*	Asteraceae (Sunflower)	Forb	Biennial	Europe
buttercup bur	*Ranunculus testiculatus*	Ranunculaceae (Buttercup)	Forb	Annual	Eurasia
buttercup, tall	*Ranunculus acris*	Ranunculaceae (Buttercup)	Forb	Perennial	Europe
campion, bladder	*Silene vulgaris*	Caryophyllaceae (Pink)	Forb	Perennial	Europe
campion, white	*Silene pratensis*	Caryophyllaceae (Pink)	Forb	Perennial Biennial	Europe
carrot, wild	*Daucus carota*	Apiaceae (Parsley)	Forb	Biennial	Europe

Appendix E. Non-native plants of WICA (NPS 2010a). (continued)

Common Name	Scientific Name	Family	Life Form	Growth	Origin
catnip	*Nepeta cataria*	Lamiaceae (Mint)	Forb	Perennial	Europe
chickweed, big (mouse-ear)	*Cerastium vulgatum*	Caryophyllaceae (Pink)	Forb	Perennial	Eurasia
chickweed, field (prairie)	*Cerastium arvense*	Caryophyllaceae (Pink)	Forb	Perennial	?
clover, rabbitfoot (crimson)	*Trifolium incarnatum*	Fabaceae (Bean)	Forb	Annual	Europe Mediterranean
corn gromwell	*Lithospermum arvense*	Boraginaceae (Borage)	Forb	Annual	Europe
cowcockle	*Vaccaria pyramidata*	Caryophyllaceae (Pink)	Forb	Annual	Europe
creeping bellflower	*Campanula rapunculoides*	Campanulaceae (Bluebell)	Forb	Perennial	Eurasia
daisy, Engelmann's	*Engelmannia pinnatifida*	Asteraceae (Sunflower)	Forb	Perennial	?
dames rocket	*Hesperis matronalis*	Brassicaceae (Mustard)	Forb	Biennial	Europe Mediterranean
candelion, common	*Taraxacum officinale*	Asteraceae (Sunflower)	Forb	Perennial	Eurasia
Deptford pink	*Dianthus armeria*	Caryophyllaceae (Pink)	Forb	Annual or Biennial	Europe
cock, curly	*Rumex crispus*	Polygonaceae (Buckwheat)	Forb	Perennial	Europe
elm, Siberian	*Ulmus pumila*	Ulmaceae (Elm)	Tree	Perennial	Asia
falseflax, littlepod (small-seeded)	*Camelina microcarpa*	Brassicaceae (Mustard)	Forb	Annual	Europe
flax, blue	*Linum perenne*	Linaceae (Flax)	Forb	Perennial	Eurasia (?)
flixweed	*Descurainia sophia*	Brassicaceae (Mustard)	Forb	Annual	Eurasia
foxtail, green	*Setaria viridis*	Poaceae (Grass)	Grass	Annual	Europe
geranium, small	*Geranium pusillum*	Balsaminaceae (Touch-Me-Not)	Forb	Annual	Europe
gooseberry, currant	*Ribes aureum villosum*	Grossulariaceae (Currant)	Shrub	Annual	?
hairy nightshade	*Solanum sarrachoides*	Solanaceae (Nightshade)	Forb	Annual	South America
hemlock, poison*	*Conium maculatum*	Apiaceae (Parsley)	Forb	Biennial	Eurasia Africa
hempnettle, splitlip	*Galeopsis bifida*	Lamiaceae (Mint)	Forb	Annual	Europe
henbane, black	*Hyoscamus niger*	Solanaceae (Nightshade)	Forb	Annual Biennial	Europe
hogweed, little	Portulaca oleracea	Portulacaceae (Purslane)	Forb	Annual	Asia
hollyhock	*Althaea rosea*	Malvaceae (Mallow)	Forb	Perennial Biennial	Eurasia

Appendix E. Non-native plants of WICA (NPS 2010a). (continued)

Common Name	Scientific Name	Family	Life Form	Growth	Origin
hops, common	*Humulus lupulus*	Cannabaceae (Hemp)	Forb	Perennial	Asia
horehound	*Marrubium vulgare*	Lamiaceae (Mint)	Forb	Perennial	Europe
hound's tongue	*Cynoglossum officinale*	Boraginaceae (Borage)	Forb	Biennial	Europe
knapweed, Russian	*Centaurea repens*	Asteraceae (Sunflower)	Forb	Perennial	Eurasia
knapweed, spotted	*Centaurea maculosa*	Asteraceae (Sunflower)	Forb	Perennial Biennial	Eurasia
kochia	*Kochia scoparia*	Amaranthaceae	Forb	Annual	Eurasia
lamb's quarters	*Chenopodium album*	Chenopodiaceae (Goosefoot)	Forb	Annual	Europe
lettuce, prickly	*Lactuca serriola*	Asteraceae (Sunflower)	Forb	Annual	Europe
lilac, common	*Syringa vulgaris*	Oleaceae (Olive)	Shrub	Perennial	Mediterranean
lopseed, American	*Phryma leptostachys*	Verbenaceae (Vervain)	Forb	Perennial	?
matrimony vine	*Lycium barbarum*	Solanaceae (Potato)	Shrub		Eurasia
motherwort	*Leonurus cardiac*	Lamiaceae (Mint)	Forb	Perennial Biennial	Eurasia
mullein, common*	*Verbascum Thapsus*	Scrophulariaceae (Figwort)	Forb	Biennial	Europe
mustard, blue	*Chorispora tenella*	Brassicaceae (Mustard)	Forb	Annual	Eurasia Asia
mustard, tumbling	*Sisymbrium altissimus*	Brassicaceae (Mustard)	Forb	Annual	Europe
nightshade, viscid (hairy)	*Solanum sarrachoides*	Solanaceae (Potato or Nightshade)	Forb	Annual	South America
olive, Russian	*Elaeagnus angustifolia*	Elaeagnaceae (Oleaster)	Shrub Small Tree	Perennial	Eurasia
orchard grass	*Dactylis glomerata*	Poaceae (Grass)	Grass	Perennial	Europe
pennycress, field	*Thlaspi arvense*	Brassicaceae (Mustard)	Forb	Annual Biennial	Europe
peppergrass, field	*Lepidium campestre*	Brassicaceae (Mustard)	Forb	Annual Biennial	Europe
peppergrass, clasping	*Lepidium perfoliatum*	Brassicaceae (Mustard)	Forb	Annual	Europe
pigweed, rough (redroot)	*Amaranthus retroflexus*	Amaranthaceae (Pigweed)	Forb	Annual	?
pimpernel, scarlet (poorman's weatherglass)	*Anagallis arvensis*	Primulaceae (Primrose)	Forb	Annual Perennial	Eurasia
plantain, common	*Plantago major*	Plantaginaceae (Plantain)	Forb	Perennial	Eurasia
quackgrass	*Agropyron repens*	Poaceae (Grass)	Grass	Perennial	Europe Asia

Appendix E. Non-native plants of WICA (NPS 2010a). (continued)

Common Name	Scientific Name	Family	Life Form	Growth	Origin
sage, azure blue	*Salvia azurea*	Lamiaceae (Mint)	Forb	Perennial	?
salsify, meadow	*Tragopogon pratensis*	Asteraceae (Sunflower)	Forb	Biennial Perennial	Eurasia
salsify, western (goat's beard)	*Tragopogon dubius*	Asteraceae (Sunflower)	Forb	Perennial Biennial	Eurasia
shepherd's purse	*Capsella bursa-pastoris*	Brassicaceae (Mustard)	Forb	Annual Biennial	Europe
silver poplar	*Populus alba*	Salicaceae	Tree	Perennial	?
sowthistle, field (perennial)*	*Sonchus arvensis*	Asteraceae (Sunflower)	Forb	Perennial	Eurasia
sowthistle, prickly	*Sonchus asper*	Asteraceae (Sunflower)	Forb	Annual	Europe
speedwell, corn	*Veronica arvensis*	Scrophulariaceae (Figwort)	Forb	Annual	Eurasia
spurge, leafy	Euphorbia esula	Euphorbiaceae (Spurge)	Forb	Perennial	Europe
stinkgrass	*Eragrostis cilian*ensis	Janchen Poaceae (Grass)	Grass	Annual	Europe
sweetclover, white	*Melilotus alba*	Fabaceae (Bean)	Forb	Annual Biennial	Eurasia
sweetclover, yellow	*Melilotus officinalis*	Fabaceae (Bean)	Forb	Annual Biennial	Eurasia
tansy, common	*Tanacetum vulgare*	Asteraceae (Sunflower)	Forb	Perennial	Europe
teasel	*Dipsacus sylvestris*	Dipsacaceae (Teasel)	Forb	Biennial	Europe
thistle, bull	*Cirsium vulgare*	Asteraceae (Sunflower)	Forb	Biennial	Europe, Eurasia
thistle, Canada*	*Cirsium arvense*	Asteraceae (Sunflower)	Forb	Perennial	Eurasia, Africa
thistle, musk*	*Carduus nutans*	Asteraceae (Sunflower)	Forb	Annual	Eurasia
thistle, Russian (tumbleweed)	*Salsola iberica*	Chenopodiaceae (Goosefoot)	Forb	Annual	Eurasia
thistle, scotch*	*Onopordum acanthium*	Asteraceae (Sunflower)	Forb	Biennial	Eurasia
timothy, common	*Phleum pratense*	Poaceae (Grass)	Forb	Perennial	Europe
toadflax, dalmation	*Linaria dalmatica*	Scrophulariaceae (Figwort)	Forb	Perennial	Europe
toadflax, yellow (butter and eggs)	*Linaria vulgaris*	Scrophulariaceae (Figwort)	Forb	Perennial	Eurasia
wheatgrass, crested	*Agropyron cristatum*	Poaceae (Grass)	Grass	Perennial	Russia
wheatgrass, intermediate	*Agropyron intermedium*	Poaceae (Grass)	Grass	Perennial	Europe
wheatgrass, tall	*Agropyron elongatum*	Poaceae (Grass)	Grass	Perennial	Mediterranean
yellowstem white willow	*Salix alba*	Salicaceae (Willow)	Tree	Perennial	?

*Identified by South Dakota as noxious weeds. South Dakota Code. 2005. South Dakota weed and pest control, Chapter 38-22, Article 12:62. State of South Dakota

Appendix F. Non-native plant inventoried or treated area by year.

Year	Area (ha)	Area (ac)	Spatial Data Source Files
1999[a]	12.6	31.2	exotics99to04poly.shp
2000[a]	1.5	3.7	exotics99to04poly.shp
2001[a]	4.3	10.5	exotics99to04poly.shp
2002[a]	15.8	39.2	exotics99to04poly.shp
2003[a]	*no data*	*no data*	exotics99to04poly.shp
2004[a]	2.7	6.8	exotics99to04poly.shp
2005	*no data*	*no data*	-
2006[b]	126.3	312.0	Exotics20006Poly.shp
2007	*no data*	*no data*	-
2008	*no data*	*no data*	-
2009	*no data*	*no data*	-
2010[c]	271.5	671	horehound shapefiles appended
unknown year[d]	14.4	35.5	exotics99to04poly.shp

[a] 1999 to 2004 contain estimates for Canada thistle only. No treatment indicated in the dataset.
[b] 2006 contains primarily white horehound, Canada thistle, hounds tongue. Also, approximately 52% of this area was mapped as opposed to pulled (11%), biologically controlled (13%), cut/bagged seed heads (14%), or mowed by maintenance (9%).
[c] 2010 is an estimate of acres of horehound infestation only. Also no treatment was indicated.
[d] Area in which no year was given in the data, but contained in the 1999 to 2004 dataset.

Appendix G. Vegetation classification area and percent composition in WICA (Cogan et al. 1999).

Vegetation Code	Description	Area (ha)	Area (ac)	% composition
16	Western Wheatgrass - Kentucky Bluegrass Complex	4,344	10,734.6	38.02%
15	Little Bluestem - Grama Grass Herbaceous Vegetation	1,892	4,676.0	16.56%
48	Ponderosa Pine Woodland Complex II	1,410	3,483.6	12.34%
46	Ponderosa Pine/Little Bluestem Woodland	1,110	27,435.5	9.72%
1	Purple Three-awn Fetid Marigold Herbaceous Vegetation	533	1,317.1	4.67%
35	Western Snowberry Shrubland	333	823.8	2.92%
45	Ponderosa Pine Woodland Complex I	322	796.8	2.82%
47	Ponderosa Pine/Chokecherry Forest	267	660.3	2.34%
33	Chokecherry Shrubland	198	489.5	1.73%
49	Young Ponderosa Pine Dense Cover Complex	162	399.3	1.41%
13	Western Wheatgrass - Kentucky Complex (with burned ponderosa pine)	157	387.7	1.37%
30	Mt. Mahogany/Sideoats Grama Shrubland II	150	371.9	1.32%
32	Lead Plant Shrubland	130	321.7	1.14%
18	Needle-and-thread - Blue Grama -Threadleaf Sedge Herbaceous Vegetation	90	221.6	0.78%
6	White Sedimentary Outcrop	65	16175	0.57%
51	Transportation Communications, Utilities	54	133.9	0.47%
31	Mt. Mahogany/Sideoats Grama Shrubland	42	102.8	0.36%
11	Little Bluestem - Sideoats Grama Herbaceous Alliance (with burned ponderosa pine)	40	99.9	0.35%
41	Boxelder/Chokecherry Forest	31	77.2	0.27%
3	Red Beds Sparse Vegetation	27	6565	0.23%
52	Mixed Urban or Built-up Land	15	37.6	0.13%
12	Chokecherry Shrubland (with burned ponderosa pine)	13	32.5	0.12%
2	Ponderosa Pine Limestone Rock Outcrop	11	28.4	0.10%
14	Emergent Wetland Herbaceous Vegetation	10	25.4	0.09%

Appendix G. Vegetation classification area and percent composition in WICA (Cogan et al. 1999). (continued)

Vegetation Code	Description	Area (ha)	Area (ac)	% composition
4	Black hills Rock Outcrop Sparse Vegetation	4	10.5	0.04%
7	Bison Wallows	4	9.9	0.04%
17	Introduced Weedy Graminoid Herbaceous Vegetation	3	6.7	0.02%
44	Birch - Aspen Stand	2	6.1	0.02%
57	Open Water	1	3.6	0.01%
40	Plains Cottonwood/Western Snowberry Woodland	1	3.1	0.01%
42	Bur Oak Stand	0	0.6	0.00%
36	Creeping Juniper / Little Bluestem Dwarf-shrubland	0	0.3	0.00%
	Total:	11,421	28,233.0	

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