National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Fossil Butte National Monument

Natural Resource Condition Assessment

Natural Resource Report NPS/FOBU/NRR—2017/1394

ON THE COVER
Sagebrush community surrounding Fossil Butte National Monument
Photograph by Tyra Olstad, courtesy of the National Park Service

Fossil Butte National Monument

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Natural Resource Report NPS/FOBU/NRR—2017/1394

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Contents

Contents (continued)

Contents (continued)

Page

Contents (continued)

Page

Contents (continued)

Page

Contents (continued)

Page

Contents (continued)

Figures

Figures (continued)

Page

Figures (continued)

Page

Tables

Page

Tables (continued)

Page

Tables (continued)

Page

Tables (continued)

Page

Photos

Appendices

Executive Summary

The Natural Resource Condition Assessment (NRCA) Program aims to provide documentation about the current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. Findings from the NRCA will help Fossil Butte National Monument (FOBU) managers to develop near-term management priorities, engage in watershed or landscape scale partnership and education efforts, conduct park planning, and report program performance (e.g., Department of the Interior's Strategic Plan "land health" goals, Government Performance and Results Act).

The objectives of this assessment are to evaluate and report on current conditions of key park resources, to evaluate critical data and knowledge gaps, and to highlight selected existing stressors and emerging threats to resources or processes. For the purpose of this NRCA, staff from the National Park Service (NPS) and Saint Mary's University of Minnesota – GeoSpatial Services (SMUMN GSS) identified key resources, referred to as "components" in the project. The selected components include natural resources and processes that are currently of the greatest concern to park management at FOBU. The final project framework contains 16 resource components, each featuring discussions of measures, stressors, and reference conditions.

This study involved reviewing existing literature and, where appropriate, analyzing data for each natural resource component in the framework to provide summaries of current condition and trends in selected resources. When possible, existing data for the established measures of each component were analyzed and compared to designated reference conditions. A weighted scoring system was applied to calculate the current condition of each component. Weighted Condition Scores, ranging from zero to one, were divided into three categories of condition: low concern, moderate concern, and significant concern. These scores help to determine the current overall condition of each resource. The discussions for each component, found in Chapter 4 of this report, represent a comprehensive summary of current available data and information for these resources, including unpublished park information and perspectives of park resource managers, and present a current condition designation when appropriate. Each component assessment was reviewed by FOBU resource managers or NPS Northern Colorado Plateau Network staff.

Existing literature, short- and long-term datasets and input from NPS scientists support condition designations for components in this assessment. However, in some cases, data were unavailable or insufficient for several of the measures of the featured components. In other instances, data establishing reference condition were limited or unavailable for components, making comparisons with current information inappropriate or invalid. In these cases, it was not possible to assign condition for the components. Current condition was not able to be determined for 7 of the 15 components (47%) assessed due to these data gaps. One component, viewscape, was not assessed for current condition.

For those components with sufficient available data, the overall condition varied. One component (elk) was determined to be in good condition with a stable trend. One component, dark night skies, was considered to be of significant concern with a declining trend, based on the expected population

growth in the Salt Lake City/Ogden areas. The remaining six components (big sagebrush community, aspen woodlands, seep, springs, and slump pond aquatic habitats, greater sage grouse, and paleontological resources) were of moderate concern. A declining trend was assigned to the aspen woodlands component; however insufficient data were available to assign trends for the other four in this category. Detailed discussion of these designations is presented in Chapters 4 and 5 of this report.

Several park-wide threats and stressors influence the condition of priority resources in FOBU. Those of primary concern include invasive exotic plant species, regional climate change, and adjacent land use. Understanding these threats, and how they relate to the condition of park resources, can help the NPS prioritize management objectives and better focus their efforts to maintain the health and integrity of the park ecosystem, as well as its cultural landscape.

Acknowledgments

We acknowledge Fossil Butte National Monument staff for the technical expertise provided during scoping, through multiple stages of review, and via phone and email; specifically, Arvid Aase, Marcia Fagnant, Nancy Skinner (retired superintendent), Brad Shattuck (acting superintendent), and Angela Wetz (superintendent). Several Northern Colorado Plateau Network Inventory and Monitoring staff provided critical review of interim documents. Special thanks to Dusty Perkins (Network Program Manager) and Walt Fertig (former Wyoming Natural Diversity Database Botanist) for their logistical insight and critical review of interim documents. Additional program guidance and reviews were provided by Donna Shorrock, Intermountain Region NRCA Coordinator, and Jeff Albright, Natural Resource Condition Assessment Coordinator. Thank you to all others who assisted the development of this document.

Acronyms and Abbreviations

AET – Actual Evapotranspiration

BADL – Badlands National Park

BCSD – Bias Correction followed by Spatial Disaggregation

BLM – Bureau of Land Management

BTNF – Bridger-Teton National Forest

CAA – Clean Air Act

CBC – Christmas Bird Count

CCD – Monochromatic Charge-Coupled Device

CCRP – Climate Change Response Program

CCVA – Climate Change Vulnerability Assessment

CL – Condition Level

CWD – Chronic Wasting Disease

dbh – Diameter at Breast Height

DDT – Dichlorodiphenyltrichloroethane

DEM – Digital Elevation Model

DINO – Dinosaur National Monument

DOI – Department of the Interior

dv – Deciview

EPA – Environmental Protection Agency

ESA – Endangered Species Act

ET – Evapotranspiration

FEIS – Fire Effects Information System

FOBU – Fossil Butte National Monument

GIS – Geographic Information System

Acronyms and Abbreviations (continued)

GMP – General Management Plan

GPRA – Government Performance and Results Act

GPS – Global Positioning System

GRI – Geologic Resources Inventory

GRTE – Grand Tetons National Park

I&M – Natural Resources Inventory & Monitoring Program

IEP – Invasive Exotic Species

IMPROVE – Interagency Monitoring of Protected Visual Environments

IPCC – Intergovernmental Panel on Climate Change

IRMA – Integrated Resource Management Application

LPR – Light Pollution Ratio

mags – V-magnitude

MDTS – Minimum Target Size

NCCSC – North Central Climate Science Center

NCDC – National Climate Data Center

NCPN – Northern Colorado Plateau Network

NED – National Elevation Dataset

NLCD – National Land Cover Dataset

NOROCK – Northern Rocky Mountain Science Center

NPS – National Park Service

NRCA – Natural Resource Condition Assessment

NSNSD – Natural Sounds and Night Sky Division

PET – Potential Evapotranspiration

PI – Principal Investigator

Acronyms and Abbreviations (continued)

PRISM – Parameter Elevation regression on Independent Slopes Model

RCP – Representative Concentration Pathway

RMBO – Rocky Mountain Bird Observatory

RSS – Resource Stewardship Strategy

SL – Significance Level

SMUMN GSS – Saint Mary's University of Minnesota Geospatial Services

SQM – Sky Quality Meter

STORET – Storage and Retrieval

Tmax – Maximum Temperature

Tmin – Minimum Temperature

USFS – U.S. Forest Service

USFWS – U.S. Fish and Wildlife Service

USGS – United States Geologic Survey

VES – Visual Encounter Survey

WCS – Weighted Condition Score

WGFD – Wyoming Game and Fish Department

WYNDD – Wyoming Natural Diversity Database

YELL – Yellowstone National Park

ZLM – Zenith Limiting Magnitude

Chapter 1. NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs Strive to Provide…

- *Credible condition reporting for a subset of important park natural resources and indicators*
- *Useful condition summaries by broader resource categories or topics, and by park areas*

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

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

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for

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

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

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

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

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

understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.
Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

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

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

Important NRCA Success Factors

- *Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline*
- *Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)*
- *Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings*

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park’s desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

NRCA Reporting Products…

Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations* ***(near-term operational planning and management)***
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values* ***(longer-term strategic planning)***
- *Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public* ***("resource condition status" reporting)***

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

[6]An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[7] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

Chapter 2. Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation

Fossil Butte National Monument (FOBU), described as "America's Aquarium in Stone," was established October 23rd 1972, signed by President Richard Nixon. The new monument was to generally follow the proposal written in 1963 (#FBMN-7200) with the revisions submitted in July 1964 (NPS 1972). The initial proposal was a drawing titled "A Proposed Fossil Butte National Monument, Wyoming." It designated 3,310 ha (8,180 ac) in the park location and the approved Act of FOBU establishment states in section one (NPS 1972):

> *Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That, in order to preserve for the benefit and enjoyment of present and future generations outstanding paleontological sites and related geological phenomena, and to provide for the display and interpretation of scientific specimens, the Fossil Butte National Monument is hereby established, to consist of lands, waters, and interest therein within the boundaries as generally depicted on the drawing entitled "A Proposed Fossil Butte National Monument, Wyoming."*

The Statement for Management of FOBU followed and was approved in March of 1977 and in March of 1980 a General Management Plan (GMP) for FOBU contained the following Significance Statement (NPS 1980):

> *Fossil Butte National Monument, which contains a small but significant part of the extensive Green River Formation, contains fossil fish that represent the evolution and modernization of Freshwater fishes better than those from any other site in the United States. According to the establishment act, Public Law 92-537, the purpose of the national monument is to preserve for present and future generations the outstanding paleontological sites and related geological phenomena and to provide for the display and interpretation of scientific specimens.*

The management objectives sought to protect the paleontological resources, serve as guidance to decide on the best use and development, and provide some management perspectives tailored to the particular assets and resources that reside within FOBU. Within the GMP a "Historic Plan" is mentioned; the NPS prepared it in 1975 identifying several retired fossil quarries and one A-frame cabin used by early fossil hunters within the park boundaries; the historic nature of the area (identified in 1974) meant that the locations were possibly eligible for a "Historic Places" nomination to the National Register of Historic Places (NPS 1980). The Chicken Creek Ranch Site was nominated in fall of 1987, but turned out to be ineligible (NPS 1991).

Periods of intense grazing began in the 1890s shortly after settlement. Upon the establishment of the park, the Act declared a time limit on grazing, that it was to cease completely within 10 years. A notice of termination was issued to ranchers in 1984 and terminated grazing on all FOBU lands in 1986 (NPS 1991). This was immediately followed by a Secretarial decision in 1987 to restore grazing at full-force levels. The decision also issued with it a timeline for eventual permanent termination of grazing; it called for a one third reduction in 1988, two thirds in 1989, and to completely eliminate all grazing on park land as of 1990 (NPS 1991). FOBU is now one of just a few areas in southwestern Wyoming where ranchers are not permitted to graze their livestock herds. The elimination of grazing meant a let-burn policy was in need to rejuvenate sagebrush (*Artemisia* spp.) and quaking aspen (*Populus tremuloides*) (NPS 1991). The Wildland Fire Management Plan was completed by the NPS in January 2005, all agencies within the Department of the Interior (DOI) that are required to do so when there is vegetation capable of sustaining wild fires within a resource area unit, and discusses fire management goals for FOBU (NPS 2005).

2.1.2. Geographic Setting

Geophysical Setting

FOBU is located in southwestern Wyoming, 21 km (13 mi) west of Kemmerer, in Lincoln County (Figure 1). The land sits at elevations from 2,018 m (6,620 ft), up to 2,464 m (8,084 ft) above sea level and has a total area covering 33.2 km^2 (12.8 mi^2) of high, cold desert terrain. Visitors are often surprised at the diversity of flora and fauna that can be found within FOBU (NPS 1985). This biodiversity is an attribute of the abrupt change from forests up high and dry grass and brushlands below, creating a diverse and abundant collection of habitats that support a menagerie of birds and mammals (NPS 1985).

Figure 1. General location of FOBU.

The boundaries of FOBU lie within the ancient bed of Fossil Lake, one of three great freshwater lakes that existed during the Eocene Epoch around 56-34 million years ago. Although Fossil Lake was the deepest, it was the smallest in area, at 3,885 km^2 (1,500 mi^2) and lasted for up to 2 million years before conditions changed and sediments of Fossil Lake were covered by the stream-deposited Wasatch Formation (Arvid Aase, FOBU Museum Specialist, written communication, 11 April 2016). The three lakes, Lake Gosiute, Lake Uinta, and Fossil Lake, formed a warm temperate lake ecosystem that is referred to now as the Green River Lake System. Today, the area is drastically different with a high-desert environment and arid climate (NPS 2006).

The landscape of FOBU is characterized by ridges and buttes with steep arroyos, intermittent streams, exposed and weathered rock sequences of ancient lacustrine, and fluvial sedimentary rock. Fossil Butte proper stands in the southeastern quadrant of the park and rises about 300 m (1,000 ft) above the valley, with springs oozing down the sides that nourish groves of quaking aspen and cottonwood (*Populus deltoides*). There are two formations of geologic strata exposed in and around the park. The Green River Formation is up to 91 m (300 ft) thick and consists of limestone, siltstone, sandstone, mudstone, dolomite, and other sedimentary rocks typically deposited in an alkaline lake (NPS 1985). The Paleocene to early Eocene aged Wasatch Formation that lies beneath and adjacent to the Green River rocks consists primarily of sandstone, mudstone, and conglomerate (NPS 1985). The two weathered layers are visually contrasted; the red-banded badlands of the Wasatch and the Green River's light colored layers enhance the viewscapes of the park (NPS 1985).

The climate at FOBU is characterized as semiarid, with mild summers and cold winters (NPS 1985, Friesen et al. 2010). Precipitation peaks in the late spring, with a relatively dry summer and a smaller peak in early autumn (Table 1).

Table 1. 1981–2010 climate normal for the Fossil Butte NM, Wyoming weather station (NCDC 2015).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Temperature (°C)	-8.7	-7.6	-1.7	3.6	8.3	12.8	17.3	16.6	11.3	4.7	-2.7	-8.2	3.9
Max	-2.1	-0.5	5.3	12.0	17.6	23.0	28.4	27.7	21.9	13.8	4.2	-1.8	12.6
Min	-15.3	-14.6	-8.6	-4.9	-1.0	2.6	6.3	5.3	0.7	-4.4	-9.5	-14.5	-4.8
Average Precipitation (cm)	1.24	1.73	2.08	2.49	3.58	2.62	2.16	2.36	2.79	2.82	2.18	1.88	27.94

Average annual precipitation is 27.9 cm (11.0 in) precipitation (WRCC 2015). The average annual snowfall is 193 cm (76 in) with the heaviest accumulations usually occurring in December and January (Friesen et al. 2010). Daily temperatures can fluctuate during the day and also vary from season to season (Friesen et al. 2010). Summers are moderately warm, with daily temperatures averaging 28.4 °C (83.1 °F) and cool nights averaging 6.3 °C (43.3 °F), with the hottest days typically approaching 32.2 °C (90 °F) (Friesen et al. 2010, WRCC 2015). Winters are cold with lows that can drop below freezing (Friesen et al. 2010). Average maximum daily temperature is -2.1 °C

(28.3 °F) with an average minimum temperature of -15.3 °C (4.5 °F) for January (WRCC 2015). Data from the National Climate Data Center (NCDC) 1981-2010 monthly normals for the weather station (Station ID 483582) at the visitor center are shown in Table 1 (WRCC 2015).

Historical Climate Trends (1895 - 2012)

FOBU is geographically located at the western extent of the Great Plains, one of the more climatically diverse regions of the country (Shafer et al. 2014). This region experiences many climate and weather hazards, including floods, droughts, severe storms and winter storms (Shafer et al. 2014). Water is central to productivity in the region (Shafer et al. 2014). Since water is such a key driver of natural and production systems, descriptions of climate variability are associated with drought or aridity are of particular interest. The growth and vigor of vegetation influences physical processes such as erosion and the dynamics of native and domestic animals. These are key processes to management, and to the evaluation of climate change vulnerability.

Large areas of the Central and Western United States experienced severe droughts in the 1930s, 1950s, and late 1990s until around the year 2004 (Woodhouse and Overpeck 1998; Cook et al. 2004). Drought conditions continued to persist in Lincoln County through mid 2014, with short periods when drought conditions were not present or where considered to be abnormally dry (USDM 2016). Since then there have been only short periods of time when drought condition where defined as moderate or abnormally dry (USDM 2016).

While recent droughts have persisted for multiple years with profound effects on natural ecosystems and on agricultural production, the longer climate record reveals sustained droughts that persisted for decades (Woodhouse and Overpeck 1998; Cook et al. 2004, Meko et al. 2007, Cook et al. 2010, Routson et al. 2011). These decades-long droughts affected processes such as broad patterns of fire (Brown et al. 2004), and they emphasize that the region is prone to precipitation deficits. Projections of future climates including temperatures that increase evaporation, or changes in precipitation that change soil water availability, are likely to be particularly important in climate analyses in this NRCA.

The climate at any location is largely determined by factors that operate primarily at global to regional scales. At a global scale, the Earth has experienced a general warming trend over the past century, closely correlated with increases in the greenhouse gas CO_2 (Figure 2) (Karl et al. 2009). Global patterns of warming are modified by very broad-scale teleconnections, regional and local conditions, and the degree of warming or cooling varies geographically. Mote and Redmond (2012) provide a clear and comprehensive review and evaluation of climate drivers at local to global scales with a focus on the Western United States.

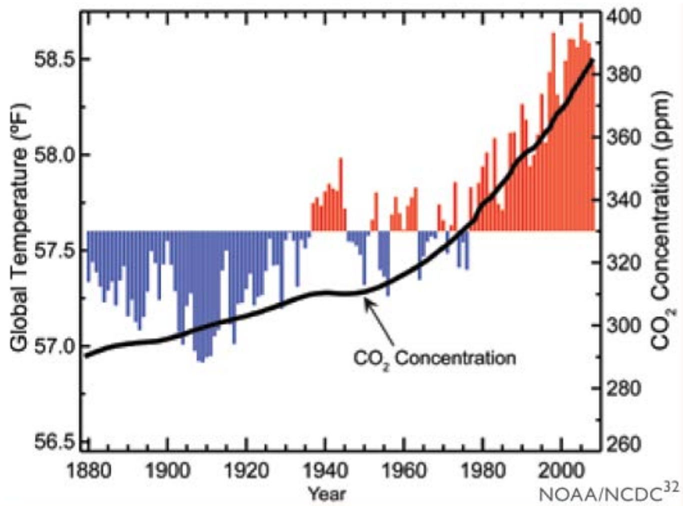

Figure 2. Annual average temperature measured over the all the Earth's land and oceans surfaces. Red and blue bars indicate years with temperatures above and below the 1901-2000 average, and the black line is the trend in atmospheric CO_2 concentration (Karl et al. 2009).

Recent historical climate patterns for FOBU were evaluated using parameter elevation regression on independent slopes model (PRISM) gridded climate data. These data are produced by the PRISM climate group at Oregon State University (Daly et al. 2002, PRISM 2015), and the analysis was completed by the North Central Climate Science Center (NCCSC). For the period of 1895-2010, the PRISM data exhibited a trend towards warming for both maximum (Tmax) and minimum (Tmin) average annual temperature and an increase in average monthly precipitation (Figure 3A, B). The linear warming trends are 0.8 °C (1.4 °F) per century for Tmax and 0.4 °C (0.7 °F) per century for Tmin (NCCC 2015, PRISM 2015)[1]. The trend in both Tmax and Tmin were determined to be significant for P > 0.01, but neither was significant for P > 0.001 (NCCSC 2015, PRISM 2015). The monthly precipitation exhibited a 1.2% per century increase, though it was determined to not be statistically significant (Figure 3C, NCCSC 2015).

[1] A change in temperature of 1 °C = a change of 1.8 °F

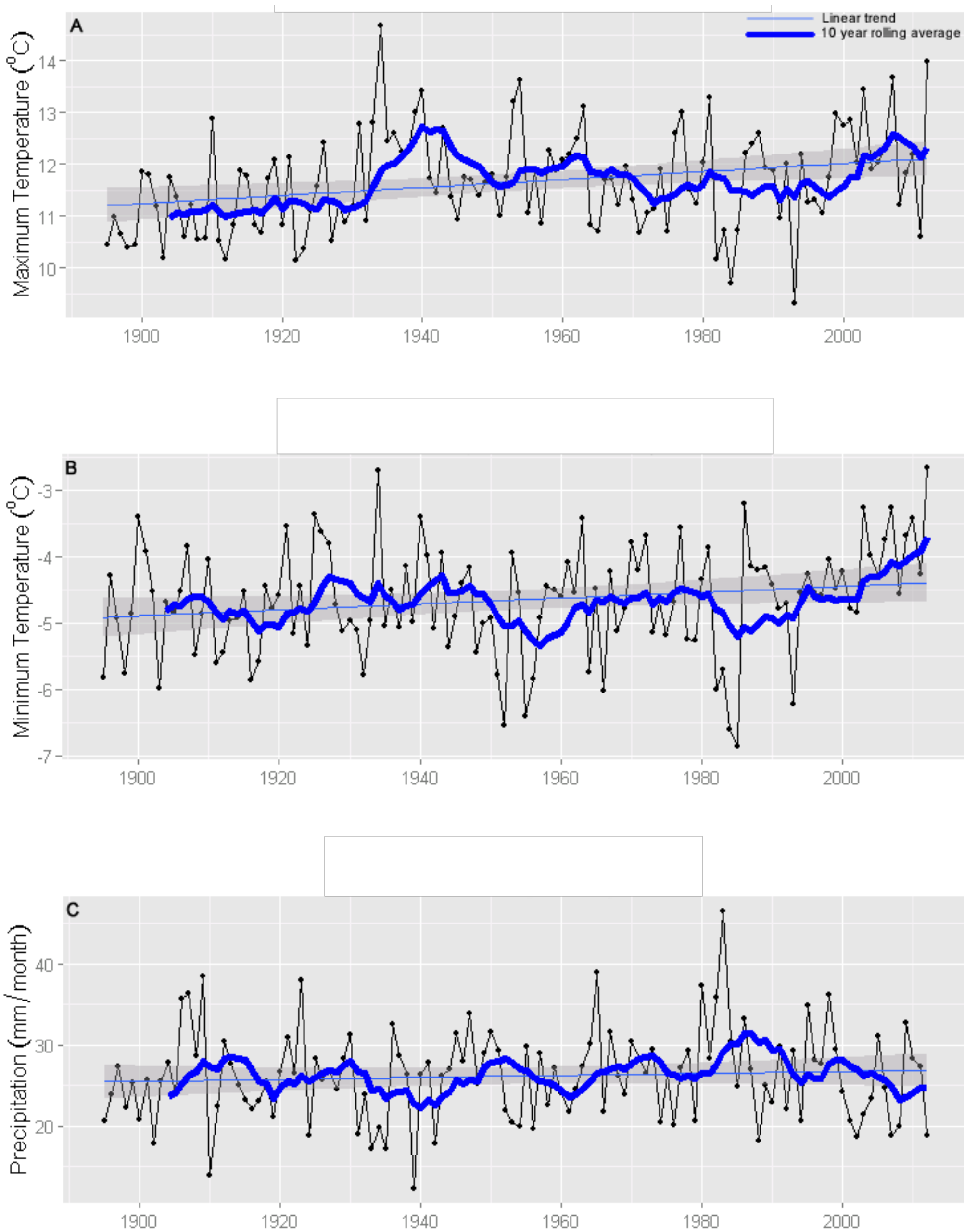

Figure 3. Trends in (A) maximum monthly temperature, (B) minimum monthly temperature, and (C) annual precipitation for FOBU. The linear regressions for Tmax and Tmin were significant for P < 0.01. The dark blue line is the calculated 10 year rolling average and the light blue line is the linear trend. Data analysis provided by NCCSC (2015).

Projected Climate Trends (2050 and 2100)

In the Great Plains region, the annual average temperature is projected to rise by approximately 2.2 °C (4 °F) by 2040-2070 and by 5.3 °C (8 °F) or higher by 2070-2100 with the continued growth in emissions under Representative Concentration Pathway (RCP) 8.5 (Cowell and Urban 2010, HPRCC 2013). Projections of changes in precipitation vary by season with an increase in winter and spring precipitation and a small decrease summer and fall precipitation amounts (HPRCC 2013, Shafer et al.

2014). Climate models predict an increase in FOBU's annual temperature and projections for all RCPs are indistinguishable until after about 2050 (Figure 4A). Average annual temperature is projected to increase by 1.6 °C (2.9 °F) by 2020 with a 5.6 °C (10.0 °F) increase by 2080 under RCP 8.5 (NCCSC 2015). This can be compared to a 0.4 °C (0.8 °F) decrease over the period of 1980-2009 (NCCSC 2015). Annual precipitation at FOBU is generally projected to increase, but there is considerable variation in the projections (Figure 4B). While confidence in projections of seasonal or total precipitaiton are low, the models consistently project increased variation in both seasonal and annual precipitation. Average monthly precipitation for FOBU is projected to increase by 3.77 mm (0.15 in) by 2030 and by 6.04 mm (0.24 in) by 2100 (NCCSC 2015). Projected change in temperature and precipitation under various RCPs is given in Table 2.

Table 2. Projected changes in average annual temperature and precipitation compared to the baseline period of 1980-2009. The value represents the mean for all available model predictions for each RCP (The values in the parenthesis reflect ±2 standard deviations). Data analysis was conducted by NCCSC (2015).

	Change in Temperature (°C)			**Change in Precipitation (Average mm/month)**		
Year	**RCP 4.5**	**RCP 6.0**	**RCP 8.5**	**RCP 4.5**	**RCP 6.0**	**RCP 8.5**
1980 to 2009 (baseline)	-0.45			2.19		
2020	1.5	1.41	1.56	3.59	3.67	3.77
	(-3.1, 6.1)	(-0.99, 3.82)	(-2.44, 5.57)	(-1.01, 8.19)	(1.26, 6.07)	(-0.24, 7.77)
2040	2.26	2.07	2.7	4.17	4.31	4.23
	(-2.78, 7.31)	(-2.26, 6.4)	(-2.19, 7.59)	(-1.88, 9.21)	(-0.02, 8.64)	(-0.65, 9.12)
2060	2.9	2.93	4.1	4.54	4.72	5.11
	(-2.75, 8.55)	(-1.44, 7.31)	(-2.6, 10.8)	(-1.1, 10.19)	(0.34, 9.09)	(-1.59, 11.81)
2080	3.36	3.86	5.58	4.46	5.92	6.04
	(-2.06, 8.79)	(-1.26, 8.98)	(-2.48, 13.64)	(-0.97, 9.89)	(0.8, 11.04)	(-2.02, 14.01)

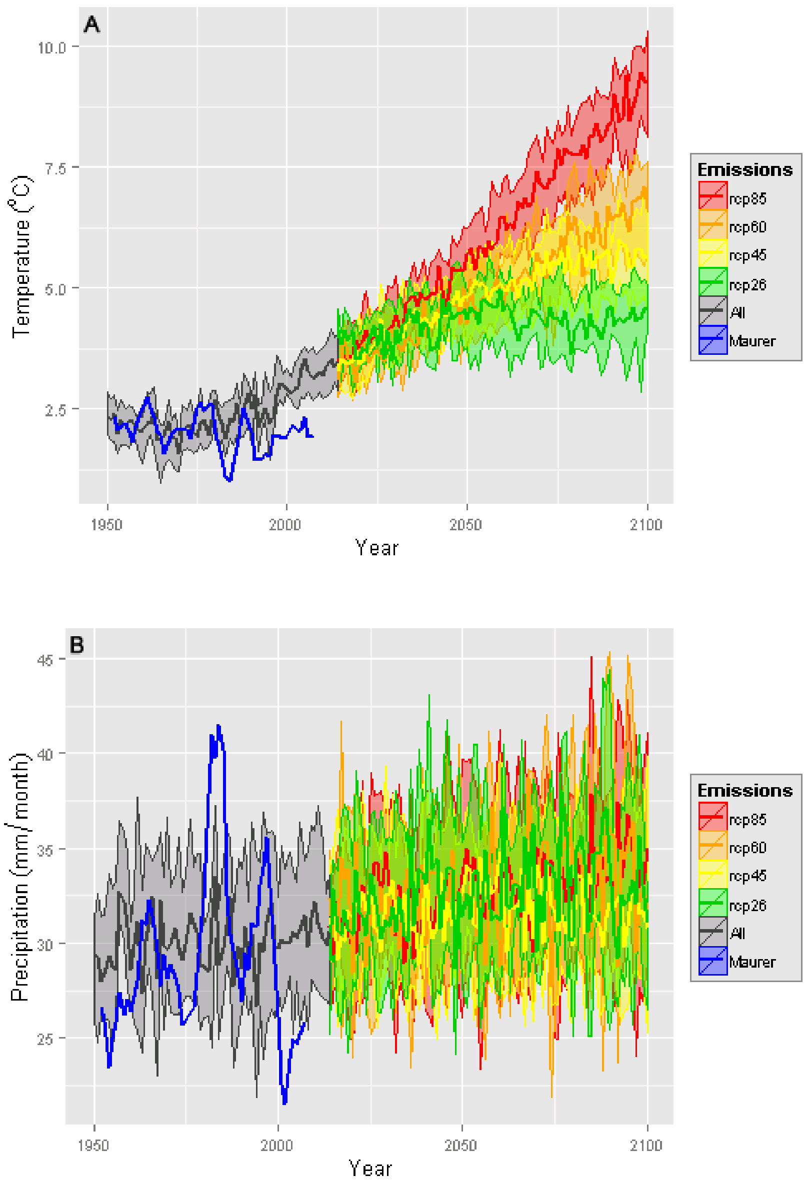

Figure 4. Projected (A) average annual temperature and (B) total annual precipitation changes from a suite of models, driven by RCP scenarios. The solid lines represent the mean for each model and the shaded area represents the 25 and 75% quartiles. Data analysis was conducted by NCCSC (2015).

Overall, the climate is likely to be much hotter and plant-available moisture will likely decline due to changes in evapotranspiration (HPRCC 2013). Evapotranspiration (ET) is the amount of moisture returned to the atmosphere through the combination of evaporation and plant transpiration. Climate scientists are concerned with two aspects of ET: actual evapotranspiration (AET) and potential evapotranspiration (PET). As its name suggests, AET is the amount of evapotranspiration that is actually occurring. PET is “a measure of the water that could be lost to the atmosphere given the (temperature-based) available energy” (Cowell and Urban 2010, p. 741). Higher temperatures will drive greater rates of evapotranspiration, thus even with an increase in precipitation, soil water levels are projected to decrease (Cowell and Urban 2010). By the end of the 21st century, Cowell and

Urban (2010) projected an increase in PET of 221 mm (8.7 in) for the Great Plains region. The projected increase in PET for the Great Plains region is nearly 10 times the projected increase in precipitation, resulting in a huge increase (161 mm [6.3 in]) in soil water deficit (Cowell and Urban 2010).

The ratio of AET to PET is used as an ‘aridity index’ that indicates the amount of moisture available to plants (TNC, Evan Girvetz, Senior Scientist, e-mail communication, 7 June 2011). For example, a 0.15 decrease in this ratio can be interpreted as a 15% increase in aridity, or 15% less moisture available for plants (E. Girvetz, e-mail communication, 8 June 2011). Projections for FOBU indicate a 12% increase in annual aridity (from a 1960-1990 reference period) by 2050 and a 17% increase by 2100 under RCP 8.5 (ClimateWizard 2014).

To summarize, models are very consistent in projecting a warmer climate for FOBU (2.2 °C (4 °F) by 2040-2070 and by 5.3 °C (8 °F) or higher by 2070-2100) than the baseline conditions present during the 1960-1990 reference period used by the models. Projections of increased temperatures, especially in the summer, can lead to increased evapotranspiration and a decrease in soil moisture (Cowell and Urban 2010). The warming climate is also projected to cause changes in the frequency and severity of extreme weather events (Cowell and Urban 2010). This includes more days with heavy precipitation and extreme cold (Cowell and Urban 2010).

2.1.3. Visitation Statistics

On average FOBU is visited by approximately 18,000 people annually (Figure 5, NPS 2013b). The lowest attendance was 1973, one year after establishment; the park received only 1,000 visitors that year, but the next year brought 13,900 visitors and has had a minimum of 10,000 annual visitors since 1977 (Figure 5, NPS 2013b). The highest attendance so far was in 1993 when FOBU was visited by 26,499 people (Figure 5, NPS 2013b). FOBU visitors are often passing by on their way to Grand Teton National Park (GRTE), Dinosaur National Monument (DINO), or Yellowstone National Park (YELL) (NPS 2006). The park is a day-use area so there are not campsites on the premises (NPS 2006). Visitor spending contributes to the local economy with an estimated $676,000 in spending attributed directly to the park and visitor generated sales supports 14 jobs within the local region (Cook 2010).

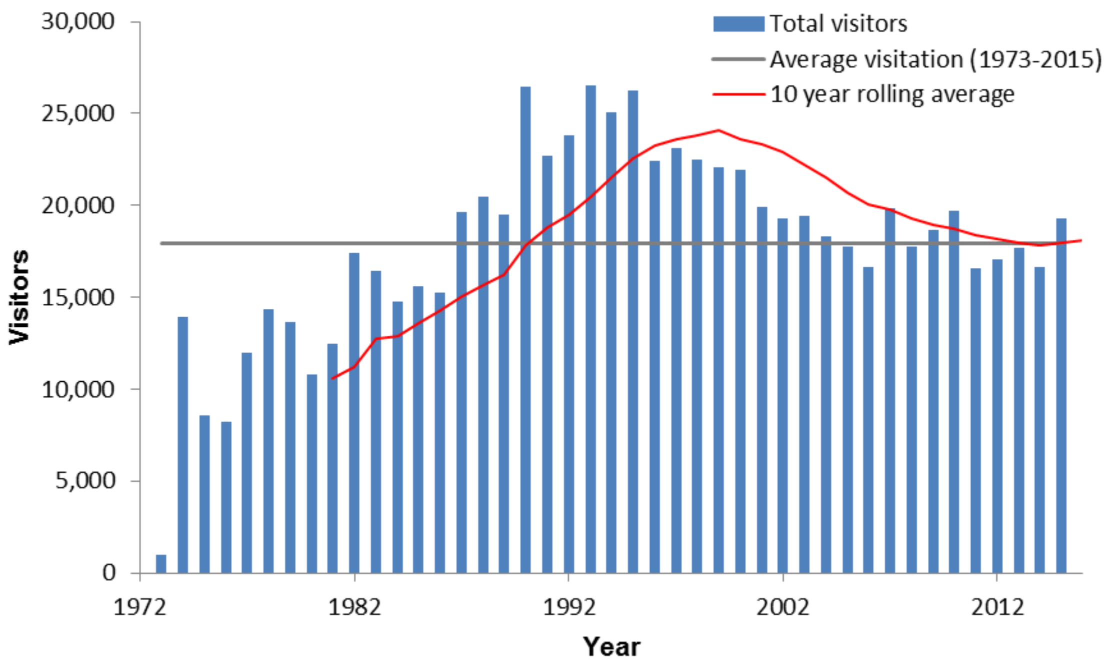

Figure 5. Visitation statistics for FOBU for 1973–2015 (NPS 2013b).

2.2. Natural Resources

2.2.1. Ecological Units and Watersheds

FOBU is located in the Wyoming Basin Level III Ecoregion (EPA 2013). This area is described as a broad intermontane basin with intermittent hills and low mountains, generally dominated by arid shrublands and grasslands (EPA 2013). The EPA divides Level III Ecoregions into smaller Level IV Ecoregions. FOBU lies in the Foothill Shrublands and Low Mountains Level IV Ecoregion. Vegetation in this ecoregion includes big sagebrush (*Artemisia tridentata*), rabbitbrush (*Chrysothamnus* spp.), prickly pear (*Opuntia* spp.), bluebunch wheatgrass (*Pseudoroegneria spicata*), and Idaho fescue (*Festuca idahoensis*) that dominate the soils; occurring commonly on rocky outcrops are Rocky Mountain juniper (*Juniperus scopulorum*), Utah juniper (*J. osteosperma*), and mountain-mahogany (*Cercocarpus montanus*) (EPA 2013). Small patches of forested areas occur at higher elevations, especially in wetter areas (aspens) and on north-facing slopes (conifers and pines). Primary land uses across the ecoregion are mostly livestock grazing and wildlife habitat (EPA 2013).

The park lies within the Twin Creek watershed which includes three sub-watersheds that are part of the park topography. These sub-watersheds are the Middle Twin Creek, North Fork Twin Creek, and Rock Creek (Figure 6).

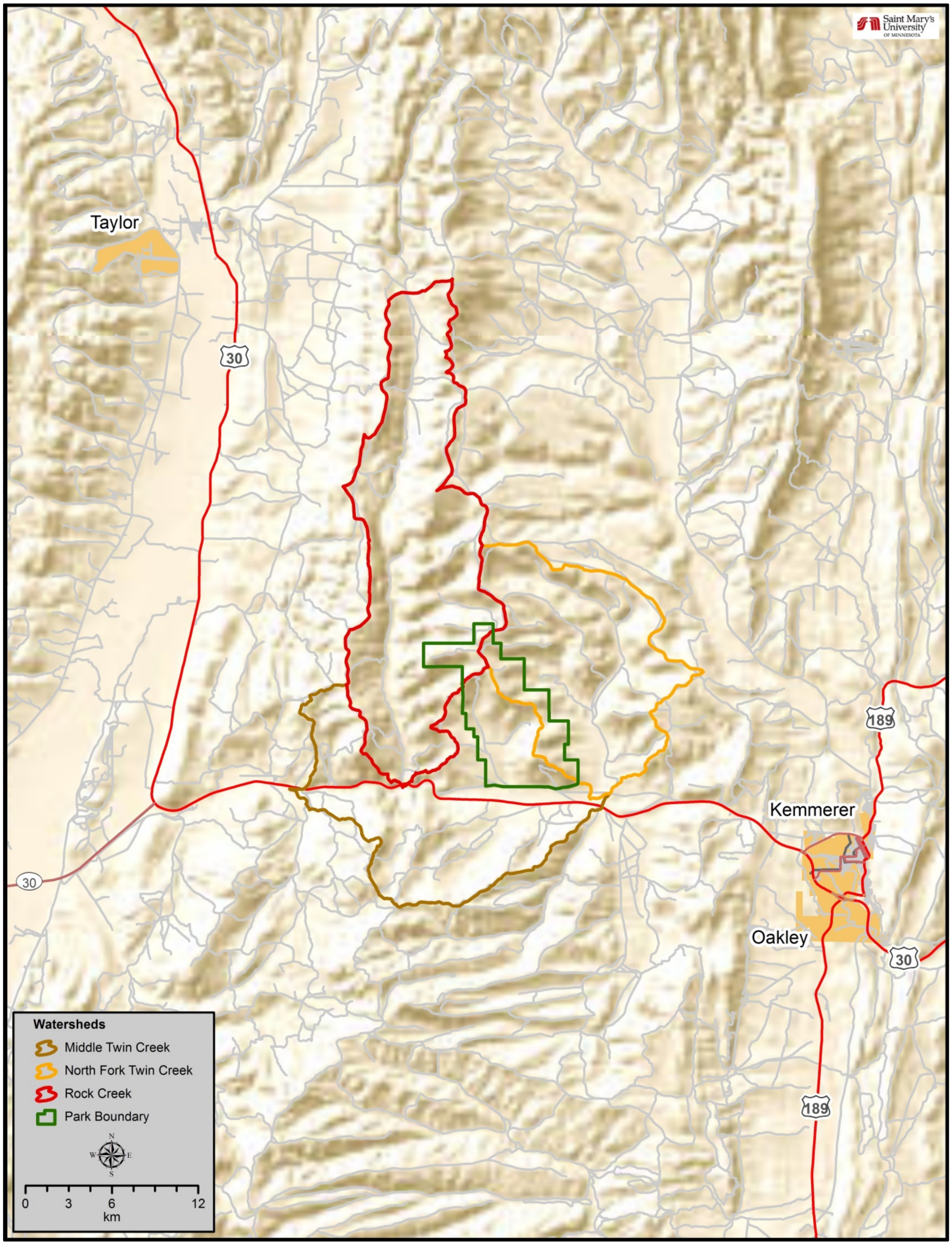

Figure 6. Watersheds within FOBU.

2.2.2. Resource Descriptions

The primary resources protected by the park are the well-preserved and abundant fossil fish found in the 51.98-million-year-old Green River Formation. What caused the exceptional preservation of the fish and other fossils is not fully understood, but it appears related to paper-thin alternating layers of carbonate mud and organic material from a microbial mat (Aase, written communication, 11 April 2016). The fossils preserved within the Green River Formation are unique for their abundance over a geographically large area and diversity of both aquatic and terrestrial organisms. Five laminated limestone beds in this formation are excavated to collect fossil fish for the commercial fossil trade (Aase, written communication, 11 April 2016). Over 50 more beds contain fossils in lesser quantities or in a poorer state of preservation and are therefore not commercially collected but are scientifically valuable to better understand ancient fossil lake. Most fossils recovered represent aquatic organisms with rarer terrestrial fossils interspersed (Aase, written communication, 11 April 2016).

There is also an impressive variety of plant and animal fossils in the fluvial sediments of the Wasatch Formation (NPS 1985). These fossils help researchers understand the paleoecology of the area, before, around, and after the time of ancient Fossil Lake. The fossils of the Wasatch Formation include early primates, horses, birds, reptiles, fish, and plants (NPS 2006, Aase, written communication, 11 April 2016).

The fossils at FOBU are a nonrenewable resource and the park protects and preserves them for future generations while carefully selecting paleontological and geologic studies that will help understand the story they tell. Fossils have been collected in Fossil Basin for over 100 years and FOBU is within the midst of active commercial collection activities (NPS 2006). FOBU encompasses less than 1% of the rock deposited by ancient Fossil Lake; to understand the full story told by the rocks, park staff must cooperate with staff at Bureau of Land Management (BLM), private land owners and quarry operators (Aase et al. 2002).

In addition to fossil resources, biological species at FOBU are fairly abundant and diverse. The park supports approximately 560 plant taxa from 68 families, including eight plants that are considered species of special concern by the Wyoming Natural Diversity Database (WYNDD) (NPS 2005, 2013a). FOBU is dominated by three major sagebrush communities: basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*), longleaf sagebrush (*Artemisia arbuscula* ssp. *longiloba*), and mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*). Mixed conifer woodlands are also found in FOBU, mainly limber pine (*Pinus flexilis*), and some quaking aspen communities (NPS 2005).

The fauna of FOBU are also quite diverse. The bird list contains 145 species, including the bald eagle (*Haliaeetus leucocephalus*), owls (*Strigidae* and *Tytonidae* spp.), hummingbirds (*Trochilidae* spp.), and hawks (*Accipitridae* spp.) (NPS 2013a). The NPS also lists 57 mammal species that have been documented in FOBU, including elk (*Cervus elaphus*), moose (*Alces alces*), pronghorn (*Antilocapra americana*), and mule deer (*Odocoileus hemionus*) (NPS 2013a). Many smaller mammals and several carnivores as also found within the park. A total of twelve bat species are known to occur within the park, although the total abundance of these mammals in FOBU is unclear (NPS 2013a). Currently, there is a statewide effort to conduct more intensive surveys on the bats of Wyoming, including those possibly feeding in or inhabiting steppe shrublands, to develop bat conservation strategies (Hester 2005). There are only two reptiles listed as occurring in FOBU: the terrestrial garter snake (*Thamnophic elegans vagrans*) and the greater short-horned lizard (*Phrynosoma hernandesi*) (NPS 2013a). The official park species list also includes three amphibian species, the western chorus frog (*Pseudacris triseriata*), northern leopard frog (*Lithobates pipiens*), and the tiger salamander (*Ambystoma tigrinum*) (NPS 2013a).

Small Mammals

The determination of what constitutes a small mammal versus a medium to large mammal is somewhat loosely defined. A general definition was present by Merrit (2010), who defined "small" to include all mammals weighing less than 5 kg (11 lbs). For the purposes of this section, this definition has been adopted, and includes rodents (*Rodentia*), bats (*Chiroptera*), and rabbits (*Leporidae*). Larger mammals are discussed in the coming sections including ungulates and predators.

Small mammals are influential members of the ecological communities where they occur (Hull Sieg 1987, Cook et al. 2006). Depending on the species composition and abundance, they can directly affect successional dynamics in their habitats by feeding on plants and insects at various intensities (Cook et al. 2006). Other activities such as burrowing and seed caching can also have an impact on plant communities (Hull Sieg 1987). Their burrows often become habitat for other organisms (e.g., birds and reptiles) (Hull Sieg 1987). They are also an important source of prey for predatory birds, herpetofauna, and other mammals (Hull Sieg 1987, Cook et al. 2006).

Mammalian inventories were conducted within the park on at least two occasions. Haymond (2003) conducted mammalian inventories for select Northern Colorado Plateau Network (NCPN) parks in 2001 and 2002. A mammal survey was also conducted at FOBU in 1976 from May through August (Rado 1976). The purpose of this inventory was threefold; to determine the number of mammal species occurring within the parks boundaries, to determine the mammal species composition within five major plant zones (identified below), and to recommend viable management plans for mammals documented in the park (Rado 1976).

For the survey conducted by Rado, plant zones were defined for the survey as open grassland, sage, limber pine, mountain-mahogany, and aspen (Rado 1976). The dominant (most common) small mammal species found in each plant zone were: Northern grasshopper mice (*Onychomys leucogaster*) in open grasslands, Richardson's ground squirrel (*Urocitellus richardsonii*) in sage, golden-mantled ground squirrel (*Callospermophilus lateralis*) in mountain-mahogany, and least chipmunk (*Tamias minimus*) in aspen (Rado 1976). Other common species included white-tailed jackrabbit (*Lepus townsendii*) in open grassland and sage and desert cottontail (*Sylvilagus audubonii*) in the open grasslands and sage zones (Rado 1976). Rodent diversity was highest in the sage community and lowest in the open grassland. Following the first survey in 1976, Rado (1977) resampled the rodent densities in 1977 in the same five plant zones the following year and found that diurnal rodent populations had greatly declined in both areas. Rado (1977) noted that the results of these surveys indicate how sensitive rodent communities are to environmental changes.

The more recent Haymond (2003) FOBU inventory resulted in additions/changes to the species database. Haymond (2003) documented new occurrences and confirmed the occurrence of other small mammal species. The new occurrences of small mammals were the masked shrew (*Sorex cinereus*) and yellow pine chipmunk (*Tamias amoenus*) (Haymond 2003). Overall, there are 36 species of small mammals confirmed within the park and four that are considered likely to be present, as shown in Table 3.

Table 3. Species of small mammals in FOBU with some counts of individuals where available (P = Present, PP = probably present, H = hypothetically present).

Scientific Name	Common Name	NPS (2013)	Rado (1976)	Rado (1977)	Haymond (2003)
Bats					
Corynorhinus townsendii	Townsend's big-eared bat	P	-	-	2
Eptesicus fuscus	big brown bat	P	H	-	2
Euderma maculatum	spotted bat	PP	-	-	
Lasionycteris noctivagans	silver-haired bat	P	-	-	1
Lasiurus cinereus	hoary bat	PP	-	-	
Myotis ciliolabrum	western small-footed myotis	P	-	-	3
Myotis evotis	long-eared myotis	P	H	-	12
Myotis lucifugus	little brown myotis	P	H	-	8
Myotis thysanodes	fringed myotis	PP	-	-	
Myotis volans	long-legged myotis	P	H	-	6
Myotis yumanensis	Yuma myotis	P	-	-	X
Tadarida brasiliensis	Brazilian free-tailed bat	P	-	-	2
Other small mammals					
Brachylagus idahoensis	pygmy rabbit	P	-	-	-
Callospermophilus lateralis	golden-mantled ground squirrel	P	P	P	P
Castor canadensis	American beaver	P	P	-	1
Cynomys leucurus	white-tailed prairie dog	P	P	-	-
Dipodomys ordii	Ord's kangaroo rat	-	P	-	-
Erethizon dorsatum	North American porcupine	P	H	-	1
Glaucomys sabrinus	northern flying squirrel	PP	H	-	-
Lemmiscus curtatus	sagebrush vole	P	H	-	-
Lepus americanus	snowshoe hare	P	-	-	-

Table 3 (continued). Species of small mammals in FOBU with some counts of individuals where available (P = Present, PP = probably present, H = hypothetically present).

Scientific Name	Common Name	NPS (2013)	Rado (1976)	Rado (1977)	Haymond (2003)
Other small mammals (continued)					
Lepus townsendii	white-tailed jackrabbit	P	-	-	1
Marmota flaviventris	yellow-bellied marmot	P	P	-	-
Microtus longicaudus	long-tailed vole	P	-	-	3
Microtus montanus	montane vole	P	-	-	5
Microtus pennsylvanicus	meadow vole	P	-	-	1
Myodes gapperi	southern red-backed vole	P	-	-	P
Neotoma cinerea	bushy-tailed woodrat	P	P	-	2
Onychomys leucogaster	northern grasshopper mouse	P	P	P	1
Perognathus parvus	Great Basin pocket mouse	P	P	P	3
Peromyscus maniculatus	deer mouse	P	P	P	110
Sorex cinereus	masked shrew	P	H	-	-
Sorex monticolus	montane shrew	P	-	-	P
Sylvilagus audubonii	desert cottontail	P	-	-	-
Sylvilagus nuttallii	mountain cottontail	P	-	-	1
Tamias amoenus	yellow-pine chipmunk	P	-	-	P
Tamias minimus	least chipmunk	P	P	P	47
Tamiasciurus hudsonicus	red squirrel	P	P	-	-
Thomomys talpoides	northern pocket gopher	P	H	-	1
Urocitellus armatus	Uinta ground squirrel	P	-	-	-
Urocitellus elegans	Wyoming ground squirrel	P	-	-	-
Urocitellus richardsonii	Richardson's ground squirrel	P	P	P	-
Zapus princeps	western jumping mouse	P	-	-	7

Bats in the park are not well studied. Currently there are nine species documented in the park, but little is known on their roosting habits or abundance. Haymond (2003) documented eight different bat species in the park (Table 3). Haymond (2003) conducted bat inventories using two different methodologies, mistnetting and acoustic survey. The highest bat species richness was observed around the beaver ponds in Moose Bones Canyon and a pond in Murder Hill Canyon (Haymond 2003). Haymond (2003) speculated that additional bat surveys employing bat detectors and mistnetting could eventually document up to four additional bat species within the park. The Haymond (2003) survey does provide a baseline for future inventory efforts in FOBU.

Ungulates

Ungulates include mule deer, pronghorn antelope, moose, and elk at FOBU and historically there may have also been bison present (Haymond 2003, NPS 2013a). Ungulates alter the landscape through modification of nutrient cycling, patch dynamics, and abiotic disturbances (e.g., fire regimes) (Hobbs 1996). The importance of ungulate presence in the park is not well studied, aside from grazing impacts regarding past livestock (e.g., sheep) presence (Dorn et al. 1984). In general, research has shown that the presence of large grazers is an active agent of ecosystem change (Hobbs 1996).

Predators

Predation is considered an organizing process that has been shown as an influential force towards levels of biodiversity that are found within an ecosystem (Estes et al. 2001). Predators are often considered keystone species within an ecosystem. Their interactions within food webs are what drive “top-down” forces within trophic cascades (Estes et al. 2001). The trophic cascade is defined as the “progression of indirect effects by predators across successively lower trophic levels” (Estes et al. 2001, p. 859). Top-down forces, the impacts that top predators have on lower levels of the food web, are considered as integral and important to ecosystem health as bottom-up forces (Estes et al. 2001). Although many species of animals in the park would be classified as a predator based on their diet, the apex and meso-predators are the focus of this section. These include large predators such as mountain lion (*Puma concolor*) and black bear (*Ursus americanus*), meso-predators such as badger (*Taxidea taxus*), weasel (*Mustela* spp.), and skunk (Family *Mephitidae*), and raptors such as hawks and owls.

Currently, there are 34 species of apex and meso-predators (10 mammals and 24 birds present in the park (Table 4). These are important members of the park fauna since they are likely influencing the diverse community of small mammals present in FOBU. Although there is not an assessment on these interactions, it may become an area of interest for future research. The most recent mammal inventory was conducted over a 2 year period (2001-2002) and recorded the bobcat (*Lynx rufus*), mountain lion, and red fox (*Vulpes vulpes*) among many mammal species found within the park (Haymond 2003). One species that may occur, but has not been documented in the park is the spotted skunk (*Spilogale putorius*).

Table 4. Predators listed in the NPSpecies database and preferred prey (Cornell University 2015, Nature Works 2015).

Scientific Name	Common Name	Preferred Prey
Accipiter cooperii	Cooper's hawk	smaller birds
Accipiter striatus	sharp-shinned hawk	smaller birds
Aegolius acadicus	northern saw-whet owl	small animals
Aquila chrysaetos	golden eagle	small/medium animals
Asio flammeus	short-eared owl	small animals
Asio otus	long-eared owl	small animals
Athene cunicularia	burrowing owl	insects/invertebrates, small animals
Bubo virginianus	great horned owl	small/medium animals
Buteo jamaicensis	red-tailed hawk	small/medium animals
Buteo lagopus	rough-legged hawk	small animals
Buteo regalis	ferruginous hawk	small/medium animals
Buteo swainsoni	Swainson's hawk	small/medium animals
Canis latrans	coyote	omnivorous
Cathartes aura	turkey vulture	carrion
Chordeiles minor	common nighthawk	insects/invertebrates
Circus cyaneus	northern harrier	small animals
Falco mexicanus	prairie falcon	small/medium animals
Falco peregrinus	peregrine falcon	smaller birds
Falco sparverius	American kestrel	insects/invertebrates, small animals
Glaucidium gnoma	northern pygmy-owl	smaller birds
Haliaeetus leucocephalus	bald eagle	fish and small animals
Lynx rufus	bobcat	small/medium animals
Megascops kennicottii	western screech-owl	insects/invertebrates, small animals
Mephitis mephitis	striped skunk	omnivorous
Mustela erminea	ermine	small animals
Mustela frenata	long-tailed weasel	small animals
Otus flammeolus	flammulated owl	insects/invertebrates
Phalaenoptilus nuttallii	common poorwill	insects/invertebrates
Procyon lotor	northern raccoon	omnivorous

Table 4 (continued). Predators listed in the NPSpecies database and preferred prey (Cornell University 2015, Nature Works 2015).

Scientific Name	Common Name	Preferred Prey
Puma concolor	mountain lion	small/medium/large animals
Spilogale gracilis	western spotted skunk	omnivorous
Taxidea taxus	American badger	small animals
Tyto alba	barn-owl	small animals
Ursus americanus	American black bear	omnivorous
Vulpes vulpes	red fox	omnivorous

Pollinators

Pollinators can include species of birds, bats, and insects. Over 75% of the world's flowering plant species rely on pollinators to transport pollen so the plants can produce fruits and seeds for reproduction (NPS 2016). For example, native bees are vital to the health and diversity of western range landscapes (Gilgert and Vaughan 2011). No comprehensive surveys or studies of FOBU's pollinators had been completed at the time this NRCA was being written, but the park was in the process of collecting baseline studies to determine pollinator status. FOBU also participated in a multi-park study of native bees during 2010 (Rykken et al. 2014).

Air Quality

Although located in a rural part of Wyoming, FOBU experiences challenges to air quality from local emissions and through contaminants carried into the region via the prevailing seasonal winds. The most current 5-year average (2006-2010) for FOBU (average interpolated from data collected at various regional monitors) indicates air quality in the area near FOBU is variable. Parameters commonly assessed include ozone concentration, wet deposition of sulfur and nitrogen, and visibility (measured in deciviews [dv], a unit of measurement representing the minimal perceptible change in visibility to the human eye). Ozone occurs naturally in the atmosphere, but at high concentrations at ground level it can cause foliar injury to many plant species, as well as acute respiratory issues in humans and animals (EPA 2012). Interpolated 5-year average (2006-2010) for 4^{th} highest 8-hour ozone concentration is 68.1 ppb (NPS 2012), which is considered a condition that warrants moderate concern. Deposition of sulfur and nitrogen can have significant effects on ecosystems, including acidification of water and soils, excess fertilization or increased eutrophication, changes in the chemical and physical characteristics of water and soils, and accumulation of toxins in soils, water, and vegetation (reviewed in Sullivan et al. 2011a and 2011b). The most current 5-year interpolated average (2006-2010) of wet deposition for total nitrogen is 1.6 kg/ha, while total sulfur is 0.7 kg/ha; average deposition of nitrogen is considered a rate of moderate concern, while the average deposition of sulfur warrants no concern. Visibility impairment occurs when airborne particles and gases scatter and absorb light; the net effect is called "light extinction," which is a reduction in the amount of light from a view that is returned to an observer (EPA 2003). In response to the mandates of the Clean Air Act (CAA) of 1977, federal and regional organizations established the Interagency Monitoring of

Protected Visual Environments (IMPROVE) in 1985 to aid in monitoring of visibility conditions in Class I airsheds; now monitoring or interpolated estimates are available for Class II airsheds as well (FOBU is a Class II airshed). The most current 5-year average (2006-2010) estimates visibility for the FOBU region as 2.9 dv above natural conditions, a condition that falls into the moderate concern category. On the 20% clearest days, visibility is 1.8 dv (warrants no concern) and on the 20% haziest days, visibility is 11.2 dv (warrants significant concern).

2.2.3. Resource Issues Overview

The major issues listed in the 1991 NPS management statement for FOBU are fire management, erosion control, protection of resources (fossils), water management, and space for storage and care of collections (NPS 1991). There are a few adjacent land issues mentioned that involve oil, gas, and coal operations (mining, drilling, etc.); the railroad and coal-fired power plant are mentioned here as well (NPS 1991).

There is a prominent need for physical space and personnel resources at FOBU for fossil work to be conducted efficiently and adequately in order to comply with the mission and purpose of the park (Aase et al. 2002). To adequately complete an all-encompassing story of Fossil Lake paleoecology, continued development of partnerships with local stakeholders and surrounding fossil quarries is needed (Aase et al. 2002). New information becomes available sporadically as new fossil specimens are discovered and research discoveries are published; FOBU exhibits need periodic updates to keep up with the current research and new discoveries (Aase et al. 2002). This process includes the acquisition of fossil specimens found outside FOBU, so they can be displayed for the education and enjoyment of park visitors and upholds the fundamental purpose of establishing the park. Additional space to accommodate the expanding reference library is also needed (Aase et al. 2002).

Climate change is an issue that will affect not only natural and cultural resources at FOBU, but also visitation patterns (Fisichelli et al. 2015). Recent changes in Earth’s climate are well documented and include such impacts as significant increases in average temperatures and precipitation over the last 50 years, increased incidence of extreme weather events (e.g., extended drought, heavy rainstorms, and increasingly powerful hurricanes), a rise in sea level, and decline of Arctic sea ice (IPCC 2007). These climatic shifts have already been linked to a number of impacts to natural systems, including such phenological changes as earlier onset of plant greenness, earlier insect emergence and flowering of plants, shifts in the onset of migration and breeding seasons, and changes in geographic ranges (Stein and Glick 2011). With carbon emissions expected to continue at the current rates, many scientists anticipate even greater influences of climate change to ecosystems and species in the next several decades. With warming temperatures, visitors may stay away during extremely hot months, but the visitation season may expand by several weeks in the spring and fall (Fisichelli et al. 2015).

In order to develop meaningful conservation strategies, managers must understand the wide range of impacts, risks, and uncertainties associated with projected climate changes, and try to estimate the relative vulnerability of different ecosystems and species to these projected changes. For instance, more vulnerable species and systems are more likely to experience greater impacts from climate change and would require a greater effort in conservation planning, while less vulnerable species and systems will be less affected, or may even benefit; this would require less intensive conservation planning. Managing for such changes in natural systems is rapidly becoming a priority for conservation agendas.

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

The 1991 management statement has specific management directives for the fossil resources at FOBU within three existing management zones. The park area classified as a Natural Environment Zone exists in about 90% of the total area, 20% of which contains “outstanding paleontological deposits of related geological phenomena.” The Historic Zone, consisting of approximately 8% of the total park area, is located in two separate places that represent remnants of early fossil hunting activity (NPS 1991). One location is an archeological site on the north end of FOBU and the other is an A-frame structure and quarry on the southeast face of Fossil Butte proper. The third zone in FOBU is park development (buildings, parking, etc.). This includes developed or proposed for development areas, and comprises 2% of the total park area (NPS 1991). Several management objectives are listed in the 1991 Management Statement for FOBU in regard to the fossil resources of the park and are as follows (NPS 1991):

- To limit extraction of the paleontological resources to scientific research that may be required in connection with monument development and to fill gaps in the knowledge of these resources that cannot be obtained elsewhere.
- To obtain a representative collection of fossil specimens to adequately display and interpret the paleontological resources to the public.
- To encourage and foster scientific research to provide information for a comprehensive and accurate interpretive program.
- To protect and preserve within the constraints of the enabling legislation all elements of the natural and historic resources of Fossil Butte.
- To provide an inventory and evaluation of the cultural resources of the monument.
- To maximize use of alternative energy sources and technology.
- To develop administrative and visitor-use facilities necessary for enjoyment and use of the national monument in a manner that will have minimum impact on the resources.
- To develop an interpretive program and facilities that will bring the visitor to understand this geological epoch in association with others (well represented in the NPS) and the vast evolutionary changes, both biological and geomorphological, that has taken place in the earth’s history.

2.3.2. Status of Supporting Science

The NCPN identifies key resources network-wide and for each of its parks that can be used to determine the overall health of the parks. These key resources are called Vital Signs. In 2005, the NCPN completed and released a Vital Signs Monitoring Plan (O’Dell et al. 2005). Table 5 shows the network Vital Signs selected for monitoring in FOBU.

Table 5. NCPN Vital Signs selected for monitoring in FOBU (O'Dell et al. 2005). Bold indicates Vital Signs that currently are or will be monitored by the NCPN. Italics indicate Vital Signs being monitored by a network park, another NPS program, or another federal or state agency, using other funding.

Category	NCPN Vital Signs
Air and Climate	Air quality (ozone, wet and dry deposition, visibility and particulate matter), *weather and climate*
Geology & Soils	Stream/ river channel characteristics, paleontology, soil function and dynamics
Water	Water chemistry, ground and surface water dynamics, aquatic macroinvertebrates and algae
Biological Integrity	**Invasive/exotic plants, insect pests**, animal diseases, riparian communities, freshwater communities, grassland vegetation, shrubland vegetation, fishes, amphibians, **birds**, bats, vegetation communities, threatened and endangered species and communities (e.g., peregrine falcon)
Human Use	Consumptive use, **non-point source human effects**, *visitor usage*
Ecosystem Pattern and Processes	**Fire and fuel dynamics, land cover and use**, night sky, soundscape, nutrient dynamics, **productivity**

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Chapter 3. Study Scoping and Design

This NRCA is a collaborative project between the NPS and Saint Mary's University of Minnesota Geospatial Services (SMUMN GSS). Project stakeholders include the FOBU resource management team and NCPN Inventory and Monitoring Program staff. Before embarking on the project, it was necessary to identify the specific roles of the NPS and SMUMN GSS. Preliminary scoping meetings were held, and a task agreement and a scope of work document were created cooperatively between the NPS and SMUMN GSS.

3.1. Preliminary Scoping

3.1.1. Natural Resource Condition Assessment

A preliminary scoping meeting was held on 5-7 November 2013. At this meeting, SMUMN GSS and NPS staff confirmed that the purpose of the NRCA was to evaluate and report on current conditions, critical data and knowledge gaps, and selected existing and emerging resource condition influences of concern to FOBU managers. Certain constraints were placed on this NRCA, including the following:

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

This condition assessment provides a "snapshot-in-time" evaluation of the condition of a select set of park natural resources that were identified and agreed upon by the project team. Project findings will aid FOBU resource managers in the following objectives:

- Develop near-term management priorities (how to allocate limited staff and funding resources);
- Engage in watershed or landscape scale partnership and education efforts;
- Consider new park planning goals and take steps to further these;
- Report program performance (e.g., Department of Interior Strategic Plan "land health" goals, Government Performance and Results Act [GPRA]).

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available data, reports, and spatial information from appropriate sources including: FOBU resource staff, the NPS Integrated Resource Management Application (IRMA) website, Inventory and Monitoring Vital Signs program, and available third-party sources. The NRCA report will provide a resource assessment and summary of pertinent data evaluated through this project.
- When appropriate, define a reference condition so that statements of current condition may be developed. The statements will describe the current state of a particular resource with respect to an agreed upon reference point.

- Clearly identify "management critical" data (i.e., those data relevant to the key resources). This will drive the data mining and gap definition process.
- Where applicable, develop GIS products that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually.
- Utilize "gray literature" and reports from third party research to the extent practicable.

3.1.2. Climate Change Vulnerability Pilot Study

The NPS is considering strategies to integrate climate change resource vulnerability into the park NRCAs. In March 2014, NPS partnered with SMUMN GSS to implement a pilot project to assess the feasibility of slightly modifying existing NRCA project scopes to accommodate an assessment of resource vulnerability to climate change. This was collaboration between the SMUMN GSS Principle Investigator (PI) for the FOBU NRCA project, the NPS involved principles (including the Climate Change Response Program [CCRP]), the NRCA Program, the NRCA Regional coordinators, FOBU staff, and the North Central Climate Science Center (NCCSC).

The pilot project's goal is to seek creative approaches to considering climate change vulnerabilities in the context of an NRCA project. A number of ongoing NRCA projects were included in this pilot, in order to provide comparative assessments; a fundamental general approach was developed. Each NRCA project in the pilot study used the following basic criteria to assess resource vulnerability to climate change:

- Information about modeled and downscaled climate change data needed to assess vulnerability was developed using existing resources through the NCCSC, the NPS CCRP, and the NPS I&M program;
- Discussion with park resource managers was conducted to identify park species, habitats, processes, communities, or landscapes viewed as most significant, iconic, or best indicator of park resource vulnerability;
- Climate change vulnerability assessment (CCVA) for selected park resources, processes, or landscapes was completed using national, regional, or local scale readily available information, literature searches, and discussion with park resource experts or others deemed relevant to this determination.

Specific pilot project expectations and outcomes include the following:

- Minimally impact the ongoing NRCA
- Implemented as a qualitative process.
- Inform the need or urgency to conduct a formal park resource CCVA.
- Inform the feasibility and potential benefits of integrating a CCVA into the NRCA process.

3.2. Study Design for Natural Resource Condition Assessment

3.2.1. Indicator Framework, Focal Study Resources and Indicators

Selection of Resources and Measures

As defined by SMUMN GSS in the NRCA process, a “framework” is developed for a park or preserve. 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., birds, plant communities), ecological processes or patterns (e.g., natural fire regime), or specific natural features or values (e.g., geological formations) 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 the 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,” which are also considered during assessment. A “stressor” is defined as any agent that imposes adverse changes upon a component. These typically refer 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 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, or are of greatest concern or highest management priority in FOBU. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with NPS resource staff.

Selection of Reference Conditions

A “reference condition” is a benchmark to which current values of a given component’s measures can be compared to determine the 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., Environmental Protection Agency [EPA] standards for air quality), or a targeted management goal/objective (e.g., a bison herd of at least 200 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 before human activity and disturbance was a major driver of ecological populations and processes, such as “pre-fire suppression.” 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” (Heinz Center 2008). Key resources for the park were adapted from the NCPN Vital Signs monitoring plan (O'Dell et al. 2005). This initial framework was presented to park resource staff to stimulate meaningful dialogue about key resources that should be assessed. Significant collaboration between SMUMN GSS analysts and NPS staff was needed to focus the scope of the NRCA project and finalize the framework of key resources to be assessed.

The NRCA framework was finalized in February 2014 following acceptance from NPS resource staff. It contains a total of 16 components (Figure 7) and was used to drive analysis in this NRCA. This framework outlines the components (resources), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each component for comparison to current conditions.

Fossil Butte National Monument
Natural Resource Condition Assessment Framework

	Component	Measures	Stressors	Reference Condition
Biotic Composition				
Ecological Communities				
	Low sagebrush Community	Community extent and change over time, Community composition, Rrend in invasive infestation, Relative abundance of *Lomatium* populations, Percent bare ground	Ungulate browsing, invasive species, adjacent land use, fire, overwatering, aging, regional climate change, sheep drive, beaver ponds, adjacent land use	Pre-settlement conditons
	Big sagebrush community	Community extent and change over time, Community composition, Trend in invasive infestation	Ungulate browsing, invasive species, adjacent land use, fire, aging, regional climate change, sheep drive, beaver ponds, adjacent land use	Pre-settlement conditons
	Aspen woodlands	Community extent and change over time, Community composition, Trend in invasive infestation, Rate of regeneration (suckers per hectare)	Ungulate browsing, invasive species, adjacent land use, disease and pests, drought, regional climate variation, Sudden Aspen Decline, beaver harvesting	Disease- and pest-free state that existed in stands prior to current conditoin
	Mixed conifer (Douglas Fir/Limber Pine) Woodlands	Community extent and change over time, Community composition, Regeneration, Age class distribution	Adjacent land use, regional climage variation, disease and pests, fire	Pre-settlement conditons
	Seeps, springs, slump pond aquatic habitat, (including longer ribbons of creek/riparian habitat)	Community extent and change over time, Community composition, Aquatic macroinverts richness, Water chemistry, Discharge, Trends in invasive plant species infestation	Regional climate variation, erosion; drought, invasive species, adjacent land use	Pre-settlement conditons
	Cushion plant communities (windswept ridges)	Relative abundance of *Physaria* , Community composition, Trends in invasive infestation	Invasive species, elk (compression and herbivory), nitrogen deposition	Pre-settlement conditons

Figure 7. Fossil Butte National Monument natural resource condition assessment framework.

Fossil Butte National Monument
Natural Resource Condition Assessment Framework

	Component	Measures	Stressors	Reference Condition
Biotic Composition				
Ecological Communities				
	Alkali flats community (greasewood, pepperweed)	Relative abundance of *Lepidium,* Community extent and change over time, Ccommunity composition, Trends in invasive infestation, Percent bare ground	Excessive precipitation, regional climate variation, nitrogen/sulfur deposition, sheep drives, invasive species, adjacent land use	Pre-settlement conditons
	Montane shrublands (mtn mahoghany, serviceberry)	Community extent and change over time, Community composition, Trend in invasive infestation, Percent bare ground	Ungulate browsing, invasive species, regional climate variation, drought	Pre-settlement conditons
Herptiles				
	Herptiles	Amphibian richness, Amphibian abundance, Distribution of ambibians, Reptile richness, Reptile abundance, Distribution of reptiles	Non-native species, habitat loss, drought; regional climate variation, erosion, disease, deposition of heavy metals/acids	Historic accounts of species present in the region
Birds				
	Birds (migratory and resident)	Summer breeding bird richness, Year-round bird richness, Raptor richness, Raptor productivity	Non-native species, habitat loss or degradation, powerlines, potential wind energy, wintering habitat loss,	Historic accounts of species present in the region
	Greater Sage grouse	Number of active leks, Male lek attendence, Apparent nest success, Brood size	Raptor impact (sport killing, predation), nesting/chicks predation, stock drive through nesting ground, fire, change in sage brush habitat, human impacts	Historic accounts of species present in the region
Mammals				
	Pygmy rabbit	Extent of suitable/preferred sagebrush habitat available, Relative abundance, Number of burrows and burrow complexes, Reproductive success, Annual survival	Changes in sagebrush, predation, removal by relocation, human impacts, disease	Historic accounts of presence and distribution, presence of stable population on monument

Figure 7 (continued). Fossil Butte National Monument natural resource condition assessment framework.

Fossil Butte National Monument
Natural Resource Condition Assessment Framework

	Component	Measures	Stressors	Reference Condition
Biotic Composition				
Mammals				
	Elk	Regional population estimate, Extent of browse on preferred food species (primary, secondary, tertiary), Male:Female ratio, Reproductive success (measured as cow:juvenile ratio)	Disease potential, disease transfer (brucelosis), population and distribution, hunting outside park boundaries, winter conditions, regional climate variation, food availability	Historic accounts of herd size
Environmental Quality				
	Dark Night Skies	NPS Night Sky Team's suite of measures	Nearby oil and gas drilling	Pre-settlement of the region
	Viewscape	To be completed as a non-evaluative piece that features a description of current viewscape and how this has changed in 10-15 year increments since the mid-1800s	Wind energy; natural gas and oil development; power transmission lines, potential development of the Hwy 30 corridor	
Physical Characteristics				
Geology				
	Paleontological Resources (fossils)	Documentation and inventory of sites in the park, Changes in specimen abundance at paleontoligical localities, Rates of erosion exposing paleontological resources	Climate change, visitor impact, theft, extreme weather	Undefined

Figure 7 (continued). Fossil Butte National Monument natural resource condition assessment framework.

3.2.2. Reporting Area

Unless specifically noted, the current condition summaries describe the condition of the resource within the boundaries of FOBU.

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 further analyzed to provide summaries of resource condition or to create new spatial representations. After all data and literature relevant to the measures of each component were reviewed and considered, a qualitative statement of overall current condition was created and compared to the reference condition when possible.

Data Mining

The data mining process (acquiring as much relevant data about key resources as possible) began at the initial scoping meeting, at which time FOBU 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, databases, tabular data, and charts. GIS data were also provided by NPS staff. Additional data and literature were 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 for the component, as well as recommendations from NPS reviewers and sources of expertise including NPS staff from FOBU and the NCPN. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Scoring Methods and Assigning Condition

Significance Level

A set of measures are useful in describing the condition of a particular component, but all measures may not be equally important. A “Significance Level” (SL) represents a numeric categorization (integer scale from 1-3) of the importance of each measure in assessing the component’s condition; each SL is defined in Table 6. This categorization allows measures that are more important for determining condition of a component (higher SL) to be more heavily weighted in calculating an overall condition. Significance Levels were determined for each component measure in this assessment through discussions with park staff and/or outside resource experts.

Table 6. Scale for a measure's Significance Level in determining a components overall condition.

Significance Level (SL)	Description
1	Measure is of low importance in defining the condition of this component.
2	Measure is of moderate importance in defining the condition of this component.
3	Measure is of high importance in defining the condition of this component.

Condition Level

After each component assessment is completed (including any possible data analysis), SMUMN GSS analysts assign a Condition Level (CL) for each measure on a 0-3 integer scale (Table 7). This is based on all the available literature and data reviewed for the component, as well as communications with park and outside experts.

Table 7. Scale for Condition Level of individual measures.

Condition Level (CL)	Description
0	Of **NO** concern. No net loss, degradation, negative change, or alteration.
1	Of **LOW** concern. Signs of limited and isolated degradation of the component.
2	Of **MODERATE** concern. Pronounced signs of widespread and uncontrolled degradation.
3	Of **HIGH** concern. Nearing catastrophic, complete, and irreparable degradation of the component.

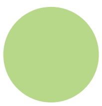
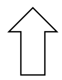
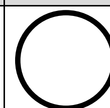
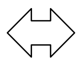
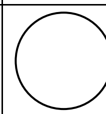
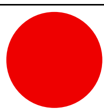
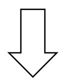
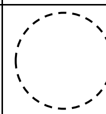
Weighted Condition Score

After the SLs and CLs are assigned, a Weighted Condition Score (WCS) is calculated via the following equation:

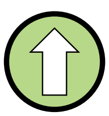
$$WCS = \frac{\sum_{i=1}^{\#\,of\,measures} SL_i * CL_i}{3 * \sum_{i=1}^{\#\,of\,measures} SL_i}$$

The resulting WCS value is placed into one of three possible categories: good condition (WCS = 0.0-0.33); condition of moderate concern (WCS = 0.34-0.66); and condition of significant concern (WCS = 0.67-1.00). Table 8 displays the potential graphics used to represent a component's condition in this assessment. The colored circles represent the categorized WCS; red circles signify a significant concern, yellow circles a moderate concern, and green circles that a resource is in good condition. White circles are used to represent situations in which SMUMN GSS analysts and park staff felt there were currently insufficient data to make a statement about the condition of a component. For example, condition is not assessed when no recent data or information are available, as the purpose of an NRCA is to provide a "snapshot-in-time" of current resource conditions. The arrows inside the circles indicate the trend of the condition of a resource component, based on data and literature from the past 5-10 years, as well as expert opinion. An upward pointing arrow indicates the condition of the component has been improving in recent times. A horizontal arrow indicates an unchanging condition or trend, and an arrow pointing down indicates deterioration in the condition of a component in recent times. These are only used when it is appropriate to comment on the trend of condition of a component. In situations where the trend of the component's condition is currently unknown, no arrow is given.

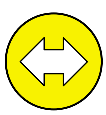
Table 8. Description of symbology used for individual component assessments.

Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

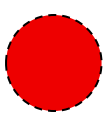
Example indicator symbols with descriptions of how they should be interpreted:



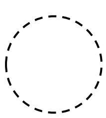
Resource is in good condition; its condition is improving; high confidence in the assessment.



Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.



Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.



Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

Preparation and Review of Component Draft Assessments

The preparation of draft assessments for each component was a highly cooperative process among SMUMN GSS analysts and FOBU and NCPN staff. Though SMUMN 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 insights into the appropriate direction for analysis and assessment of each component. This step is especially important when data or literature is limited for a resource component.

The process of developing draft documents for each component began with a detailed phone or e-mail conversation with an individual or multiple individuals considered local experts on the resource components under examination. These conversations were a way for analysts to verify the most relevant data and literature sources that should be used and also to formulate ideas about current condition with respect to the NPS staff opinions. Upon completion, draft assessments were forwarded to component experts for initial review and comments.

Development and Review of Final Component Assessments
Following review of the component draft assessments, analysts used the review feedback from resource experts to compile the final component assessments. As a result of this process, and based on the recommendations and insights provided by FOBU resource staff and other experts, the final component assessments represent the most relevant and current data available for each component and the sentiments of park resource staff and outside resource experts.

Format of Component Assessment Documents
All resource component assessments are presented in a standard format. The format and structure of these assessments is described below.

Description
This section describes the relevance of the resource component to the park and the context within which it occurs in the park setting. For example, a component may represent a unique feature of the park, it may be a key process or resource in park ecology or it may be a resource that is of high management priority. Also emphasized are interrelationships that occur among the featured component and other resource components included in the NRCA.

Measures
Resource component measures were defined in the scoping process and refined through 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.

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 NPS experts or SMUMN 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 are presented and interpreted in this section.

Threats and Stressor Factors
This section provides a summary of the threats and stressors that may impact the 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 resource experts and NPS 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 or trend 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 seeking 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 using the WCS method. Condition is determined after thoughtful review of available literature, data, and any insights from NPS 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. Also included in this section are the graphics used to represent the component condition.

Sources of Expertise
This is a listing of the individuals (including their title and affiliation with offices or programs) who had a primary role in providing expertise, insight, and interpretation to determine current condition (and trend when appropriate) for each resource component.

3.3. Study Design for Climate Change Vulnerability Pilot

3.3.1. Component Selection and Assessment Variables

Selection of Resources

A landscape scale community-based assessment was employed for the purpose of this pilot study. The selection of this type of assessment was based on the premise that plant communities and their related landscapes are the foundations for habitat and species. Plant communities are often priority resources that park managers express concern over when looking at ongoing park threats and long-term park resource sustainability. SMUMN GSS, the FOBU NRCA project team, and the NPS climate change integration pilot team worked together to select two vegetation communities from the NRCA framework for an analysis of potential impacts from ongoing and future climate change. By selecting communities from this framework, the climate change integration pilot study would be a park-centric approach and could build on the established NRCA process. Several considerations were taken into account during the discussions on selecting the components for inclusion in the pilot study. A specific set of selection criteria were not established; however, FOBU resource managers were asked to consider their long-term management as part of the selection process. With guidance from SMUMN GSS and the NPS CCRP, FOBU resource managers selected montane shrublands, an iconic and important park plant community, and seep, spring and slump pond aquatic habitats, which depend upon unique physical resources, as the two communities to include in the pilot study. It is important to note that the climate assessment will be based on how representative plant communities within these habitats could be affected by climate change. This assessment will only have a limited analysis of how climate change will affect the availability of water or the overall aquatic habitat.

Variables of Interest

The approach utilized in this study is based on a modified community assessment methodology used by Amberg et al. (2012) in a climate change vulnerability assessment completed for Badlands National Park (BADL). Amberg et al. (2012) employed a modified adaptation of an approach originally developed by Hector Galbraith (Manomet Center for Conservation Sciences, Manomet, MA) that was used to assess the vulnerability of habitats in 13 northeastern states. Galbraith’s original approach used 11 variables to assess vulnerability (Galbraith 2011). Each variable was designed to capture to some degree either sensitivity, exposure, or adaptive capacity of a diversity of ecological communities, in an effort to assess their overall vulnerability to climate shifts (Figure 8). Amberg et al.’s (2012) adaptation of Galbraith’s approach selected six of the original variables to assess the vulnerability of the BADL plant communities to climate change. These six variables are (descriptions based on Galbraith 2011):

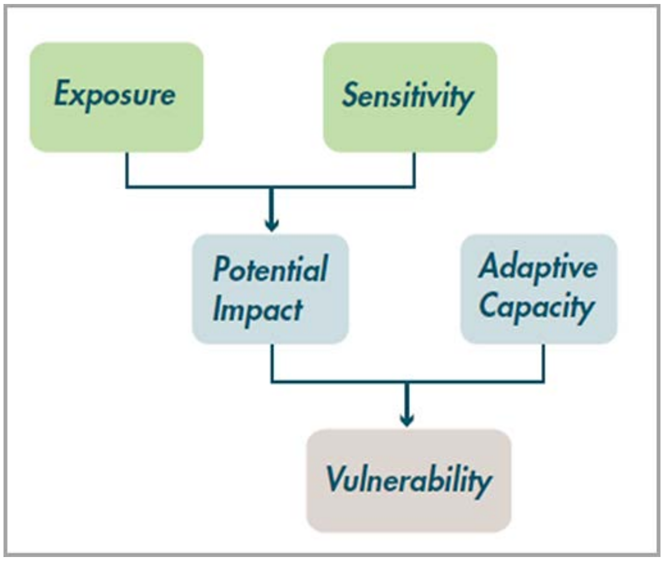


Figure 8. Relationship between exposure, sensitivity, and adaptive capacity (Stein et al. 2011).

- Location in geographical range of plant community. Plant communities near the southern extremes of their distributions or close to the southern edges of their climatic tolerance range may be more vulnerable to a warming climate than communities that are further north of these bioclimatic edge zones. Plant communities closer to the northern edge of their current range/limit may benefit by being able to extend northward.
- Sensitivity to extreme climatic events. Some plant communities may be more vulnerable than others to extreme climatic events or climate-induced events (drought, floods, ice storms, windstorms). Such events are projected to become more frequent and/or intense under climate change.
- Dependence on specific hydrologic conditions. Some plant communities are confined to areas with specific and relatively narrow hydrologic conditions. Changes in precipitation amount, type (snow vs. rain), and timing are projected under all climate change models (though the direction and degree of change vary across models), potentially threatening these community types.
- Intrinsic adaptive capacity. All plant communities are likely to have characteristics that may enable them to withstand some effects of climate change. However, their adaptive capacities (the ability to resist or recover from stress) will vary, depending on their intrinsic and extrinsic characteristics and their condition:
  - The physical diversity within which a plant community exists may affect its resilience and adaptive capacity. Communities with diverse physical and topographical characteristics (variety in aspects, slopes, geologies and soil types, elevations) may be more able to survive climate change than communities that are less varied. The former, by existing across widely differing conditions, may be at lower risk of being eliminated by any future climatic conditions.
  - Some plant communities may be intrinsically more resistant to stressors due to more rapid regeneration times. Communities with shorter recovery periods (<20 years) may have greater

intrinsic adaptive capacities than slower- developing communities (recovery times of >20 years). For example, woodlands may take a hundred years or more to recover from fire or pest impacts. This may render them intrinsically more vulnerable to the potential intervening effects of climate change than plant communities with shorter recovery periods (e.g., grasslands or shrub communities).

  - The current conditions of plant communities will also affect their adaptive capacities. Communities that support their full complement of species (or close to that), have high biodiversity, and that are relatively free from non-climate stressors are likely to be both more resistant and resilient to the effects of a changing climate. In contrast, plant communities that are in "poorer" condition with comparatively impoverished biodiversity, or that are being impacted by other stressors, may be less resilient and have lower adaptive capacity

- Vulnerability of ecologically influential species to climate change. Ecologically influential species are those that have substantial influences on community structure. Examples are abundant plant species, such as big sagebrush in sagebrush shrublands, whose disappearance from the system would significantly alter plant composition and community structure. If there is reason to believe that ecologically influential species in a plant community are particularly vulnerable to climate change, the whole community may be in jeopardy.
- Potential for climate change to exacerbate impacts of non-climate stressors. For some plant communities, it is likely that significant impacts of climate change will be expressed through their exacerbating or mitigating effects on current or future non-climate stressors. One example is the potential magnifying effects of warming temperatures on cold-limited pest species (e.g., bark beetles) or invasive species. This variable is intended to capture the potential effects of this interaction between climate change and non-climate change stressors.

3.3.2. General Approach and Methods

This CCVA involved gathering and reviewing existing literature and data relevant to the two selected ecological communities. No new data were collected for this study; however, where appropriate, existing data were further analyzed to provide summaries of resource condition or to create new spatial representations.

<u>Data Mining</u>

Recent historical climate patterns for FOBU were evaluated using PRISM gridded climate data. These data are produced by the PRISM climate group at Oregon State University (Daly et al. 2002, PRISM 2015), and the analysis was completed by the NCCSC.

The PRISM climate group uses point data, a digital elevation model, and other spatial data sets to generate gridded estimates of monthly, yearly, and event-based climatic parameters, such as precipitation, temperature, and dew point. PRISM is constantly updated to map climate in all situations, including high mountains, rain shadows, temperature inversions, coastal regions, and other complex climatic regimes. The PRISM system uses data from about 8,000 climate observation stations, and the results are considered state-of-the-art (Daly et al. 2002).

While PRISM data are both spatially and temporally complete, older data are estimated from fewer on-the-ground observations and these data are thus generally less reliable than more modern observations. PRISM data for the FOBU area are likely highly reliable at the spatial and temporal scale of this analysis. Davey et al. (2006) inventoried climate observation stations relevant to monitoring parks in the NCPN, and included 17 records of stations relevant to evaluating FOBU's climate. Two of these 17 stations included climate observations from earlier than 1910. PRISM uses correlations between stations for infilling missing data, and the more than 100 years of observations provides a very rich climate data set. PRISM data are well-suited for evaluating regional-scale and longer-term climate patterns and dynamics, but they cannot capture weather dynamics at the scale of local convection storms that occur between observation stations, for example.

Climate projection summaries for FOBU were produced using statistically downscaled model projections for temperature (minimum and maximum), precipitation, and aridity. These datasets provide bias-corrected and spatially downscaled climate projections and are typically referred to as Bias Correction followed by Spatial Disaggregation (BCSD). They were corrected for model-observation biases in mean monthly temperature and then processed at various spatial scales (i.e., 'disaggregated') to accommodate mismatches between the global model outputs and local topographical and other effects.

Data Development and Analysis

For this assessment, historical climate patterns and projected climate changes out to the year 2100 were examined for the FOBU region. Historical climate patterns (mean minimum and maximum temperatures and total precipitation) were analyzed to create a picture of climate in FOBU during the past century. Using PRISM climate data, historical temperature and precipitation patterns for the FOBU area were summarized and evaluated to build a context of historical climate to which future climatic projections may be compared. Specifically, mean monthly minimum and maximum temperature (°C) and total monthly precipitation (mm) from 1895 to present were examined.

Given the limited funding and scope of this pilot project, analyses were only possible for a single future climate projection. For the purposes of the vulnerability assessments in this study, the climate change integration team selected the "business as usual" representative concentration pathway (RCP) 8.5 scenario and a general circulation model (GCM) ensemble average. This is recognized as a necessary limitation of this pilot effort. The high emissions RCP 8.5 is considered a "baseline" scenario, as it does not assume a climate mitigation target (Riahi et al. 2011). For more information on the RCP and how they were developed, please refer to Appendix A.

Scoring Methods and Assigning Vulnerability Score

Each of the six variables defined above were independently assessed and assigned a "best estimate" score from 1 (least vulnerable) to 5 (most vulnerable) on the likely vulnerability of a plant community to future climate change (based on the available scientific literature, data, and expert opinion). Scores were summed to produce an overall score of a plant community's vulnerability. The total minimum score was six and the total maximum score was 30. The overall score was then classified into one of four categories: critically vulnerable, highly vulnerable, moderately vulnerable, and less vulnerable (Table 9). These translate into community response categories, ranging from a plant community likely to be eradicated or greatly reduced in extent within the study area to a plant community that may sustain modest reduction or actually increase in extent within the study area.

Table 9. Scale for results of climate change vulnerability analysis.

Vulnerability Score	Description
6-13	Least vulnerable - plant communities that may not be at adverse risk from climate change, or that may benefit and increase their extents within the study area.
14-19	Moderately Vulnerable – plant communities at risk of being considerably reduced (by 20-50%) in extent by climate change.
20-25	Highly vulnerable – plant communities at high risk of being greatly reduced (>50%) in extent by climate change.
26-30	Critically vulnerable – plant communities at high risk of being eliminated entirely from the study area by climate change.

Uncertainty Evaluation and Confidence in Vulnerability Assessments

Uncertainty is inherent at many stages in assessing climate change vulnerability, including the climate modeling process, assumptions about vulnerabilities of resources to climate shifts and/or non-climate stressors (and how these interact), and assumptions about the adaptive capacities of the resources. Many uncertainties are unavoidable despite best modeling and data gathering efforts. It is crucial to provide a comprehensive and detailed appraisal of certainty in vulnerability scores so that resource managers can determine how best to use the vulnerability information presented to them on the potential impacts of climate change.

Uncertainty in the plant community assessments is addressed in two ways: certainty evaluations/scores and alternative scores. Certainty scores are a method of documenting how confident analysts are regarding the validity and accuracy of the original vulnerability scores assigned to each variable (not the alternative scores). The scale of certainty scores used in this draft assessment is the same scale used by Galbraith (2011), which is an adaptation of a category scale developed by Moss and Schneider (2000) for the Intergovernmental Panel on Climate Change (IPCC). One of three certainty scores – Low (1), Moderate (2), or High (3) – was applied to the original vulnerability score for each variable. The certainty scores for each variable were then summed up to determine a certainty evaluation for the overall vulnerability score of the plant community. The total minimum score was six and the total maximum score was 18. These certainty scores translate to a level of confidence – low, moderate, or high confidence – about the judgments made regarding the vulnerability scores for each variable (Table 10).

Table 10. Scale for results of CCVA uncertainty analysis.

Uncertainty Score	Description
6-10	Low confidence - Low certainty (approximates <30% certainty).
11-14	Moderate confidence - Moderate certainty (approximates 30% to 70% certainty).
15-18	High confidence - High certainty (approximates >70% certainty).

When a clear "best estimate" vulnerability score did not stand out, the analyst had the option of assigning an alternative score (a highly possible but less likely outcome than the best estimate) in addition to the best estimate score. The alternative score is the "next best estimate" of vulnerability for a variable, taking into account the uncertainty attached to a variable (i.e., the lack of information or understanding about a plant community or a species). These alternative scores, in conjunction with the best estimate vulnerability score, serve to capture the range of highly likely possibilities that may exist for the vulnerability of a plant community (adapted from Galbraith and Price 2011). When certainty is high, vulnerability will likely be represented by a single value; when certainty is low, vulnerability will be represented by a range of scores. The alternative scores also show the potential direction of the vulnerability, in that an alternative score for a variable may reflect a lesser or greater vulnerability due to uncertainty or data gaps in the literature (see Table 11 below as an example). For instance, the sensitivity of an ecologically influential plant or tree species in a community to extended periods of drought (variable = sensitivity to extreme climatic events) may be debated in the scientific literature in that several sources show a drought tolerance while another source reports an intolerance or sensitivity to drier conditions. In this case, alternative scores could represent lesser or greater vulnerability due to conflicting scientific literature. As another example, a resource may be assigned an alternative score that represents a higher degree of vulnerability due to high uncertainty related to very little or no available scientific data or information.

Table 11. An example of certainty and alternative vulnerability scores for plant community assessment variables. For individual certainty scores, 3 = high, 2 = moderate, and 1 = low; total ranges are 6-10 = low confidence, 11-14 = moderate confidence, 15-18 = high confidence.

Variable	Certainty Score	Vulnerability Score	Alternative Scores
Location in geographical range/distribution of plant community	3	3	N/A
Sensitivity to extreme climatic events (e.g., drought, flash floods, windstorms)	2	4	3,5
Dependence on specific hydrologic conditions	2	4	N/A
Intrinsic adaptive capacity	1	3	4
Vulnerability of ecologically influential species to climate change	2	4	3
Potential for climate change to exacerbate impacts of non-climate stressors	2	5	N/A
Total	**12**	**23**	**21-25**

Preparation and Review of Climate Change Vulnerability Analysis

Narratives for each assessment were created to clearly explain why certain assumptions and/or scores were adopted over other possibilities. It is important that this explanation provide sufficient detail and transparency to allow a reader to be able to clearly and easily follow the process and logic-steps that led analysts to conclusions about vulnerability. The purpose of the narratives is to clearly outline the review and evaluation of the scientific literature and the thought processes and assumptions that result in assigning the vulnerability scores to each of the variables of interest. When appropriate, GIS products, such as maps of distributions and ranges, were developed and included in the assessment to add depth and graphical representation to the interpretation of literature and data.

Once each narrative assessment was completed, it went through an iterative review process among SMUMN GSS analysts for consistency. Assessments were then provided to FOBU resource experts and other outside experts (e.g., university researchers, government scientists) for an external review in which the document was examined for accuracy of content, validity and accuracy of categorizations, and appropriateness of interpretation of available scientific literature. Following review by experts, the vulnerability assessment was modified to reflect feedback.

Integration of Climate Change Analysis into Natural Resource Condition Assessment Document

The resource component assessments will be presented in the standard format as described in Section 3.2.2 with the following changes made to incorporate the climate change analysis.

Current Condition and Trend

This section will be amended to include the discussion of the components vulnerability to climate change. The climate vulnerability subsection will precede the “Threats and Stressors” subsection. This includes how the projected change in climate will affect the variables of interest.

Overall Condition

This section provides a qualitative summary statement of the current condition that was determined for each of the resource components using the WCS method as described in Section 3.2.2. In addition, the vulnerability scoring for components that are part of the pilot study will be incorporated here, just prior to the “Weighted Condition Score” subsection. The vulnerability score is determined after thoughtful review of available literature and data regarding the component’s vulnerability to climate change that was presented in the Current Condition and Trend section. Also included in this section is a table with the results of the component’s climate change vulnerability assessment. This section will also include a brief summary of any uncertainty and related alternative scoring that may have been applied to the analysis of climate change vulnerability.

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Chapter 4. Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the 16 key resource components in the project framework. The following sections discuss the key resources and their measures, stressors, and reference conditions. The summary for each component is arranged around the following sections:

1. Description
2. Measures
3. Reference Condition
4. Data and Methods
5. Current Condition and Trend (including threats and stressor factors, data needs/gaps, and overall condition)
6. Sources of Expertise
7. Literature Cited

The order of components follows the project framework (Figure 7):

4.1 Low sagebrush community

4.2 Big sagebrush community

4.3 Aspen woodlands

4.4 Mixed conifer woodlands

4.5 Seeps, springs, and slump pond aquatic habitat

4.6 Cushion plant communities

4.7 Alkali flats community

4.8 Montane shrublands

4.9 Herptiles

4.10 Birds

4.11 Greater sage grouse

4.12 Pygmy rabbit

4.13 Elk

4.14 Dark night skies

4.15 Viewscape

4.16 Paleontological resources

4.1. Low Sagebrush Community

4.1.1. Description

Low sagebrush communities are common throughout FOBU (Jones 1993, Friesen et al. 2010). They occur at all elevations ranging from low lying flats to high elevation ridgelines (Friesen et al. 2010). They also can be found on valley sides (Friesen et al. 2010). In the most current vegetation mapping for FOBU the low sagebrush communities are mapped as low sagebrush shrubland and black sagebrush shrubland (Friesen et al. 2010). The black sagebrush shrubland is comprised of one plant association, the black sagebrush (*Artemisia nova*)/bluebunch wheatgrass shrublands, while the low sagebrush shrubland classification is comprised of eight plant associations (Friesen et al. 2010). These are the longleaf (alkali) sagebrush (*Artemisia arbuscula* ssp. *longiloba*)/cushion plants dwarf shrublands, longleaf sagebrush/streambank wheatgrass (*Elymus lanceolatus*) shrublands, longleaf sagebrush/muttongrass (*Poa fendleriana*) shrublands, longleaf sagebrush/Sandberg bluegrass (*Poa secunda*) shrub herbaceous vegetation, longleaf sagebrush/bluebunch wheatgrass shrub herbaceous vegetation, longleaf sagebrush shrubland, Gardner's saltbush (*Atriplex gardneri*) dwarf-shrubland, and Gardner's saltbush-longleaf sagebrush dwarf shrubland (Friesen et al. 2010).

Low sagebrush shrublands tend to be found in large patches or stands throughout the park (Friesen et al. 2010). They are found on deep, clay soils of relatively high salinity and alkalinity on valley floors, slopes, and ridges (Friesen et al. 2010, NPS 2015a). These sites have slopes ranging from gentle to steep (1-34°) and are normally found between 2,030-2,450 m (6,660-8,038 ft) in elevation (Friesen et al. 2010). They are found on all aspects except northern (Friesen et al. 2010). The black sagebrush shrubland was found in only two patches within FOBU, both located on Cundick Ridge, which connects The Bullpen and Fossil Butte (Friesen et al. 2010). Both sites have rapidly drained silt loam soil and a southwest aspect (Friesen et al. 2010). These sites occur at 2,352 m (7,717 ft) in elevation and have a gentle (2°) slope (Friesen et al. 2010).

Low sagebrush communities are characterized by a sparse to open shrub canopy that may contain other low shrub species (Friesen et al. 2010). The cover in the herbaceous layer is variable, and could have been reduced based on the history of livestock grazing (Friesen et al. 2010). Grasses provide the majority of the understory cover, however forbs are more abundant and diverse in the stands at higher elevations, were the low-growing plants more typical of FOBU's windswept ridges are dominant (Friesen et al. 2010).

The low sagebrush communities are important habitats for the greater sage grouse (*Centrocercus urophasianus*), providing areas for breeding and nesting as well as foraging areas (Blaisdell et al. 1982). Low sagebrush is also important habitat for small mammals, reptiles, and birds, although it does not generally provide much cover for larger mammals (Tilley and St. John 2012). However, mule deer and pronghorn will utilize low sagebrush and black sagebrush in certain locations under specific situations (Blaisdell et al. 1982).

4.1.2. Measures

- Extent and change over time
- Community composition
- Trend in invasive infestation
- Relative abundance of Lomatium populations
- Percent bare ground

4.1.3. Reference Conditions/Values

Park managers suggested the reference condition could be determined from the historic conditions described in the early United States Geological Survey (USGS) surveys by Hayden (1872), conditions of the area pre-settlement/grazing, or from information from railroad archives. Pollen profiles suggest that between about 5,000 and 200 years ago, FOBU was primarily open sagebrush-grassland (Dorn et al. 1984). Historical records (1834-1890) from government reports and naturalists indicate that FOBU was a sagebrush shrubland prior to European settlement, with the exception of a few trees at higher elevations, much as it is today (Dorn et al. 1984). Deteriorating sagebrush habitat due to ungulate grazing within FOBU is apparent in certain areas, increasing erosion and causing perennial grasses and forbs to be replaced by annual weeds and bare ground (Dorn et al. 1984). Areas impacted by this grazing include areas along Chicken Creek and its tributaries and around water developments in the northeast part of FOBU, with the rest of the park in good condition (Dorn et al. 1984).

It was determined that the Hayden (1872) surveys would not be suitable as a reference conditions, mainly due to the fact that the closest account was for Fort Bridger, Wyoming (approximately 64 km [40 mi] southeast of FOBU). Also this survey mainly describes the geologic features, providing little insight to the historic condition of the historic condition of the low sagebrush community. For the purposes of this assessment the pre-settlement condition described by Dorn et al. (1984) will be used as the reference condition for this assessment.

4.1.4. Data and Methods

Vegetation classification was first completed for FOBU in 1973 with a vegetation survey and mapping project conducted by Beetle and Marlow (1974). The purpose of this survey was two-fold, to create a map of the vegetation within FOBU and to create a baseline study of range conditions. This mapping project resulted in the definition of 12 vegetation classes within FOBU (Beetle and Marlow 1974). In 1984 Dorn et al. conducted field surveys for the purpose of updating the vegetation map and range conditions created by Beetle and Marlow. This project also analyzed the impacts of grazing at FOBU in the early 1980’s (Dorn et al. 1984). The project conducted by Dorn et al. (1984) resulted in the mapping of 12 vegetation types. The distribution of the vegetation types was primarily due to the depth, clay content and moisture content of the soil; however the distribution of some classes was controlled, at least partially, by exposure to wind (Dorn et al. 1984). Dorn et al. (1984) produced a vegetation map of these communities based on unrectified aerial photographs at a scale of 1:15,840 (Jones 1993, Friesen et al. 2010).

In 1992, the NPS contracted with The Nature Conservancy to classify and map the natural plant communities at FOBU (Jones 1993). The goals of this project were to confirm the accuracy of the Dorn et al. (1984) mapping and update as needed, and to describe the composition of the resultant map units based on common species present and estimates of their canopy cover (Jones 1993). Jones (1993) used field reconnaissance to ground-truth the accuracy of the vegetation polygons delineated by Dorn et al. (1984) and to determine if any of the vegetation polygons should be divided or combined. Jones (1993) found that the mapping produced by Dorn et al. (1984) was an accurate representation of vegetation within the park. Based on this field reconnaissance, a new vegetation map was digitized at a scale of 1:15,600 (Jones 1993). This map had only minor changes from the Dorn et al. (1984) map; boundaries between map units were slightly changed in several places and map labels (representing vegetation classification) were changed on several map units as well (Jones 1993). Jones (1993) also produced a companion document describing the dominant vegetation in each of the vegetation classes identified and surveyed during this study.

In 2000 (Fertig) compiled information (i.e. voucher specimens, literature, species lists) on the vascular plant species within FOBU. This was used to review and revise the existing plants list to eliminate synonyms and erroneously reported species (Fertig 2000). This new checklist included annotations on global and state abundance, state distribution pattern, growth form, major biome type, and initial year of discovery at FOBU (Fertig 2000). Fertig (2000) also conducted a data query of vascular plant species that occur in Lincoln County and compiled a list of those not reported in FOBU. This list of plant species was then cross-checked with range maps from the Rocky Mountain Herbarium to establish a record of plant species that were likely be found within FOBU, based on their known distributions and habitat preferences (Fertig 2000).

Fertig and Kyte (2009) further reviewed and developed the comprehensive list of plant species found within the park. This effort involved reviewing existing literature and re-examining specimens in the FOBU herbarium. It also included field work to confirm unverified species and to potentially locate new species. This list includes plants by habitat type, one of which is sage shrub, which includes plants from “big sagebrush or alkali (longleaf) sagebrush grassland and montane shrub communities.”

In 2001, a NCPN vegetation classification and mapping project, which included FOBU, was launched (Friesen et al. 2010). The goals of this project were to inventory, describe, and map the existing vegetation for parks within the network (Friesen et al. 2010). Data collection began with collection of stereo aerial photography in July 2004 (Friesen et al. 2010). Meetings to determine the FOBU project boundary, biophysical model parameters, supplemental fuels data and park specials were held in March 2005 (Friesen et al. 2010). The collection of vegetation plot and observation point data was conducted from 2005-2008 (Friesen et al. 2010). The completed vegetation mapping shows the location of 39 vegetation map classes present within FOBU and its surrounding area (Friesen et al. 2010). For the purposes of this assessment only the vegetation inventory and mapping within the FOBU administrative boundary was analyzed.

Invasive species monitoring has been conducted at FOBU beginning in 2008 (Perkins 2015). Perkins and Weissinger (2009) conducted the initial field surveys during the 2008 field season. Additional follow-up field surveys were conducted in 2009, 2010, 2012, and 2014 (Perkins 2015). The field surveys were conducted based on a list of priority invasive exotic species (IEPs) that had been developed by the staff at FOBU and the NCPN (Perkins 2015). All the field surveys used a minimum detection target size (MDTS) of 40 m^2 (431 ft^2 or approximately 20 x 20 ft) (Perkins 2015). Monitoring was conducted along routes and quadrats that were established along the roads, major drainages, and trails in the park (Perkins 2015). In addition to invasive species composition, data was also collected on several other attributes including canopy cover, infestation size class, and evidence of prior treatment (Perkins 2015).

4.1.5. Current Condition and Trend

<u>Community Extent and Change over Time</u>

Currently low sagebrush communities comprise approximately 1,164 ha (2,877 ac) or 35% of FOBU's vegetation (Figure 9, Friesen et al. 2010). In general, FOBU and the surrounding areas retain much of the same appearance and characteristics as it would have had prior to European settlement (Dorn et al. 1984). However, a closer look reveals that actions, such as heavy grazing occurring after settlement, may have altered the understory species at FOBU (Dorn et al. 1984). In some places perennial grasses and forbs have been replaced by weeds and invasive species or have been entirely removed leaving bare ground (Dorn et al. 1984). Additionally, the height of the sagebrush communities has increased overall (Dorn et al. 1984). Historical data also suggests that fire was a frequent part of FOBU's vegetation cycle, but has been suppressed since European settlement (Dorn et al. 1984).

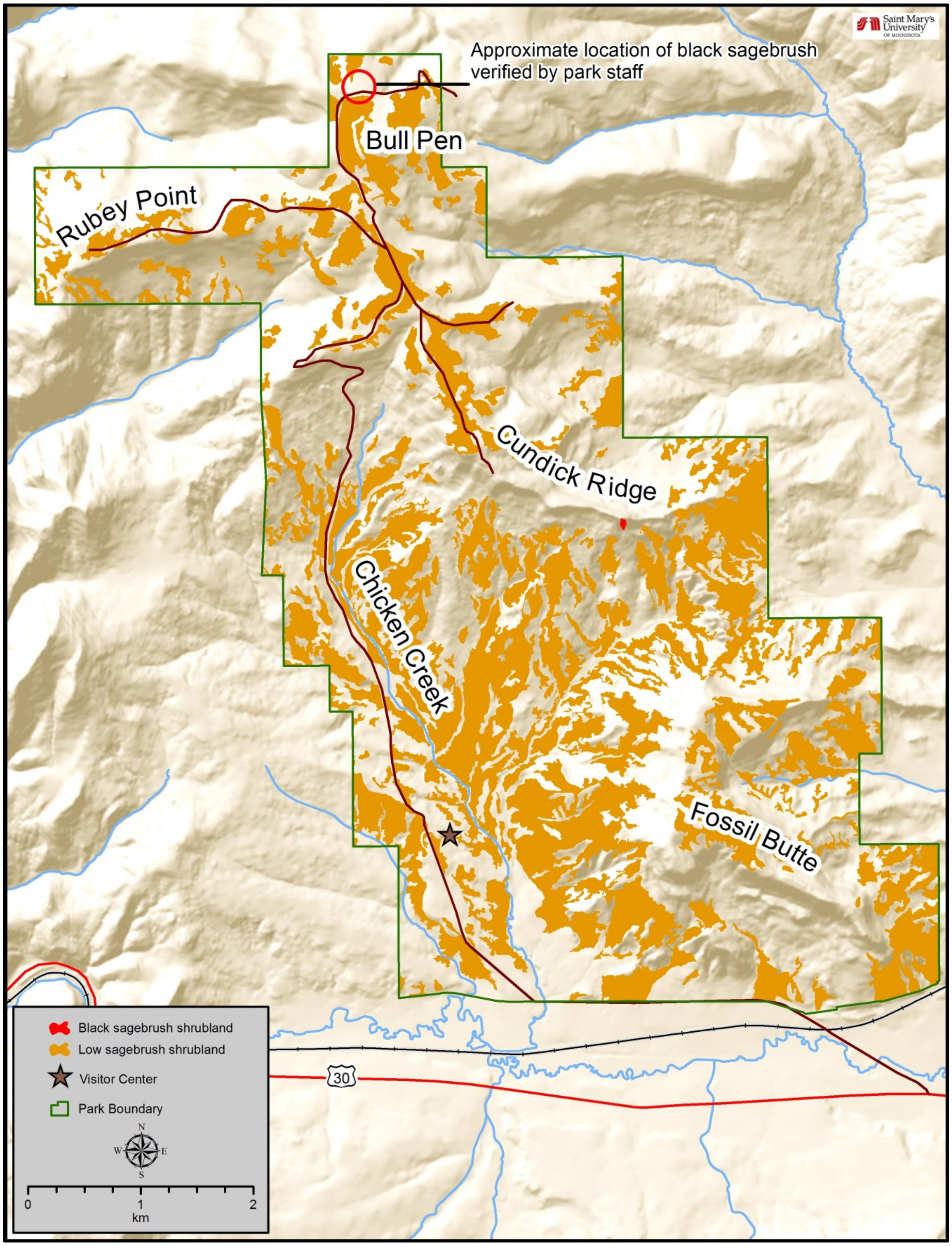

Figure 9. Low sagebrush vegetation classes mapped by Friesen et al. (2010).

A reference dataset that is comparable to the Friesen et al. (2010) vegetation mapping is needed in order to determine what, if any, change in extent has occurred in the low sagebrush communities at

FOBU. Beetle and Marlow (1973) mapped low sagebrush communities, but the data are not available in a digital, spatially rectified format. The vegetation mapping conducted by Dorn et al. (1984) is available but cannot be used as a reference condition due to spatial inaccuracies in the mapped vegetation classifications resulting from the process used to create the vegetation class boundaries. Dorn et al. (1984) used unrectified aerial imagery to create maps of vegetation boundaries (Friesen et al. 2010). The use of unrectified aerial imagery can result in errors placement of vegetation polygon boundaries, as well as the actual on the ground location of these polygons (Friesen et al. 2010). These errors could have been compounded with the transfer to the USGS 1:24,000 scale quadrangle maps and subsequent digitizing of these boundaries to create a spatial dataset (Friesen et al. 2010). Also, the study conducted by Dorn et al. (1984) was a grazing study and not an all-inclusive vegetation survey. The vegetation study and mapping conducted by Jones (1993), while not as comprehensive as Friesen et al. (2010) and utilizing different vegetation classifications, does have data that can be used as a reference condition for this measure.

Both Dorn et al. (1984) and Jones (1993) classified and mapped these communities as alkali sagebrush map units. Jones (1993) described this classification as a major map unit. These stands are found throughout the park, occurring on deep, clay-rich soils (Dorn et al. 1984, Jones 1993). Based on the updates to the Dorn et al. (1984) mapping, Jones (1993) found that alkali sagebrush communities covered approximately 23% (753 ha [1,861 ac]) of the park.

Currently the low sagebrush shrubland communities are common throughout FOBU and can be found at all elevations (Figure 9, Friesen et al. 2010). The longleaf sagebrush/cushion plants dwarf shrublands are found along the high slope of Rubey Point and on a slope within the Chicken Creek drainage (Friesen et al. 2010). The longleaf sagebrush/streambank wheatgrass shrublands occur on the tops of Rubey Point and Fossil Butte (Friesen et al. 2010). Longleaf sagebrush/muttongrass shrublands are located on a badlands formation associated with Chicken Creek, near The Bullpen, and on the high slopes of Rubey Point (Friesen et al. 2010). The longleaf sagebrush/Sandberg bluegrass shrub herbaceous vegetation association is found throughout the southern half of FOBU (Friesen et al. 2010). The longleaf sagebrush/bluebunch wheatgrass shrub herbaceous vegetation association is located on the tops of Rubey Point and Fossil Butte and on a low ridge to the east of the visitor center (Friesen et al. 2010).

The longleaf sagebrush shrubland association occurs throughout the southern half of FOBU (Friesen et al. 2010). Gardner's saltbush dwarf-shrubland is located on toeslopes, alluvial fans and a ridge along the southern boundary of FOBU (Friesen et al. 2010). Gardner's saltbush-longleaf sagebrush dwarf shrubland is located on alluvial fans, a swale, and a badlands formation near the southern border of FOBU and near the historic quarry (Friesen et al. 2010). Friesen et al. (2010) located only one stand of the black sagebrush/bluebunch wheatgrass shrubland association during their vegetation inventory. This stand was located on the top of Cundick Ridge (Figure 9, Friesen et al. 2010). The current existence of this stand could not be verified by park staff; however they did confirm the presence black sagebrush in the extreme northern portion of the park (Marcia Fagnant, Chief of Interpretation FOBU, written communication, 6 April 2016, Figure 9).

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Community Composition

As previously cited in this chapter, several vegetation identification/mapping projects have been undertaken at FOBU. Two of the 12 vegetation classes identified by Beetle and Marlow (1974), "alkali (longleaf) sagebrush and grass complex" and "shadescale saltbush (*Atriplex confertifolia*) and alkali (longleaf) sagebrush complex," could be considered low sagebrush communities. Fertig and Kyte (2009) included "big sagebrush or alkali (longleaf) sagebrush grassland and montane shrub communities" within their classification system. Both of these projects could be used in determining community composition, however since they are not exclusively "low sagebrush communities" other species could also be included in the species lists provided by these projects. Dorn et al. (1984) identified a total of 80 plant species within the low sagebrush community. They consisted of 12 shrubs, 13 grasses and 55 forbs. The shrub stratum in this community was dominated by longleaf sagebrush (Dorn et al. 1984). The most common species in the understory included the grasses spike fescue (*Leucopoa kingii*), Cusick's bluegrass (*Poa cusickii* ssp. *cusickii*), slender wheatgrass (*Elymus trachycaulus* ssp. *trachycaulus*) and the forbs Columbia groundsel (*Senecio integerrimus* var. *exaltatus*), leafy bluebells (*Mertensia oblongifolia*), hollyleaf clover (*Trifolium gymnocarpon* ssp. *plummerae*), Eaton's daisy (*Erigeron eatonii*), spreadingpod rockcress (*Boechera divaricarpa*) and many-flowered phlox (*Phlox multiflora*) (Dorn et al. 1984). Due to the problems with the Dorn et al. (1984) dataset explained in the section above, this could also not be used as a reference condition. While Jones (1993) updated the accuracy of the Dorn et al. (1984) mapping, specific information on the composition of each vegetation classification was limited to select stands and does not provide a comprehensive examination of composition. At this time, no reference condition for community composition is available and therefore it is considered a data gap.

Friesen et al. (2010) listed 47 plant species found within low sagebrush communities of FOBU. These species consisted of 16 shrubs, 8 grasses, and 23 forbs. The most commonly occurring shrub species in the Friesen et al. (2010) vegetation mapping include longleaf sagebrush, Gardner's saltbrush, green rabbitbrush (*Chrysothamnus viscidiflorus* ssp. *viscidiflorus*), spiny saltbush, and winterfat. In the herbaceous strata the most common plants consisted of the grasses muttongrass and thickspike wheatgrass and the forbs hollyleaf clover, shortstem buchwheat and various species of *Phlox* including Hood's phlox (*Phlox hoodii*) and may-flowered phlox (Friesen et al. 2010). A list of the species identified by Friesen et al. (2010) within the low sagebrush communities are listed in Table 12, Table 13, and Table 14. These tables are organized by vegetation type.

Table 12. Shrub species found in low sagebrush communities of FOBU by Friesen et al. (2010). The table includes the NPSpecies abundance level for (NPS 2015b).

Scientific Name	Common Name	NPSpecies Abundance
Amelanchier utahensis	Utah serviceberry	Common
Artemisia arbuscula ssp. *longiloba*	longleaf sagebrush	Common
Artemisia frigida	fringed sagebrush	Uncommon
Artemisia nova	black sagebrush	Rare
Artemisia tridentata ssp. *tridentata*	basin big sagebrush	Abundant
Artemisia tridentata ssp. *vaseyana*	mountain big sagebrush	Abundant
Artemisia tripartita	threetip sagebrush	No data
Atriplex confertifolia	spiny saltbush	Uncommon
Atriplex gardneri	Gardner's saltbrush	Uncommon
Cercocarpus montanus	true mountain-mahogany	Common
Chrysothamnus viscidiflorus ssp. *viscidiflorus*	green rabbitbrush	Common
Ericameria nauseosa	rubber rabbitbrush	Uncommon
Eriogonum microthecum	slenderbush buckwheat	Uncommon
Krascheninnikovia lanata	winterfat	Common
Symphoricarpos oreophilus var. *utahensis*	Utah snowberry	Common
Tetradymia spinosa	catclaw horsebrush	Uncommon

Table 13. Grass species found in low sagebrush communities of FOBU by Friesen et al. (2010). The table includes the NPSpecies abundance level for (NPS 2015b).

Scientific Name	Common Name	NPSpecies Abundance
Achnatherum hymenoides	Indian ricegrass	Common
Elymus elymoides ssp. *elymoides*	bottlebrush squirreltail	Uncommon
Elymus lanceolatus ssp. *lanceolatus*	thickspike wheatgrass	Uncommon
Leymus cinereus	Great Basin wildrye	Common
Pascopyrum smithii	western wheatgrass	Common
Poa fendleriana	muttongrass	Common
Poa secunda ssp. *juncifolia*	big bluegrass	Uncommon
Pseudoroegneria spicata	bluebunch wheatgrass	Common

Table 14. Forb species found in low sagebrush communities of FOBU by Friesen et al. (2010). The table includes the NPSpecies abundance level for (NPS 2015b).

Scientific Name	Common Name	NPSpecies Abundance
*Alyssum desertorum**	desert alyssum	Uncommon
Antennaria dimorpha	low pussytoes	Uncommon
Astragalus bisulcatus var. *bisulcatus*	two-grooved milkvetch	Rare
Astragalus jejunus	starveling milkvetch	Uncommon
Astragalus vexilliflexus	bent-flowered milkvetch	No data
Balsamorhiza sagittata	arrowleaf balsamroot	Uncommon
Comandra umbellata	bastard toad-flax	Uncommon
Cordylanthus ramosus	bushy birdbeak	Uncommon
Eremogone hookeri	Hooker's sandwort	No data
Erigeron nanus	dwarf daisy	Uncommon
Eriogonum brevicaule	shortstem buckwheat	Uncommon
Eriogonum umbellatum	sulfur buckwheat	Uncommon
Iva axillaris	poverty-weed	Uncommon
Linum lewisii	blue flax	Uncommon
Minuartia nuttallii	Nuttall's sandwort	Uncommon

* Non-native species

Table 14 (continued). Forb species found in low sagebrush communities of FOBU by Friesen et al. (2010). The table includes the NPSpecies abundance level for (NPS 2015b).

Scientific Name	Common Name	NPSpecies Abundance
Phlox hoodii	Hood's phlox	Common
Phlox longifolia	long-leaf phlox	Uncommon
Pteryxia terebinthina	turpentine spring-parsley	Uncommon
*Ranunculus testiculatus**	hornseed buttercup	Uncommon
Sedum lanceolatum	lanceleaved stonecrop	Uncommon
Stenotus acaulis	stemless goldenweed	Uncommon
*Taraxacum officinale**	common dandelion	Uncommon
Trifolium gymnocarpon ssp. *plummerae*	hollyleaf clover	Uncommon

* Non-native species

Trend in Invasive Infestation

Extensive surveys for IEPs were performed in FOBU in 2008, 2009, 2010, 2012 and 2014 (Perkins 2015). Data are collected based on a priority invasive plants list (Table 15) that was developed by the NCPN and park staff in 2008 (Perkins 2015). The list was developed based on the review of past park literature, state and county weed lists, and consultation with park staff and county weed managers (Perkins 2015). Prior to each field season, the list is reviewed and amended based on park staff recommendations (Perkins 2015). Currently there are 24 high priority IEPs listed, including both existing IEPs and potential IEPs of high management concern (Perkins 2015). After the 2014 field season, FOBU staff requested that Japanese brome (*Bromus japonicus*) be added to the priority list for future invasive species monitoring (Perkins 2015).

Table 15. Priority IEP list for FOBU (Perkins 2015).

Scientific Name	Common Name
Alopecurus arundinaceus[A]	creeping foxtail
Arctium minus[D]	burdock
Bromus tectorum[B]	cheatgrass
Carduus nutans[D]	musk thistle
Centaurea diffusa[D]	diffuse knapweed

A = 2010-2014 only

B = 2014 only

C = 2012-2014 only

D = WY state noxious weed (WWPC 2015)

Table 15 (continued). Priority IEP list for FOBU (Perkins 2015).

Scientific Name	Common Name
Centaurea stoebe[D]	spotted knapweed
Cirsium arvense[D]	Canada thistle
Cirsium vulgare	bull thistle
Convolvulus arvensis[D]	field bindweed
Cynoglossum officinale[D]	common houndstongue
Descurainia sophia[C]	flixweed
Elymus repens[D]	quackgrass
Hyoscyamus niger[D]	black henbane
Isatis tinctoria[D]	Dyer's woad
Kochia scoparia	kochia
Lepidium appelianum	hairy whitetop
Lepidium chalepensis	orbicular whitetop
Lepidium latifolium[D]	perennial pepperweed
Linaria dalmatica[D]	Dalmatian toadflax
Melilotus officinalis	yellow sweetclover
Rhaponticum repens	Russian knapweed
Sonchus arvensis[D]/ *S. uliginosus*	perennial sowthistle
Tamarix ramosissima	tamarisk
Verbascum thapsus	woolly mullein

A = 2010-2014 only

B = 2014 only

C = 2012-2014 only

D = WY state noxious weed (WWPC 2015)

The same survey routes are used for each IEP survey period. Figure 10, from the 2012 survey, shows the routes where the invasive surveys are being conducted. In general, the results of the IEP surveys continue to show that the number of IEP detections decrease as you move away from the riparian areas and the Main Park Road (Perkins 2015). Additional analysis shows that the priority species that were consistently recorded from 2008-2014 (Table 15) have remained relatively similar and many have declined (Perkins 2015).

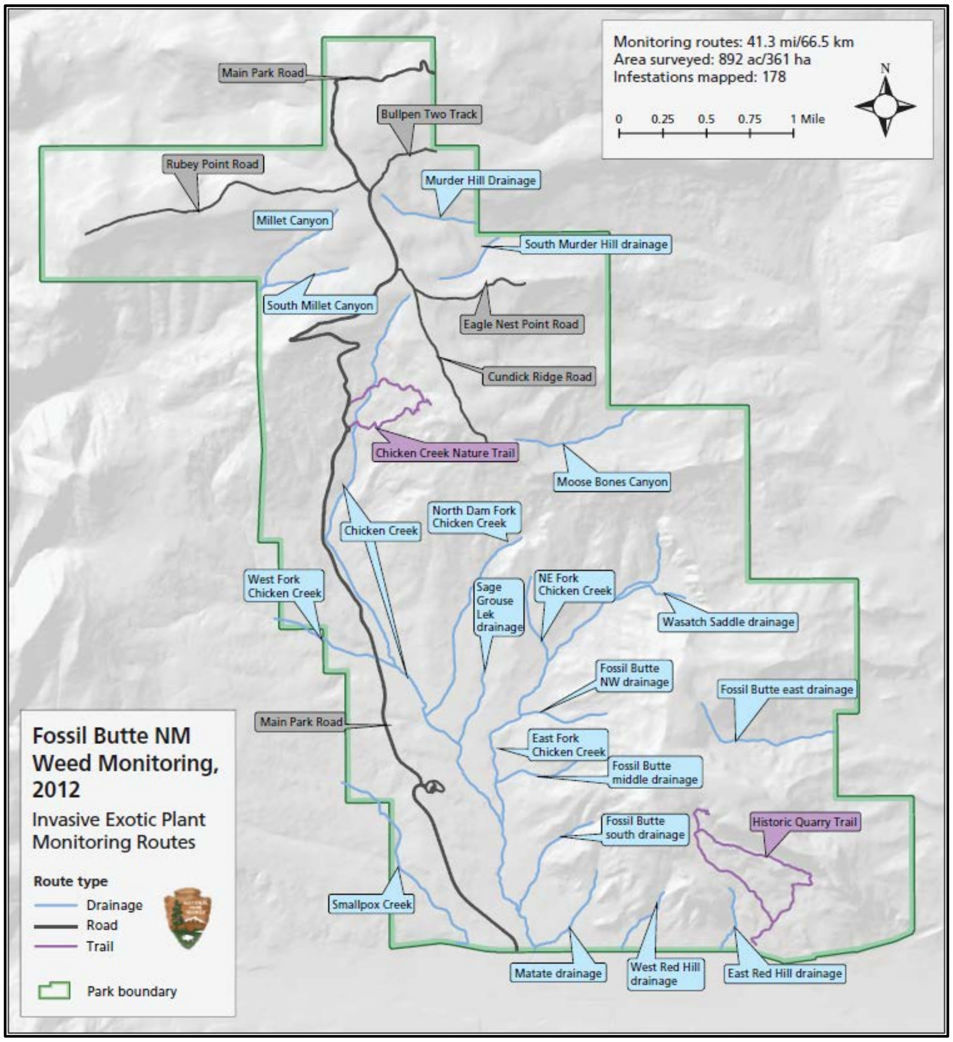


Figure 10. Survey routes inventoried in 2012. Reproduced from Perkins (2013).

The 2014 survey results showed that the priority IEP infestations, in both number and density, were similar to that of the 2012 survey (Table16, Perkins 2015). It is of note that the 2014 survey results were the second lowest of the four sample periods (Perkins 2015). However, the most recently added species, cheatgrass (*Bromus tectorum*), flixweed (*Descuraina sophia*), and creeping foxtail (*Alopecurus arundinaceus*), all have demonstrated large increases since 2012 (Perkins 2015). Creeping foxtail had the largest increase since 2012, in both the southern and northern drainages (Perkins 2015). Cheatgrass and flixweed had increased in patch density along the Main Park Road, which has been consistently monitored for cheatgrass since 2009 and for flixweed since 2012 (Perkins 2015). Since 2012, flixweed has increased in the northern drainages and trails of FOBU (Perkins 2015). Perkins (2015) reported that a few other priority IEPs have shown increases from 2012-2014; including yellow sweetclover (along the Main Park Road), Canada thistle (in the southern drainages), and musk thistle (in the northern drainages). There was a notable decrease in quackgrass along the Main Park Road from 2012-2014 (Perkins 2015). The 2014 field surveys also found invasive species in six routes where previous surveys had not recorded any infestation (Perkins

2015). These were the East Fork of Chicken Creek, East Red Hill Drainage, Fossil Butte Middle Drainage, Northeast Fork of Chicken Creek, West Fork of Chicken Creek, and West Red Hill Drainage, leaving only the Fossil Butte Northwest Drainage and Wasatch Saddle Drainage as the remaining routes where monitoring surveys have yet to find invasive species (Perkins 2015).

Table 16. Total number of IEP patches (number per kilometer) detected at FOBU by year (reproduced from Perkins 2015).

Scientific Name	Common Name	2008-2009	2010	2012	2014
Alopecurus arundinaceus[A]	creeping foxtail	-	63 (0.94)	58 (0.87)	123 (1.85)
Bromus tectorum[B]	cheatgrass	-	-	-	199 (2.99)
Lepidium chalepensis	orbicular whitetop	2 (0.03)	1 (0.01)	0 (0.00)	1 (0.02)
Carduus nutans	musk thistle	27 (0.44)	37 (0.55)	19 (0.24)	30 (0.45)
Centaurea stoebe	spotted knapweed	0 (0.00)	1 (0.01)	4 (0.06)	6 (0.09)
Cirsium arvense	Canada thistle	66 (1.07)	54 (0.81)	9 (0.14)	19 (0.29)
Cirsium vulgare	bull thistle	7 (0.11)	9 (0.13)	6 (0.09)	0 (0.00)
Convolvulus arvensis	field bindweed	4 (0.06)	1 (0.01)	0 (0.00)	2 (0.03)
Descurainia sophia[C]	flixweed	-	-	3 (0.05)	165 (2.48)
Elymus repens	quackgrass	53 (0.86)	95 (1.42)	23 (0.35)	5 (0.08)
Hyoscyamus niger	black henbane	21 (0.34)	5 (0.07)	4 (0.06)	4 (0.06)
Isatis tinctoria	Dyer's woad	2 (0.03)	0 (0.00)	0 (0.00)	0 (0.00)
Melilotus officinalis	yellow sweetclover	54 (0.87	54 (0.81)	10 (0.15)	20 (0.30)
Total priority species		**260 (4.20)**	**320 (4.79)**	**133 (2.00)**	**574 (8.62)**

A = 2010-2014 only

B = 2014 only

C = 2012-2014 only

Data from the 2014 IEP survey was compared to the locations of low sagebrush communities mapped by Friesen et al. (2010). This was completed through spatial analysis to select any IEP data point that was located within a mapped low sagebrush community or within 100 m (328 ft) of a mapped low sagebrush community. Table 17 and Figure 11 show the results of this analysis. Approximately 79% of the total IEP points were selected by the spatial queries. The vast majority of these (94%) were infestations that were within 100m of the mapped low sagebrush vegetation. The most common IEP's identified by the spatial queries as being within the mapped low sagebrush communities were flixweed (15 points), cheatgrass (4), and creeping foxtail (4). These three species were also the most often selected as being within 100 m of the mapped low sagebrush, the only difference being cheatgrass was the most common followed by flixweed and creeping foxtail. Only one species (Japanese brome) that is currently not on the priority species list had recorded infestations in 2014 that matched the selection criteria. As noted earlier, this species will be added to the priority list for future monitoring surveys.

Table 17. Number of IEP infestation patches from 2014 survey that are within or near a low sagebrush community.

		Number of patches		
Scientific Name	**Common Name**	**Within mapped patch**	**Within 100 m of mapped patch**	**Total**
Priority IEPs				
Alopecurus arundinaceus	creeping foxtail	4	98	**102**
Bromus tectorum	cheatgrass	4	129	**133**
Lepidium chalepensis	orbicular whitetop	-	1	**1**
Carduus nutans	musk thistle	1	21	**22**
Centaurea stoebe	spotted knapweed	-	4	**4**
Cirsium arvense	Canada thistle	-	10	**10**
Convolvulus arvensis	field bindweed	-	2	**2**
Descurainia sophia	flixweed	15	118	**133**
Elymus repens	quackgrass	-	4	**4**
Hyoscyamus niger	black henbane	-	3	**3**
Melilotus officinalis	yellow sweetclover	1	14	**15**
Other non-native species of interest				
Bromus japonicus	Japanese brome	1	20	**21**
Total		**26**	**424**	**450**

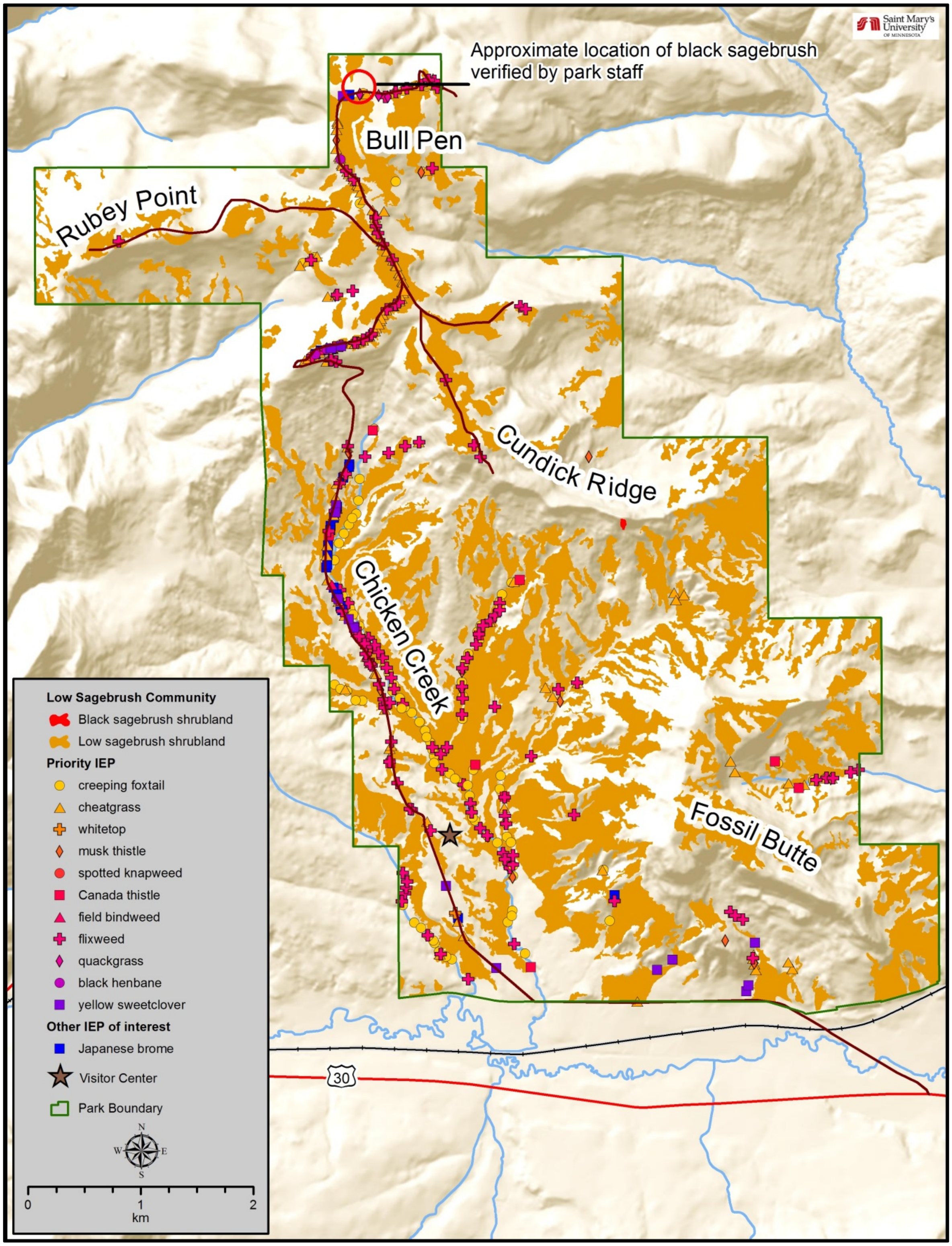


Figure 11. Location of IEP's and other non-native species of interest identified in the 2014 field survey and in relation to mapped low sagebrush communities.

Relative Abundance of *Lomatium* Populations

While FOBU does not contain any threatened or endangered plants under the U.S. Endangered Species Act, the WYNDD currently lists a *Lomatium* species (Wasatch biscuitroot [*Lomatium bicolor*]) found within the low sagebrush community as a species of potential concern (WYNDD 2015). The species of potential concern designation indicates that while the species is relatively secure it is moderately to extremely vulnerable in Wyoming (Fertig and Kyte 2009). With the specific data needed to determine the current condition of relative abundance of *Lomatium* populations within low sagebrush communities unavailable the measure is considered a data gap at this time.

Percent Bare Ground Cover

"Bare ground" refers to areas lacking any protective cover, whether it is living vegetation, plant litter, biological soil crusts, or rocks/gravel. Percent bare ground is an important measure as it can directly impact soil stability. Soil stability can be improved with increases in percent ground cover, as vegetation and other cover helps to prevent wind erosion (Witwicki et al. 2013). Similarly, a high percent ground cover has been associated with an increased susceptibility to water erosion (Kachergis et al. 2011). No quantitative data are available for percent bare ground in FOBU vegetation communities, but some insight into potential maximum bare ground values can be inferred from vegetation cover data. In the longleaf sagebrush associations, vegetation cover ranges from 2-75% combined with low to high exposures of small and large rocks, leaf litter, downed wood, and bare soil (Friesen et al. 2010). The ground cover in the black sagebrush association is comprised of 57% vegetation cover with high cover of small rocks, low cover from leaf litter, and sparse large rock cover and bare ground (Friesen et al. 2010). The vegetation class descriptions provided by Friesen et al. (2010) suggest that the longleaf sagebrush communities have a larger percentage of bare ground cover. However, specific data on percent ground cover is not available to verify this assumption. Information on ground cover was not contained in any of the historical vegetation studies reviewed, and therefore no analysis of trends could be completed. Due to the lack of specific data on ground cover, this measure is considered a data gap.

Threats and Stressor Factors

Threats to low sagebrush communities of FOBU that were identified by park managers include ungulate browsing, invasive species, adjacent land use, fire, regional climate change, and the annual sheep drive (introducing invasive species west of the main park road).

Ungulate herbivory can influence the structure and function of ecosystems by altering nutrient cycling and competition between species (Hobbs 1996); ungulates also influence fire regimes by altering the available fuel load. In shrublands, ungulates can increase the likelihood of crown fires while decreasing the likelihood of surface fires (Hobbs 1996). While black sagebrush is browsed by pronghorn, mule deer, and elk, these animals tend to prefer big sagebrush over black sagebrush (Wambolt 1996). Although big sagebrush is usually preferred, black and low sagebrush may be preferred in certain situations or locations (Blaisdell et al. 1982). While park managers identified ungulate browsing as a threat or stressor for low sagebrush communities, big sagebrush communities are likely at greater risk as ungulates prefer big sagebrush over low and black sagebrush.

IEPs include exotic plants “whose introduction does or is likely to cause economic or environmental harm or harm to human health” (Executive Order 13112). Exotic species, along with habitat loss, are among the greatest threats to biodiversity (Wilcove et al. 1998). IEPs negatively affect natural environments in a number of ways: IEPs fragment native ecosystems, displace native plants and animals, and can alter the performance of ecosystem functions (Scott and Wilcove 1998, Perkins 2015). Additionally, IEPs can alter fire regimes, reduce native plant communities and animal habitat, and increase park management activities (Perkins 2015). Six of the IEPs detected in or near FOBU’s low sagebrush communities are designated as noxious weeds by the state of Wyoming, meaning they are considered detrimental, destructive, or injurious, and landowners are required to control them (Table 17, WPCC 2015).

Adjacent land use can negatively impact a park’s resources. Resource issues vary from park to park, although common issues of concern include habitat structure alteration, watershed impacts, airborne and waterborne pollutants, introduction of exotic plants and animals, soundscape quality, light pollution, and viewsheds (Evenden et al. 2002).

Black and low sagebrush are very susceptible to fire damage, though these low sagebrush communities rarely support enough fuel to carry a fire (Blaisdell et al. 1982, Steinberg 2002). Low and black sagebrush are usually killed by fire (Steinberg 2002, Fryer 2009). While low sagebrush generally regenerates by wind-dispersed seeds, black sagebrush regenerates primarily by an existing seed bank from the year prior, though wind dispersed seeds are also a method of regeneration. This recovery generally takes 2 to 5 years for low sagebrush (Steinberg 2002) and several years for black sagebrush (Fryer 2009).

Climate in FOBU is considered harsh due to a large range of temperatures, with extremes of -45.6 °C (-50 °F) in winter to 37.8 °C (100 °F) in the summer (NPS 2000). FOBU and the surrounding area only receive about 27.9 cm (11 in) of precipitation a year, mostly in the form of snow (NPS 1985, 2000, WRCC 2015). Long-term climate change may alter the distribution of individual plant species, creating new community compositions (Graham and Grimm 1990, Bradley 2010). Short-term climate change may influence plant succession, especially following a disturbance event. Air temperature and soil moisture fluctuation can affect the understory of low sagebrush communities, determining whether plants die as early as late spring or as late as late summer (Miller and Eddleman 2001). Since summer precipitation and temperature are the best indicators of sagebrush distribution, changes to summer climatic conditions may have the most impact on species distribution (Bradley 2010). Warmer and drier conditions in the summer could lead to the replacement of sagebrush communities by salt desert shrubland or IEPs (Bradley 2009, 2010).

Approximately 400 cattle and 5,000 sheep are herded through FOBU each spring and fall. Though park managers expressed concern over the spread of IEPs due to sheep drive, Kyte (2006) does not believe there is a direct correlation between sheep drive and existing stands of IEPs. If distributions of IEPs with respect to the stock trail route were known, the route could be altered to help prevent the spread of existing IEPs (Kyte 2006).

Overwatering and aging were also identified as threats or stressors by park managers, though no information could be found on these topics with respect to low sagebrush communities.

Data Needs/Gaps

Two of the measures identified for assessing the condition of the low sagebrush community at FOBU are largely data gaps, based on the research of the available literature and data: the relative abundance of *Lomatium* populations and percent bare ground. Neither of these measures is considered a complete data gap, as some basic information was identified through the literature and data review. Each measure is lacking the specific information needed to thoroughly describe the current condition and each is also lacking a reference condition.

Currently available data identify the occurrences of *Lomatium* within FOBU and the low sagebrush communities at FOBU (Friesen et al. 2010, NPS 2015b). However, these data do not contain the specific information needed to address current condition or trends, such as the location of these communities or any information on exact population size. While the NPSpecies data (NPS 2015b) have information on relative abundance, the species are generically described as common, uncommon, abundant, or rare. This type of information does not allow for the interpretation of population size or change in population size with any degree of certainty or accuracy. Specific data or studies that contain the location and population size of *Lomatium* would be needed to assess this measure. Once these data have been collected, they could be used as the current condition. These data could also be used as a reference condition against which data from on-going monitoring could be compared to determine any trends in the *Lomatium* population at FOBU.

General information in terms of percent bare ground cover within the low sagebrush community was identified through the literature and data review. The vegetation descriptions provided by Friesen et al. (2010) identified ranges of vegetation cover in the vegetation class descriptions, however in terms of bare ground cover, it was described as sparse or low to high cover. As was the case in the *Lomatium* measure above, this type of information does not allow for the interpretation of the data with any degree of certainty or accuracy. Data specific to the ground cover and the associated components of ground cover within the low sagebrush communities, or FOBU as a whole, would be needed in order to assess the current condition of this measure. Once collected, these data could also serve as a reference condition for future analysis of ground cover within the low sagebrush communities at FOBU.

Two other measures have reference conditions that are considered to be partial data gaps. These are the extent and community change over time and community composition measures. Vegetation mapping conducted by Dorn et al. (1984) and verified by Jones (1993) has information that could be used to assess community extent and change, but this is based on generalized vegetation classifications and not the more specific classifications used by Friesen et al. (2010). Neither of these earlier vegetation studies have the comprehensive species lists that are available in Friesen et al. (2010). The vegetation mapping conducted by Friesen et al. (2010) would provide a baseline condition against which additional vegetation mapping studies could be compared to provide a means of monitoring changes in low sagebrush community extent and composition over time.

The monitoring of invasive species at FOBU is an ongoing process. A report was recently published with the results of the 2014 field season, but was not incorporated into this review due to the timing of the release being at the end of the NRCA process.

<u>Overall Condition</u>

Community Extent and Change over Time
This measure was assigned a *Significance Level* of 3. A 1992 vegetation study created updated, accurate mapping of vegetation communities at FOBU (Jones 1993). At that time, low sagebrush communities accounted for 753 ha (1,861 ac) or 23% of the vegetation cover at FOBU. In the latest available vegetation inventory, Friesen et al. (2010) mapped 1,164 ha (2,877 ac) or 35% of FOBU's vegetation as low sagebrush communities. While the Jones (1993) study had a differing methodology in terms of vegetation classification than Friesen et al. (2010), the data does indicate that a *Condition Level* of 0, meaning no concern, is warranted at this time.

Community Composition
The community composition measure was assigned a *Significance Level* of 3. Although Fertig and Kyte (2009) developed a comprehensive list of plants present within FOBU, it is unclear which of these species are present within low sagebrush communities. Due to the differences in the project methodologies, the Dorn et al. (1984), Jones (1993), and Friesen et al. (2010) vegetation compositions also are not comparable to the Fertig and Kyte (2009) study or each other. Due to lack of a comparable dataset, a *Condition Level* cannot be assigned at this time.

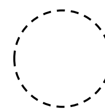
Trend in Invasive Infestation
A *Significance Level* of 2 was assigned to this measure. Monitoring has shown a decline in the number of infestations from 2008 to 2012 for most IEPs (Perkins 2015). In terms of infestation trends within the low sagebrush community, analysis of the 2014 data showed that a large number of the infestation points collected were within 100 m (328 ft) of low sagebrush communities. This number was higher than what was identified using the same analysis on the 2012 survey data. This was due to an increase in the number of cheatgrass, flixweed and creeping foxtail patches. Although the majority of IEP infestations are declining park-wide, due to the high number of IEP infestation points associated with the low sagebrush communities a *Condition Level* of 2 was assigned to this measure, indicating moderate concern. As data becomes available from future IEP studies that have location specific infestation data, this measure could be reassessed using the Perkins (2013) dataset as a reference.

Relative Abundance of Lomatium Populations
This measure was assigned a *Significance Level* of 3. While three species in the *Lomatium* genus are known to occur in FOBU within the low sagebrush communities, it is unclear exactly where they occur and at what level of abundance. With the relevant data to assess this measure unavailable, it is considered to be a data gap and a *Condition Level* cannot be assigned to the measure at this time.

Percent Bare Ground
The percent bare ground measure was assigned a *Significance Level* of 2. The historical vegetation mapping and inventory projects researched did not provide specific information on ground cover, so

a reference condition could not be identified for this measure. In terms of determining current condition, Friesen et al. (2010) does provide generic information on ground cover in the vegetation class descriptions. However, it is not detailed enough to make a determination on the current condition of the percent of bare ground associated with the overall ground cover within the low sagebrush community. Due to these factors this measure is considered a data gap and a *Condition Level* cannot be assigned at this time.

Weighted Condition Score
A *Weighted Condition Score* for FOBU's low sagebrush communities cannot be assigned at this time due to the majority of the measures having data gaps. The current condition and any trend for this resource are unknown.

Low Sagebrush Communities			
Measures	**Significance Level**	**Condition Level**	**WCS = N/A**
Community Extent and Change over Time	3	0	
Community Composition	3	N/A	
Trends in Invasive Infestation	2	2	
Relative Abundance of Lomatium Populations	3	N/A	
Percent Bare Ground Cover	2	N/A	

4.1.6. Sources of Expertise

- This assessment relied on available spatial data and published literature as the primary sources of expertise, with review by FOBU staff.

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4.2. Big Sagebrush Community

4.2.1. Description

The vegetation within FOBU is dominated by four taxa of sagebrush, which account for approximately 75% of the vegetative cover (Fertig and Kyte 2009). Longleaf sagebrush is dominant on the clay-rich soils found over much of the valley floors or in scattered inclusions on ridge tops and slopes (Fertig and Kyte 2009). These low sagebrush communities are described in detail in the previous chapter (Chapter 4.1). The other three taxa (mountain big sagebrush, basin big sagebrush, and Wyoming big sagebrush [*Artemisia tridentata* ssp. *wyomingensis*]) comprise the big sagebrush communities (Photo 1) and are the focus of this chapter.

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Photo 1. Big sagebrush (NPS Photo).

Mountain big sagebrush is dominant on the deep loamy soils at higher elevations within FOBU, such as on the summit of Cundick Ridge or to a lesser extent on top of Fossil Butte (Fertig and Kyte 2009, Friesen et al. 2010). Moving down to the middle elevations, mountain big sagebrush is gradually replaced by basin big sagebrush, such as on the lower slopes or gravelly stream deposits in the bottom of Fossil Basin (Fertig and Kyte 2009, Friesen et al. 2010). In the latest vegetation mapping project (conducted by Friesen et al. 2010), big sagebrush communities were mapped as five vegetation alliances. Friesen et al. (2010) defined these classes as: sagebrush (mountain big sagebrush/Wyoming big sagebrush) - serviceberry (*Amelanchier utahensis*) shrubland, basin big sagebrush/Great Basin wildrye shrubland, basin big sagebrush/bluegrass shrubland, mountain big sagebrush shrublands, and Wyoming big sagebrush shrublands. Except for the mountain big sagebrush shrublands and the Wyoming big sagebrush shrublands, each vegetation alliance consists of a single plant association, of the same name as the alliance (Friesen et al. 2010). Mountain big sagebrush and Wyoming big sagebrush shrublands are broken down into 10 and five plant associations respectively by Friesen et al. (2010) and are listed below.

- Mountain big sagebrush shrublands
    - mountain big sagebrush/Letterman's needlegrass (*Achnatherum lettermanii*) shrubland
    - mountain big sagebrush/arrowleaf balsamroot shrubland
    - mountain big sagebrush/streambank wheatgrass shrubland
    - mountain big sagebrush/spike fescue shrubland
    - mountain big sagebrush/Great Basin wildrye shrubland
    - mountain big sagebrush/western wheatgrass shrubland
- Mountain big sagebrush/muttongrass shrubland
- Mountain big sagebrush/Kentucky bluegrass sagebrush shrubland
- Mountain big sagebrush/Sandberg bluegrass shrubland
- Mountain big sagebrush/bluebunch wheatgrass shrubland
- Wyoming big sagebrush shrublands
    - Wyoming big sagebrush/streambank wheatgrass shrubland
    - Wyoming big sagebrush/disturbed understory semi-natural shrubland
    - Wyoming big sagebrush/Great Basin wildrye shrubland
    - Wyoming big sagebrush/Sandberg bluegrass shrubland
    - Wyoming big sagebrush/bluebunch shrubland

Big sagebrush communities are a major foraging source and provide critical habitat for the greater sage grouse (Rosentreter 2005). Big sagebrush communities also provide habitat for many other wildlife species including the sage sparrow (*Amphispiza belli*), Brewer's sparrow (*Spizella breweri*), sage thrasher (*Oreoscoptes montanus*), and pygmy rabbit (*Brachylagus idahoensis*) (Bates et al. 2004).

4.2.2. Measures

- Community extent and change over time
- Community composition
- Trends in invasive infestation

4.2.3. Reference Conditions/Values

Park managers suggested the reference condition used in assessing the big sagebrush communities should be similar to that used for the low sagebrush community. Suggested reference conditions included: historical conditions described in early USGS surveys by Hayden (1872), conditions in the area prior to European settlement or the introduction of grazing, or the habitat described in railroad archives. Based on historical accounts and pollen data, this area has been dominated by woody sagebrush vegetation since approximately 7,000 to 10,000 years ago (Dorn et al. 1984). This pollen data also indicates that between 5,000 and 200 years ago, the area became an open sagebrush-grassland, very similar in appearance to the current conditions (Dorn et al. 1984). For the purposes of this assessment the pre-settlement condition described by Dorn et al. (1984) will be used as the reference condition.

4.2.4. Data and Methods

Vegetation studies were conducted at FOBU as early as 1973, and will provide the majority of the information for this analysis. These studies ranged from vegetation surveys and mapping conducted by Beetle and Marlow (1974) to the latest vegetation mapping project conducted by Friesen et al. (2010). Other studies, such as Fertig (2000) and Fertig and Kyte (2009), compiled and verified a species checklist for FOBU. Invasive species surveys have also been completed for FOBU, beginning in 2008 (Perkins 2015). A more detailed account of these and other vegetation studies completed at FOBU can be found in Chapter 4.1.4.

The primary data source used in the analysis of the big sagebrush community at FOBU will be a vegetation mapping project completed by Friesen et al. (2010). Earlier vegetation studies at FOBU (Dorn et al. 1984, Jones 1993) did contain information on vegetation communities at FOBU that was sufficient and complete enough to provide a baseline against which the current community extent could be evaluated. However, since neither Dorn et al. (1984) nor Jones (1993) were comprehensive vegetation inventories, they cannot be used in determining the full community composition or the changes in composition of the big sagebrush community over time.

4.2.5. Current Condition and Trend

<u>Community Extent and Change over Time</u>

According to the latest vegetation mapping project, big sagebrush communities comprise approximately 41% (1,394 ha [3,444 ac]) of the total vegetation cover at FOBU (Friesen et al. 2010). The areal extent of each of the big sagebrush vegetation classifications is listed in Table 18. Mountain big sagebrush was found throughout FOBU, while the basin big sagebrush was found in the extreme southern portion (Figure 12).

Table 18. Composition of the big sagebrush community at FOBU (Friesen et al. 2010). Area is given in hectares with the acre equivalent in parenthesis.

Big Sagebrush Community	**Area hectares (acre)**
Mountain big sagebrush shrublands	999.9 (2,470.8)
Sagebrush - serviceberry shrubland	205.4 (507.6)
Wyoming big sagebrush shrublands	132.8 (328.1)
Basin big sagebrush/bluegrass shrubland	46.0 (113.7)
Basin big sagebrush/Great Basin wildrye shrubland	9.6 (23.8)

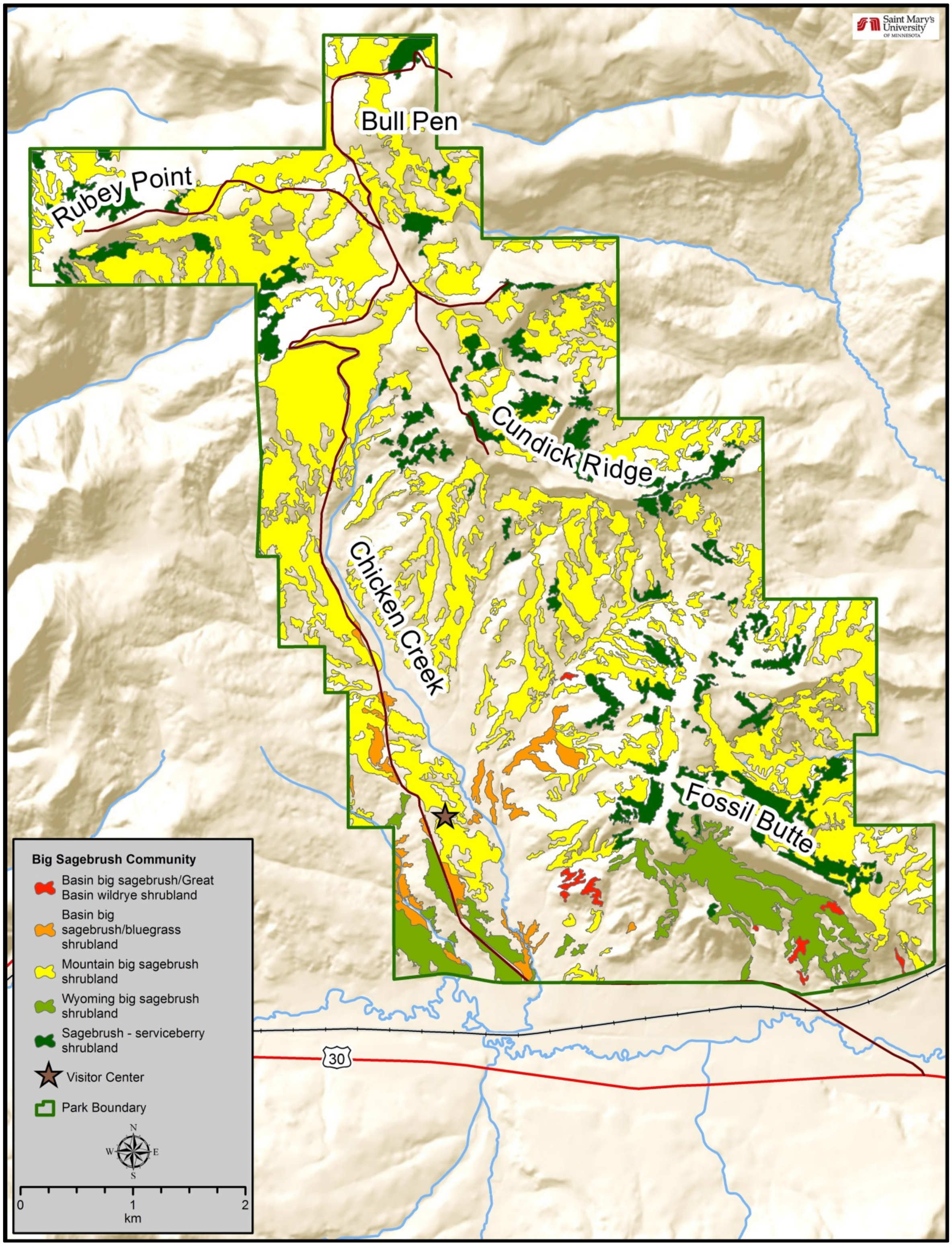

Figure 12. Big sagebrush community locations within FOBU (Friesen et al. 2010).

In terms of general appearance and characteristics, the vegetation in FOBU and the surrounding area is mostly the same today as it was prior to European settlement (as reviewed in Dorn et al. 1984).

However, some changes have occurred in the understory that can be attributed to heavy grazing (Dorn et al. 1984). Historically, fire has also altered the sagebrush communities, as after fire they are generally replaced by grass/forb dominated vegetation communities (Dorn et al. 1984).

The basin big sagebrush and mountain big sagebrush classifications originally mapped by Dorn et al. (1984) and verified by Jones (1993) can serve as a baseline condition for determining change in the extent of big sagebrush communities. Both Dorn et al. (1984) and Jones (1993) classified and mapped these communities as basin big sagebrush or mountain big sagebrush map units. Together, these two map units accounted for just under half (49%) of the park's vegetative cover (Jones 1993). Basin big sagebrush covered 31% (1,045 ha [2,582 ac]) of the park and was found primarily on gentle slopes and broad ridges in the Chicken Creek Valley and to the north, east, and south of Fossil Butte (Jones 1993).

Community Composition

As stated in previous chapters, several vegetation studies have been undertaken at FOBU. Beetle and Marlow (1974) identified 12 vegetation classifications in their survey and mapping of vegetation at FOBU. This mapping included two big sagebrush communities: 'mountain big sagebrush and shrub complex' and 'basin big sagebrush complex'. Fertig and Kyte (2009) included 'big sagebrush or alkali (longleaf) sagebrush grassland and montane shrub communities' within their classification system. Both of these projects could be used in determining community composition; however, since they are not exclusively 'big sagebrush communities', other species could also be included in the species lists provided by these projects. Dorn et al. (1984) identified a total of 142 plant species within the big sagebrush community. They consisted of one tree, 22 shrub, 20 grass and 99 forb species. The shrub stratum was dominated by mountain big sagebrush and basin big sagebrush. Other common shrub species included green rabbitbush and rubber rabbitbush (Dorn et al. 1984). The most common species in the understory included spike fescue, Sandberg bluegrass, Cusick's bluegrass, thickspike wheatgrass, slender wheatgrass, muttongrass, sulfur buckwheat, leafy bluebells, Hood's phlox, Columbia groundsel, and narrow-leaved sedge (*Carex duriuscula*) (Dorn et al. 1984). This study was a grazing impact study and not a full vegetation inventory so it also cannot be used to determine any type of change in community composition. Jones (1993) updated the accuracy of the Dorn et al. (1984) mapping; however, specific information on the composition of each vegetation classification was limited to select stands and does not provide a comprehensive examination of composition.

Friesen et al. (2010) identified 85 plant species found within big sagebrush communities of FOBU. They consisted of two tree, 19 shrub, 25 grass, and 39 forb species.The most commonly occurring shrub species included Utah serviceberry, mountain big sagebrush, basin big sagebrush, Utah snowberry (*Symphoricarpos oreophilus* var. *utahensis*), and green rabbitbush (Friesen et al. 2010). In the herbaceous strata the most common plants consisted of the grasses Great Basin wildrye, muttongrass, western wheatgrass, and thickspike wheatgrass, and the forbs sulfur buckwheat, western gromwell, arrowleaf balsamroot and long-leaf phlox (Friesen et al. 2010). A complete listing of the species identified by Friesen et al. (2010) is given in Table 19, Table 20, Table 21 and Table 22.

Table 19. Tree species found in big sagebrush communities of FOBU. Abundance level is from NPSpecies and is for the park as a whole, not sagebrush communities specifically (Friesen et al. 2010, NPS 2015).

Scientific Name	Common Name	NPSpecies Abundance
Pinus flexilis	limber pine	Uncommon
Populus tremuloides	quaking aspen	Common

Table 20. Shrub species found in big sagebrush communities of FOBU. Abundance level is from NPSpecies and is for the species across the park as a whole (Friesen et al. 2010, NPS 2015).

Scientific Name	Common Name	NPSpecies Abundance
Amelanchier utahensis	Utah serviceberry	Common
Artemisia arbuscula ssp. *longiloba*	longleaf sagebrush	Common
Artemisia cana	silver sagebrush	Uncommon
Artemisia tridentata ssp. *tridentata*	basin big sagebrush	Abundant
Artemisia tridentata ssp. *vaseyana*	mountain big sagebrush	Abundant
Artemisia tridentata ssp. *wyomingensis*	Wyoming big sagebrush	Common
Atriplex confertifolia	spiny saltbrush	Uncommon
Atriplex gardneri	Gardner's saltbrush	Uncommon
Berberis repens	creeping Oregon-grape	Uncommon
Cercocarpus montanus	true mountain-mahogany	Common
Chrysothamnus viscidiflorus	green rabbitbrush	Common
Ericameria nauseosa	rubber rabbitbrush	Uncommon
Eriogonum microthecum var. *laxiflorum*	slenderbush buckwheat	Uncommon
Gutierrezia sarothrae	broom snakeweed	Uncommon
Krascheninnikovia lanata	winterfat	Common
Purshia tridentate	antelope bitterbrush	Common
Ribes cereum	wax currant	Uncommon
Salix scouleriana	Scouler willow	Uncommon
Symphoricarpos oreophilus var. *utahensis*	Utah snowberry	Common

Table 21. Grass species found in big sagebrush communities of FOBU. Abundance level is from NPSpecies and is for the species across the park as a whole (Friesen et al. 2010, NPS 2015).

Scientific Name	Common Name	NPSpecies Abundance
Achnatherum hymenoides	Indian ricegrass	Common
Achnatherum lettermanii	Letterman's needlegrass	Uncommon
Achnatherum nelsonii	Nelson's needlegrass	Uncommon
Achnatherum pinetorum	pine needlegrass	No data
Agropyron cristatum	crested wheatgrass	Uncommon
*Bromus inermis**	smooth brome	Uncommon
*Bromus tectorum**	cheatgrass	Uncommon
Carex filifolia	thread-leaved sedge	No data
Carex geyeri	elk sedge	No data
Carex rossii	Ross sedge	Common
Elymus elymoides var. *elymoides*	bottlebrush squirreltail	Uncommon
Elymus lanceolatus var. *lanceolatus*	thickspike wheatgrass	Uncommon
Elymus trachycaulus var. *trachycaulus*	slender wheatgrass	Common
Juncus balticus	Baltic rush	Uncommon
Koeleria macrantha	prairie junegrass	Uncommon
Leucopoa kingii	spikefescue	Common
Leymus cinereus	Great Basin wildrye	Common
Melica bulbosa	oniongrass	Uncommon
Pascopyrum smithii	western wheatgrass	Common
*Phleum pretense**	timothy	Uncommon
Poa fendleriana	muttongrass	Common
*Poa pratensis**	Kentucky bluegrass	Uncommon
Poa secunda	Sandberg bluegrass	Common
Pseudoroegneria spicata	bluebunch wheatgrass	Common

*Non-native species

Table 22. Forb species found in big sagebrush communities of FOBU. Abundance level is from NPSpecies and is for the park as a whole, not sagebrush communities specifically (Friesen et al. 2010, NPS 2015).

Scientific Name	Common Name	NPSpecies Abundance
Achillea millefolium var. *lanulosa*	common yarrow	Common
Agastache urticifolia	nettle-leaf giant-hyssop	Uncommon
*Alyssum desertorum**	desert alyssum	Uncommon
Antennaria dimorpha	low pussytoes	Uncommon
Antennaria microphylla	small-leaf pussytoes	Common
Antennaria rosea	rosy pussytoes	Common
Artemisia ludoviciana ssp. *ludoviciana*	Louisiana sagebrush	Uncommon
Balsamorhiza sagittata	arrowleaf balsamroot	Uncommon
Cirsium undulatum var. *undulatum*	wavy-leaf thistle	No data
Comandra umbellata ssp. *pallida*	bastard toad-flax	Uncommon
Crepis acuminata	tapertip hawksbeard	Uncommon
Delphinium nuttallianum	Nuttall's larkspur	Uncommon
Erigeron concinnus	Navajo fleabane	No data
Eriogonum brevicaule	shortstem buckwheat	Uncommon
Eriogonum cernuum	nodding buckwheat	Uncommon
Eriogonum flavum	alpine golden buckwheat	No data
Eriogonum umbellatum var. *majus*	sulphur-flower buckwheat	Uncommon
Iva axillaris	poverty-weed	Uncommon
Lepidium virginicum	tall peppergrass	Uncommon
Linum lewisii	blue flax	Uncommon
Lithospermum ruderale	western gromwell	Uncommon
Lupinus argenteus ssp. *rubricaulis*	silvery lupine	Common
Lupinus sericeus	silky lupine	Common
Maianthemum stellatum	spikenard	Common
Mertensia oblongifolia	leafy bluebells	Uncommon
Phlox hoodii	Hood's phlox	Common

* Non-native species

Table 22 (continued). Forb species found in big sagebrush communities of FOBU. Abundance level is from NPSpecies and is for the park as a whole, not sagebrush communities specifically (Friesen et al. 2010, NPS 2015).

Scientific Name	Common Name	NPSpecies Abundance
Phlox multiflora	many-flowered phlox	Uncommon
Potentilla spp.	cinquefoil	Uncommon
Pteryxia terebinthina	turpentine spring-parsley	Uncommon
*Ranunculus testiculatus**	hornseed buttercup	Uncommon
*Salsola tragus**	Russian thistle	Uncommon
Senecio integerrimus var. *exaltatus*	Columbia groundsel	Uncommon
Solidago spp.	goldenrod	Uncommon
Stenotus acaulis	stemless goldenweed	Uncommon
Streptanthus cordatus	heart-leaved streptanthus	Uncommon
*Taraxacum officinale**	common dandelion	Uncommon
Trifolium gymnocarpon var. *plummerae*	hollyleaf clover	Uncommon
Wyethia amplexicaulis	northern mule's-ears	Uncommon

* Non-native species

Trends in Invasive Infestation

IEP surveys were conducted at FOBU during 2008, 2009, 2010, 2012, and 2014 (Perkins 2015). The surveys are conducted based on a priority IEP list developed by the NCPN and park staff (Perkins 2015). Information on invasive infestations collected during these surveys is not limited to those species on the priority list. Information on other species of note, such as Japanese brome, is also collected.

Data from the 2014 IEP survey was compared to the locations of big sagebrush communities mapped by Friesen et al. (2010). This was completed through spatial analysis to select any IEP data point that was within 100 m (328 ft) of a mapped big sagebrush community. Table 23 and Figure 13 show the results of this analysis. Nearly all (571 of 574) of the IEP patches recorded during the 2014 field survey matched the spatial criteria of the queries. Just over 17% were located within a mapped big sagebrush community; the remaining patches were located within 100 m (328 ft) of a mapped big sagebrush community.

Table 23. Number of IEP infestation patches from 2014 survey that are within or near a big sagebrush community.

Number of patches				
Scientific Name	**Common Name**	**Within mapped patch**	**Within 100 m of mapped patch**	**Total**
Priority IEPs				
Alopecurus arundinaceus	creeping foxtail	17	99	**116**
Bromus tectorum	cheatgrass	42	146	**188**
Lepidium chalepensis	orbicular whitetop	-	1	**1**
Carduus nutans	musk thistle	5	25	**30**
*Centaurea stoebe**	spotted knapweed	1	5	**6**
*Cirsium arvense**	Canada thistle	8	11	**19**
*Convolvulus arvensis**	field bindweed	-	2	**2**
Descurainia sophia	flixweed	22	137	**159**
*Elymus repens**	quackgrass	1	4	**5**
*Hyoscyamus niger**	black henbane	-	4	**4**
Melilotus officinalis	yellow sweetclover	2	17	**19**
Other non-native species of interest				
Bromus japonicus	Japanese brome	-	22	**22**
Total		**98**	**473**	**571**

* Species designated as noxious weeds by the state of Wyoming (WPCC 2015)

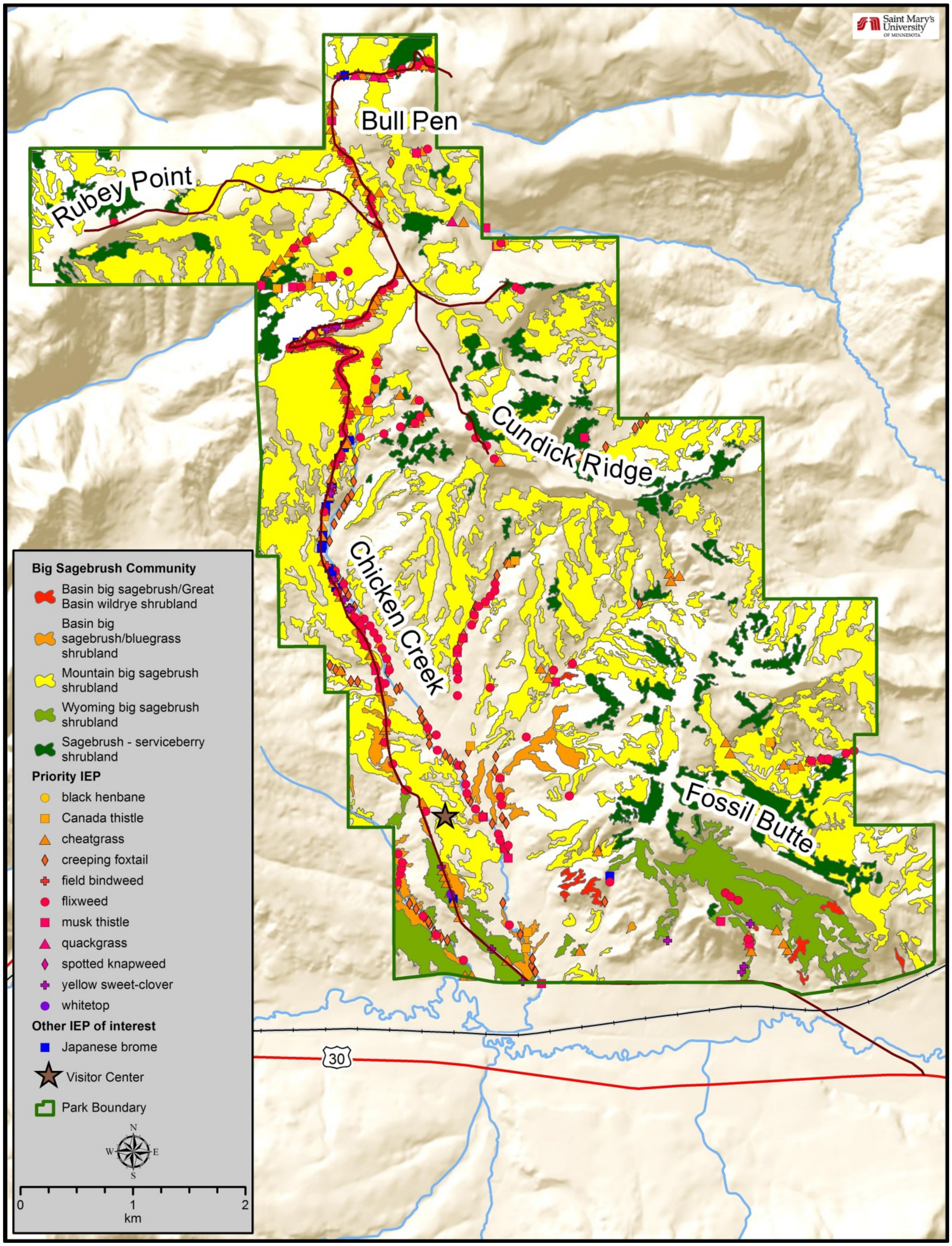

Figure 13. IEP infestations associated with mapped big sagebrush communities.

The most common IEPs within the big sagebrush communities were cheatgrass (42 patches), flixweed (22 patches) and creeping foxtail (17 patches). Cheatgrass was also the most prevalent of the invasive species that were found in proximity to big sagebrush, with 146 patches meeting the spatial criteria. Flixweed was the next most common with 137 patches followed by creeping foxtail with 99 patches. One other invasive species, Japanese brome, meet the proximity criteria. While not currently on the priority species list, it is to be added for the next survey (Perkins 2015).

Threats and Stressor Factors

Threats to FOBU's big sagebrush communities identified by park managers include ungulate browsing, invasive species, adjacent land use, fire, aging of sagebrush, sheep drives (introducing invasive species west of the main park road), and regional climate change.

Ungulate herbivory can influence the structure and function of ecosystems by altering nutrient cycling and competition between plant species (Hobbs 1996); ungulates also influence fire regimes by altering the available fuel load. In shrublands, ungulates can increase the likelihood of crown fires while decreasing the likelihood of surface fires (Hobbs 1996). Singer and Renkin (1995) suggest that browsing from elk, pronghorn, and mule deer can affect Wyoming big sagebrush by restricting height, size, and recruitment. Pronghorn are likely to have the biggest impact on big sagebrush communities, as a larger portion of their diet consists of big sagebrush (Singer and Renkin 1995). Big sagebrush that is not browsed can have over 200% greater canopy cover than those that are browsed (Wambolt and Sherwood 1999). Additionally, excessive browsing can result in significant big sagebrush mortality, killing up to 35% of the plants (Wambolt 1996). Germination, establishment, and survival of mountain big sagebrush and basin big sagebrush may actually be enhanced by ungulate grazing in some areas, possibly due to secondary effects (e.g., reduced competition) (Singer and Renkin 1995). No information could be found on herbivory impacts to FOBU's sagebrush communities specifically, although elk numbers have increased recently (see Chapter 4.13) and may be a concern.

Fire is a natural and integral part of sagebrush communities, but has been suppressed at FOBU for nearly 100 years (NPS 2005). The FOBU fire management plan (NPS 2005) organizes vegetation communities into fire regimes and condition classes. Fire regimes are a way to categorize vegetation types by the typical number of years between fires under natural/historical conditions (i.e., no human interference). Condition classes, in contrast, provide the current status of fire need for the vegetation community in question (Table 24) (NPS 2005). Most vegetation communities in the park are in Condition Class 1, but some big sagebrush stands are in Condition Class 2 (NPS 2005), having missed at least one fire cycle.

Table 24. Fire condition class definitions (NIFC 2003).

Condition Class	Description	Potential Risks
1	Within the natural (historical) range of variability of vegetation characteristics (fuel composition, fire frequency, etc.)	Fire behavior, effects, and other associated disturbances are similar to those that occurred prior to fire exclusion (suppression) and other types of management that do not mimic the natural fire regime
2	Moderate departure from the natural (historical) regime of vegetation characteristics	Risk of loss of key ecosystem components (e.g. native species, large trees, and soil) are low; composition and structure of vegetation and fuel are moderately altered
3	High departure from the natural (historical) regime of vegetation characteristics	Risks of loss of key ecosystem components are moderate; composition and structure of vegetation and fuel are highly altered

There is some uncertainty regarding the historic fire regimes of big sagebrush communities. According to the U.S. Forest Service's (USFS) Fire Effects Information System (FEIS), mountain big sagebrush falls into fire regime 1 with a typical cycle of 10 to 30 years (NPS 2005). Recent research from Dinosaur National Monument (DINO) in northwestern Colorado suggests that the fire return interval in mountain big sagebrush communities there may be over 125 years (Bukowski and Baker 2013). Mountain big sagebrush is sensitive to fire and can easily be killed, as regeneration occurs by seed and not re-sprouting. Leaving behind patches of sagebrush in prescribed burns enables faster regeneration of the sagebrush communities (NPS 2005).

Based on the FEIS, basin big sagebrush is also placed into fire regime 1 with a typical cycle of 15 to 70 years (NPS 2005). Basin big sagebrush is also readily killed by fire and regenerates by seed rather than re-sprouting. The time since the last fire within three of the basin big sagebrush stands was 60 to 70 years, indicating that these stands are at the long end of their fire return cycle (NPS 2005).

According to the FEIS, Wyoming big sagebrush communities have a typical fire return interval of 10 to 70 years (Howard 1999). However, research from DINO suggests that fire intervals there may have been over 150 years (Bukowski and Baker 2013). Fires within Wyoming big sagebrush communities are generally not continuous. Plants that survive a fire, as well as the existing seedbank, are the primary means of reproduction for this species following a fire (Howard 1999).

Aging of sagebrush stands is also a concern related to fire regime. In the absence of fire or other disturbance, mature sagebrush can shade out native grasses and wildflowers (USDA 2006), reducing the overall diversity of the community.

Burning of big sagebrush stands is not recommended where cheatgrass cover exceeds 50% or the cover of fire-resistant native grasses is less than 20% (Tirmenstein 1999). If the dominant native grass is not a fire-resistant species or if native grasses were in poor condition prior to a fire, cheatgrass is more likely to become established in the area after a fire (Tirmenstein 1999). Fire hazard in areas infested by cheatgrass can be five times as great as those that are not infested, leading to drastically altered fire regimes (Howard 1999).

IEPs include exotic plants “whose introduction does or is likely to cause economic or environmental harm or harm to human health” (Executive Order 13112). Exotic species, along with habitat loss, are among the greatest threats to biodiversity (Wilcove et al. 1998). IEPs negatively affect natural environments by fragmenting native ecosystems, displacing native plants and animals, and altering the performance of ecosystem functions (Scott and Wilcove 1998, Perkins 2015). Additionally, IEPs can alter fire regimes, reduce native plant communities and animal habitat, and increase park maintenance activities (Perkins 2015). Six of the IEPs detected in or near FOBU’s low sagebrush communities are designated as noxious weeds by the state of Wyoming (Table 23, WPCC 2015).

Adjacent land use can negatively impact a park’s resources. Resource issues vary from park to park, although common issues of concern include habitat structure alteration, watershed impacts, airborne and waterborne pollutants, introduction of exotic plants and animals, and light pollution (Evenden et al. 2002).

Climate in FOBU is considered harsh due to a large range of temperatures, with extremes of -45.6 °C (-50 °F) in winter to 37.8 °C (100 °F) in the summer (NPS 2000). FOBU and the surrounding area only receive about 27.9 cm (11 in) of precipitation a year, mostly in the form of snow (NPS 1985, 2000, WRCC 2015). Long-term climate change may alter the distribution of individual plant species, creating new community compositions (Graham and Grimm 1990, Bradley 2010). Short-term climate change may influence plant succession, especially following a disturbance event. Air temperature and soil moisture fluctuations can affect the understory of big sagebrush communities, determining whether plants die back as early as late spring or as late as late summer (Miller and Eddleman 2001). Since summer precipitation and temperature are the best indicators of sagebrush distribution, changes to summer climatic conditions may have the most impact on species distribution (Bradley 2010). Warmer and drier conditions in the summer could lead to the replacement of sagebrush communities by salt desert shrubland or IEPs (Bradley 2009, 2010).

Approximately 400 cattle and 5,000 sheep are herded through FOBU each spring and fall. Though park managers expressed concern over the spread of IEPs due to the sheep drive, Kyte (2006) does not believe there is a direct correlation between the sheep drive and existing stands of IEPs. If distributions of IEPs with respect to the stock trail route were known, the route could be altered to help prevent the spread of existing IEPs (Kyte 2006).

Data Needs/Gaps

Historic data on the extent of vegetation communities at FOBU is considered to be a partial data gap. While vegetation mapping conducted by Dorn et al. (1984) and verified by Jones (1993) does have information that could be used to assess community extent and change, this is based on generalized vegetation classifications and not the more specific classifications used by Friesen et al. (2010). Neither of these earlier vegetation studies have the comprehensive species lists that are available in Friesen et al. (2010). The vegetation mapping conducted by Friesen et al. (2010) would provide a baseline condition against which additional vegetation mapping studies could be compared to provide a means of monitoring changes in big sagebrush community extent and composition over time. Further research on the cause of the shifts in the dominant big sagebrush species would also provide a clearer picture of the condition of big sagebrush habitat within FOBU. Continued monitoring of IEPs will provide park managers with a valuable long-term data set that will accurately depict trends in the number and extent of infestations.

Overall Condition

Community Extent and Change over Time

This measure was assigned a *Significance Level* of 3. In comparing vegetation mapping conducted by Jones (1993) to that conducted by Friesen et al. (2010), it appears that in general there has been some loss of big sagebrush habitat, from 49% (1,651 ha [4,079 ac]) of all vegetation cover in 1992 to 41% (1,394 ha [3,444 ac]) in 2010. Although the Jones (1993) vegetation study is not as detailed in terms of the vegetation classifications, the data does indicate that there is a difference in the amount and location of both mountain big sagebrush and basin big sagebrush cover within the park. In 1992, basin big sagebrush was more widespread throughout the southern portions of the park with mountain big sagebrush located mainly in the northern half of the park (Jones 1993). Friesen et al. (2010) mapped mountain big sagebrush throughout the park and basin big sagebrush was found mainly in the extreme southern portion of the park, to the south of Fossil Butte and in the extreme southeastern corner of the park. While these two vegetation projects did not use identical methodologies or the same vegetation classifications, there is evidence that the big sagebrush community in FOBU was smaller in scale during the 2010 study than what was found in 1992. Due to these likely changes, a *Condition Level* of 1, meaning low concern was assigned.

Community Composition

The community composition measure was assigned a *Significance Level* of 3. Although Fertig and Kyte (2009) developed a comprehensive list of plants present within FOBU, it is unclear which of these species are present within the big sagebrush community. Due to the differences in the project methodologies, the Dorn et al. (1984), Jones (1993), and Friesen et al. (2010) vegetation compositions also are not directly comparable. However, based on expert opinion (Walt Fertig, Former Wyoming Natural Diversity Database Botanist, written communication, 7 December 2015), community composition is considered of low concern at this time (*Condition Level* = 1).

Trend in Invasive Infestation

A *Significance Level* of 2 was assigned to this measure. IEP monitoring has shown a decline in the number of infestations from 2008 to 2014 (Perkins 2015). Spatial analysis showed that nearly every infestation point collected during the 2014 survey was associated with a big sagebrush community, either located within it, or within 100 m (328 ft) of a big sagebrush community. Although some IEP infestations have declined park-wide, others seem to have increased. A *Condition Level* of 2 was assigned to this measure, due to proximity of infestations to the mapped big sagebrush communities. As location-specific infestation data become available from future studies, this measure could be reassessed using this data analysis as a baseline.

Weighted Condition Score

The *Weighted Condition Score* for FOBU's big sagebrush communities is 0.42, indicating moderate concern. An overall trend could not be determined. Due to the limited data for some measures, a moderate confidence border has been assigned.

Big Sagebrush Community			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.42**
Community Extent and Change Over Time	3	1	
Community Composition	3	1	
Trends in Invasive Infestation	2	2	

4.2.6. Sources of Expertise

- Walt Fertig, Former Wyoming Natural Diversity Database Botanist
- Dana Witwicki, NCPN Ecologist

4.2.7. Literature Cited

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4.3. Aspen Woodlands

4.3.1. Description

Isolated aspen stands in FOBU typically occur downhill from areas of snow melt on north or east facing slopes or near springs that provided the necessary moisture (Photo 2, Dorn et al. 1984, Fertig and Kyte 2009). These woodlands are dominated by quaking aspen. Aspen stands provide essential habitat for many resident and migratory birds known to occur in FOBU and are often under grazing pressure from elk that inhabit the park (Friesen et al. 2010). Common avian species found within aspen stands include the cordilleran flycatcher (*Empidonax occidentalis*) and the dusky flycatcher (*E. oberholseri*) (Carr 2011, NPS 2015). Rare birds observed in aspen stands are the great horned owl (*Bubo virginianus*) and hairy woodpecker (*Picoides vilosus*) (Carr 2011, NPS 2015).

Photo 2. An isolated aspen stand at FOBU (Shannon Amberg, SMUMN GSS 2013).

4.3.2. Measures

- Community extent and change over time
- Community composition
- Trends in invasive infestation
- Rate of regeneration (suckers per hectare)

4.3.3. Reference Conditions/Values

While pre-European settlement condition may be the ideal reference condition for this component, no information particular to aspen stands is available from this time period. Therefore, the reference condition for this assessment will be to restore current stands to a disease and pest-free state with no degradation from current (early 21st century) condition.

4.3.4. Data and Methods

Dorn et al. (1984) conducted a grazing impact study for FOBU and the surrounding region by reviewing historical literature from government reports, reports of naturalists, and even diaries of travelers. Dorn et al. (1984) briefly described site characteristics and species composition of aspen stands and included a plant list that identified species found in aspen woodlands. Dorn et al. (1984) did contain some information on vegetation communities at FOBU, however since it was not a specific vegetation study and had inherent spatial inaccuracies (due to the nature of how the data were created, see Chapter 4.1.4), it cannot be used in determining the community composition or the change in extent over time of the aspen woodland community. With just a few minor edits, Jones (1993) ground-truthed and converted Dorn et al.'s (1984) data to a GIS dataset.

Bertram and Kyte (2001) conducted a beaver survey on six areas that were previously surveyed in 1990. The survey searched for presence of beaver and signs of beaver activity, as well as describing the stages of aspen regeneration occurring within selected areas.

Guyon (2006) conducted a visual survey of FOBU aspen woodland sites and documented the various stressors on the aspen populations including diseases, insect activity, drought, and animal damage. This document is an internal memorandum that includes photo examples of each stressor. Guyon (2014) returned to FOBU on 8-9 July 2014 for an assessment and monitoring survey of forest health, particularly the aspen woodlands, in an attempt to identify the cause of recent diebacks of aspen trees. Damage was documented with photos and descriptions of each factor implicated in the aspen tree diebacks.

Fertig and Kyte (2009) provided a plant list that includes the community type(s) where each species occurs. The FOBU certified species list (NPS 2015) catalogs all plant species that have been documented within the park. Details of occurrence, abundance, and nativity are included when available and are updated regularly.

Friesen et al. (2010) completed a vegetation mapping project for all plant associations in FOBU. The mapping project involved initial field reconnaissance, aerial photo interpretation, spatial database development, and field verification. Aspen woodlands include four plant associations identified by Friesen et al. (2010): aspen complex (consisting of three aspen-dominated vegetation associations), aspen/red-osier dogwood (*Cornus sericea* ssp. *sericea*) woodland, aspen/chokecherry (*Prunus virginiana*) woodland, and aspen/buffaloberry (*Shepherdia*)-invasive grass woodland (Friesen et al. 2010).

4.3.5. Current Condition and Trend

<u>Community Extent and Change over Time</u>

The extent of the aspen woodland as mapped by Friesen et al. (2010) is shown in Figure 14. Of the four aspen woodland types identified, the aspen complex had the largest extent with a combined total of 127.4 ha (314.7 ac). The least extensive type was the aspen/red-osier dogwood woodland at only 1.8 ha (4.5 ac), occurring in just one stand near the center of the park (Figure 14, Table 25). In total, Friesen et al. (2010), mapped 160.2 ha (395.8 ac) of aspen woodlands. This is less than the area of aspen woodland cover of 174 ha (430 ac) previously mapped by Jones (1993).

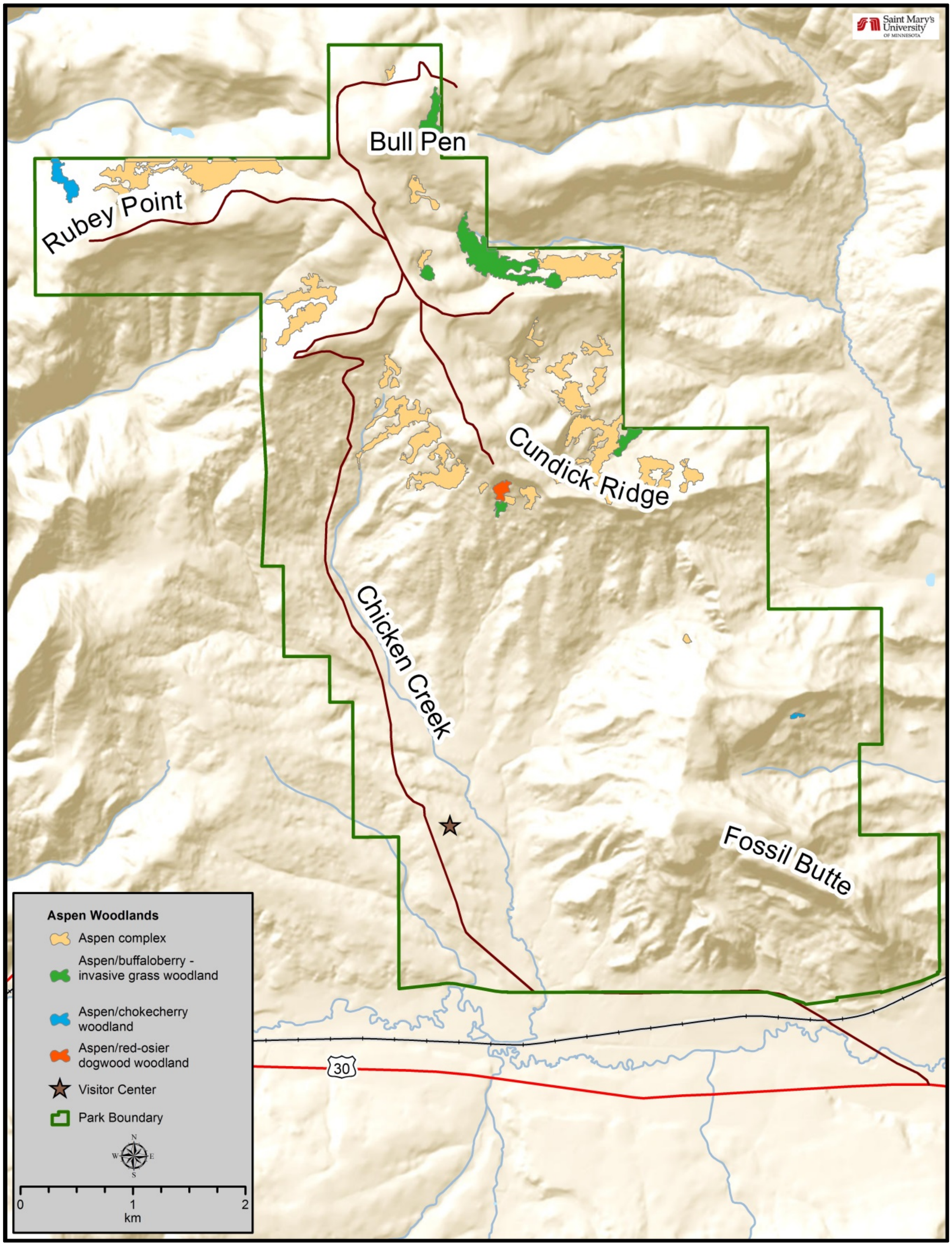


Figure 14. Aspen woodlands locations mapped by Friesen et al. (2010).

Table 25. Extent of aspen woodlands in FOBU (Friesen et al. 2010).

Aspen Forest Type	Hectares	Acres
Aspen/buffalo-berry-invasive grass woodland	26.7	66.0
Aspen chokecherry woodland	4.3	10.6
Aspen/red-osier dogwood woodland	1.8	4.5
Aspen complex	127.4	314.7
Total	**160.2**	**395.8**

Community Composition

A review of historical data completed in 1984 listed 76 vascular plant species occurring in FOBU's aspen woodlands (Dorn et al. 1984, Appendix B). These species are still present within FOBU today, according to the NPS certified species list (NPS 2015). Understory species associated with aspen woodlands include: Canada/russet buffalo-berry (*Sheperdia canadensis*), saskatoon serviceberry (*Amelanchier canifozia*), ballhead waterleaf (*Hydrophyllum capitatum*), fernleaf lovage (*Ligusticum filicinum*), butterweed groundsel (*Senecio serra*), hookedspur violet (*Viola adunca*), northern bedstraw (*Galium boreale*), and sticky geranium (*Geranium viscosissimum*) (Dorn et al. 1984). Fertig and Kyte (2009) identified 125 species as occurring in aspen woodlands, including all but two of the species listed by Dorn et al. (1984) (Appendix B).

Trends in Invasive Infestation

As discussed in previous sections, surveys for IEPs were performed in FOBU in 2008, 2009, 2010, 2012 and 2014, focusing along roads, trails, and drainages (Perkins 2015). Overall the number of infestations within the park has decreased since monitoring began (Perkins 2015). Using spatial queries, the known patches of IEPs relative to mapped aspen woodlands were selected from the 2014 survey data and the results are shown in Figure 15 and Table 26. This spatial analysis identified seven species that were either within a mapped aspen woodland community or within 100 m (328 ft) of a mapped aspen woodland community (Table 26). Six of these were priority IEPs, as determined by park and NCPN staff, and the seventh (Japanese brome) is to be added to the priority list for the next round of surveys (Perkins 2015). Creeping foxtail (five patches), musk thistle (*Carduus nutans*) (four patches), Canada thistle (*Cirsium arvense*) (four patches), cheatgrass (three patches), and flixweed (two patches) matched the spatial criteria of being within a mapped aspen woodland community. Patches of these five species along with patches of quackgrass (*Elymus repens*) and Japanese brome were identified as being within 100 m (328 ft) of a mapped aspen woodland community. Cheatgrass, creeping foxtail, and flixweed were the most prevalent with 21, 13, and 13 patches (Table 26).

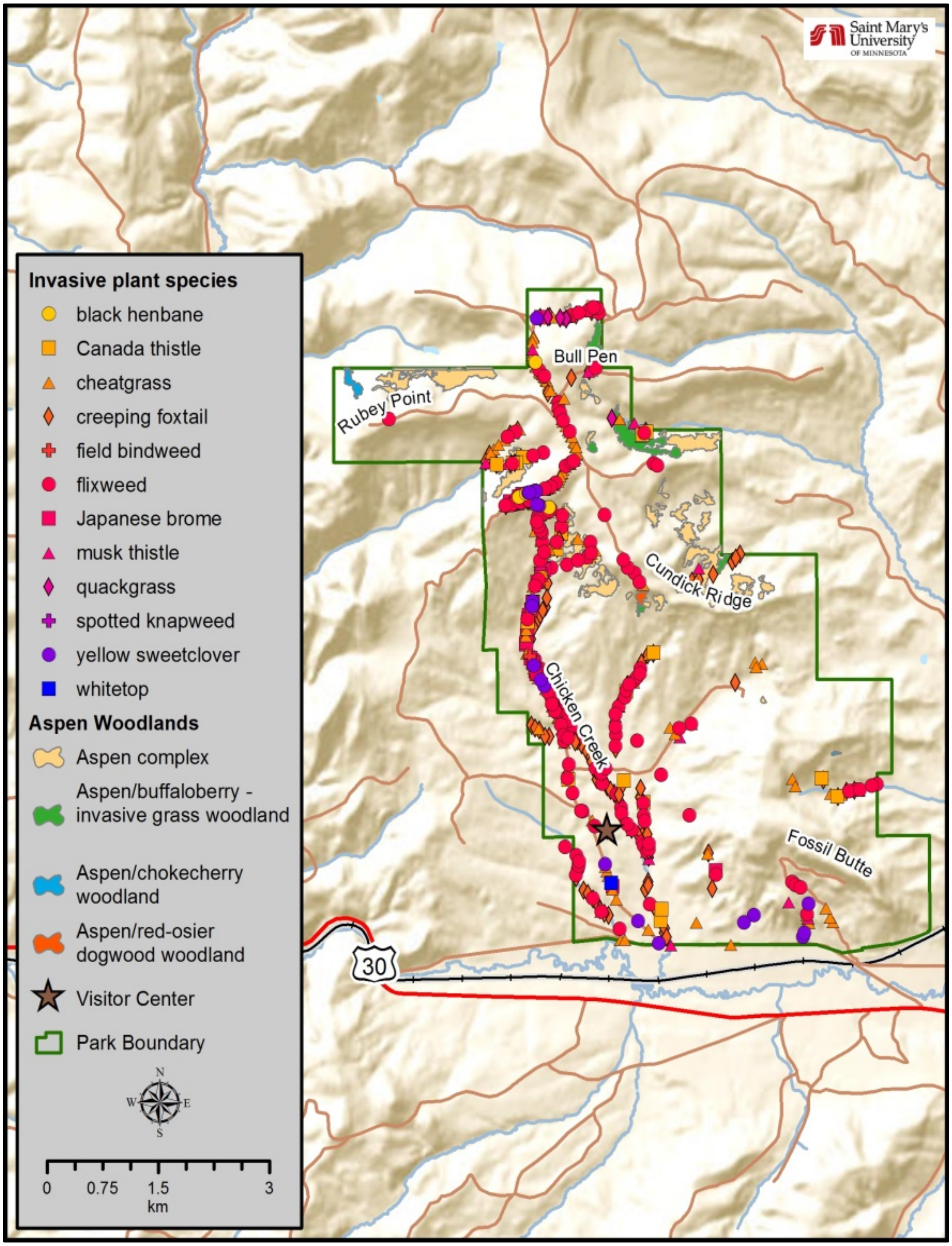


Figure 15. Known locations of invasive plant species in FOBU relative to the aspen woodlands.

Table 26. Number of IEP infestation patches from 2014 survey that are within or near an aspen woodland community.

		Number of patches		
Scientific Name	**Common Name**	**Within mapped patch**	**Within 100 m of mapped patch**	**Total**
Priority IEPs				
Alopecurus arundinaceus	creeping foxtail	5	13	**18**
Bromus tectorum	cheatgrass	3	21	**24**
*Carduus nutans**	musk thistle	4	5	**9**
*Cirsium arvense**	Canada thistle	4	5	**9**
*Descurainia sophia**	flixweed	2	13	**15**
Elymus repens	quackgrass	-	3	**3**
Other non-native species of interest				
Bromus japonicus	Japanese brome	-	3	**3**
Total		**18**	**63**	**81**

* Species designated as noxious weeds by the state of Wyoming (WPCC 2015)

<u>Rate of Regeneration (suckers per hectare)</u>

Aspen regeneration rates have not been quantitatively measured in FOBU. Bertram and Kyte (2001) described the regeneration of aspens in four different areas of FOBU as part of an ongoing beaver survey in 2001 that aimed to assess beaver activity/presence. The areas are located throughout the park (Figure 16):

- Area 1 - headwater area of Chicken Creek between the Nature Trail and Spring #1, NW1/4 Section 23
- Area 2 - Millet Canyon, SW1/4 Section 14 & NW1/4 Section 23
- Area 3 - North Canyon Slope, S1/2 Section 13
- Area 6 - Moose Bones Canyon, S1/2 SE1/4 Section 24 & N1/2 NE1/4 Section 25

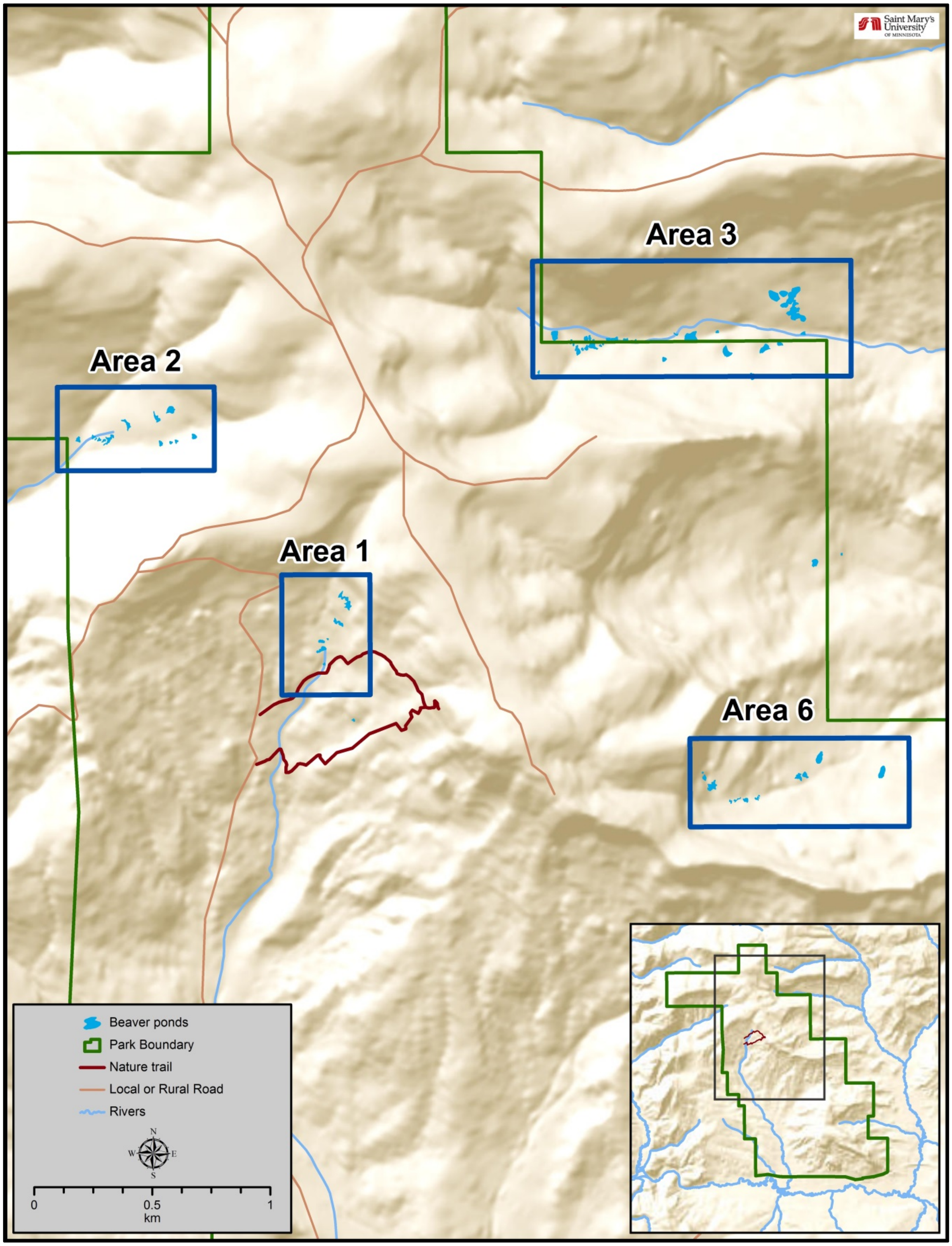


Figure 16. General locations of beaver survey areas within FOBU where aspen regeneration rates were noted (NPS 2003).

According to Bertram and Kyte (2001), spring 1 inside of Area 1 had a "supply of mature aspens" and excellent regeneration with an abundance of aspens with basal diameters ranging from 1.3 to 5.1 cm (0.5-2 in). Signs of regeneration of aspen in pond "H" were present in areas where beaver had previously harvested; around ponds I-P, which were dry, suckers were common (Bertram and Kyte 2001). In Area 2, the lowermost pond had mature aspens and signs of regeneration were observed with some areas supporting small <5.1 cm (<2 in) diameter aspen trees (Bertram and Kyte 2001). Area 3 has an area of aspen fall with very low to nearly no regeneration occurring in the Area 3 ponds. No observations regarding aspen regeneration in Area 6 were noted in the survey report.

The rate of regeneration of aspen clones in FOBU depends on the overall condition of each stand. The health of aspen stands at the park are seriously threatened due to a combination of insect and disease activity, browsing and bark damage by animals, along with drought stress over the previous 5 years (Guyon 2006). The use of prescribed fire has been suggested as a tool to stimulate sucker growth (Guyon 2006, 2014). However, in order for this to succeed, heavy browsing of new growth would need to be prevented (Guyon 2006).

Threats and Stressor Factors

Guyon (2006) uncovered a large portion of trees in certain aspen stands that had browsing and bark damage. Guyon (2006) also observed that insect and disease damage was more prevalent on trees with browsing or grazing damage. Guyon (2014) observed varying degrees of browsing damage to aspen sprouts throughout the park. Ungulate browsing and climate change are the two primary threats to aspen woodlands (Guyon 2014).

In the latest invasive species survey at FOBU, 12 invasive exotic plant species were detected, eleven of which are "priority" species, meaning they are of high management concern (Perkins 2015). Members of this priority list identified as being within or near aspen woodlands through spatial data queries are creeping foxtail, cheatgrass, musk thistle, Canada thistle, flixweed, and quackgrass (Figure 15, Table 26). One non-priority invasive plant species (Japanese brome) was also detected in the aspen woodlands. Three of the IEPs detected in or near FOBU's aspen woodlands are designated as noxious weeds by the state of Wyoming, meaning they are considered detrimental, destructive, or injurious (Table 23, WPCC 2015).

Much of the land along park boundaries is managed by the BLM. Other adjacent properties are state land, along the northwest park boundary, and a few sections of private land (Friesen et al. 2010). The BLM lands are still used as grazing areas for sheep and cattle, and permitted livestock drives cross the park twice a year to transfer animals to and from pastures located east and north of the park boundary (Friesen et al. 2010). Sheep travel from south to north in June and cattle cross from east to west in July (Brad Shattuck, Acting Superintendent FOBU, written communication, 27 May 2015). This may be a contributing factor in the invasive plant introductions as indicated by Figure 17.

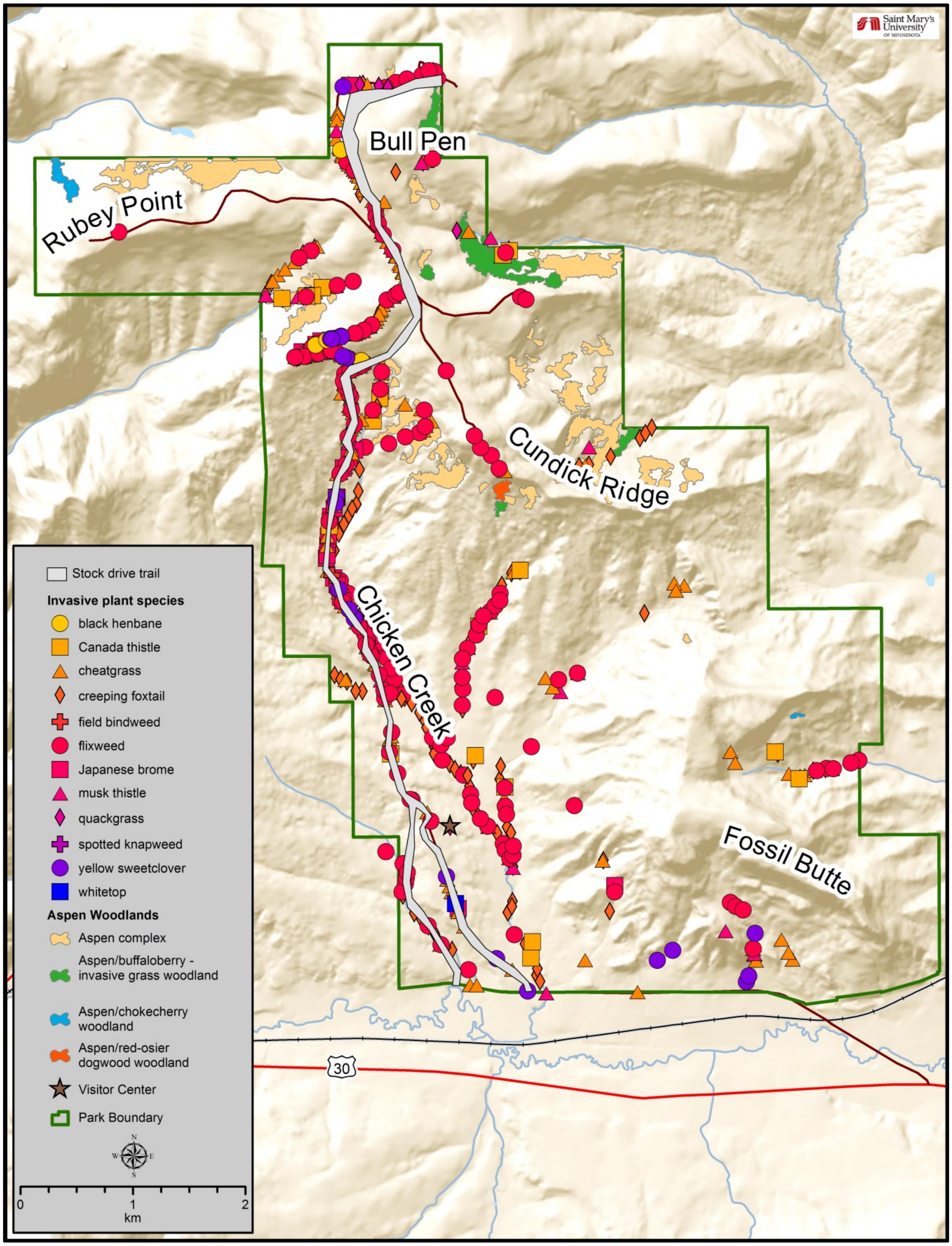


Figure 17. The stock trail follows the roadway through the park and both seem to align with the highest concentrations of invasive plant occurrence as detected by Perkins (2013).

Areas that have recently had large diebacks of aspens are heavily infected by the cytospora canker (*Cytospora chrysosperma*) which is a known pathogen of stressed trees (Guyon 2006). Infections such as these are likely due to nearly every aspen stand suffering from drought and browsing damage (Guyon 2006, 2014).

The aspen stands at the northern end of FOBU were frequently infected by various borer species including poplar borer (*Saperda calcarata*) (Photo 3) and the metallic poplar borer (*Agrilus liragus*) (Table 27). Farther into the stands, the aspens showed heavy defoliation due to a combination of large aspen tortrix (*Choristoneura confictana*) and marssonina blight (*Marssonina populi*) (Guyon 2006). Other diseases and pests commonly found in FOBU aspen stands are a few species of leaf rollers, such as birch-aspen leaf roller (*Epinotia criddleana*), and the sooty bark canker (*Encoelia pruinosa*) (Photo 3) (Guyon 2006, Table 27). Follow-up examination of aspen woodlands found primary agents of damage to trees were again the poplar borer and metallic poplar borer insects and the sooty bark canker disease (Guyon 2014). Additionally, the cytospora canker (*Cytospora chrysoperma*) was considered an increased concern in aspen declines at the park (Guyon 2014). Defoliation observed in the aspen woodlands was caused by several agents at the time of Guyon's (2014) visit; all agents involved with the damages observed in the park are listed in Table 27.

Photo 3. Two commonly observed attacks on aspen trees are the poplar borer (*Saperda calcarata*), pictured left, and the sooty bark canker (*Encoelia pruinosa*), pictured right (Guyon 2014).

Table 27. Insects and diseases found in aspen woodland sites at FOBU (Guyon 2006, 2014).

Scientific Name	Common Name	2006	2014
Pseudodexntera oregonana	aspen leaf roller	X	X
Enargia decolor	aspen two leaf tier	-	X
Epinotia criddleana	birch-aspen leaf roller	X	X
Certatocystis fimbriata	black canker	X	X
Cytospora chrysosperma	cytospora canker	X	X
Ciborinia whetzelii	ink spot	X	X
Choristoneura confictana	large aspen tortrix	X	-
Phyllocnistis populiella	leaf miner	X	X
Marssonina populi	Marssonina leaf blight	X	X
Agrilus liragus	metallic poplar borer	X	X
Anacampsis niveopulvella	pale-headed aspen leaf roller	X	X
Saperda calcarata	poplar borer	X	X
Encoelia pruinosa	sooty bark canker	X	X
Rhinocyllus conicus	true weevil	X	-
Ganoderma applanatum	ganoderma root disease	-	X
Phellinus tremulae	white trunk rot	X	X

Drought has afflicted the area of Wyoming where the park is situated, and it is currently considered abnormally dry (USDM 2015). These droughts are symptomatic of global climate change in the western United States, including Wyoming, and are associated with increased average temperatures occurring throughout this region (Guyon 2006, Saunders et al. 2008, Guyon 2014). Drought stress is known to greatly increase aspen vulnerability to insect and disease infestations (Guyon 2014). The warming temperatures associated with climate change decrease snow pack, which aspen woodlands are often reliant upon for necessary moisture levels (Saunders et al. 2008, Carr 2011).

Climate in FOBU is considered harsh due to a large range of temperatures, with -45.6 °C (-50 °F) in winter to 37.8 °C (100 °F) in the summer (NPS 2000). Weather can change rapidly relative to elevation in FOBU, with 26.7 °C (80 °F) and sunny one day and -1.1 °C (30 °F) and snowing the next (NPS 2013). FOBU and the surrounding area only receive about 27.9 cm (11 in) of precipitation a year, mostly in the form of snow (NPS 2000, WRCC 2015). The western United States, including Wyoming, has experienced decreased snowpack and snowfall, early snowmelt, and rain events in winter (Saunder et al. 2008). These factors have created drought conditions because the primary source of precipitation is normally snow that slowly melts, providing around 70% of the water sources to the ecosystem (Saunders et al. 2008). This is a threat to aspen woodlands since they tend to rely upon the snowpack/snowmelt patterns to sustain moisture and are vulnerable following extended periods of drought (Carr 2011, Guyon 2014).

Aspen decline has not been thoroughly investigated at FOBU, but is thought to be due to a combination of stressors including: insect activity, disease, animal damage, and drought (Guyon 2006 and 2014). Global warming is the primary driver of drought stress leading to aspen diebacks (sudden aspen declines); drought leaves the trees highly susceptible to invasion of pests and diseases (Saunders et al. 2008). Sudden aspen decline has afflicted thousands of acres of aspen forests throughout the west in states such as Colorado, Utah, and Montana, starting in the late 20th century (Saunders et al. 2008).

Bertram and Kyte (2001) conducted a beaver survey on six areas that had been previously surveyed in 1990. Of the areas surveyed, only areas 1, 2, 5 and 6 could potentially sustain beaver colonies, and only if the water supply improved (Figure 16). Area 1 consisted of the Chicken Creek headwaters located between the Nature Trail (formerly called Fossil Lake Trail) and Spring #1 in the northwest quarter of section 23. The ponds near the spring contained a small amount of water but the beaver dams showed no sign of upkeep and no other signs of beaver activity were seen at this location. The aspen showed excellent regeneration, especially in the area below the spring (Bertram and Kyte 2001). The pond H area contained harvestable aspen and enough water to support beavers but there was no sign of beaver activity. The majority of aspen had been harvested near ponds I-P, and aspen regeneration and suckers were present throughout (Bertram and Kyte 2001).

Area 2 is located in Millet Canyon in the southwest quarter of section 14 and the northwest quarter of section 23. This area is comprised of several ponds, labeled A-O. Pond A had enough water to support beaver but no activity was observed. Ponds H and Ah (Ag) contained active beaver lodges and food caches but were beginning to dry up. Ponds B-I were dry or unable to support a beaver colony. Aspen near the ponds have been harvested and the only available aspen was 45-73 m (150-240 ft) away. A small amount of regeneration was observed in older harvested areas (Bertram and Kyte 2001).

Area 3 is on North Canyon Slope (also known as Murder Hill) in the southern half of section 13. All the ponds in this area were dry except the large aspen fall area which contained only a small amount of water. This area only had signs of beaver activity along the eastern corner on the boundary fence. Beaver from an active pond located about 24.4 m (80 ft) north of the fence showed signs of harvesting aspen just inside the park boundary. Aspen regeneration was poor to nonexistent in this area (Bertram and Kyte 2001).

Area 5 is on the south facing slope of Cundick Ridge in the northern half of section 25. This area showed no beaver activity but had adequate water and aspen and will remain under surveillance (Bertram and Kyte 2001).

Area 6 is located in Moose Bones Canyon in the southern half and southeastern quarter of section 24 and the northern half and northeastern quarter section of 25. Only the two western-most ponds contained water, one of which was Moose Bones Pond. Beaver sign of peeled aspen, turbid water, and well-traveled runways were observed at Moose Bones Pond (Bertram and Kyte 2001).

Bertram and Kyte (2001) noted that the beaver population of FOBU had declined since the prior survey in 1999, primarily due to the drought. Aspen populations had also declined and had become scarce near ponds. Areas 1, 2, 5, and 6 had the potential to sustain small beaver colonies for a few years if water levels were maintained or increased. However, if the drought continued or worsened, then none of the beavers were likely to survive (Bertram and Kyte 2001).

Data Needs/Gaps

More information is needed to assess the rate of regeneration in aspen stands. There is mention of regeneration occurring at various rates in the aspen woodlands in Guyon (2014), but a study to directly assess this measure is not available at this time and it is considered a data gap.

Overall Condition

Community Extent and Change over Time

The project team assigned this measure a *Significance Level* of 3. Aspen woodlands make up a very small percentage of FOBU and are declining due to drought, disease, pests, and browsing damage (Guyon 2006). Due to this declining trend, a *Condition Level* of 2 was assigned.

Community Composition

The project team assigned this measure a *Significance Level* of 2. Recent data on plant species occurrence (Fertig and Kyte 2009, NPS 2015) show similar species occurring in aspen woodlands as those found in a review of historical data (Dorn et al. 1984). An assignment of *Condition Level* is not possible at this time due to the lack of historic data that had sufficient detail on species found specifically in the aspen woodlands.

Trend in Invasive Infestation

The project team assigned this measure a *Significance Level* of 2. Currently, seven invasive plant species are known to occur in aspen woodlands. A *Condition Level* of 1, or of low concern, was assigned to this measure since monitoring and control of invasive plants are continuing to combat the spread to other areas.

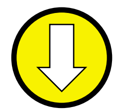
Rate of Regeneration

The project team assigned this measure a *Significance Level* of 3. The rate of regeneration of aspen clones in FOBU depends on the overall condition of each stand. The health of aspen stands at the park are seriously threatened due to a combination of insect and disease activity, browsing and bark damage by animals, along with drought stress over the previous 5 years (Guyon 2006). The general decline in aspen stands, even with signs of regeneration in some areas, has resulted in a *Condition Level* of 2.

Weighted Condition Score

Even though there are data gaps for FOBU's aspen woodlands, the available information suggests a serious decline and the persisting dry conditions are not conducive to recovery. The *Weighted*

Condition Score based on three measures is 0.58, or of moderate concern. Continued monitoring and control of further invasive plant infestation are considered a high priority in the park’s aspen woodlands.

Aspen Woodlands			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.58**
Community Extent and Change Over Time	3	2	
Community Composition	2	N/A	
Trends in Invasive Infestation	2	1	
Rate of Regeneration	3	2	

4.3.6. Sources of Expertise

- Brad Shattuck, FOBU Acting Superintendent
- Arvid Aase, FOBU Museum Specialist
- Marcia Fagnant, FOBU Chief Naturalist

4.3.7. Literature Cited

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4.4. Mixed Conifer Woodlands

4.4.1. Description

Mixed conifer woodlands are one of the three dominant vegetation types in FOBU. The north-facing slopes at mid to high elevations are where the mixed conifer woodlands tend to occur (Photo 4, McGinnis 2004, Fertig and Kyte 2009). Four types of mixed conifer woodland occur in the park, dominated by three conifer species: the limber pine, Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), and Rocky Mountain juniper (Friesen et al. 2010). Many additional plant species occur within mixed conifer woodlands, including common yarrow (*Achillea millefolium*), mountain-mahogany, Utah snowberry (*Symphoricarpos oreophilus* var. *utahensis*), Utah serviceberry and native grasses (Friesen et al. 2010). Mixed conifer woodlands provide valuable wildlife habitat; for example, a number of bird species have been documented in these communities that are found nowhere else in the park (NPS 2015).

Photo 4. An example of mixed conifer woodland in FOBU (Shannon Amberg, SMUMN GSS).

4.4.2. Measures

- Community extent and change over time
- Community composition
- Regeneration
- Age class distribution

4.4.3. Reference Conditions/Values

The reference condition for this component is the condition of mixed conifer woodlands prior to European settlement and grazing. Unfortunately, little information is available from this time, particularly for community composition, regeneration, and age class distribution.

4.4.4. Data and Methods

Fertig (2000) reviewed and revised the FOBU plant checklist to eliminate synonyms and falsely reported taxa. Fertig and Kyte (2009) further reviewed FOBU voucher specimen plants in 2004 and created an annotated species list. Annotations included park-specific distribution, population size, and flowering periods along with general information on geographic range and nomenclature updates (Fertig and Kyte 2009).

The primary vegetation inventory used in the analysis of the mixed conifer woodland community at FOBU will be a vegetation mapping project completed by Friesen et al. (2010). Friesen et al. (2010) mapped and described the plant associations occurring in FOBU. This mapping project was conducted from 2005 through 2008 as part of the NCPN Inventory and Monitoring Program and the USGS-NPS National Vegetation Mapping Program (Friesen et al. 2010). The mapping project involved initial field reconnaissance, aerial photo interpretation, spatial database development, and field verification. Earlier vegetation projects that were used in this assessment include a study analyzing the impacts of grazing at FOBU (Dorn et al. 1984) and a follow-up vegetation mapping project (Jones 1993) that verified and refined the map created by Dorn et al. (1984). While not a comprehensive vegetation inventory, the Jones (1993) study did contain information on vegetation communities at FOBU that was sufficient and complete enough to provide a baseline against which the current community extent could be evaluated. However, since neither Dorn et al. (1984) nor Jones (1993) were comprehensive vegetation inventories, they cannot be used in determining the full community composition or the changes in composition over time in the mixed conifer woodland community.

4.4.5. Current Condition and Trend

Community Extent and Change over Time

There are four distinct types of mixed conifer woodlands in the park: Douglas-fir/mountain snowberry forest, Rocky Mountain juniper/basin big sagebrush woodland, limber pine/alderleaf mountain-mahogany - Utah serviceberry woodland, and limber pine/mountain snowberry woodland. According to NPS (2005), the extents of the park's vegetation communities are largely the same as they were prior to settlement. According to the Friesen et al. (2010) mapping results, there are a total of 96.7 ha (238.9 ac) of mixed conifer woodlands in FOBU (Table 28). These conifer woodlands mostly occur on north-facing slopes that provide shade throughout much of the day (NPS 2005, Fertig and Kyte 2009). Only one Rocky Mountain juniper woodland (Rocky Mountain juniper/basin big sagebrush woodland) stand occurs in FOBU, located near the Natural Trail, and consists of a stand covering less than a hectare of area (Table 28 and Figure 18, Friesen et al. 2010).

Table 28. Extent of each mixed conifer woodland type; limber pine woodland consists of two types combined (Friesen et al. 2010).

Woodland Type	Hectares	Acres
Douglas-fir forest	19.1	47.2
limber pine woodland	77	190.2
Rocky Mountain juniper woodland	0.6	1.5
Total	**96.7**	**238.9**

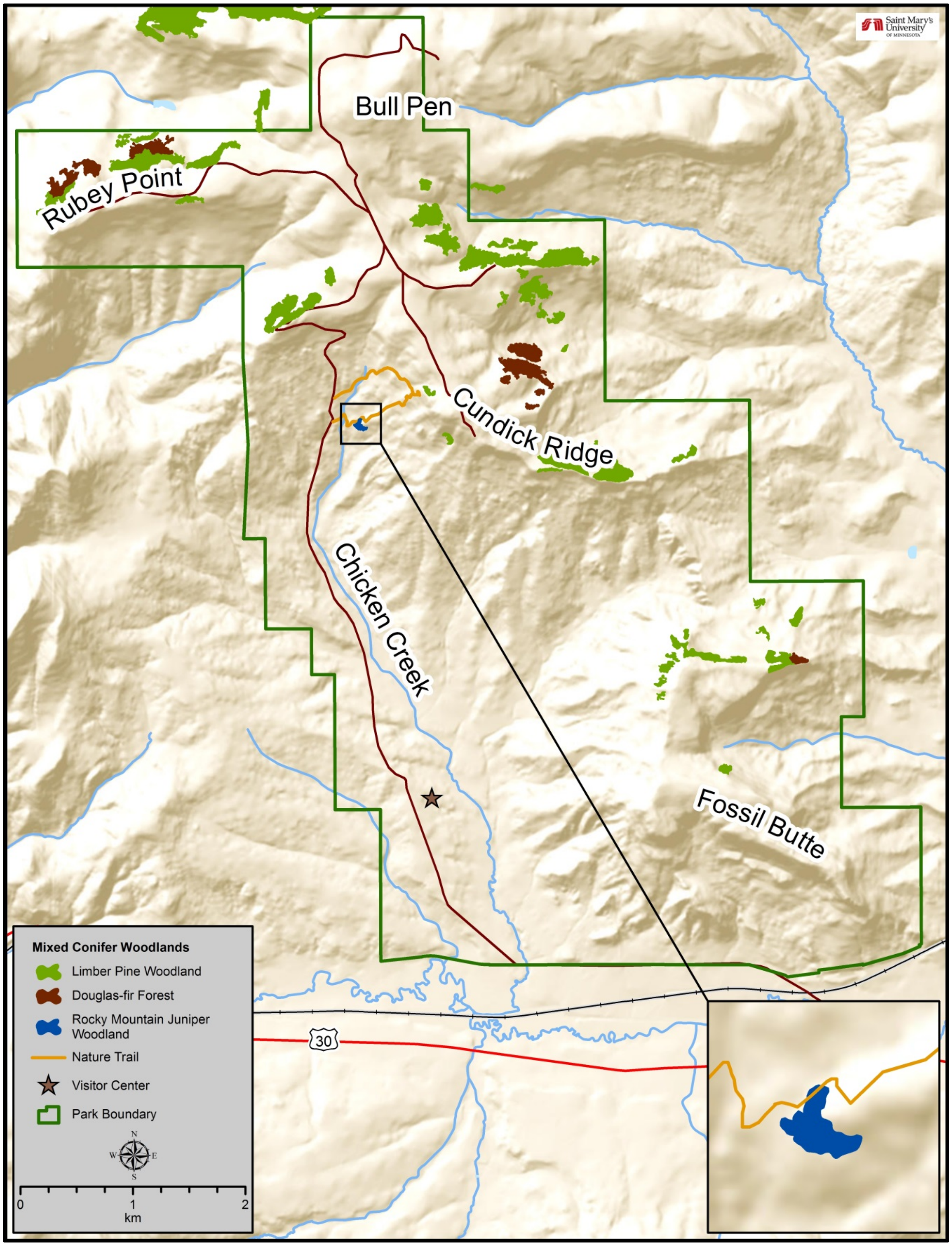

Figure 18. Mixed conifer woodland in FOBU; the limber pine woodland consists of two types combined (Friesen et al. 2010).

Douglas-fir forests (Douglas-fir/mountain snowberry forest) are considered uncommon in FOBU and only add up to 19.1 ha (47.2 ac) of park land (Table 28). Two primary stands of this forest type occur in the northern half of the park; one along Cundick Ridge (formerly called Dempsey Ridge) and one situated upon a butte near Rubey Point (Figure 18, Friesen et al. 2010).

The most extensive types are the limber pine woodlands, which consist of two different associations covering a combined 77 ha (190.0 ac) area inside the park (Table 28, Friesen et al. 2010). These two unique woodland associations are only known to occur in FOBU (Friesen et al. 2010). The limber pine/alderleaf mountain-mahogany - Utah serviceberry woodland type is found on Rubey Point and Cundick Ridge, as well as along the rims and upper slopes of ridges and buttes of the park. Limber pine/mountain snowberry woodlands are similarly distributed along the rims and high slopes of ridges and additionally on the toeslope of Fossil Butte (Figure 18, Friesen et al. 2010).

The current extent of mixed conifer woodland is similar to the extent of mixed timber map units identified during the 1992 vegetation mapping project (Jones 1993). Jones (1993, p. 26) defined mixed timber map units as containing Douglas fir woodlands, limber pine woodlands, and transition vegetation to montane shubland. Jones (1993) mapped a total of 97 ha (239.7 ac) of mixed timber map units, the majority of which were found on east- and north-facing slopes in the Fossil Butte and Cundick Ridge vicinities (Jones 1993).

Community Composition

The species list in Fertig (2000) did not provide habitat/community information for each plant species. However, this list has been compared with species that are listed as occurring in the mixed conifer woodlands in Fertig and Kyte (2009) and by Friesen et al. (2010) (Appendix C). Mixed conifer woodlands were grouped as one community type in FOBU by Fertig and Kyte (2009). A list of 52 species occurring, or reported to occur, within this generalized habitat is also included in Appendix C. Friesen et al. (2010) listed dominant tree species for each of the three mixed conifer woodland types classified in FOBU as well as other, secondary species associated with each type (Table 29).

Table 29. Plant species found in mixed conifer woodlands of FOBU; note the two limber pine woodland types, these are combined as "limber pine forest" in Figure 18 (Friesen et al. 2010).

Mixed Conifer Woodland Type	Scientific Name	Common Name
Rocky Mountain Juniper / Basin Big Sagebrush Woodland		
Tree canopy	*Juniperus scopulorum*	Rocky Mountain juniper
Tall shrub/sapling	*Amelanchier utahensis*	Utah serviceberry
Short shrub/sapling	*Artemisia tridentata* ssp. *vaseyana*	mountain big sagebrush

A = *Symphoricarpos oreophilus* var. *utahensis* was formerly classified as only *Symphoricarpos oreophilus*, mountain snowberry, including in Friesen et al.'s (2010) vegetation association names.

B = Non-native species

Table 29 (continued). Plant species found in mixed conifer woodlands of FOBU; note the two limber pine woodland types, these are combined as "limber pine forest" in Figure 18 (Friesen et al. 2010).

Mixed Conifer Woodland Type	Scientific Name	Common Name
Others	*Symphoricarpos oreophilus* var. *utahensis*[A]	Utah snowberry
	Purshia tridentata	antelope bitterbrush
Others	*Rosa woodsii*	Wood's rose
	Leymus cinereus	Great Basin wildrye
	Achnatherum hymenoides	Indian ricegrass
	Bromus tectorum[B]	cheatgrass
	Cirsium arvense[B]	Canada thistle
	Penstemon procerus	pincushion beardtonge
	Phlox hoodii	Hood's phlox
Limber Pine / Alderleaf Mountain-mahogany-Utah Serviceberry Woodland		
Tree canopy	*Pinus flexilis*	limber pine
Tall shrub/sapling	*Amelanchier utahensis*	Utah serviceberry
Short shrub/sapling	*Cercocarpus montanus*	true mountain-mahogany
Others	*Pseudotsuga menziesii* var. *glauca*	Douglas-fir
	Juniperus scopulorum	Rocky Mountain juniper
	Symphoricarpos oreophilus var. *utahensis*[A]	Utah snowberry
	Artemisia tridentata ssp. *vaseyana*	mountain big sagebrush
	Prunus virginiana	chokecherry
	Berberis repens	creeping Oregon-grape
	Chrysothamnus viscidiflorus	green rabbitbrush
	Holodiscus discolor var. *dumosus*	oceanspray
	Ribes cereum	wax currant
	Shepherdia canadensis	russet buffalo-berry
	Leymus cinereus	Great Basin wildrye
	Poa fendleriana	muttongrass
	Poa secunda	Sandberg bluegrass
	Pascopyrum smithii	western wheatgrass
	Mertensia oblongifolia	leafy bluebells

A = *Symphoricarpos oreophilus* var. *utahensis* was formerly classified as only *Symphoricarpos oreophilus*, mountain snowberry, including in Friesen et al.'s (2010) vegetation association names.

B = Non-native species

Table 29 (continued). Plant species found in mixed conifer woodlands of FOBU; note the two limber pine woodland types, these are combined as "limber pine forest" in Figure 18 (Friesen et al. 2010).

Mixed Conifer Woodland Type	Scientific Name	Common Name
Others	*Pteryxia terebinthina*	turpentine spring-parsley
	Eriogonum umbellatum	sulfur buckwheat
	Eriogonum brevicaule	shortstem buckwheat
	Cirsium undulatum	wavy-leaf thistle
	Achillea millefolium	common yarrow
	Lithospermum ruderale	western gromwell
	Trifolium gymnocarpon	hollyleaf clover
Limber Pine / Mountain Snowberry Woodland		
Tree canopy	*Pinus flexilis*	limber pine
Tall shrub/sapling	*Amelanchier utahensis*	Utah serviceberry
Short shrub/sapling	*Symphoricarpos oreophilus* var. *utahensis*[A]	Utah snowberry
Others	*Pseudotsuga menziesii* var. *glauca*	Douglas-fir
	Cercocarpus montanus	true mountain-mahogany
	Rosa woodsii	Wood's rose
	Berberis repens	creeping Oregon-grape
	Artemisia tridentata ssp. *vaseyana*	mountain big sagebrush
	Ribes cereum	wax currant
	Shepherdia canadensis	russet buffalo-berry
	Poa pratensis[B]	Kentucky bluegrass
	Poa fendleriana	muttongrass
	Leymus cinereus	Great Basin wildrye
	Mertensia oblongifolia	leafy bluebells
	Lappula occidentalis	western stickseed
	Delphinium nuttallianum	Nuttall's larkspur
	Achillea millefolium	common yarrow

A = *Symphoricarpos oreophilus* var. *utahensis* was formerly classified as only *Symphoricarpos oreophilus*, mountain snowberry, including in Friesen et al.'s (2010) vegetation association names.

B = Non-native species

Table 29 (continued). Plant species found in mixed conifer woodlands of FOBU; note the two limber pine woodland types, these are combined as "limber pine forest" in Figure 18 (Friesen et al. 2010).

Mixed Conifer Woodland Type	Scientific Name	Common Name
Others	*Pteryxia terebinthina*	turpentine spring-parsley
	Lithospermum ruderale	western gromwell
Douglas Fir/Mountain Snowberry Forest		
Tree canopy	*Pseudotsuga menziesii* var. *glauca*	Douglas-fir
Short shrub/sapling	*Symphoricarpos oreophilus* var. *utahensis*[A]	Utah snowberry
Others	*Pinus flexilis*	limber pine
	Amelanchier utahensis	Utah serviceberry
	Poa secunda	Sandberg bluegrass
	Leymus cinereus	Great Basin wildrye
	Elymus lanceolatus	streambank wheatgrass
	Balsamorhiza sagittata	arrowleaf balsamroot
	Arnica cordifolia	heart-leaf arnica

A = *Symphoricarpos oreophilus* var. *utahensis* was formerly classified as only *Symphoricarpos oreophilus*, mountain snowberry, including in Friesen et al.'s (2010) vegetation association names.

B = Non-native species

Regeneration

Regeneration has not been specifically studied in FOBU's mixed conifer woodlands. The FOBU fire management plan (NPS 2005) states that the absence of fire has resulted in higher densities of conifer seedling and young trees, suggesting elevated regeneration in the park. The last substantial fire was estimated to have occurred in 1981; the fire burned 105.2 ha (260 ac) of various vegetation types (NPS 2005). The mixed conifer woodlands are thought to have last burned around 34 to 83 years ago as of 2005 (NPS 2005).

Age Class Distribution

Although the actual ages of trees are not discussed in Friesen et al. (2010), there are brief descriptions for each woodland type in terms of canopy coverage and the average diameter at breast height (dbh) which may be used to estimate the age class distribution of trees.

In the Douglas-fir/mountain snowberry forests, Douglas-fir formed a dense canopy of 10-25 m (32.8-82 ft) tall trees with an average dbh of 13.6 cm (5.4 in) in sample plots. The limber pine trees in this forest type are scattered, providing a sparse, subcanopy cover and are an average of 5-10 m (16.4-32.8 ft) tall (Friesen et al. 2010). Seedlings also provide sparse cover and are scattered among the herbaceous layer of grasses and forbs (Friesen et al. 2010). A few of the largest Douglas-fir trees within the study plot bore scars from fire events (Friesen et al. 2010).

The Rocky Mountain juniper/basin big sagebrush woodland is less densely vegetated than the Douglas-fir forest (Friesen et al. 2010). It has an open canopy of 2-5 m (6.6-16.4 ft) tall juniper trees mixed with moderate coverage of mountain big sagebrush (Friesen et al. 2010). The juniper trees average dbh was 16.6 cm (6.5 in).

Limber pine/alderleaf mountain-mahogany – Utah serviceberry woodlands can have an open or dense canopy, depending on the area. Limber pines in this woodland are typically 10-20 m (32.8-65.6 ft) in height with an average dbh of 30 cm (11.8 in) (Friesen et al. 2010). Often dependent on the percent coverage of canopy, the shrub understory ranges from 10 to 50% and mostly consists of Utah serviceberry and mountain-mahogany (Friesen et al. 2010).

The limber pine/mountain snowberry woodland is only known to occur in the park (Friesen et al. 2010). These open to dense canopies are comprised of 10-15 m (32.8-49 ft) tall limber pines with an average dbh of 12.3cm (4.8 in) (Friesen et al. 2010). Limber pine and Douglas-fir saplings also create a sparse understory and average 2-5 m (6.6-16.4 ft) in height (Friesen et al. 2010).

<u>Threats and Stressor Factors</u>

Threats to FOBU's mixed conifer woodlands include adjacent land uses, altered fire regimes, diseases and pests, climate variation, and invasive plant species. Adjacent land is primarily owned by the BLM, with some private and state land. The most influential factors that have altered vegetation communities are fire suppression and livestock grazing (NPS 2005). Grazing has been eliminated from the park property as of 1989 (NPS 2005).

Fire regimes have been altered by humans since early settlement in the late 1800s. The fires at FOBU were historically of low intensity and much more frequent (NPS 2005). Without periodic burns, the natural build-up of fuels can result in very intense fires that are difficult to control and also cause higher mortality of flora and fauna (NPS 2005).

Regional climate variation at the park as a result of global climate change may impact the extent and composition of mixed conifer woodlands in the future. The most likely negative impacts are from drought which not only causes trees and plants to die from direct stress, but also exacerbates other problems such as worsened water quality and availability, fuel accumulation, and susceptibility to infestation of pests and disease (Saunders et al. 2008).

The Douglas-fir beetle (*Dendroctonus pseudotsugae*) infests and kills Douglas-fir trees by introducing fungus, yeast, and other pests as they feed under the bark (USFS 2010). The intensity of impacts to Douglas-fir trees is dependent on several factors; the tree health (e.g., drought stressed and scorched trees), the stand condition (e.g., age class structure, densities), and weather (e.g., drought) will dictate whether the beetle population will reach outbreak levels (USFS 2010). The Douglas-fir beetle targets fire damaged trees and tends toward the largest trees in a stand. With proper management, Douglas-fir beetles can be kept at bay even in areas where they are common (USFS 2010).

The mountain pine beetle (*Dendroctonus ponderosae*) is an aggressive pest of several types of pine trees (USFS 2010). The limber pine is one host to this type of beetle and is at risk of infestation in

FOBU. The most effective preventative method for controlling mountain pine beetle infestation is forest management techniques that increase the natural tree and stand resistances (USFS 2010). According to Guyon (2014), the mountain pine beetle was the cause of limber pine mortality in FOBU, but the damage was estimated to be 2 years old at the time of the survey. Guyon (2014) recommended that the park make monitoring a priority due to the aggressive nature of this pest.

Guyon (2014) identified atropellis canker (*Atropellis pinicola*) infections on some smaller (<13 cm [<5 inch] diameter) limber pine trees, but did not consider these to be a major concern. In each observed case the infected area was where animals had rubbed the tree open, leaving a vulnerable area. Needle scale (*Chionaspis pinifoliae*) was also observed on limber pines in the park; heavy infestation of needle scale can cause premature needle drop and occasional twig dieback (Guyon 2014).

Invasive plant species can negatively affect vegetation communities by fragmenting native ecosystems, displacing native plants and animals, and altering ecosystem functions (e.g., fire regime) (Perkins 2013). Canada thistle, an invasive exotic plant, was documented in the mixed conifer woodland areas by Friesen et al. (2010) and is included on the species list in Fertig (2000). This invasive plant is designates as a noxious weed by the state of Wyoming (WPCC 2015). Another exotic species, cheatgrass, was documented in Rocky Mountain juniper/basin big sagebrush woodland by Friesen et al. (2010).

<u>Data Needs/Gaps</u>

Historic data on the extent of vegetation communities at FOBU is considered to be a partial data gap. Vegetation mapping conducted by Jones (1993) can be used to assess community extent and change, but is based on generalized vegetation classifications and not the more specific classifications used by Friesen et al (2010). No data was found regarding regeneration within mixed conifer woodlands. In addition, very little is known about age class distribution in these stands. Future monitoring efforts in mixed conifer woodlands focused on collecting specific age class structure, community composition, and regeneration conditions would be very helpful in assessing long-term trends for this community.

<u>Overall Condition</u>

Community Extent and Change over Time

The extent and change over time of the mixed conifer woodlands was assigned a *Significance Level* of 3. According to the available sources, the current distribution of these woodlands is thought to be similar to their extent during the early settlement period in the late 1800s. Therefore, the *Condition Level* was assigned a level of 0, meaning no concern.

Community Composition

Community composition was assigned a *Significance Level* of 2. Fertig and Kyte (2009) listed species by vegetation type and included a general “mixed conifer” species checklist derived from archival review and some field work, while Friesen et al. (2010) documented the primary plant species in each of the four types of conifer woodlands. Although there is not an ideal reference condition for this measure, the woodland-specific accounts of species in Fertig and Kyte (2009) and

Friesen et al. (2010) can serve as a baseline for future assessments. For this reason, the *Condition Level* is not assigned at this time.

Regeneration

The regeneration of conifer woodlands was assigned a *Significance Level* of 3. Data on regeneration in FOBU's conifer woodlands were not found, but there is supporting literature that suggests regeneration has been elevated due to the suppression of natural fires (NPS 2005, Friesen et al. 2010). This is based on the presence of seedlings and saplings that would have been removed during a fire. Since regeneration has increased understory density, risks are now greater for the occurrence of high intensity wildfire (North 2006, Friesen et al. 2010). This is because saplings and seedlings are "ladder fuels" that carry fire upwards causing "crown fire" that kills the older trees (North 2006). Due to this increased risk of high intensity fires, this measure is assigned a *Condition Level* of 1, or of low concern.

Age Class Distribution

The age class distribution of conifer woodlands was assigned a *Significance Level* of 3. The available data from Friesen et al. (2010) indicates that there are both young and older trees of reproductive age in these stands. Presence of seedlings and saplings and dbh measurements were observed and recorded at the time of the vegetation mapping project. Although the reference condition for this measure is uncertain, the current age class structure has likely shifted from the pre-settlement period. This is an assumption based on the anecdotal accounts suggesting that the number of seedlings have increased from a lack of recent fires. However, the historic fire regime of conifer woodlands is not well understood; limber pine woodlands are thought to have had a variety of fire-regimes that are as diverse as the ecological settings where stands have become established, as seen in FOBU (Friesen et al. 2010, Coop and Schoettle 2011). Without a reference condition for age class distribution and only suggestive data to analyze the current condition or identify any trends, a *Condition Level* is not assigned at this time.

Weighted Condition Score

A *Weighted Condition Score* was not calculated for mixed conifer woodlands due to unknown *Condition Levels* for two of the four measures. The current condition and trend for this resource at FOBU are unknown.

Mixed Conifer Woodlands			
Measures	**Significance Level**	**Condition Level**	**WCS = N/A**
Community Extent and Change over Time	3	0	
Community Composition	2	N/A	
Regeneration	3	1	
Age Class Distribution	3	N/A	

4.4.6. Sources of Expertise

- Brad Shattuck, FOBU Acting Superintendent
- Arvid Aase, FOBU Museum Specialist
- Marcia Fagnant, FOBU Chief Naturalist

4.4.7. Literature Cited

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4.5. Seeps, Springs, and Slump Pond Aquatic Habitat

4.5.1. Description

Photo 5. Elk drinking from a pond in FOBU (NPS Photo).

Spring ecosystems are noted for their productivity and diversity, but are also among the most threatened ecosystems on the Colorado Plateau (Springer et al. 2006). Seeps and springs in arid regions such as FOBU may be considered keystone ecosystems, as they provide wildlife with water and habitat that is not available in surrounding areas. Springs may also be utilized by livestock as important water sources, impacting the water quantity and quality (Springer et al. 2006). Slump ponds form when rock or sediment on a slope move or slide downhill and create depressions where water can collect.

In addition to providing important sources of water for wildlife species, seeps and springs can serve as indicators of change in local and regional aquifers, due to their reliance on groundwater (SCPN 2012). Alteration of precipitation regimes and groundwater withdrawals, primarily outside park boundaries, threaten the flow of springs and composition and structure of plants and animals within these communities (SCPN 2012). Human impacts to seeps, springs, and slump ponds, such as water pollution, social trailing, and trampling are also potential causes of concern. Known spring and seep locations in FOBU are shown in Figure 19.

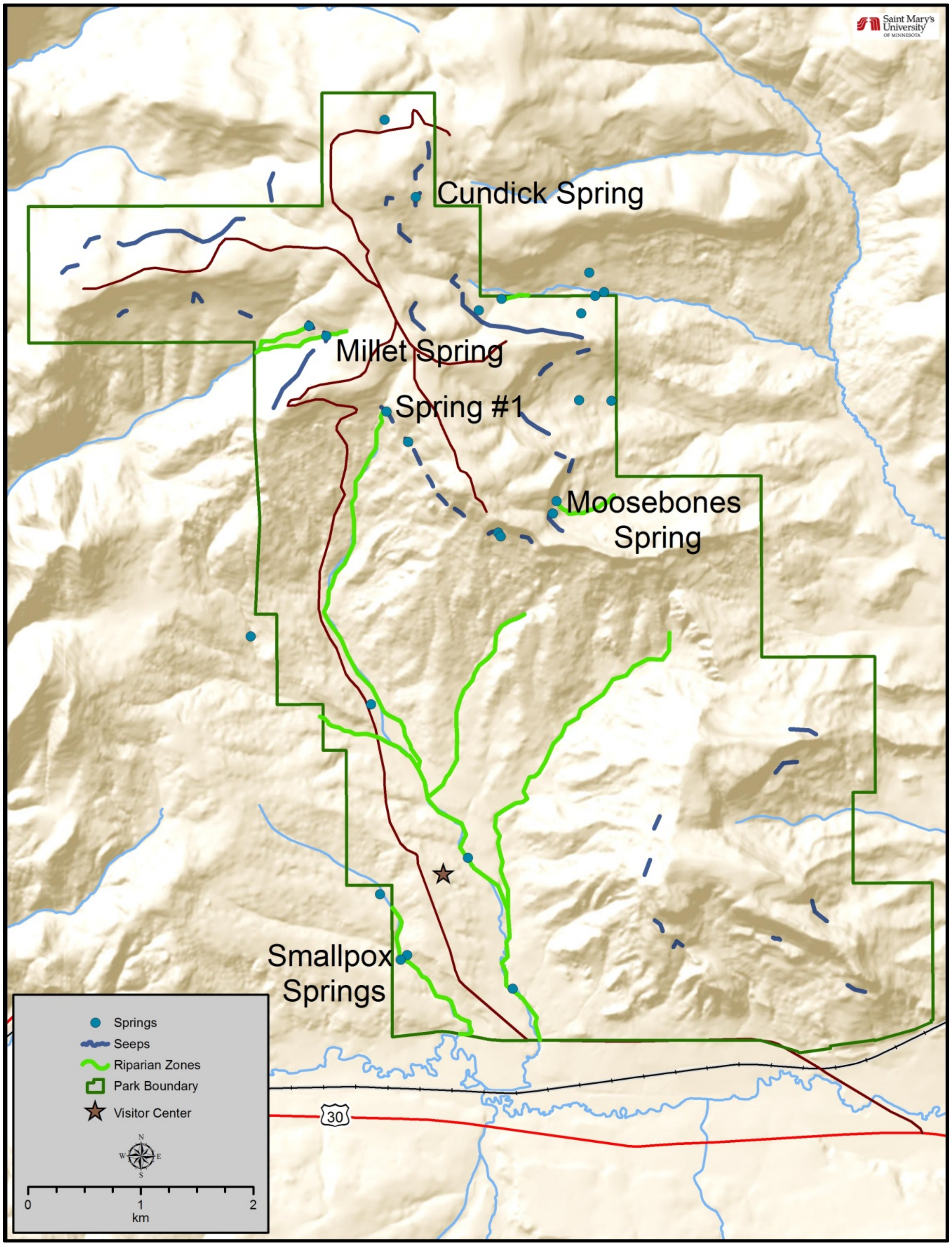

Figure 19. Seeps, springs, and riparian zone locations within FOBU. Slump ponds are not included in map as a complete GIS dataset was not available.

4.5.2. Measures

- Community extent and change over time
- Community composition
- Aquatic macroinvertebrate richness
- Water chemistry
- Discharge
- Trends in invasive infestation

4.5.3. Reference Conditions/Values

The ideal reference condition for this component would be the condition of seeps, springs, and slump ponds prior to settlement and grazing. However, little information is available from this time. For the purposes of this assessment, the pre-settlement condition described by Dorn et al. (1984) will be used as the reference condition. Some of the data presented here (e.g., discharge, water chemistry) could be used as baselines for future assessments.

4.5.4. Data and Methods

The following discussion of data and methods pertains to the condition assessment for the seeps, springs, and slump pond aquatic habitat component. The data and methods for the climate change vulnerability assessment are located in Chapter 2 and Chapter 3.

Springer et al. (2006) inventoried 75 springs across 26 NPS units in the Northern and Southern Colorado Plateau Networks. Field work was conducted in 2005 and included vegetation and invertebrate surveys, water quality analyses, and water quantity measurements (Springer et al. 2006). Four springs were surveyed at FOBU: Spring #1, Millet Spring, Moosebones Spring, and Cundick Spring (Figure 19).

In the NCPN plan for resource monitoring, Evenden et al. (2002) briefly commented on water chemistry and the aquatic invertebrate community at FOBU springs. Water discharge rates at several spring/seep locations within FOBU were discussed by Martin (2008) in a report on surplus water availability. Additional spring flow and water quality data were obtained from the EPA's Storage and Retrieval (STORET) water quality database management system (http://www.epa.gov/storet/dw_home.html).

Kyte and Santucci (1997) reported on restoration efforts in the Chicken Creek watershed that have resulted in changes to FOBU's spring and pond communities. Man-made stock pond dams were removed from the watershed in the late 1990s, in an effort to return it to more natural conditions.

Dorn et al. (1984) produced a vegetation map and plant community descriptions for the park. This vegetation map was later verified for spatial and vegetation classification accuracy by Jones (1993). Three of the vegetation communities described by Dorn et al. (1984) and Jones (1993) are likely supported by springs or seeps: wet meadow, cottonwood, and willow. Vegetation mapping and community descriptions were completed more recently by Friesen et al. (2010). Data collection for this project was completed from 2005-2008. Communities described by Friesen et al. (2010) that occur around seeps and springs are narrowleaf cottonwood (*Populus angustifolia*) woodland, Scouler's willow (*Salix scouleriana*) shrubland, yellow willow (*Salix lutea*) shrubland, and wet meadow herbaceous.

Fertig and Kyte (2009) developed a comprehensive list of plant species found within the park by habitat type. One of these habitat types was wetland areas (including pond margins, wet meadows, and willow thickets). This effort involved reviewing existing literature and specimens in the FOBU herbarium, as well as field work to confirm unverified species and to potentially locate new species. Lastly, data from IEP surveys conducted by Perkins (2015) were used to assess any trends in IEPs within FOBU. Field surveys were conducted along park roads, trails, and major drainages from 2008-2010, 2012 and in 2014 (Perkins 2015).

4.5.5. Current Condition and Trend

<u>Community Extent and Change over Time</u>

According to Friesen et al. (2010), vegetation communities supported by seeps and springs cover just over 86 ha (213 ac) of the park. The majority of this vegetation was wet meadow, at 85 ha (210 ac) (Table 30). The two willow vegetation types together cover just 0.3 ha (1.0 ac). Locations of these communities as mapped by Jones (1993) and Friesen et al. (2010) are shown in Figure 20. It is notable that Jones (1993) mapped a larger extent of cottonwood than did Friesen et al. (2010). This variance is likely not due to differences in methodology or vegetation mapping technologies. However, because differences in methodology do exist, the change cannot be verified. The potential that a decrease has occurred in the area of the narrowleaf cottonwood community over time may be of concern to FOBU resource managers.

Table 30. Areal extent of seep- and spring-associated vegetation communities identified in the Friesen et al. (2010) vegetation mapping project. Units are in hectares, followed by the acre equivalent in parentheses.

Vegetation Community	Area Hectares (acres)
Narrowleaf cottonwood	2.9 (1.2)
Willow	1.0 (0.3)
Scouler's willow	0.4 (0.1)
Yellow willow	0.6 (0.2)
Wet meadow herbaceous	210.0 (85.0)
Total	**214.9 (86.8)**

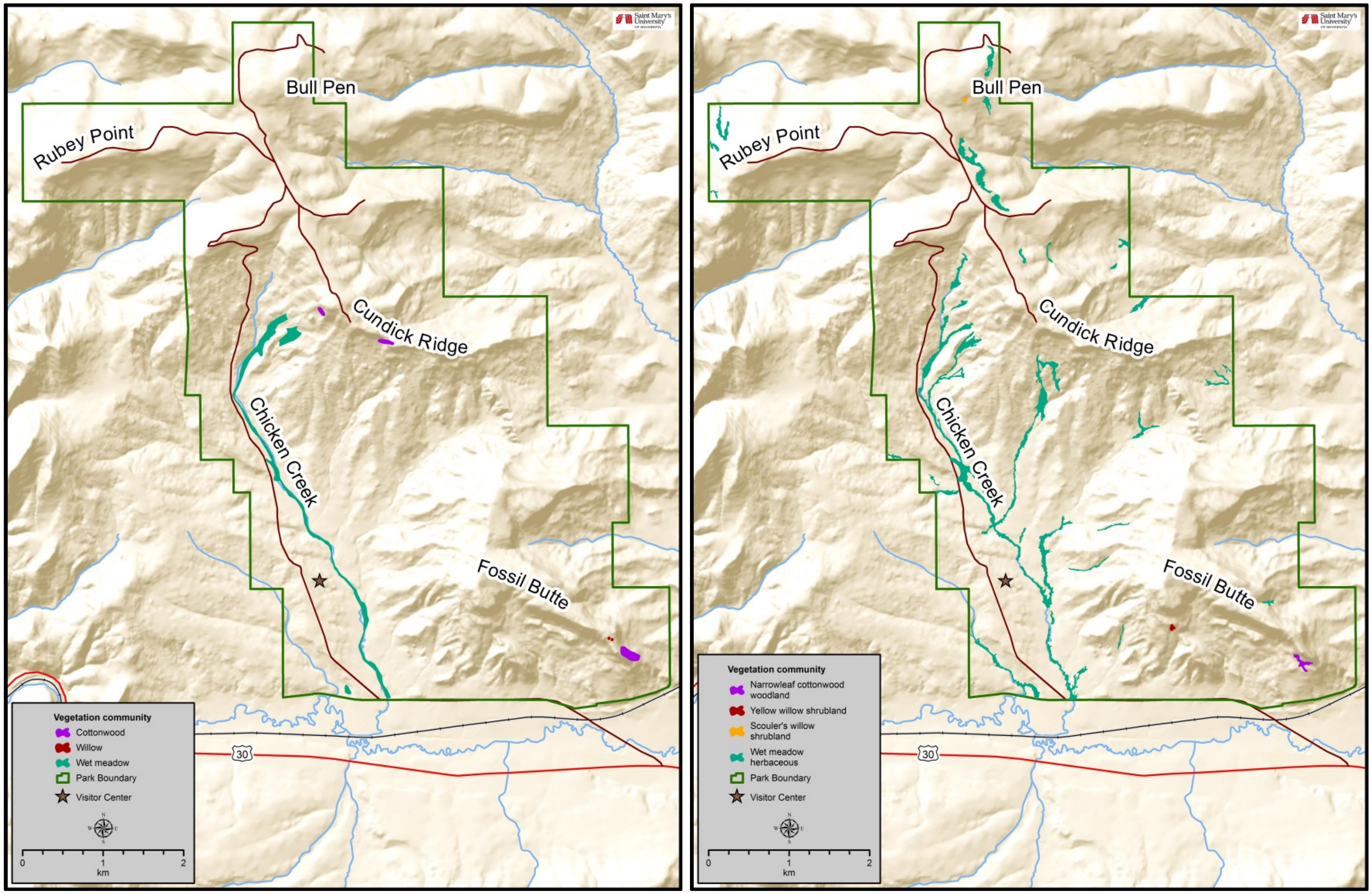

Figure 20. Seep- and spring-associated vegetation communities mapped by Jones (1993) (left) and Friesen et al. (2010) (right).

Changes to FOBU's spring and pond communities were also documented by Kyte and Santucci (1997) in a report on restoration efforts in the Chicken Creek watershed. Five man-made stock pond dams were present in this watershed prior to the establishment of the park in 1972 (Kyte and Santucci 1997). These dams disrupted the hydrologic functioning of Chicken Creek by impounding water, diverting the stream from its historical channel, and causing sediment deposition, erosion, and gullying. Three of the dams were removed in the late 1990s, in an effort to return the watershed to more natural, pre-settlement conditions (Kyte and Santucci 1997, Graham 2012). These efforts also included re-engineering and re-contouring the stream channel and floodplain, as well as planting native vegetation in the floodplain (Kyte and Santucci 1997, Graham 2012).

Community Composition

The seeps, springs, and slump pond communities of FOBU support a great diversity of plant species. The four springs surveyed by Springer et al. (2006) had an average plant species richness of 62.5 species, with two springs (Cundick and Spring #1) supporting over 65 species (Table 31). The total number of species observed between all four sampled springs was just over 130 (Appendix D). Fertig and Kyte's (2009) comprehensive plant list for FOBU included 184 plant species present in what were classified as "wetland areas (including pond margins, wet meadows, and willow thickets)." These 184 plant species included one tree, 11 shrubs, 97 perennial forbs, 22 annual forbs, 48 perennial graminoids, three annual graminoids, and two ferns and allies.

Table 31. Total number of plant species by site (Springer et al. 2006).

Spring Name	Total Plant Species
Spring #1	66
Millet Spring	56
Moosebones Spring	65
Cudnick Spring	63
Average	**62.5**

Dorn et al. (1984) and Friesen et al. (2010) briefly described some of the common plant species in each of FOBU's mapped vegetation communities. According to Friesen et al. (2010), the narrowleaf cottonwood community is dominated by cottonwood with basin big sagebrush, Utah serviceberry, Great Basin wildrye (*Leymus cinereus*), and gray aster (*Eurybia glauca*) common in the understory. Additional species present in the understory include mountain snowberry, Woods' rose (*Rosa woodsii*), Geyer's sedge (*Carex geyeri*), muttongrass, Sandberg bluegrass (*Poa secunda*), bastard toadflax (*Comandra umbellata*), starry false lily of the valley (*Maianthemum stellatum*), and two-grooved milkvetch (*Astragalus bisulcatus*). Dorn et al. (1984) lists yellow willow, starry false lily of the valley, and fireweed (*Chamerion angustifolium*) as common understory species. The most abundant species within this community, as described by Friesen et al. (2010) can be found in Table 32.

Table 32. Most abundant species in the narrowleaf cottonwood woodland community (Friesen et al. 2010).

Stratum	Scientific Name	Common Name
Narrowleaf cottonwood woodland		
Tree canopy	*Populus angustifolia*	narrowleaf cottonwood
Tall shrub/sapling	*Artemisia tridentata* ssp. *tridentata*	basin big sagebrush
Short shrub/sapling	*Artemisia arbuscula* ssp. *longiloba*	little sagebrush
Herbaceous	*Leymus cinereus*	Great Basin wildrye
Herbaceous	*Eurybia glauca*	gray aster

Dorn et al.'s (1984) willow community type is dominated by yellow willow with an understory of Baltic rush (*Juncus balticus*) and starry false lily of the valley. Friesen et al. (2010) gave a similar description for the yellow willow shrubland, with the addition of Great Basin wildrye, common yarrow, clustered field sedge (*Carex praegracilis*), muttongrass, and bastard toadflax as associated understory species. The shrubs basin big sagebrush and Woods' rose may be present as well. Friesen et al. (2010) also described a single stand of Scouler's willow shrubland. This community was dominated by Scouler's willow, with a dense understory including bluejoint grass (*Calamagrostis canadensis*), mountain snowberry, oniongrass (*Melica bulbosa*), Kentucky bluegrass (*Poa pratensis*), sweetcicely (*Osmorhiza berteroi*), veiny meadow-rue (*Thalictrum venulosum*), and threepetal bedstraw (*Galium trifidum*). The most abundant species for both willow communities are listed in Table 33.

Table 33. Most abundant species in the yellow and Scouler's willow shrubland communities (Friesen et al. 2010).

Stratum	Scientific Name	Common Name
Yellow willow shrubland		
Tall shrub/sapling	*Salix lutea*	yellow willow
Herb	*Leymus cinereus*	Great Basin wildrye
Scouler's willow shrubland		
Tall shrub/sapling	*Salix scouleriana*	Scouler's willow
Herbaceous	*Calamagrostis canadensis*	bluejoint grass
Herbaceous	*Osmorhiza berteroi*	sweetcicely
Herbaceous	*Melica bulbosa*	oniongrass

Dorn et al. (1984) describes the wet meadow type as dominated by sedges (*Carex* spp.), Baltic rush, and tufted hairgrass (*Deschampsia cespitosa*). Additional common species were alkali buttercup

(*Ranunculus cymbalaria*), common camas (*Camassia quamash*), Geyer's onion (*Allium geyeri*), and dark-throat shootingstar (*Dodecatheon pulchellum*). Friesen et al. (2010) divided wet meadows into two vegetation associations: Nebraska sedge (*Carex nebrascensis*) herbaceous vegetation and Baltic rush herbaceous vegetation. The first association is dominated by Nebraska sedge with scattered shrubs including rubber rabbitbrush (*Ericameria nauseosa*) and silver sagebrush (*Artemisia cana*). Other herbaceous species include Baltic rush, silverweed cinquefoil (*Potentilla anserina*), Pennsylvania cinquefoil (*Potentilla pensylvanica*), and Tweedy's plantain (*Plantago tweedyi*). The second association is dominated by Baltic rush, with silver sagebrush and greasewood (*Sarcobatus vermiculatus*) along the edges (Friesen et al. 2010). Additional graminoids include Kentucky bluegrass, clustered field sedge, tufted hairgrass, meadow barley (*Hordeum brachyantherum*), Nebraska sedge, prairie Junegrass (*Koeleria macrantha*), plains bluegrass (*Poa arida*), and slender-beak sedge (*Carex athrostachya*). Forbs present include silverweed cinquefoil, slender cinquefoil (*Potentilla gracilis*), common yarrow, northern bedstraw, common dandelion (*Taraxacum officinale*), short-beaked agoseris (*Agoseris glauca*), and bur buttercup (*Ranunculus testiculatus*) (Friesen et al. 2010). The most abundant species for these two wet meadow communities, as described by Friesen et al. (2010) can be found in Table 34.

Table 34. Most abundant species in the two wet meadow herbaceous communities described by Friesen et al. (2010).

Stratum	Scientific Name	Common Name
Nebraska sedge herbaceous vegetation		
Herbaceous	*Carex nebrascensis*	Nebraska sedge
Herbaceous	*Leymus cinereus*	Great Basin wildrye
Herbaceous	*Juncus balticus*	Baltic rush
Mountain (Baltic) rush herbaceous vegetation		
Herbaceous	*Juncus balticus*	Baltic rush

Aquatic Macroinvertebrate Richness

Aquatic macroinvertebrates are often used as indicators of water quality and overall watershed health (Kenney et al. 2009). Some species are tolerant of pollution or poor water quality, while others are highly sensitive to it. The presence or absence of tolerant and intolerant species can, therefore, be an indication of a water body's condition and water quality (Kenney et al. 2009). A 1970s report (Rado 1977) lists commonly found insects, including those from the aquatic orders *Ephemeroptera* (mayflies), *Odonata* (damselflies and dragonflies), and *Trichoptera* (caddisflies) (Evenden et al. 2002). The spring inventory by Springer et al. (2006) recorded total invertebrate taxa at each site, but most specimens have only been identified down to the Order level. Orders detected at each spring by qualitative and quantitative (kicknet) aquatic samplings are shown in Table 35. Of all the sites surveyed within NPS units, Spring #1 and Cundick Spring supported greater invertebrate species richness than any other spring surveyed. Millet Spring and Moosebones Spring also had relatively high invertebrate species richness when compared with other NPS units (Springer et al. 2006). Unfortunately, it is not known what proportions of these invertebrate species were aquatic, so the data cannot be used to assess this measure. If the original species data for FOBU springs could be obtained, it may be possible to determine how many of the species identified are aquatic macroinvertebrates.

Table 35. Invertebrate orders observed at FOBU springs during 2005 qualitative (qual.) and quantitative (quan.) (kicknet) sampling by Springer et al. (2006). Quantitative sampling could not be conducted at Cundick Spring due to low flows.

Invertebrate Orders	Spring #1		Millet Spring		Moosebones Spring		Cundick Spring
	qual.	quan.	qual.	quan.	qual.	quan.	qual. only
Amphipoda	-	X	-	-	-	X	-
Annelida	-	X	-	-	-	X	X
Arachnida	-	X	-	-	-	-	-
Chilopoda	-	-	-	-	-	-	X
Coleoptera	X	X	-	-	X	X	X
Diptera	-	X	-	X	-	X	-
Ephemeroptera	-	-	X	-	-	-	X
Hemiptera	X	-	-	-	X	-	-
Mollusca	-	X	X	X	-	X	X
Odonata	-	X	-	-	X	-	-
Trichoptera	-	X	-	X	-	X	-
Turbellaria	-	X	-	X	-	X	-

Water Chemistry

Water chemistry has a significant impact on organisms living in and around a water body, and on potential uses of that water (e.g., human or livestock consumption, recreation) (USGS 2010). Chemistry parameters of interest include pH, specific conductance, dissolved solids, and ion levels (e.g., nitrates, phosphates, metals, salts). Information regarding the water chemistry of FOBU's springs is limited. Some historic data for four FOBU springs (Cundick Ridge #2, Spring #1, Smallpox Springs, and Chicken Creek Spring) were obtained from the EPA's STORET database (EPA 2015). These data were collected in 1977 and 1988-89 (Table 36). While some dissolved solids measurements were high (particularly Chicken Creek Spring), all sulfate, chloride, and nitrate levels were below EPA standards or recommendations for drinking water (EPA 2009) In addition to measurements included in Table 36, the data show that iron levels were relatively low in sampled springs, never exceeding 0.16 mg/L (EPA 2015). Small amounts of magnesium were detected in all four springs; low levels of manganese and selenium were also present in some Cundick Ridge Spring

#2 samples. Constituents tested for but never detected at any springs included lead, mercury, arsenic, copper, silver, cadmium, and orthophosphate (EPA 2015).

Table 36. Available water chemistry data for selected parameters from four FOBU springs (EPA 2015).

Spring Name	pH	Dissolved Solids[A] (mg/L)	Specific Conductance (µS/cm)	Hardness (Ca + Mg) (mg/L)	Sulfate[B] (SO_4) (mg/L)	Chloride[B] (mg/L)	Nitrate[C] as N (mg/L)
Cundick Ridge Spring #2							
7/26/1977	-	324	524	280	120	6.7	1.2
5/5/1988	7.84	448	320	371	-	-	-
4/21/1989	-	440	-	350	170	11	-
Smallpox Spring							
6/8/1975	7.8	496	815	330	64	24	0.7
5/5/1988	7.59	682	800	736	-	-	-
Spring #1							
7/26/1977	-	398	635	320	140	7.3	-
Chicken Creek Spring							
5/5/1988	7.88	1,240	1,800	300	-	-	-

A = The recommended maximum contaminant level (MCL) for total dissolved solids in drinking water is 500 mg/L (EPA 2009). There is no set EPA aquatic life standard for dissolved solids (EPA 2016).

B = The recommended MCL for sulfate and chloride in drinking water are 250 mg/L (EPA 2009). The chloride standard for protection of aquatic life is 230 mg/L; there is no aquatic life standard for sulfate (EPA 2016).

C = The MCL for nitrate in drinking water is 10 mg/L (EPA 2009). There is no aquatic life standard for nitrate.

Springer et al. (2006) collected similar water quality data from four sampled springs during summer 2005, with the addition of dissolved oxygen (DO) levels (Table 37). DO measurements met the levels recommended by the state of Wyoming for the protection of aquatic life (WDEQ 2013). Nitrate concentrations were well below the EPA drinking water standard of 10 mg/ L. No significant phosphate concentrations were detected in any of Springer et al.'s (2006) samples.

Table 37. Available water chemistry data for selected parameters from four FOBU springs (EPA 2015). Spring locations are shown in Figure 19.

Spring Name	pH	Dissolved Solids (mg/L)	Specific Conductance (µS/cm)	Dissolved Oxygen* (mg/L)	Sulfate (SO_4) (mg/L)	Chloride (mg/L)	Nitrate as N (mg/L)
Spring #1	7.75	520	388	9.89	99.7	16.9	1.8
Millet Spring	8.06	320	312.7	7.35	64.4	22.2	1.2
Moosebones Spring	8.19	340	247.9	6.36	107.5	6.7	0.9
Cundick Spring	8.19	260	389.9	5.23	4.9	25.4	0.5

*The state of Wyoming recommends levels above 4.0-5.0 mg/L for the protection of aquatic life (WDEQ 2013)

<u>Discharge</u>

An abundance of geologic formations with low permeability limit the groundwater resources of FOBU (Martin 2008). Water discharge from most seeps and springs in the park is low. The main sources of water in FOBU include Spring #1, Spring #2, Smallpox Spring, and Cundick Spring, all of which provide water for riparian resources. The only seeps and springs with flow sufficient enough to be developed as water supply sources include Cundick Spring and Spring #2 (at the head of the Chicken Creek drainage) (Martin 2008). Cundick Spring provides seasonal drinking water for cattle east of the spring while Spring #2 is the source of potable water for park facilities. FOBU captures discharge of Spring #2 and pipes it to a 75,708 liter (20,000 gallon) storage tank for use at park facilities, using approximately 340,687 liters (90,000 gallons) of water per year (Lord 2009).

The discharge rates of Cundick Ridge Spring #2 and Smallpox Springs were measured several times between May 1988 and March 1989 (Table 38, EPA 2015). Flows at these springs and several more were also estimated during July and August 2003 field visits (NPS 2013). Discharge from East Smallpox Springs was consistently between 7.6-9.8 lpm (2.0-2.6 gpm) in 1988-1989 (Table 38). West Smallpox Springs discharge was also consistent in 1988, although at lower rates between 0.4-1.9 lpm (0.1-0.5 gpm), but then increased significantly in March 1989. No measurable flow was reported at these sites in August 2003 (NPS 2013). Discharge at Cundick Ridge Spring #2 was more variable in 1988-1989, ranging from 18.9-45.4 lpm (5.0-12.0 gpm). The flow in August 2003 was on the low end of this range, estimated at <18.9 lpm (<5 gpm) (NPS 2013). These data suggest that discharge at the three springs was lower in 2003 than in 1988-89. However, given the limited nature of the data, it cannot be determined if this represents an actual decline in spring discharge over time or natural variation (e.g., due to precipitation variability). Additional flow estimates or observations made in 2003 are reported in Table 39. Several of these springs had no measurable flow at that time (NPS 2013).

Table 38. Discharge (flow) measurements for sampled springs at FOBU. 2003 estimates are from NPS (2013); all other data are from EPA (2015). Values are given in liters per minute (lpm) with gallons per minute (gpm) in parentheses.

Spring Name/Date	Discharge (lpm/gpm)	Spring Name/Date	Discharge (lpm/gpm)
Cundick Ridge Spring #2		**East Smallpox Spring**	
5/5/1988	22.0 (5.8)	6/15/1988	9.0 (2.38)
6/15/1988	45.4 (12.0)	6/29/1988	8.2 (2.16)
6/19/1988	31.8 (8.41)	7/14/1988	8.4 (2.22)
7/14/1988	31.7 (8.38)	7/27/1988	9.2 (2.44)
7/27/1988	30.8 (8.14)	8/19/1988	9.8 (2.6)
8/19/1988	23.1 (6.1)	8/26/1988	8.9 (2.34)
8/26/1988	20.4 (5.38)	9/1/1988	8.7 (2.31)
9/1/1988	20.7 (5.48)	9/14/1988	9.5 (2.5)
9/14/1988	18.9 (5.0)	8/2003	no flow, soil wet
3/15/1989	29.3 (7.74)	**West Smallpox Spring**	
8/2003	est. <18.9 (<5.0)	6/15/1988	1.7 (0.45)
Chicken Creek Spring		6/29/1988	1.2 (0.32)
5/5/1988	2.3 (0.6)	7/14/1988	0.8 (0.22)
Smallpox Spring*		7/27/1988	0.7 (0.18)
6/8/1975	7.6 (2.0)	8/19/1988	0.6 (0.16)
5/5/1988	11.4 (3.0)	8/26/1988	0.5 (0.12)
		9/1/1988	0.5 (0.13)
		9/14/1988	0.5 (0.13)
		3/15/1989	20.1 (5.32)
		8/2003	no flow, soil wet

*These records did not state whether they were from the east or west spring; given the other measurements in this table, they are likely from the east spring, but this is not certain.

Table 39. Estimated discharge measurements for additional FOBU springs visited in July and August 2003 (NPS 2013). Values are given in liters per minute (lpm) with gallons per minute (gpm) in parentheses.

Spring Name	Discharge (lpm/gpm)	Spring Name	Discharge (lpm/gpm)
Millet Can (primary)	est. <11.4 (<3)	Spring #2	est. <37.8 (<10)
Millet Can (secondary)	est. <3.8 (<1)	Rock Spire Spring	est. <7.6 (<2)
Homestead Spring	est. <11.4 (<3)	Reach 2 Chicken Creek	channel wet for 50 yds
Head of Moosebones Canyon	no flow, soil wet	Chicken Cr. E. of visitor center	channel wet for 50 yds
Moosebones Spring (primary)	est. <37.8 (<10), 2 ponds full	Slump pond with sedge	no flow, soil wet
Spring #1	est. 11.4 (3.0)	Seeping slope at leaning pine	est. <3.8 (<1)
Murder Hill	nearly dry	Aspen fall beaver ponds	nearly dry
Murder Hill pond (at fenceline)	no flow, soil moist	-	-

Springer et al. (2006) also recorded discharge at four FOBU springs during 2005 sampling (Table 40). These measurements are generally higher than reports from 2003 (NPS 2013, Table 39), but this may be due to the timing of sampling (1 month earlier).

Table 40. Discharge (flow) measurements for FOBU springs sampled by Springer et al. (2006) during late June/early July 2005. Values are given in liters per minute (lpm) with gallons per minute (gpm) in parentheses. Spring locations are shown in Figure 19.

Spring Name	Discharge lpm (gpm)
Spring #1	24 (6.3)
Millet Spring	48 (12.7)
Moosebones Spring	60 (15.9)
Cundick Spring	36 (9.5)

Trends in Invasive Infestation

IEP surveys were performed within FOBU in 2008, 2009, 2010, 2012, and 2014 (Perkins 2015); refer to Chapter 4.1 of this assessment for details on priority species and survey routes. These efforts were not comprehensive park-wide surveys but focused on common vectors for IEP spread such as roads, trails, and waterways. Data from the 2014 IEP survey was compared to the locations of seep- and spring-associated vegetation communities mapped by Friesen et al. (2010). Spatial queries were used to select any IEP data point that was either within these vegetation communities or was within 100 m (328 ft) of these communities. The result of this spatial analysis is shown in Figure 21 and Table 41. The IEPs that the spatial queries identified as being most commonly found within these vegetation communities were creeping foxtail (82 points) and flixweed (41 points). Cheatgrass and flixweed (44 points each) were the most common IEPs found in proximity to the vegetation communities associated with seeps and springs. Japanese chess was the only species identified that is not on the priority species list, and as stated previously, it is to be added to the list for future IEP surveys (Perkins 2015).

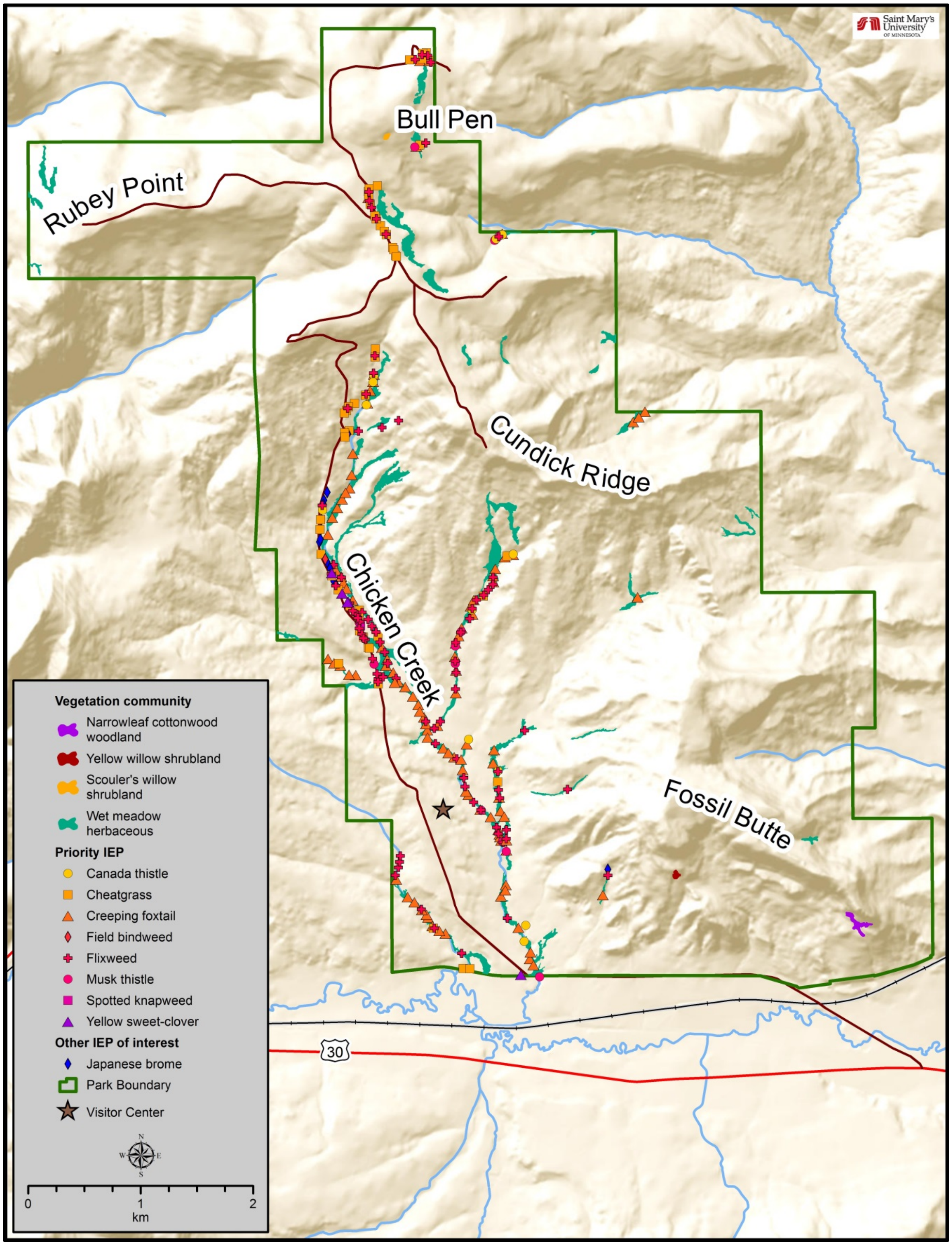

Figure 21. Number of IEP infestation patches from 2014 survey that are within or near vegetatoin communities associated with seeps and springs.

Table 41. Number of IEP infestation patches from 2014 survey that are within or near seeps and springs.

		Number of Patches		
Scientific Name	**Common Name**	**Within Mapped Patch**	**Within 100 m of Mapped Patch**	**Total**
Priority IEPs				
Alopecurus arundinaceus	creeping foxtail	82	17	**99**
Bromus tectorum	cheatgrass	7	44	**51**
Carduus nutans	musk thistle	5	7	**12**
Centaurea stoebe	spotted knapweed	-	1	**1**
Cirsium arvense	Canada thistle	4	8	**12**
Convolvulus arvensis	field bindweed	-	1	**1**
Descurainia sophia	flixweed	41	44	**85**
Melilotus officinalis	yellow sweetclover	-	5	**5**
Other non-native species of interest				
Bromus japonicus	Japanese brome	-	13	**13**
Total		**139**	**140**	**279**

Vulnerability to Climate Change

The seeps, springs, and slump pond aquatic habitats at FOBU were selected (along with montane shrublands [Chapter 4.8.5]) for additional analysis of their vulnerability to climate change (See Chapter 3.3.2). The extent and composition of the plant communities supported by seeps, springs, and slump pond habitats is discussed in detail in the above sections. Based on this discussion, two species were selected to determine the vulnerability of seeps, springs, and slump pond habitats to climate change. Narrowleaf cottonwood was selected to represent the narrowleaf cottonwood woodlands, due to the potential loss in areal extent and the possibility that this may be related to the changing climate over the last 30 years. Baltic rush was selected to represent the wet meadow herbaceous plant community as it is common to both plant associations in this community (Friesen et al. 2010). The vulnerability of narrowleaf cottonwood and Baltic rush will be assessed based on six factors: location within the community's geographic range, sensitivity to extreme climatic events, dependence on hydrologic conditions, the community's adaptive capacity, vulnerability of ecologically influential species, and the potential for climate change to increase the impacts of non-climate stressors. A detailed description of this methodology and definitions of these six variables are presented in Chapter 3.3 of this report.

Narrowleaf cottonwood is primarily found in mountainous areas ranging from Alberta and Saskatchewan to Texas and to areas east of the Sierra Nevada Mountains in Oregon and California (Figure 22A, Nesom 2008). Baltic rush is widespread throughout the western United States and is the most common rush found in the Great Basin and Dry Intermountain Regions (Figure 22B, Stevens et al. 2012).

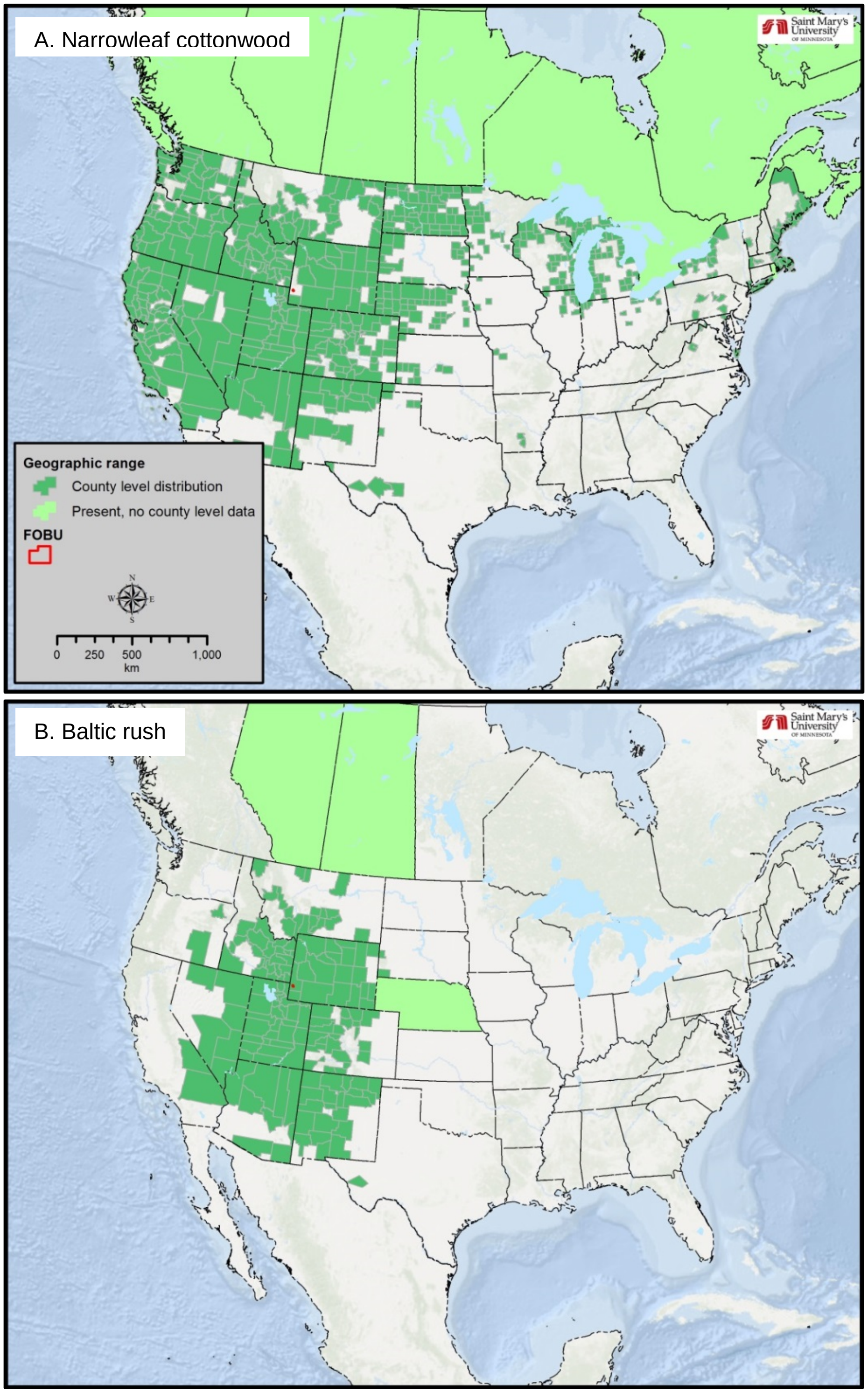

Figure 22. Geographic extent of seeps, springs, and slump pond habitat keystone species (A. narrowleaf cottonwood and B. Baltic rush) used in the climate change vulnerability analysis. The geographic extents are based on county level data from NRCS (2015).

Within FOBU, Friesen et al. (2010) only found narrowleaf cottonwood woodlands on the spring-fed slump topography on the southeast face of Fossil Butte between 2,167 and 2,171 m (7,110 - 7,123 ft) in elevation. The wet meadow herbaceous community containing Baltic rush occupies mesic soils associated with drainages, streambeds, and seeps and springs between 2,019 and 2,230 m (6,624 - 7,316 ft) in elevation (Friesen et al. 2010).

FOBU is centrally located in the geographic range of both narrowleaf cottonwood and Baltic rush (Figure 22). Therefore, location alone likely would not cause them to be significantly vulnerable to an increase in temperature and aridity causing a northern and/or westward shift in their preferred climatic conditions. However, since these plant communities require mesic soil conditions, changes to temperature and evapotranspiration will likely have a substantial influence on these species. Both of these variables are projected to change to conditions that are less favorable for riparian habitats. Climate models project warmer and drier (more arid) conditions for FOBU by the year 2100 using the RCP 8.5 scenario. The mean annual temperature for FOBU is projected to increase by 4.7 °C (8.5 °F) and mean temperatures are projected to increase during each season (ClimateWizard 2014). The most notable increases are in summertime temperatures (June-August) with a projected increase of 5.7 °C (10.2 °F) and fall temperatures (September-November) with an increase of 5.1 °C (9.2 °F) by 2100 (Figure 23, ClimateWizard 2014). Annual precipitation is projected to increase slightly, however there is not a high degree of certainty (Leung et al. 2004). The majority of the projections for increased precipitation fall within ± 5% of the historical average (Christensen et al. 2007). Despite the potential minor increase in annual precipitation, higher temperatures will result in greater evapotranspiration rates which lead to large increases in aridity (HPRCC 2013). Modeled aridity results for the FOBU region exhibit an overall increase in annual and seasonal aridity (ClimateWizard 2014). Annual aridity is predicted to increase by 17% (Figure 25, ClimateWizard). Winter (December-February) aridity levels show a minor increase (1%), most likely due to the likelihood of an increase in the intensity and frequency of winter precipitation events (Melillo et al. 2014). Aridity shows large increase during the other seasons, with a projected increase of 18% for fall, 17% for spring (March-May) and a 16% increase for summer (Figure 24, ClimateWizard 2014).

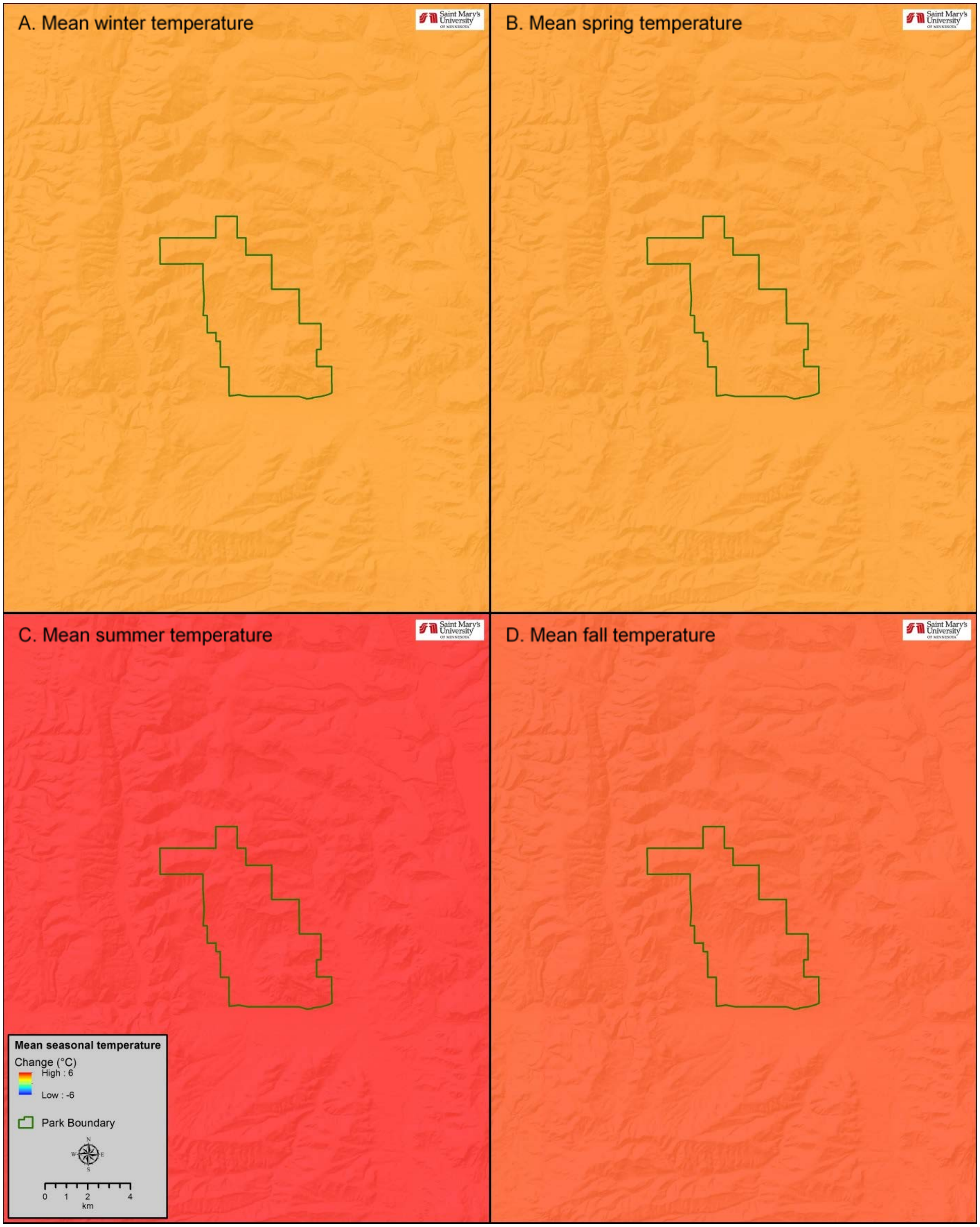

Figure 23. Change in mean A) winter, B) spring, C) summer, and D) fall seasonal temperatures for FOBU by 2070–2100 (ClimateWizard 2014). Temperatures are from the E50 ensemble with the RCP 8.5 scenario; change is determined as the departure from a 1961-1990 baseline. A 1 °C change equals a 1.8 °F change in temperature.

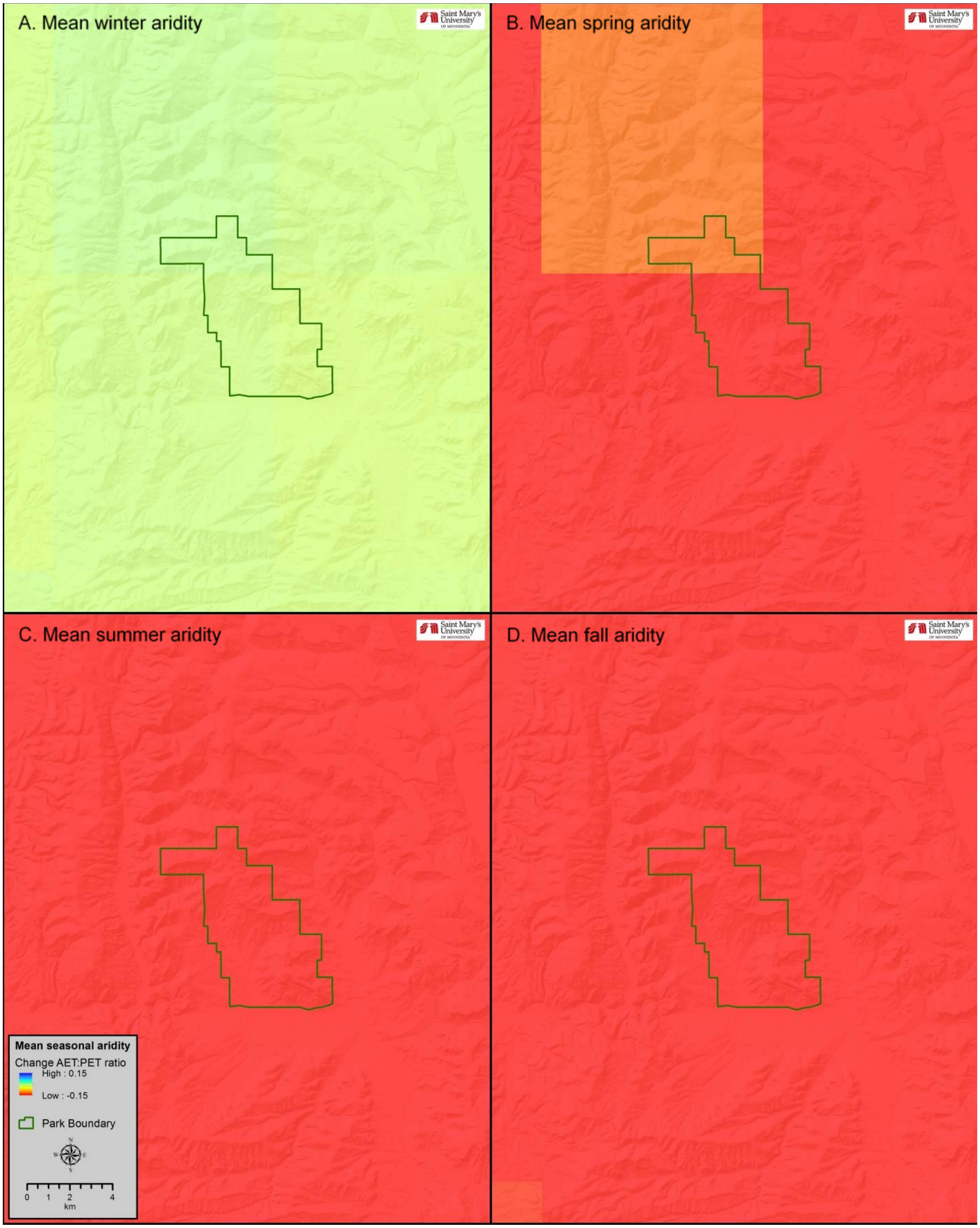

Figure 24. Change in mean A) winter, B) spring, C) summer, and D) fall seasonal aridity for FOBU by 2070–2100 (ClimateWizard 2014). Aridity values are presented as the change in the ratio of actual evapotranspiration to potential evapotranspiration. Aridity values are from the E50 ensemble with the RCP 8.5 scenario; change is determined as the departure from a 1961-1990 baseline as the percent change from the baseline period of 1961-1990. A -0.15 change is equal to a 15% increase in aridity.

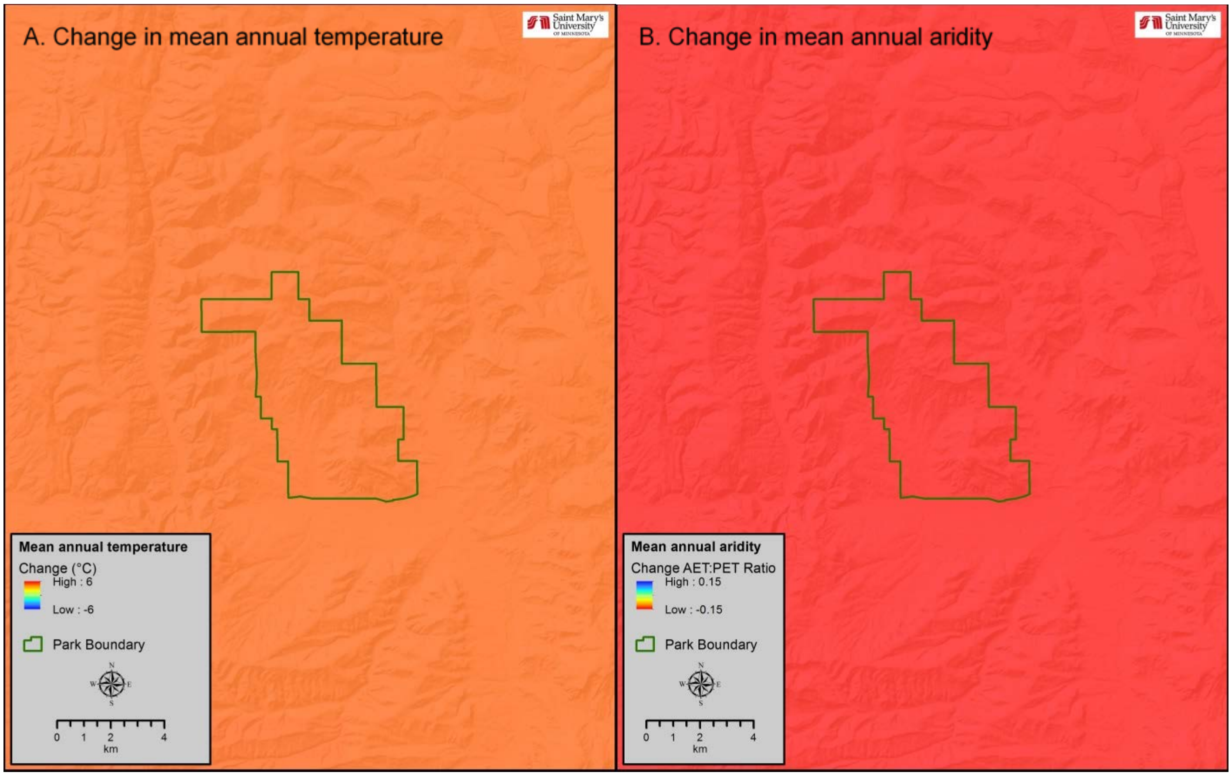

Figure 25. Changes in A) mean annual temperature and B) mean annual aridity for FOBU by 2070–2100 (ClimateWizard 2014, NCCSC 2015). Temperature and aridity values are from the E50 ensemble with the RCP 8.5 scenario; change is determined as the departure from a 1961-1990 baseline.

The climate model projections of drier conditions, with more frequent and severe droughts, are likely to negatively affect seep, spring, and slump pond communities. Baltic rush can tolerate seasonal drought, whereas riparian species such as cottonwood and willows are generally drought-intolerant, with seedlings showing the highest vulnerability to extended dry conditions (Nesom 2008, Stella and Battles 2010, Stevens et al. 2012). During the most recent vegetation mapping effort (Friesen et al. 2010), the narrowleaf cottonwood community was only found on top of a slump on the southern face of Fossil Butte. Prolonged dry periods would greatly reduce or eliminate seedling recruitment, potentially increasing the risk that this community could decline or disappear from the park.

Groundwater supplying the seeps and springs at FOBU is dependent on annual and seasonal precipitation, including meltwater from winter snowpack (Evenden et al. 2002). During droughts, groundwater recharge will decline and, in turn, contribute to a decline in seep and spring discharge. Reduced water availability will negatively impact the vegetation and wildlife that rely on these sites, potentially reducing biodiversity. The opposite weather extremes of heavy precipitation and flooding can also pose a threat to seeps and springs. These events can trigger mudslides, move boulders and trees, and erode streambanks, all of which could alter or destroy spring, seep, and slump pond habitats (Richard 2004).

These riparian vegetation communities rely on the soil moisture and groundwater supplied by seeps, springs, and slump pond habitats. They are not expected to have significant adaptive capacity, due to the limited areas in which suitable soil moisture conditions occur within the park. Wet soil conditions are needed for seed germination and the change in precipitation patterns could affect the timing of precipitation events that provide necessary soil moisture. A hotter, drier climate could also increase the rate at which water from seeps and springs or slump ponds is lost to evaporation, meaning it will be available to plants and wildlife for a shorter time (Figure 24, ClimateWizard 2014, Lamm et al. 2014). Warmer, drier conditions will likely lead to the replacement of these vegetation communities by other, more well-adapted vegetation communities or non-native species (Decker and Rondeau 2014).

The hotter and drier conditions expected in FOBU over the next century will likely exacerbate many of the current non-climate stressors of the seep, spring, and slump pond habitats. Development of the seeps and springs within the park as water sources would negatively impact the associated vegetation under current conditions (Martin 2008). If groundwater withdrawals for agricultural or domestic uses were to increase in the park or nearby, seep and spring flow would be significantly negatively impacted, potentially to the point of drying up completely.

It is difficult to assess how the warmer and drier conditions projected for FOBU will affect the non-native plants already invading the narrowleaf cottonwood and wet meadow herbaceous communities. The warmer climate with its associated shifts in temperature and precipitation patterns is likely to favor invasive species over natives in the Great Plains Region (HPRCC 2013). Currently, non-native species are not dominant in numbers or areal coverage in the seeps, springs, and slump pond habitats at FOBU. However, future conditions could lead to a decrease in the discharge of seeps and springs, allowing the potential encroachment of native and invasive species that are tolerant of drier conditions.

Threats and Stressor Factors

Threats and stressors to seeps, springs, and slump pond communities include regional climate variation, erosion, drought, invasive species, and adjacent land use. Trampling of vegetation caused by visitation and grazing can lead to loss of soil, increased erosion, and increased runoff (Evenden et al. 2002). Headcutting and erosion are apparent in Chicken Creek and are most likely related to channelization for an old railroad bed, grazing, and livestock pond dams (NPS 1991, Evenden et al. 2002). Woody species (willows) and riparian grasses that once helped reduce erosion in the Chicken Creek drainage have been reduced, most likely due to grazing (NPS 2000). Staff began planting willows in this area in 1986 to replace those lost to grazing. The survival rate of these willows was low, possibly due to drought conditions within the park (NPS 2000).

Droughts can reduce seep and spring flow, and some springs within FOBU may stop flowing during extended periods of drought (Evenden et al. 2002). This can stress plants and wildlife that rely on these habitats. During droughts, reduced flow in ephemeral streams can cause sediment to be unevenly distributed within the streambed (Kyte 1998). This may contribute to excessive stream velocity and channel over-steepening during runoff events. Droughts can also reduce vegetation cover, which in turn may decrease soil stability and increase erosion (Kyte 1998).

Invasive plants may impact spring, seep, and pond communities in a number of ways. They can displace native plants that, in turn, can alter ecosystem functions such as water and nutrient cycling (Perkins 2015). IEPs may use more water than native species; for example, saltcedar (*Tamarix* spp.) infestations have reduced spring flow or even caused springs to dry up in several southwestern states (Westbrooks 1998).

Adjacent land uses have the potential to negatively impact park resources. Human activities have the potential to impact groundwater, threatening seep and spring water quality. Possible sources of contaminants include saline water from oil and gas development, automobile associated products, wastewater, and pesticides (Evenden et al. 2002). Such contamination could negatively impact the plants and wildlife that rely on these water sources. Local coal-fired power plants may contribute to atmospheric and water pollution in FOBU.

<u>Data Needs/Gaps</u>

A comprehensive plant species list and full community composition descriptions are not available for FOBU's seep- and spring-associated vegetation communities. These communities also have not been surveyed specifically for invasive plants and their potential impacts. No aquatic macroinvertebrate-specific surveys have been conducted at FOBU's springs and ponds. While limited data are available for the discharge and water chemistry measures, most of these measurements are over a decade old (NPS 2013, EPA 2015). More recent data are necessary to assess the current condition and any trends for these measures. More accurate discharge estimates could be obtained for Cundick Spring (and perhaps others) by installing a water meter on the distribution line (Martin 2008).

<u>Overall Condition</u>

Community Extent and Change over Time

This measure was assigned a *Significance Level* of 3. The Friesen et al. (2010) vegetation mapping project identified a greater extent of seep- and spring-supported plant communities than earlier efforts by Dorn et al. (1984) and Jones (1993). While this increase is likely due to differences in methodology rather than actual change in extent, it does suggest that the overall extent of these communities is not decreasing. However, the extent of cottonwood vegetation did appear to decline during the time period between the two studies (Table 30). Therefore, a *Condition Level* of 1, indicating low concern, was assigned to this measure.

Community Composition

The community composition measure was assigned a *Significance Level* of 3. FOBU's springs, seeps, and slump ponds support a great diversity of plant species (Springer et al. 2006, Fertig and Kyte 2009). Descriptions of seep- and spring-associated plant communities by Dorn et al. (1984) and Friesen et al. (2010) are largely similar, suggesting little change in community composition over time. As a result, a *Condition Level* of 0 was assigned to this measure, indicating no concern.

Aquatic Macroinvertebrate Richness

A *Significance Level* of 2 was assigned to this measure. Although Springer et al. (2006) inventoried invertebrates at four FOBU springs; no distinction was made between terrestrial and aquatic species; because of this, the species richness data cannot be used to assess this measure. No other studies of aquatic macroinvertebrates have been conducted at FOBU's spring, seep, and slump pond communities. Therefore, a *Condition Level* could not be assigned.

Water Chemistry
This measure was assigned a *Significance Level* of 2. Water chemistry data for FOBU's springs is limited; the most recent available data are from 2005 (Springer et al. 2006). These data show that nitrate, chloride, and sulfate levels are in an acceptable range. However, because no recent data are available, a *Condition Level* could not be assigned for this measure.

Discharge
The discharge measure was assigned a *Significance Level* of 2. Martin (2008) suggests that water discharge at most seeps and springs within FOBU is low. Limited discharge data are available for several FOBU springs from 1988-1989, 2003 and 2005. The measurements suggest that spring flow at some springs was lower in 2003 than in 1988-89 (NPS 2013, EPA 2015). While it is unclear if this represents an actual decline in spring discharge over time or natural and seasonal variation, the possibility of a decline is cause for moderate concern; because of this, a *Condition Level* of 2 is assigned to this measure.

Trends in Invasive Infestation
A *Significance Level* of 2 was assigned to this measure. Spatial analysis conducted by SMUMN GSS of the data collected by Perkins (2015) identified eight of the 12 priority IEP species, along with Japanese chess, to be in or near seep- and spring-associated vegetation communities. While a park-wide survey of these communities for IEPs has not been conducted, Perkins (2013, 2015) reported a notable increase in the number of creeping foxtail infestations in the southern drainages from 2010 to 2014. As a result, this measure was assigned a *Condition Level* of 2, indicating moderate concern.

Climate Change Vulnerability Assessment
Analysis of the seeps, springs, and slump pond habitats within FOBU showed that they are highly vulnerable to the projected impacts of climate change, with an overall score of 23 (Table 42). While the certainty scores are in the "high" category with a value of 15, alternative scores were assigned to some of the variables, as the degree of impact is difficult to assess due to the differences in the selected species' geographic ranges, adaptability, vulnerability and impacts to groundwater resources in the region.

Table 42. Certainty, vulnerability, and alternative vulnerability scores for seep, spring, and slump pond habitat community assessment variables. For individual variables, certainty scores are 3 = high, 2 = moderate, and 1 = low.

Variable	Certainty[A] Score	Vulnerability[B] Score	Alternative Scores
Location in geographical range/distribution of plant community	3	3	2
Sensitivity to extreme climatic events (e.g., drought, flash floods, windstorms)	3	4	-
Dependence on specific hydrologic conditions	3	4	-
Intrinsic adaptive capacity	2	4	5
Vulnerability of ecologically influential species to climate change	2	4	-
Potential for climate change to exacerbate impacts of non-climate stressors	2	4	5
Total	**15**	**23**	**22-25**

A = The certainty ranges are 6-10 = low confidence,11-14 = moderate confidence,15-18 = high confidence
B = The vulnerability ranges are 6-13 = least vulnerable, 14-19 = moderately vulnerable, 20-25 = highly vulnerable, 26-30 = critically vulnerable

To address some of the uncertainty in the potential impact of climate change on individual species within this assessment, alternative scores were identified for several variables in addition to the best estimate scores (Table 42). Alternative scores create a range of likely vulnerability for the plant community. The "location in the geographic range/distribution of the plant community," the "intrinsic adaptive capacity," and the "potential for climate change to exacerbate impacts of non-climate stressors" variables were assigned alternative scores for a number of reasons. There are wide ranging differences in the geographic extents of the species assessed; while Baltic rush is more widespread, the narrowleaf cottonwood is rare within the park and has a smaller geographic distribution. Due to this, a lower alternative score was assigned. An alternative score was also assigned to the "intrinsic adaptive capacity" variable, as the narrowleaf cottonwood is less adaptable to changing climate conditions than Baltic rush. This can be seen by its larger geographic distribution and also due to the potential for a worst-case scenario of the potential for loss of narrowleaf cottonwood from the park under projected future climate conditions. The "potential for climate change to exacerbate impacts of non-climate stressors" was also given a higher alternative score due to the potential for total loss of the narrowleaf cottonwood woodlands under projected climate change and water use scenarios. When factored in, the range of vulnerability scores for seep, spring, and slump pond habitats is 22 to 25, placing it potentially in the "critically vulnerable" category under a worst-case scenario. With the high certainty score, this suggests that, despite some uncertainty in the degree of impact to the selected species, the classification of seep, spring, and slump pond aquatic habitats as highly vulnerable is fairly accurate. The scoring worksheet developed for the seep, spring, and slump pond aquatic habitats is included in Appendix E.

Weighted Condition Score

The *Weighted Condition Score* for FOBU's seeps, springs, and slump pond aquatic habitat is 0.37, indicating that the resource is of moderate concern. Due primarily to a lack of recent data for discharge and water chemistry measures and park-wide community-specific information on invasive plant infestations, a trend was not assigned.

Seeps, Springs, and Slump Pond Aquatic Habitat			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.37**
Community Extent and Change over Time	3	1	
Community Composition	3	0	
Aquatic Macroinvertebrate Richness	2	N/A	
Water Chemistry	2	N/A	
Discharge	2	2	
Trends in Invasive Infestation	2	2	

4.5.6. Sources of Expertise

- Marian Talbert, North Central Climate Science Center Research Statistician
- Nicholas Fisichelli Ph.D. NPS Climate Change Response Program Ecologist

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4.6. Cushion Plant Communities

4.6.1. Description

The cushion plant is a low, woody, plant that grows into pads or mats of densely entangled branches, often with microphyllous foliage, and is usually associated with alpine or tundra environments (FGDC 1997). FOBU is known for its diverse mosaic of vegetation (Friesen et al. 2010). This includes four cushion plant communities (Friesen et al. 2010). These communities are known to support endemic and rare plant species (Friesen et al. 2010). In FOBU, cushion plant communities occur along windswept ridges and are also scattered amongst the low sagebrush shrublands (Friesen et al. 2010). They consist of the species typically found in cushion plant pads and mats; such as shortstem buckwheat, turpentine spring-parsley (*Pteryxia terebinthina*), spoonleaf milkvetch (*Astragalus spatulatus*), dwarf daisy (*Erigeron nanus*), Hood's phlox, stemless goldenweed (*Stenotus acaulis*), Hooker's sandwort (*Eremogone hookeri*), fringed sagebrush (*Artemisia frigida*), Sandberg bluegrass, and bluebunch wheatgrass (Friesen et al. 2010). Also found within these communities is tufted twinpod (*Physaria condensate*, Photo 6) a rare, endemic species that can be found in two of FOBU's cushion plant communities (Fertig 2002). The BLM lists the tufted twinpod as a sensitive species due to its limited range and very specific habitat features requirements (Fertig 2002). Starveling milkvetch (*Astragalus jejunus*), a Wyoming listed imperiled plant due to its limited distribution, is also found within three of the four cushion plant community types in FOBU (Evenden 2002, Friesen et al. 2010).

Photo 6. The tufted twinpod is found in cushion plant communities in FOBU and is listed as a species of concern (Shannon Amberg, SMUMN GSS 2012).

4.6.2. Measures

- Relative abundance of *Physaria*
- Community composition
- Trends in invasive infestation

4.6.3. Reference Conditions/Values

Dorn et al. (1984) defined 12 distinct, but merged vegetation groups in FOBU while conducting a grazing impact study. Dorn et al. (1984) reported that the unvegetated/barren and grass-forb vegetation classifications supported populations of *Physaria*, however no estimate of abundance or population size was reported. Figure 26 shows the distribution of the unvegetated/barren areas delineated by Dorn et al. (1984). Fertig (2002) estimated of the relative abundance of *Physaria* within a 4 ha (10 ac) study area at FOBU as approximately 7,000 plants. This estimate does not address *Physaria* in terms of its abundance park-wide or in terms of the vegetation communities where it was found. Therefore, a reference condition for the relative abundance of *Physaria* cannot be established at this time.

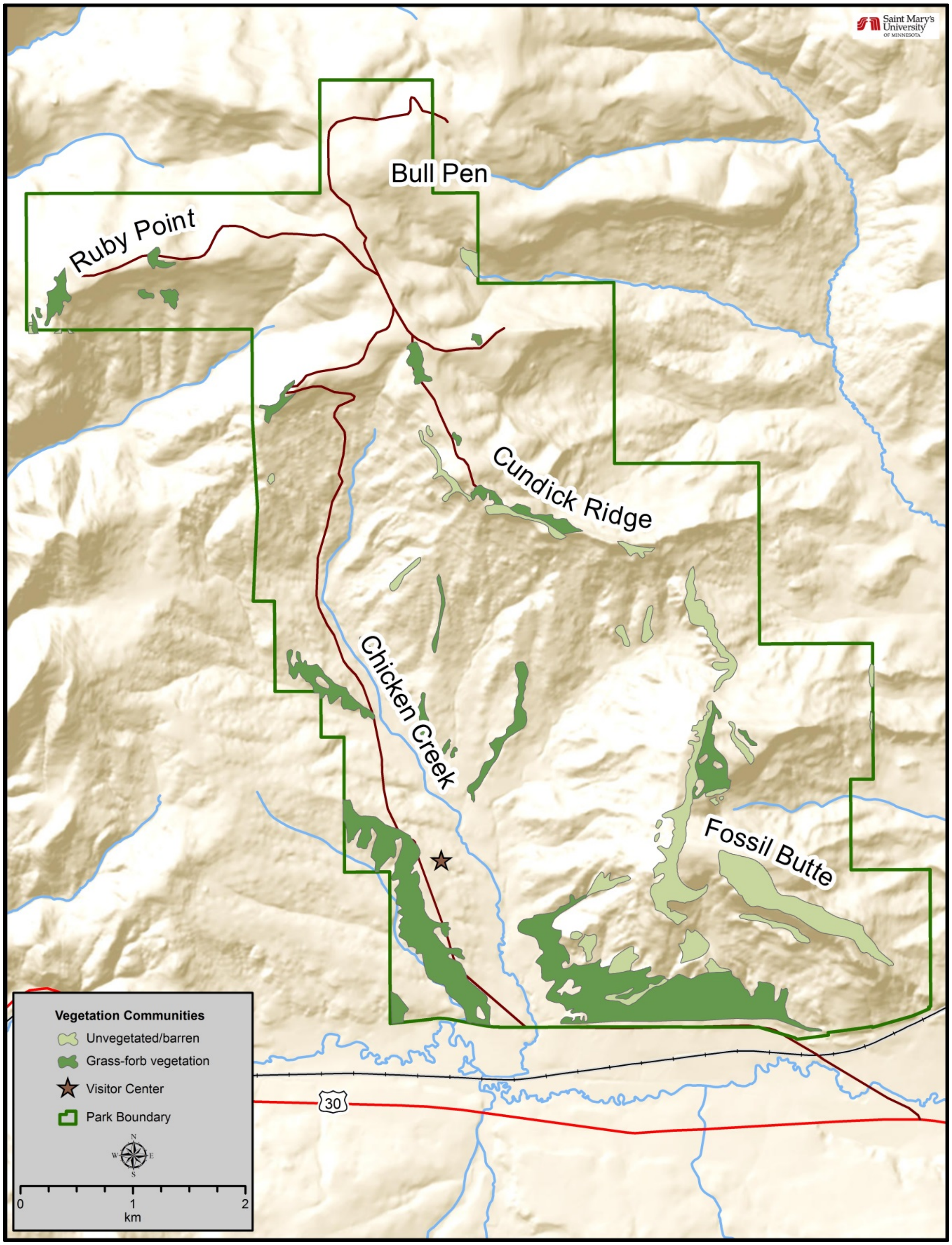

Figure 26. Vegetation communities where cushion plant communities and tufted twinpod and starveling milkvetch were observed by Dorn et al. (1984).

Cushion plant communities were not one of the 12 vegetation communities mapped by Dorn et al. (1984); however they are mentioned as occurring in the description of the grass-forb and unvegetated barren communities. Dorn et al. (1984) listed the following species found in cushion form as commonly found in the grass-forb vegetation community; bluebunch wheatgrass, Indian ricegrass (*Achnatherum hymenoides*), stemless goldenweed, starveling milkvetch, winterfat, tufted twinpod, and Hood's phlox. The species commonly found in cushion form within the unvegetated barren community were scattered plants consisting of; shortstem buckwheat, tufted twinpod, starveling milkvetch, gumweed aster (*Xanthisma grindelioides*), and tufted evening primrose (*Oenothera cespitosa*). A complete list of plant species Dorn et al. (1984) observed within the grass-forb and unvegetated barren communities were compared to the species Friesen et al. (2010) listed in each of their four cushion plant community classifications. It was determined from this review that the information in Dorn et al. (1984) is not adequate as a reference condition, but Friesen et al. (2010) could serve as a reference condition for future analysis.

Trends in invasive plants within the cushion plant communities or areas populated by tufted twinpod have not been specifically researched at FOBU. The majority of these communities have been mapped as point observations and not as patches, so a spatial query could not be conducted to identify observations from the invasive species monitoring with the mapped cushion plant communities. Dorn et al. (1984) did list two non-native plant observations within the grass-forbs and barren vegetation, but these are not specific to the cushion plant communities or the areas occupied by the tufted twinpod.

4.6.4. Data and Methods

Dorn et al. (1984) completed a literature review of vegetation, pollen and fossil studies at FOBU as part of a grazing impact study. This literature review was used to establish the original plant community composition for FOBU (Dorn et al. 1984). Dorn et al. (1984) conducted field work from 4 June through 22 June, and 9 and 10 August of 1984 to establish the composition of the vegetation in FOBU. Field observations also included details on soil type, topography, snow drifting patterns, seepage areas, and signs of disturbance such as fire (Dorn et al. 1984).

Fertig (2000) compiled information (i.e. voucher specimens, literature, species lists) on the vascular plant species within FOBU and created a plants checklist and a rare plants list. This checklist included annotations on global and state abundance, state distribution pattern, growth form, major biome type, and initial year of discovery at FOBU (Fertig 2000). Fertig (2000) also conducted a data query of vascular plant species that occur in Lincoln County and compiled a list of those not reported in FOBU. This list of plant species was then cross-checked with range maps from the Rocky Mountain Herbarium to establish a record of plant species that were likely be found within FOBU, based on their known distributions and habitat preferences (Fertig 2000).

Fertig (2002) collected information on the habitat and distribution of the tufted twinpod from scientific literature, herbaria specimens from both FOBU and Rocky Mountain Herbarium, New York Botanical Garden digital specimen database, unpublished reports, and from individuals with knowledge of the plant species. Fertig (2002) used mapping resources to identify areas with suitable habitat for tufted twinpod ground surveys. Ground surveys were conducted in these areas from 1996 through 2000 (Fertig 2002). Data was collected on habitat, reproduction, phenology, and associated species using the WYNDD (Fertig 2002). Tufted twinpod locations were mapped on 7.5 minute USGS topographic maps and digitized (Fertig 2002). Voucher specimens were collected and deposited in the Rocky Mountain Herbarium and the field data was entered into the Element Occurrence Database of the WYNDD (Fertig 2002). A potential tufted twinpod habitat model was also developed using a Classification Tree Analysis approach and GIS, this included data on both known point locations and absent areas along with environmental factors surrounding these areas (Fertig 2002). In 2009, random sample plots were established to collect plant counts of *Physaria* by an intern from the Chicago Botanical Gardens (Aase, written communication, 7 October 2015).

A total vegetation survey project was completed in 2010 (Friesen et al. 2010) that mapped and described all the plant associations in FOBU. This project was conducted from 2005 through 2008 as part of the NCPN Inventory and Monitoring Program and the USGS-NPS National Vegetation Mapping Program (Friesen et al. 2010). The mapping project involved field reconnaissance, aerial photo interpretation, spatial database development, and field verification.

4.6.5. Current Condition and Trend

Relative Abundance of *Physaria*

Physaria (tufted twinpod) is a state listed endemic plant of high conservation priority (Fertig 2000). It is known to occur in two of the cushion plant communities within FOBU (Friesen et al. 2010). The tufted twinpod is found within the winterfat/Indian ricegrass dwarf-shrubland, shadscale-greasewood shrubland, and the bitterbrush/rockloving wavewing shrubland associations in FOBU (Friesen et al. 2010). Data from random plant counts collected in 2009 were available that could have potentially been used to establish the relative abundance of *Physaria* within the park. However, there was no metadata available on the purpose of the data collection or the methodology of how these random plots were selected. Without this information it could not be determined if this data represented the entire population of *Physaria* within FOBU. Fertig (2000) does discuss the relative abundance of rare plants found within FOBU. In terms of the three endemic rare plants found within FOBU, tufted twinpod was the most abundant, with an estimated population in the tens of thousands in the southern Green River Basin and foothills of the Overthrust Belt (Fertig 2000). The Tunp Range twinpod (*P. dornii*) is a close relative of the tufted twinpod and is also considered a rare endemic species in Wyoming (Fertig 2000). Although this species has not been observed within FOBU, it occurs less than 6.5 km (4 mi) to the west in similar habitat, so further field surveys may reveal its presence in FOBU (Fertig 2000). Due to the lack of data that represent the population of *Physaria* within FOBU, assessing current condition or trends in abundance is not possible at this time.

Community Composition

Cushion plant communities are found generally found along windswept ridges (Friesen et al. 2010). Locations of windswept ridges and the known cushion plant communities are shown in Figure 27. Friesen et al. (2010) identified four separate cushion plant community associations within FOBU. They are the longleaf sagebrush/cushion plant shrubland, bluebunch wheatgrass-cushion plants herbaceous vegetation, shortstem buckwheat-cushion plant community, and the cushion plants sparse shale vegetation (Friesen et al. 2010).

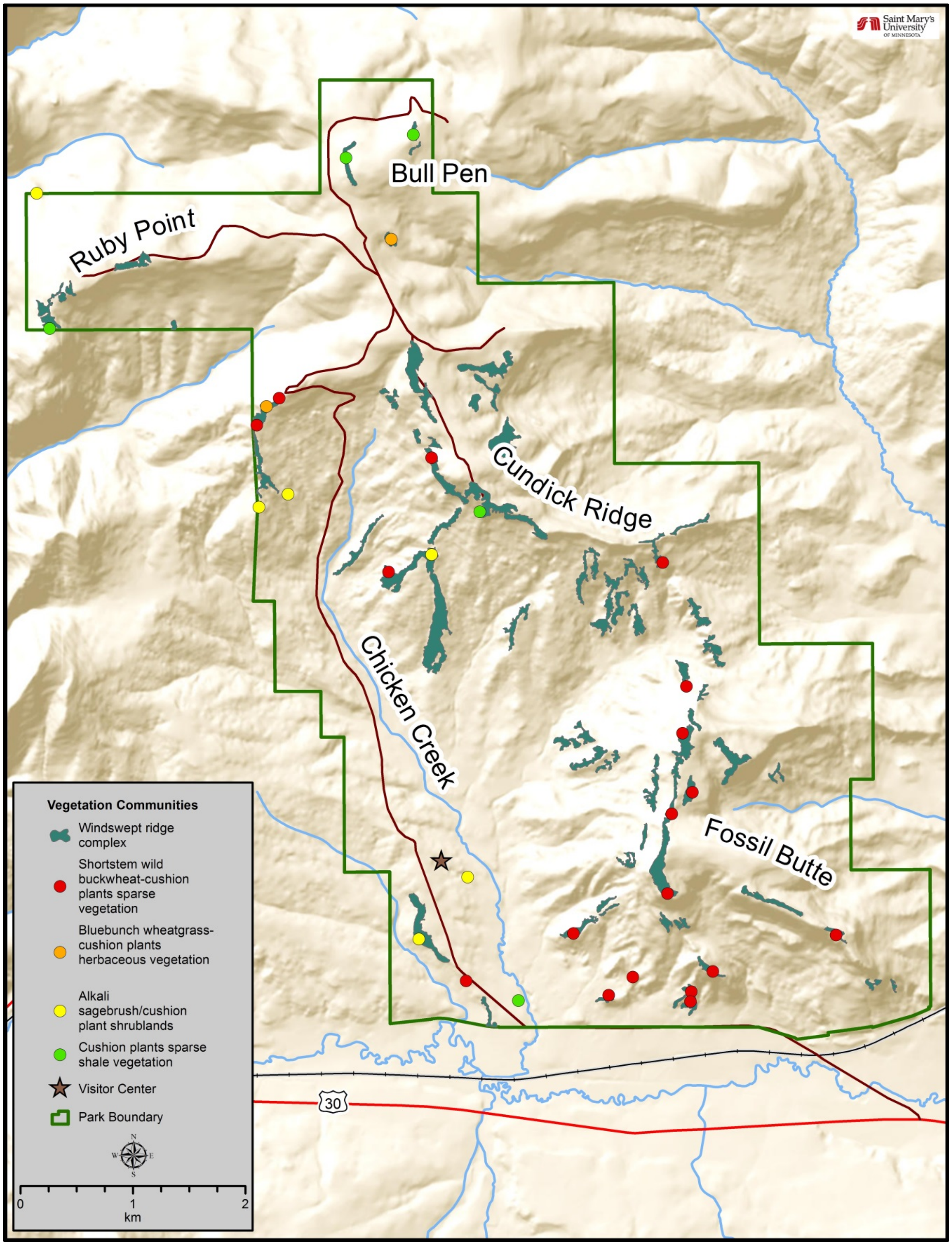

Figure 27. Location of windswept ridge complexes and the observation points where cushion plant communities were identified (Friesen et al. 2010).

The longleaf sagebrush/cushion plants shrublands community consist of moderately vegetated (20-38% cover) stands found along two areas of FOBU; one on the high slope of Rubey Point and the other on the slope of Chicken Creek (Friesen et al. 2010). This community is dominated by (8-16% cover) little sagebrush (*Artemisia arbuscula* ssp. *arbuscula*) with dominant cushion plants of shortstem buckwheat, stemless goldenweed, hollyleaf clover, and Hood's phlox (Friesen et al. 2010). Other less abundant cushion plant species found include Hooker's sandwort , two-grooved milkvetch, low pussytoes (*Antennaria dimorpha*), Nuttall's sandwort (*Minuartia nuttallii*), and starveling milkvetch (Friesen et al. 2010). A complete list of plant species observed within this community is listed in Table 43. In total, 18 plant species are found within this community (Friesen et al. 2010). Table 43 also includes the community types (grass-forb or barren vegetation) were Dorn et al. (1984) cushion form plants.

Table 43. The Friesen et al. (2010) community composition of longleaf sagebrush/cushion plants shrublands in FOBU compared with Dorn et al. (1984) grass-forb (gf) and barren (b) vegetation classification.

Scientific Name	Common Name	Dorn et al. (1984)
Achnatherum hymenoides	Indian ricegrass	gf
Antennaria dimorpha	low pussytoes	gf
Artemisia arbuscula spp. *longiloba*	longleaf sagebrush	gf
Artemisia frigida	fringed sagebrush	gf
Astragalus bisulcatus	two-grooved milkvetch	gf,b
Astragalus jejunus	starveling milkvetch*	gf
Atriplex gardneri	Gardener's saltbush	gf,b
Elymus lanceolatus	streambank wheatgrass	gf
Eremogone hookeri	Hooker's sandwort	-
Eriogonum brevicaule	shortstem buckwheat	gf,b
Krascheninnikovia lanata	winterfat	gf
Minuartia nuttallii	Nuttall's sandwort	-
Pascopyrum smithii	western wheatgrass	-
Phlox hoodii	Hood's phlox	gf
Poa secunda	Sandberg bluegrass	gf,b
Stenotus acaulis	stemless goldenweed	gf,b
Tetradymia spinosa	catclaw horsebrush	b
Trifolium gymnocarpon	hollyleaf clover	gf

* Non-native species

The bluebunch wheatgrass cushion plants herbaceous vegetation community was found on ridges to the west of Rubey Point and near the Bullpen (Friesen et al. 2010). The vegetation cover is between 20% and 25% and dominated by bluebunch wheatgrass (Friesen et al. 2010). Cushion plant species found within this community include; shortstem buckwheat, blue flax (*Linum lewisii*), Hood's phlox, and species of sandwort (*Arenaria* spp.) (Friesen et al. 2010). A complete list of plant species observed within this community is listed in Table 44. In total, 12 plant species are found within this community (Friesen et al. 2010). Table 44 also includes the community types (grass-forb or barren vegetation) were Dorn et al. (1984) cushion form plants.

Table 44. The Friesen et al. (2010) community composition of bluebunch wheatgrass- cushion plants herbaceous vegetation in FOBU compared with Dorn et al. (1984) grass-forb (gf) and barren (b) vegetation classification.

Scientific Name	Common Name	Dorn et al. (1984)
Arenaria spp.	sandwort species	-
Artemisia frigida	fringed sagebrush	gf
Astragalus spatulatus	spoonleaf milkvetch	gf
Eriogonum brevicule	shortstem buckwheat	gf,b
Krascheninnikovia lanata	winterfat	gf
Leucopoa kingii	spike fescue	-
Linum lewisii	blue flax	-
Phlox hoodii	Hood's phlox	gf
Poa fendleriana	Muttongrass	gf
Poa secunda	Sandberg bluegrass	gf,b
Pseudoroegneria spicata	bluebunch wheatgrass	gf

Shortstem buckwheat-cushion plants sparse vegetation communities were found on the exposed slopes of Rubey Point, Cundick Ridge, and Fossil Butte (Friesen et al. 2010). They were also found in the badlands formation near Chicken Creek, the historic quarry, and near FOBU's southern border (Friesen et al. 2010). Total vegetation cover was varied between localities and ranged from 1% to 34% (Friesen et al. 2010). Shortstem buckwheat cover (<1% to 10%) characterized these communities (Friesen et al. 2010). Each plot differed in dominant cushion plant species composition, but the most abundant cushion species were spoonleaf milkvetch, shortstem buckwheat, stemless goldenweed, and Sandberg bluegrass (Friesen et al. 2010). This community has a total of 34 species (Table 45, Friesen et al. 2010). This community also includes the rare and endemic tufted twinpod (Friesen et al. 2010). Table 45 also includes the community types (grass-forb or barren vegetation) were Dorn et al. (1984) cushion form plants.

Table 45. The Friesen et al. (2010) community composition of shortstem buckwheat-cushion plants sparse vegetation in FOBU compared to Dorn et al. (1984) grass-forb (gf) and barren (b) vegetation classification.

Scientific Name	Common Name	Dorn et al. (1984)
Achnatherum hymenoides	Indian ricegrass	gf
Antennaria dimorpha	low pussytoes	gf
Artemisia arbuscula ssp. *longiloba*	longleaf sagebrush	gf
Artemisia frigida	fringed sagebrush	gf
Astragalus jejunus	starveling milkvetch	gf
Astragalus spatulatus	spoonleaf milkvetch	gf
Astragalus vexilliflexus	bent-flowered milkvetch	b
Atriplex confertifolia	spiny saltbush	b
Atriplex gardneri	Gardener's saltbush	gf,b
Chrysothamnus viscidiflorus	green rabbitbrush	gf,b
Comandra umbellata	bastard toad-flax	b
Cryptantha caespitosa	tufted cryptantha	b
Elymus lanceolatus	streambank wheatgrass	gf
Ericameria nauseosa	rubber rabbitbrush	gf,b
Erigeron nanus	dwarf daisy	-
Eriogonum brevicule	shortstem buckwheat	gf,b
Eriogonum umbellatum	sulfur buckwheat	-
Hedysarum boreale	boreal sweet-vetch	-
Iva axillaris	poverty-weed	b
Krascheninnikovia lanata	winterfat	gf
Leymus cinereus	Great Basin wildrye	-
Minuartia nuttallii	Nuttall's sandwort	-
Packera cana	woolly groundsel	gf
Pascopyrum smithii	western wheatgrass	-
Phlox hoodii	Hood's phlox	gf
Physaria acutifolia	sharpleaf twinpod	-
Physaria condensata	tufted twinpod	gf,b
Poa secunda	Sandberg bluegrass	gf,b

Table 45 (continued). The Friesen et al. (2010) community composition of shortstem buckwheat-cushion plants sparse vegetation in FOBU compared to Dorn et al. (1984) grass-forb (gf) and barren (b) vegetation classification.

Scientific Name	Common Name	Dorn et al. (1984)
Pseudoroegneria spicata	bluebunch wheatgrass	gf
Pteryxia terebinthina	turpentine spring-parsley	-
Stenotus acaulis	stemless goldenweed	gf,b
Toxicoscordion paniculatum	panicled death-camas	-
Trifolium gymnocarpon	hollyleaf clover	gf

Cushion plants sparse shale vegetation communities were found along the exposed slopes of Rubey Point, in the Bullpen, and in the badlands near Chicken Creek (Friesen et al. 2010). It has been categorized as “park special,” meaning that it is unusual, found in only very small stands, and appears to be unique to FOBU (Friesen et al. 2010). The total vegetation cover ranged from 1% to 33% and no particular species was dominant (Friesen et al. 2010). Each of the stands had a slightly different composition of dominant species which included; Hood’s phlox, spoonleaf milkvetch, dwarf daisy, stemless goldenweed, and Sandberg bluegrass (Friesen et al. 2010). All the species found within this community are listed in Table 46. In total, there are 26 plant species in this community (Friesen et al. 2010). Table 45 also includes the community types (grass-forb or barren vegetation) were Dorn et al. (1984) found cushion form plants.

Table 46. The Friesen et al. (2010) community composition of cushion plants sparse shale vegetation [park special] in FOBU compared to Dorn (et al. 1984) grass-forb (gf) and barren (b) vegetation classification.

Scientific Name	Common Name	Dorn et al. (1984)
Artemisia arbuscula ssp. *longiloba*	longleaf sagebrush	gf
Artemisia frigida	fringed sagebrush	gf
Artemisia tridentata ssp. *tridentata*	basin big sagebrush	gf
Astragalus jejunus	starveling milkvetch	gf
Astragalus spatulatus	spoonleaf milkvetch	gf
Atriplex gardneri	Gardener's saltbush	gf,b
Elymus lanceolatus	streambank wheatgrass	gf
Eremogone hookeri	Hooker's sandwort	-
Erigeron nanus	dwarf daisy	-
Eriogonum caespitosum	mat buckwheat	gf

Table 46 (continued). The Friesen et al. (2010) community composition of cushion plants sparse shale vegetation [park special] in FOBU compared to Dorn (et al. 1984) grass-forb (gf) and barren (b) vegetation classification.

Scientific Name	Common Name	Dorn et al. (1984)
Eriogonum ovalifolium	cushion buckwheat	gf
Eriogonum umbellatum	sulfur buckwheat	-
Herrickia glauca	blueleaf aster	-
Krascheninnikovia lanata	winterfat	gf
Packera cana	woolly groundsel	gf
Pascopyrum smithii	western wheatgrass	-
Phlox hoodii	Hood's phlox	gf
Physaria condensata	tufted twinpod	gf,b
Poa fendleriana	muttongrass	gf
Poa secunda	Sandberg bluegrass	gf,b
Pseudoroegneria spicata	bluebunch wheatgrass	gf
Ranunculus testiculatus *	hornseed buttercup	-
Sedum lanceolatum	lanceleaved stonecrop	-
Stenotus acaulis	stemless goldenweed	gf,b

* Non-native species

The cushion plant communities identified by Friesen et al. (2010) can be compared with the data in Dorn et al. (1984); however this does not provide enough information to adequately assess any trends in the composition of the communities. This is due mainly to the differences in the how the vegetation types were defined and the amount of detail in how they were described.

<u>Trends in Invasive Infestation</u>

Dorn et al. (1984) did not specifically list plants found in the cushion plant communities, but did identify that plants in cushion form were found in the grass-forb vegetation and barren vegetation classes. The lists of species found in the grass-forb and barren vegetation classes each contained one non-native species, desert alyssum (*Alyssum desertorum*) was found in the grass-forb classification and alfalfa (*Medicago sativa*) was found in the barren vegetation classification (Dorn et al. 1984). In the species listed as present by Friesen et al. (2010) in the plant associations that make up the cushion plant community at FOBU, only one species (bur buttercup) is listed as a non-native species by NPSpecies (2015). None of these species is listed on the priority invasive plant list for FOBU as it appears in Perkins (2015).

The targeted species for FOBU are creeping foxtail, spotted knapweed (*Centaurea stoebe*), Canada thistle, bull thistle (*Cirsium vulgare*), musk thistle, common hound's-tongue (*Cynoglossum officinale*), hoary cress (*Lepidium draba*), and black henbane (*Hyoscyamus niger*) (Perkins 2013).

Invasive species monitoring had been conducted at FOBU in 2008, 2009, 2010, 2012, and 2014 to monitor IEPs in FOBU (Perkins 2015). These surveys concentrated on pathways of infestation such as roads, trails, and drainages. The overall trend for IEP infestation for FOBU is downward (Perkins 2015). Although there hasn't been data collected specifically for the cushion plant or tufted twinpod communities, based on the surveys conducted by Friesen et al. (2010) and Perkins (2013) it appears that these communities are relatively free of the targeted IEP species at this time.

Threats and Stressor Factors

The management at FOBU has expressed concern about the invasive exotic cheatgrass. While it had not been reported specifically within the cushion plant communities in 2010 (Friesen et al.), it was recorded in nearly every route and quadrat surveyed in 2012 and 2014 (Perkins 2015). However, in the last two field surveys (2012 and 2014) very few IEP patches were detected along the Rubey Point Road and the Bullpen Two Track routes which are in the vicinity of where cushion plant communities occur (Perkins 2013, 2015).

FOBU managers are concerned about the potential impacts of elk compressing soil and grazing in these cushion plant communities. At this time, it has not been directly assessed, so impacts specifically from grazing elk are unknown. However, Fertig (2002) noted that while the community may not be directly affected by grazing, it could be impacted by the associated effects of soil compaction and/or erosion, and increased competition from non-native species.

Nitrogen deposition is generally measured as wet-deposition, even though dry-deposition occurs, as 10-year trends by summing the total nitrogen content from nitrate and ammonium to calculate the total concentration in precipitation (NPS ARD 2013). The deposition of excess nitrogen via precipitation is a threat to plants, particularly in sensitive areas such as those found in National Parks (i.e. FOBU), since it can cause the acidification of soil and surface water (NPS ARD 2013).

Data Needs/Gaps

The abundance of tufted twinpod within FOBU is not well known and therefore considered a data gap. While there is a baseline inventory of species found within the cushion plant communities, without data to compare assessing a trend in community composition is not possible at this time. The survey and monitoring of invasive plants is an ongoing process at FOBU. However, the invasive plant surveys by nature do not address infestations by vegetation community. They primarily focus on where infestations typically occur or are most likely to spread. A survey of cushion plant communities specifically to assess the presence, or lack, of invasive plants would confirm the presence/absence of infestations.

Overall Condition

Relative Abundance of Physaria

Since the relative abundance of the tufted twinpod in FOBU hasn't been systematically assessed, this is considered a data gap. The relative abundance was assigned a *Significance Level* of 2, however due to the data gap a *Condition Level* cannot be assigned at this time.

Community Composition

The community composition component was assigned a *Significance Level* of 3. Friesen et al. (2010) classified cushion plant communities specifically for the first time in FOBU and listed the species composition. The Friesen et al. (2010) data are useful as a baseline for future assessment of the cushion plant community composition, but there are no other data to compare it to in order to assess condition or trend. Due to this, a *Condition Level* cannot be assigned.

Trends in Invasive Infestation

Trends in invasive plant infestation was assigned a Significance Level of 3, at this time the available data suggests that there are no priority invasive species within the cushion plant communities. The surveys use a priority list of species, and the potential presence of other invasive species not on that list is unknown. The overall trend in invasive species within FOBU is declining; however the overall threat from cheat grass is a concern. Due to this, the Condition Level is assigned a 1, or low concern.

Weighted Condition Score

The WCS cannot be calculated at this time due to gaps in data for the measures that address the estimated abundance of tufted twinpod and the composition of cushion plant communities. There are data suggesting that the cushion plant communities are free of target invasive plant species at this time, but this *Condition Level* is not adequate to calculate the WCS.

Cushion Plant Communities			
Measures	**Significance Level**	**Condition Level**	**WCS = N/A**
Relative Abundance of *Physaria*	2	N/A	
Community Composition	3	N/A	
Trends in Invasive Infestation	3	1	

4.6.6. Sources of Expertise

- Arvid Aase, FOBU Museum Specialist

4.6.7. Literature Cited

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4.7. Alkali Flats Community

4.7.1. Description

The alkali flats community of FOBU, also called saline flats shrubland, occurs in areas of flat bottomland and badlands on gentle slopes where dense to well-drained alkaline and saline, clay-rich soils have accumulated as alluvium (Friesen et al. 2010). Most of these occur in the southern portion of FOBU where the soils were derived from the Wasatch Formation (Friesen et al. 2010). The sparse flats and mild slopes typical of this area are primarily dappled with small shrub stands dominated by greasewood, and a few herbaceous perennials with bare ground in between (Dorn et al. 1984, Friesen et al. 2010). The entire-leaved peppergrass (*Lepidium integrifolium*), a rare and sensitive species, occurs in several patches within FOBU (Photo 7).

Photo 7. Entire-leaved peppergrass (NPS Photo).

4.7.2. Measures

- Relative abundance of *Lepidium integrifolium*
- Community extent and change over time
- Community composition
- Trends in invasive infestation
- Percent bare ground

4.7.3. Reference Conditions/Values

The ideal reference condition for the alkali flats community would be the condition of the community at FOBU prior to cattle and sheep grazing. Cattle and sheep were brought to the area in conjunction with European settlement. Since information from this time is not available, the earliest available data will be used to establish reference conditions in FOBU for the alkali flats community and the relative abundance of entire-leaved peppergrass.

Entire-leaved peppergrass has a small geographic range, endemic to northeastern Utah, and parts of Wyoming and perhaps Arizona (Figure 28) (Heidel 2004, Fertig and Heidel 2014, USDA 2015). It currently is listed by the BLM as a sensitive plant species in the state of Wyoming (Heidel 2004, Fertig and Heidel 2014). The initial discovery of this species in the park was in the mid-1990s by Clayton Kyte, an NPS biological technician (Fertig 2000). At the time of discovery, the population in FOBU was estimated to be between 3,500-10,000 plants (Heidel 2004).

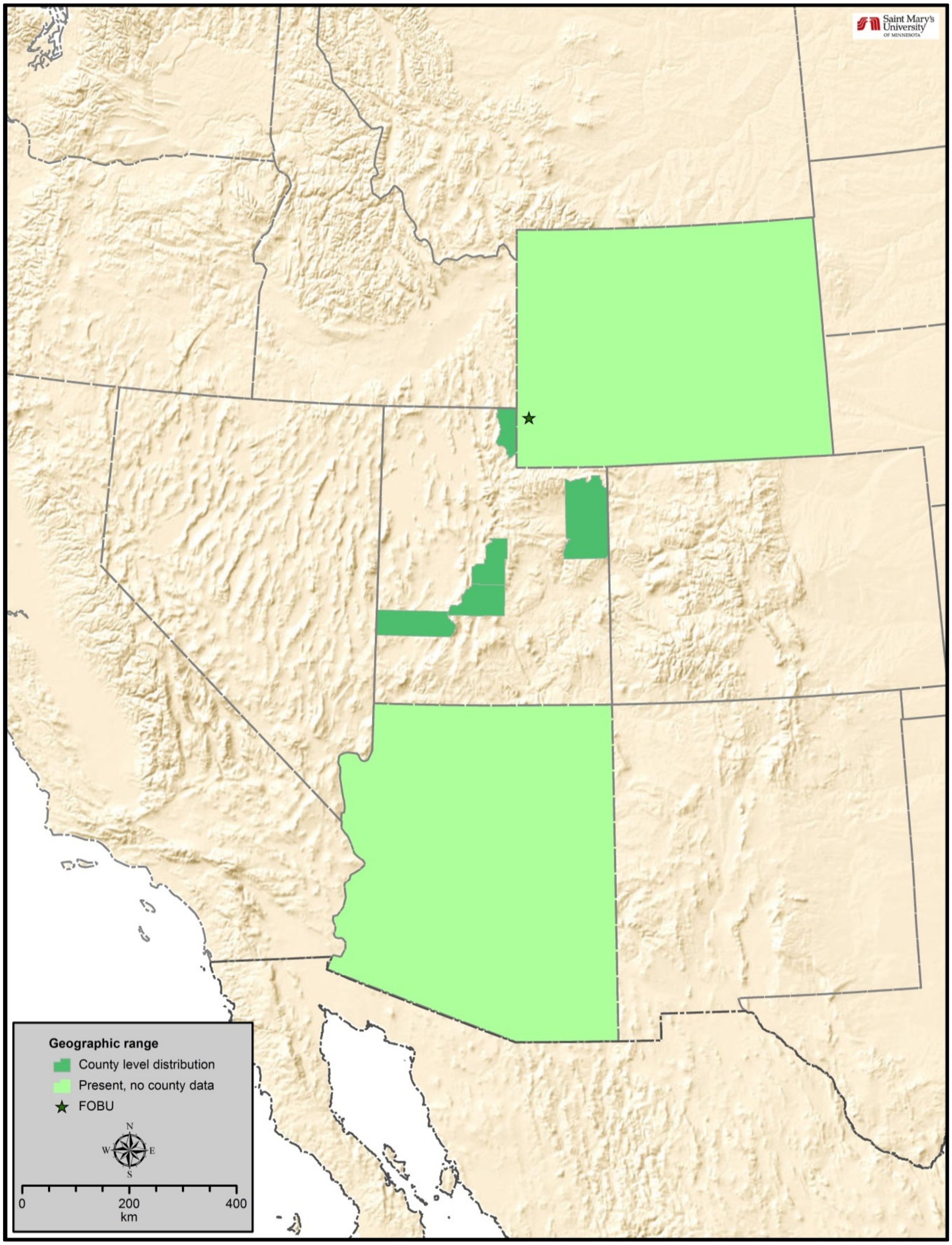


Figure 28. Geographic extent of Lepidium integrifolium (entire-leaved pepperplant). The geographic extents are based on county level data from NRCS (2015).

4.7.4. Data and Methods

A variety of vegetation mapping and data collection studies were reviewed for potential as part of this assessment. Vegetation classification was first completed for FOBU in 1973 with a vegetation survey and mapping project conducted by Beetle and Marlow (1974). The purpose of this survey was two-fold, to create a map of the vegetation within FOBU and to create a baseline study of range conditions. This mapping project resulted in the definition of 12 vegetation classes within FOBU (Beetle and Marlow 1974). In the summer of 1984, Dorn et al. (1984) conducted field surveys for the purpose of updating the vegetation map and range conditions created by Beetle and Marlow (1974). This project also analyzed the impacts of grazing at FOBU in the early 1980s (Dorn et al. 1984). The project conducted by Dorn et al. (1984) resulted in the mapping of 12 vegetation types. The distribution of vegetation types was primarily due to the depth, clay content and moisture content of the soil, although the distribution of some classes was controlled, at least partially, by exposure to wind (Dorn et al. 1984). While Dorn et al. (1984) identified 12 vegetation classes, including the "saline type vegetation" they cannot be used as a reference condition due to the data collection and spatial mapping methodologies used, as has been discussed in previous chapters of this document. As stated earlier, Jones (1993) verified and updated the mapping conducted by Dorn et al. (1984). However, due to the small size and number of map units designated as saline, no fieldwork outside of verification of map unit boundaries was conducted (Jones 1993).

Heidel (2004) conducted surveys in FOBU to determine the estimated population size of the rare endemic entire-leaved peppergrass. Using known distributions, a potential distribution was modeled and used as guidance in fieldwork planning (Heidel 2004). Several polygons of potential habitat were then surveyed from 17-22 and 29 June 2003 (Heidel 2004).

Friesen et al. (2010) mapped vegetation in an area which included the entire park and adjacent BLM land. Field work was conducted from 2005-2008 to document the composition and structure of the various vegetation classifications that occur there (Friesen et al. 2010). In addition to field surveys, the project involved use of imagery to establish polygons to represent each vegetation type (Friesen et al. 2010).

Fertig (2012) surveyed FOBU for rare plant species during six separate visits from June 2010 through June 2012. A review of existing distribution maps and species occurrence records pertaining to the target species was done prior to field surveys to determine areas of focus (Fertig 2012). Once target species populations were located, the coordinates of the approximated center of the area were recorded along with environmental details (Fertig 2012). Details included associated species, phenology, geology, and possible management issues (Fertig 2012). For each of the rare plant species surveyed, a final distribution map was created and specimens were collected for addition to the park's vascular plant location database (Fertig 2012).

4.7.5. Current Condition and Trend

Relative Abundance of Entire-leaved Peppergrass

Heidel (2004) produced the first known population estimate for FOBU and serves as a reference for comparison with subsequent population estimates. The population consisted of multiple subpopulations (separate clusters) and could be found in streambeds, alluvial flats and the margins of foothill and valley bottom areas where saline soil was present (Figure 29, Heidel 2004). At the time of discovery, the number of plants occurring in or just outside FOBU was estimated at 3,500-10,000 (Figure 29, Heidel 2004). Using the data from the 2010-2012 rare plant field surveys and the original locations identified by Heidel (2004), the remaining population was remapped (Fertig 2012). Fertig (2012) estimated the entire-leaved peppergrass population at FOBU was now comprised of three main subpopulations, with an estimated size between 2,485 and 4,995 individual plants (Figure 30). Comparing these estimates and seeing the change spatially suggests a decline in peppergrass relative abundance as well as distribution within FOBU.

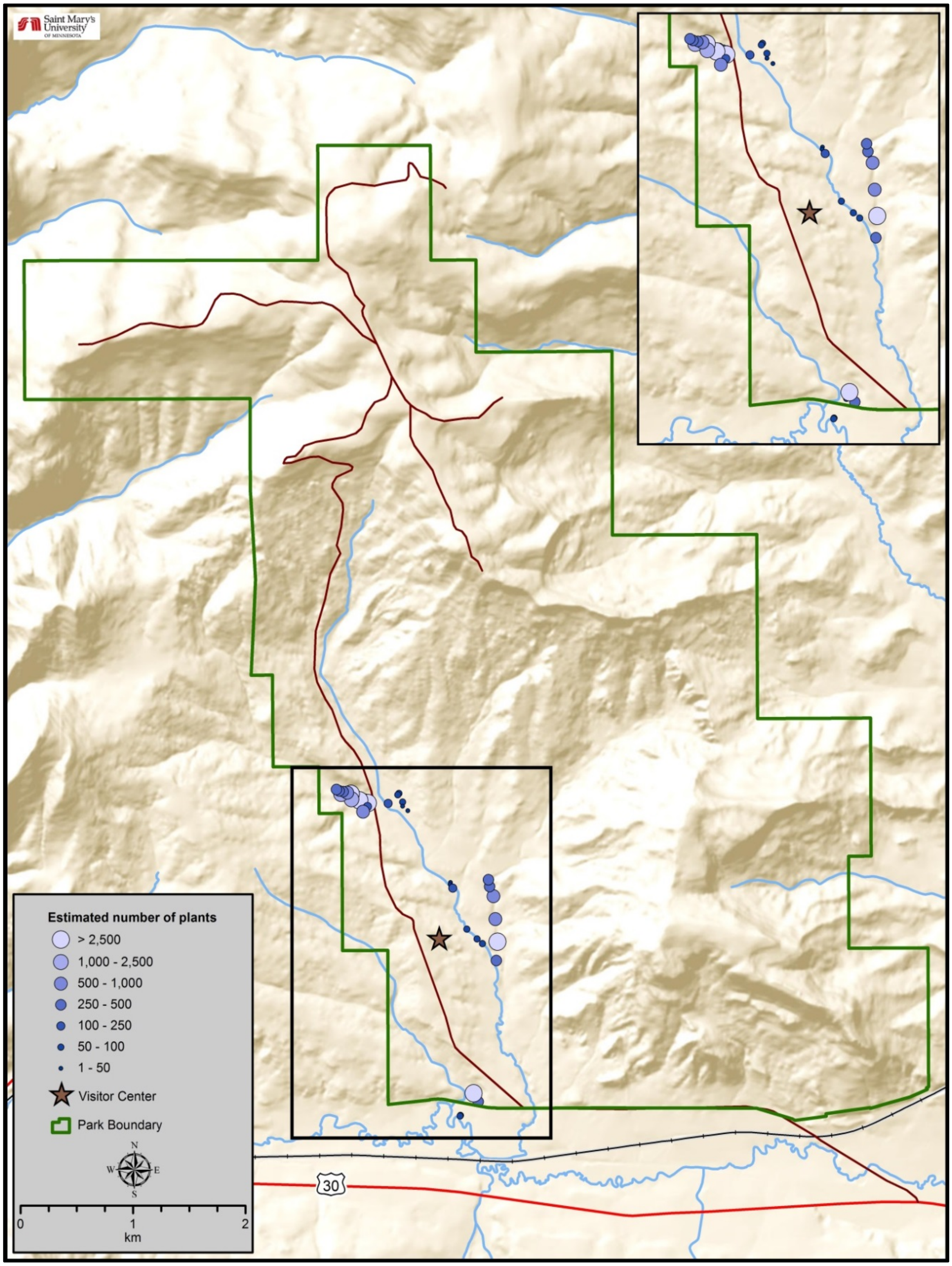


Figure 29. Location and estimated population of entire-leaved peppergrass plants as of 2003 (Heidel 2004).

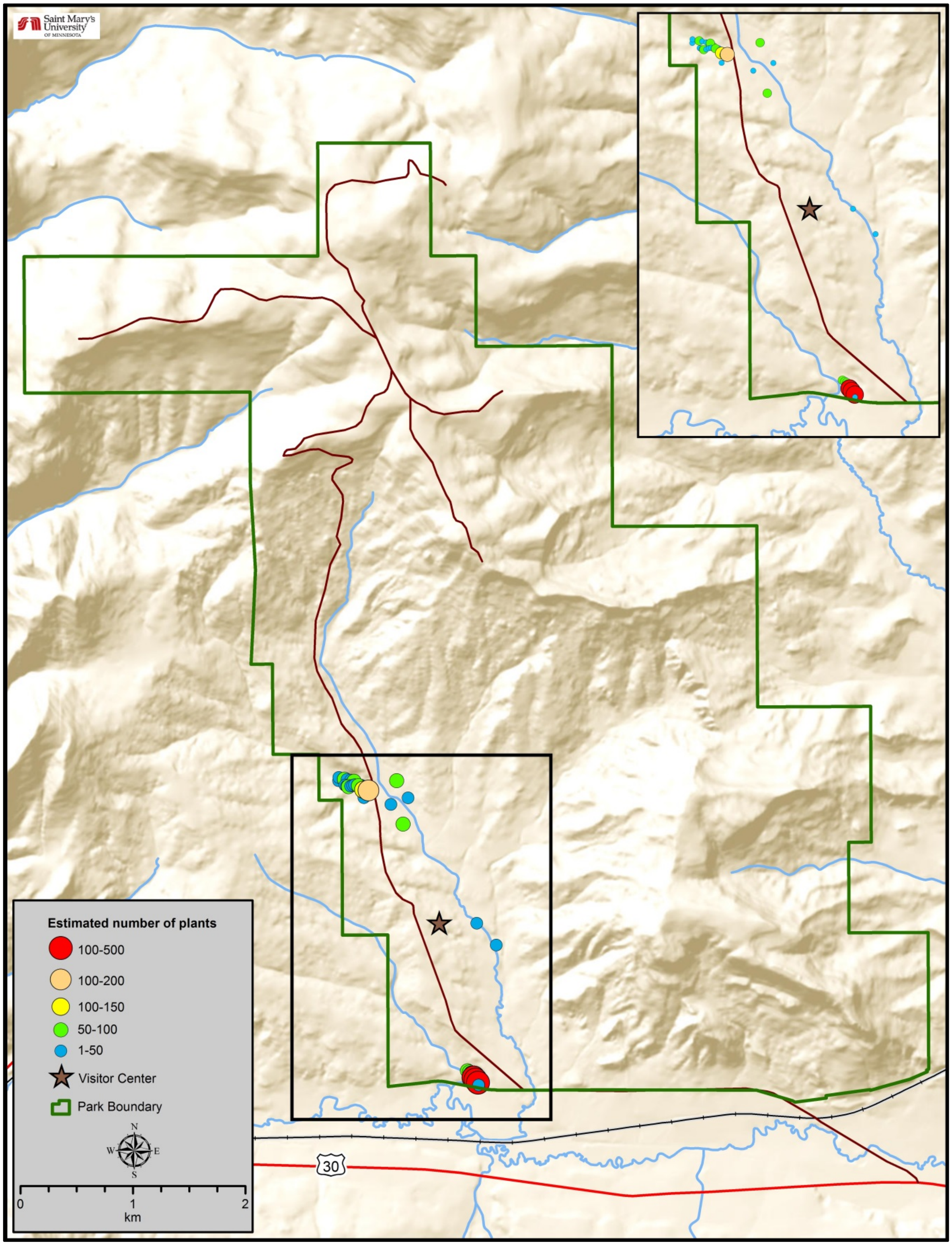


Figure 30. Location and estimated population of entire-leaved peppergrass plants as of 2011 (Fertig 2012).

Community Extent and Change over Time

The alkali flats community occurs in the flats and low badlands of FOBU, most of which are found in the southern half of the park (Friesen et al. 2010). An estimated total of 118.0 ha (291.4 ac) of saline flats shrublands were mapped by Friesen et al. (2010). The saline flats shrublands include three distinct vegetation alliances that were classified during field work, all considered uncommon on the park (Friesen et al. 2010). These three alliances are shadscale-greasewood, greasewood/basin big sagebrush, and greasewood/Gardener's saltbush shrublands (Figure 31, Friesen et al. 2010). Shadscale-greasewood shrubland was represented by one plot along the southern boundary of the park on a south-facing toeslope of Fossil Butte (Friesen et al. 2010). The greasewood/basin big sagebrush shrubland was represented by a plot near the park entrance (Friesen et al. 2010). The greasewood/Gardener's saltbush shrubland was represented by a plot near the entrance along a drainage terrace of Smallpox Creek and a plot on a badlands slope just south of Fossil Butte (Friesen et al. 2010).

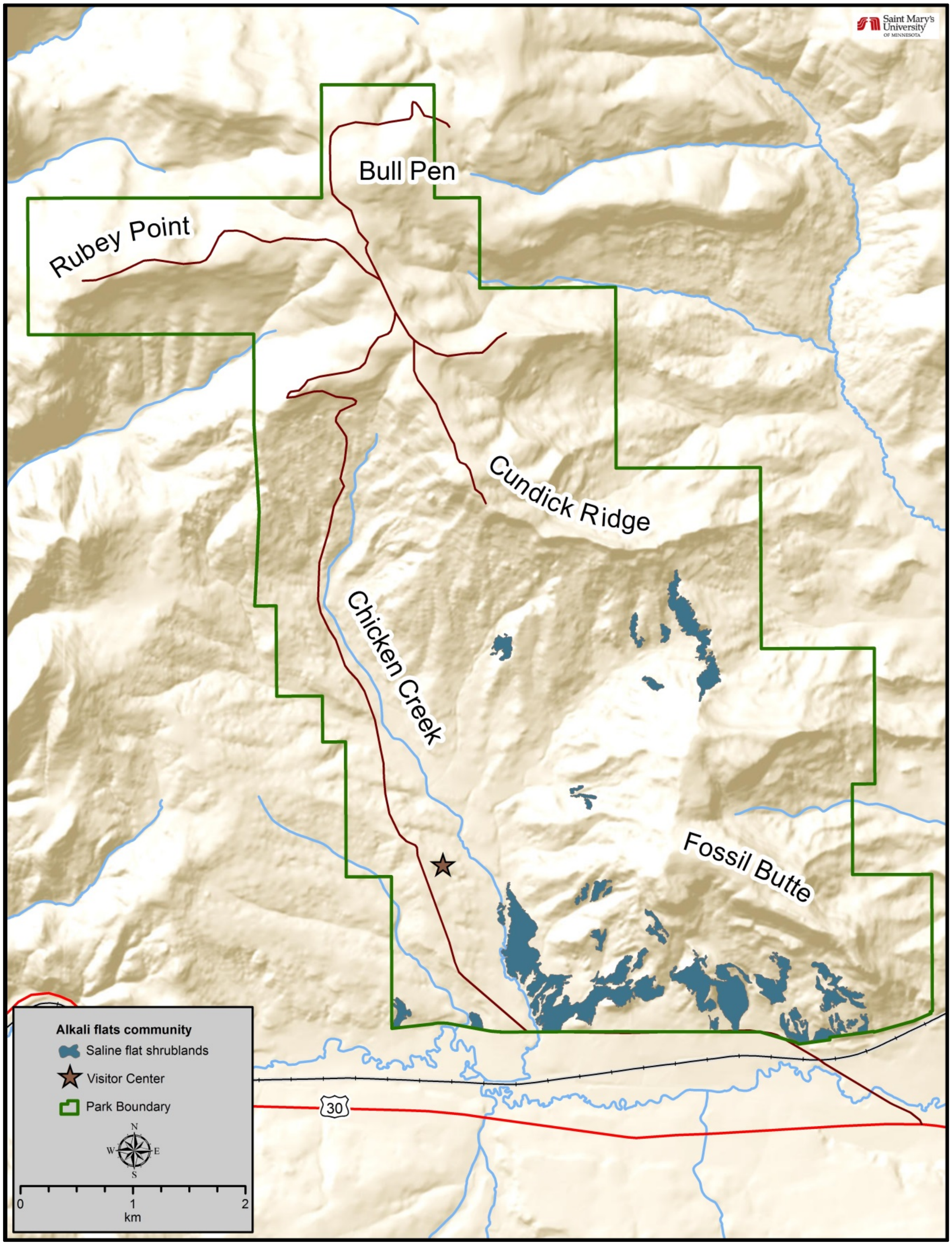


Figure 31. Alkali flats community locations within FOBU (Friesen et al. 2010).

Jones (1993) verified the location of the saline map units in the southern portion of the park as described by Dorn et al. (1984). Based on the mapping produced by Jones (1993), saline map units accounted for 16 ha (39.5 ac) of the vegetation in the park. These patches were located in the same general vicinity to the south of Fossil Butte where they were found by Friesen et al. (2010).

Community Composition

Friesen et al. (2010) identified 25 plant species within the alkali flats community of FOBU. They consisted of nine shrub, six grass, and 10 forb species. The most commonly occurring shrub species was greasewood (Friesen et al. 2010). In the understory, when present, the most commonly found species were Indian ricegrass and poverty-weed (Friesen et al. 2010). The specific community species composition based on the 2010 vegetation mapping (Friesen et al. 2010) is listed in Table 47.

Table 47. Composition of alkali flats community within FOBU by association. Abundance level is from NPSpecies (Friesen et al. 2010, NPS 2015). A = shadscale-greasewood shrubland, B = greasewood/basin big sagebrush shrubland, C = greasewood/Gardener's saltbush shrubland.

Scientific Name	Common Name	Association	NPSpecies Abundance
Shrubs			
Artemisia tridentata ssp. *tridentata*	big basin sagebrush	B,C	Abundant
Artemisia tridentata ssp. *wyomingensis*	Wyoming big sagebrush	B	Common
Atriplex confertifolia	spiny saltbush	A,B	Uncommon
Chrysothamnus viscidiflorus ssp. *viscidiflorus*	green rabbitbrush	A,B	Common
Ericameria nauseosa	rubber rabbitbrush	A	Uncommon
Krascheninnikovia lanata	winterfat	B	Common
Sarcobatus vermiculatus	greasewood	A,B,C	Uncommon
Symphoricarpos oreophilus var. *utahensis*	Utah snowberry	A	Common
Tetradymia canescens	gray horsebrush	C	Uncommon
Graminoids			
Achnatherum hymenoides	Indian ricegrass	A,C	Common
Elymus lanceolatus spp. *lanceolatus*	thickspike wheatgrass	B,C	Uncommon
Leymus cinereus	Great Basin wildrye	A	Common
Poa fendleriana	muttongrass	A	Common
*Poa pratensis**	Kentucky bluegrass	C	Uncommon
Poa secunda	Sandberg bluegrass	B,C	Common

*Non-native species

Table 47 (continued). Composition of alkali flats community within FOBU by association. Abundance level is from NPSpecies (Friesen et al. 2010, NPS 2015). A = shadscale-greasewood shrubland, B = greasewood/basin big sagebrush shrubland, C = greasewood/Gardener's saltbush shrubland.

Scientific Name	Common Name	Association	NPSpecies Abundance
Forbs			
Amaranthus blitoides *	prostrate pigweed	C	Uncommon
Antennaria dimorpha	low pussytoes	B	Uncommon
Astragalus jejunus	starveling milkvetch	A	Uncommon
Erigeron concinnus	Navajo fleabane	C	No data
Eriogonum brevicaule var. *brevicaule*	shortstem buckwheat	A	Uncommon
Iva axillaris	poverty-weed	A	Uncommon
Lepidium perfoliatum *	clasping peppergrass	C	Uncommon
Phlox hoodii	Hood's phlox	B	Common
Physaria condensata	tufted twinpod	A	Uncommon
*Ranunculus testiculatus**	bur buttercup	B	Uncommon

*Non-native species

Trends in Invasive Infestation

Trends in invasive plants have not been specifically assessed by vegetation association at FOBU. Friesen et al. (2010) did note the presence of three non-native plant species (Kentucky bluegrass, clasping pepperweed, and prostrate pigweed) in the descriptions of the saline flat communities. Monitoring of invasive species at FOBU has been conducted since 2008 (Perkins 2015). Invasive species often become established or spread in riparian corridors and along roadways and trails used by humans (Perkins 2015). The on-going monitoring efforts have focused on these high traffic areas and in drainage channels rather than trying to survey the entire park (Perkins 2015). The surveys are conducted based on a priority IEP list developed by the NCPN and park staff (Perkins 2015). Information on invasive infestations collected during these surveys is not limited to those species on the priority list. Information on other species of note, such as Japanese brome, is also collected. Monitoring for IEPs was most recently conducted in FOBU in 2014 (Perkins 2015).

Data from the 2014 IEP survey was compared to the locations of alkali flats communities mapped by Friesen et al. (2010). This was completed through spatial analysis to select any IEP data point that was within 100 m (328 ft) of a mapped alkali flats community. Table 48 and Figure 32 show the results of this analysis. Only a small number of the invasive species patches (≈10%) recorded by the 2014 survey met the criteria of the spatial queries. Only six IEP data points met the spatial criteria of being within a mapped alkali flats community. Cheatgrass was the most common IEP the spatial queries selected as within the mapped community. Creeping foxtail (20 points), flixweed (12 points), and cheatgrass (11 points) were the most prevalent among the IEP species that were identified in the proximity to alkali flats by the spatial queries. One invasive species (Japanese brome) selected by the proximity query is not currently on the IEP priority list for FOBU, but is scheduled to be included on the list for upcoming field surveys (Perkins 2015).

Table 48. Number of IEP infestation patches from 2014 survey that are within or near an alkali flats community.

		Number of Patches		
Scientific Name	**Common Name**	**Within Mapped Patch**	**Within 100 m of Mapped Patch**	**Total**
Priority IEPs				
Alopecurus arundinaceus	creeping foxtail	-	20	**20**
Bromus tectorum	cheatgrass	4	11	**15**
Carduus nutans	musk thistle	1	4	**5**
Cirsium arvense	Canada thistle	-	2	**2**
Descurainia sophia	flixweed	-	12	**12**
Melilotus officinalis	yellow sweetclover	1	4	**4**
Other non-native species of interest				
*Bromus japonicas**	Japanese brome	-	1	**1**
Totals		**6**	**54**	**60**

*Non-native species

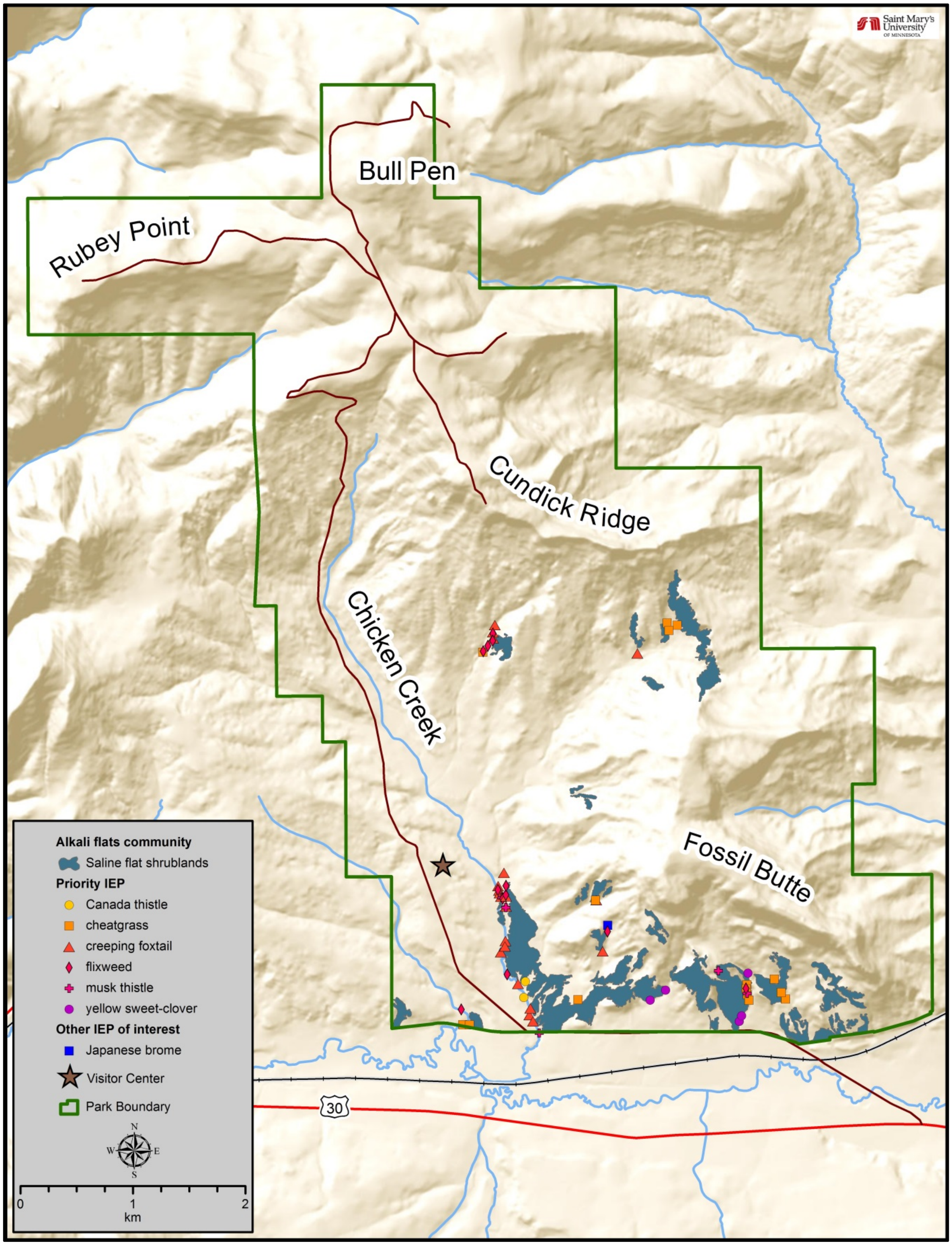


Figure 32. IEP infestations associated with mapped alkali flats communities.

Percent Bare Ground

This measure is considered a data gap, as literature or data assessing the percent of bare ground in the alkali flats communities were not available. Bare ground is defined as soil surfaces that are devoid of both biotic and abiotic features such as plants, dead plant debris/litter, and gravel or rocks which protect soil from erosive forces of wind and water (NRCS 2010). The larger the area of bare ground, the more vulnerable the soil becomes to saltation and erosion (NRCS 2010). The alkali flats may have some areas with naturally high percentages of bare ground, where salts have accumulated and inhibit plant growth (Fertig, written communication, 7 December 2015). However, an increase in the percent of bare ground can negatively impact both hydrology and biotic communities (NRCS 2010).

Threats and Stressor Factors

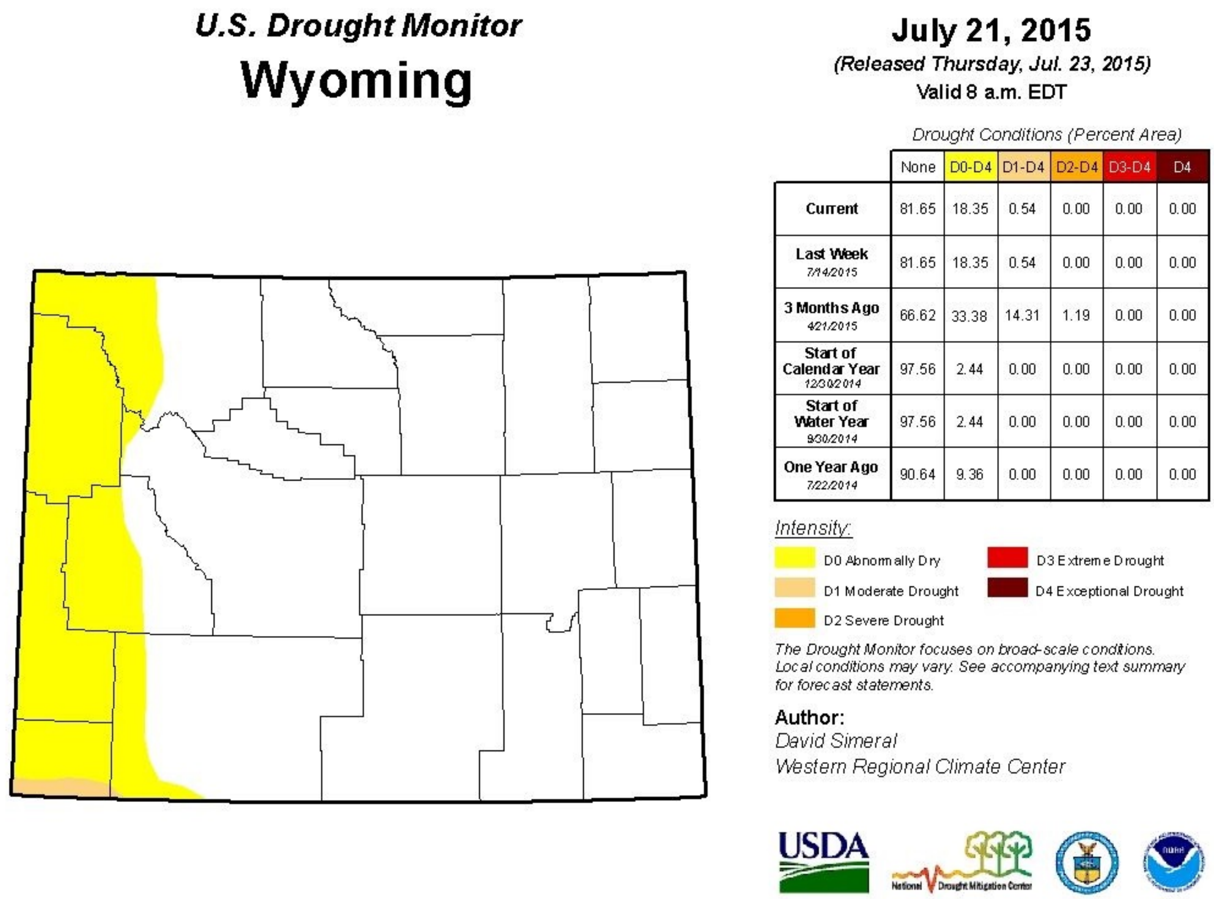
There are several threats and stressors to the alkali flats community that are of concern to resource managers at FOBU. These include activities or processes inside and outside the park. Threats to the native vegetation in the alkali flats community include invasive plant species, changes in the regional climate, and livestock drives.

Portions of the western boundary of the park are adjacent to private ranch land and the rest of the surrounding land is BLM-managed grazing land (Friesen et al. 2010). These range lands pose a threat to the alkali flats communities that are near the park borders because of human and livestock activities that can occur nearby. Additional threats from adjacent land use include current and potentially new gas and oil exploration/extraction activities and groundwater pumping.

Although grazing inside FOBU by livestock was discontinued in 1989, there are still periodic sheep herd drives through the park (NPS 2005). These drives pose the threat of the introduction of invasive plant seeds into the park, either on the animals' bodies (e.g., hooves, fur) or in the digestive tract, that could cause new infestations (Belsky and Gelbard 2000). Invasive plants are a threat as they degrade the native ecology by competing with native plants for space and nutrients, and over time they can reduce the faunal diversity of an area (Belsky and Gelbard 2000). The park no longer permits grazing by livestock within its boundaries, but livestock incursions may occur if boundary fences are damaged. These incursions and the sheep drives still threaten the native vegetation, including the alkali flats community.

IEPs include exotic plants "whose introduction does or is likely to cause economic or environmental harm or harm to human health" (Executive Order 13112). Exotic species, along with habitat loss, are among the greatest threats to biodiversity (Wilcove et al. 1998). IEPs negatively affect natural environments by fragmenting native ecosystems, displacing native plants and animals, and altering the performance of ecosystem functions (Scott and Wilcove 1998, Perkins 2015). Additionally, IEPs can alter fire regimes, reduce native plant communities and animal habitat, and increase park management activities (Perkins 2015). In recent entire-leaved peppergrass surveys at FOBU, the IEPs posing the greatest threat to the rare species were clasping pepperweed (*Lepidium perfoliatum*) and bur buttercup (Fertig, written communication, 7 December 2015).

Currently, Lincoln County, where FOBU is located, is experiencing abnormally dry conditions (Figure 33, USDM 2015). This scenario is likely to continue in the western states, particularly in areas like FOBU which are considered semi-arid or arid regions where snowfall is the primary form of precipitation. Wyoming is experiencing a change in its climate, as data show a trend towards hotter and drier conditions (Saunders et al. 2008). The regional climate is changing and is characterized by decreased snowpack, less snowfall, earlier snowmelt, more winter rain events, increased peak winter flows, and reduced summer flows (Saunders et al. 2008). This change can lead to ecosystem disturbances that may impact alkali flats communities in multiple ways, such as decreases in plant cover, increased percentage of bare ground cover, and increased erosion (Saunders et al. 2008).



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	81.65	18.35	0.54	0.00	0.00	0.00
Last Week 7/14/2015	81.65	18.35	0.54	0.00	0.00	0.00
3 Months Ago 4/21/2015	66.62	33.38	14.31	1.19	0.00	0.00
Start of Calendar Year 12/30/2014	97.56	2.44	0.00	0.00	0.00	0.00
Start of Water Year 9/30/2014	97.56	2.44	0.00	0.00	0.00	0.00
One Year Ago 7/22/2014	90.64	9.36	0.00	0.00	0.00	0.00

Figure 33. The July 2015 droughts monitor statistics for the state of Wyoming (USDM 2015). Lincoln County, where FOBU is located, is the L-shaped county along the western border.

<u>Data Needs/Gaps</u>

At this time, data on the extent of vegetation communities at FOBU is considered to be a partial data gap. Vegetation mapping conducted by Dorn et al. (1984) and verified by Jones (1993) has information that could be used to assess community extent and change, but this is based on generalized vegetation classifications and not the more specific classifications used by Friesen et al. (2010). Neither of these two earlier vegetation studies have the comprehensive speices lists that are available in Friesen et al. (2010). Additionally, data on percent ground cover is insufficient to determine the condition of this measure in the alkali flats communities. Additional vegetation mapping studies would provide a means of monitoring changes in alkali flats community extent and composition. Continued monitoring of IEPs will provide park managers with a valuable long-term data set that will accurately depict trends in the number and extent of infestations.

Overall Condition

Relative Abundance of Entire-leaved Peppergrass
The relative abundance of the rare entire-leaved peppergrass was assigned a *Significance Level* of 3. Population estimates in 2003 and again during 2010 and 2011 indicate a decline in FOBU's population of peppergrass. Due to this trend, a *Condition Level* of 2 was assigned, indicating moderate concern.

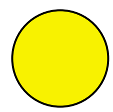
Community Extent and Change over Time
The community composition extent and change over time measure was assigned a *Significance Level* of 3. Data on alkali communities collected and mapped by Dorn et al. (1984) and later verified by Jones (1993) indicates that, when compared to the recent vegetation inventory (Friesen et al. 2010), there has been an increase in both areal extent and in the locations where this community is present. Since the data suggests an increase in both the areal extent and locales where the community is found, a *Condition Level* of 0, meaning no concern, has been assigned. It should be noted that this assignment is based on the fact that there has not been any decline in areal extent. How the apparent increase in areal extent affects the overall condition of this community has not been investigated at this time.

Community Composition
The community composition measure was assigned a *Significance Level* of 3. Although Fertig and Kyte (2009) developed a comprehensive list of plants present within FOBU, it is unclear which of these species are present within the alkali flats community. Due to the differences in the project methodologies, the Dorn et al. (1984), Jones (1993), and Friesen et al. (2010) vegetation compositions also are not comparable. Due to lack of a comparable dataset, a *Condition Level* cannot be assigned at this time.

Trends in Invasive Infestation
This measure was also assigned a *Significance Level* of 3. The most recent monitoring efforts compared consecutive years of monitoring in the park and found that, in general, there is a downward trend in both infestation size and frequency park-wide. A spatial analysis of the IEP and vegetation mapping identified six IEP species associated with alkali flats communities. This includes cheatgrass, flixweed, and creeping foxtail, three IEP species that have shown an increase in number of infestations since 2012 (Perkins 2015). Although the park wide trend is one of declining infestations, the potential for invasive species infestations in the alkali community merits a *Condition Level* of 2, or moderate concern. Since new infestations can occur at any time, the presence is considered a threat to all plant communities, including the alkali flats communities.

Percent Bare Ground
The *Significance Level* for percent bare ground was assigned a 3, but this measure is considered a data gap. Since data are not available to assess any trends in the percent of bare ground in the alkali flats community of FOBU, a *Condition Level* cannot be assigned at this time.

Weighted Condition Score
The *Weighted Condition Score* for FOBU's alkali flats communities is 0.44, indicating that the resource is of moderate concern. Due primarily to a lack of reference data for community composition, percent bare ground, and park-wide community-specific information on invasive plant infestations, a trend was not assigned.

Alkali Flats Community			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.44**
Relative Abundance of *Lepidium*	3	2	
Community Extent and Change over Time	3	0	
Community Composition	3	N/A	
Trends in Invasive Infestation	3	2	
Percent Bare Ground	2	N/A	

4.7.6. Sources of Expertise
- Walt Fertig, Former Wyoming Natural Diversity Database Botanist

4.7.7. Literature Cited

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4.8. Montane Shrublands

4.8.1. Description

Photo 8. True mountain-mahogany (NPS Photo).

Montane shrublands are a transitional zone between grasslands and montane forest (Hanophy and Teitelbaum 2003). Sagebrush shrublands border the montane shrublands at the lower limits of their elevation, while ponderosa pine can be found at the upper edge of their elevation (Vankat 2013). The montane shrublands within FOBU are comprised of the following plant communities: bitterbrush shrubland, chokecherry shrubland, mixed mountain shrubland, mountain snowberry shrubland, and sagebrush-serviceberry shrubland (Friesen et al. 2010).

In general these communities tend to grow on exposed sites on the steep upper slopes of Rubey Point, Fossil Butte, and Cundick Ridge at elevations between 1,500-2,900 m (4,921-9,514 ft) (Jones 1993, Friesen et al. 2010). Only one bitterbrush shrubland community is found within FOBU (Friesen et al. 2010) located near the southern rim of Fossil Butte on a silt loam soil (Friesen et al. 2010). It occurs on a steeply sloped site (25°) at 2,269 m (7,444 ft) in elevation (Friesen et al. 2010). Chokecherry shrubland communities within FOBU can be found on gentle to moderately steep slopes (5-20°) between 2,207 and 2,311 m (7,241 and 7,582 ft) in elevation (Friesen et al. 2010). Soils are generally clay loams (Friesen et al. 2010). Though uncommon, this community can be found in areas of relatively moist soil, for example in snow-catching depressions on top of Fossil Butte, on cool, protected slopes with a northeast aspect, or below a bench on Fossil Butte. Mixed mountain shrubland communities within FOBU can be found on gentle to steep slopes (1-46°) between 2,191 and 2,424 m (7,188 and 7,953 ft) in elevation (Friesen et al. 2010). Soils are generally loamy sand, silt loam, sandy clay loam, silt clay loam, silty clay, or clay (Friesen et al. 2010). This community type can be found on steep, exposed slopes and ridges (Friesen et al. 2010). A single mountain snowberry shrubland community is found within FOBU (Friesen et al. 2010). It is located on a moderately steep slope (9°) north facing slump bench at 2,216 m (7,270 ft) in elevation (Friesen et al. 2010). The soil on this site is clay loam (Friesen et al. 2010).

These communities are interspersed with mountain big sagebrush and may represent an earlier seral stage of Douglas-fir or limber pine forests (Fertig and Kyte 2009). Common shrubs found within these communities include Utah serviceberry, true mountain-mahogany (*Cercocarpus montanus*), chokecherry, Utah snowberry, and antelope bitterbrush (*Purshia tridentata*) (Jones 1983, Friesen et al. 2010). Great Basin wildrye is a grass commonly found in these shrublands. Other grass/forb species commonly associated with montane shrublands include arrowleaf balsamroot (*Balsamorhiza sagittata*), western gromwell (*Lithospermum ruderale*), oneflower helianthella (*Helianthella uniflora*), and turpentine spring-parsley (Friesen et al. 2010).

Montane shrublands support a variety of wildlife. Mule deer, elk, black bears, cottontails (*Sylvilagus* spp.), and a variety of small rodents can be found in this ecosystem due to the abundance of seeds, acorns and berries (Hanophy and Teitelbaum 2003, Vance and Luna 2010). Red fox, bobcats, skunks, and coyotes (*Canis latrans*) actively hunt rodents in this ecosystem. Birds found within montane shrublands include golden eagle (*Aquila chrysaetos*), various hawks, and many songbird species (Order Passeriformes) (Hanophy and Teitelbaum 2003, Vance and Luna 2010).

4.8.2. Measures

- Community extent and change over time
- Community composition
- Trends in invasive infestation
- Percent bare ground

4.8.3. Reference Conditions/Values

Park managers suggested the reference condition could be determined from the historic conditions described in early USGS surveys by Hayden (1872), conditions of the area presettlement/grazing, or from information from railroad and quarry archives. A variety of conditions were reviewed in order to determine a reference condition for the vegetation components within this assessment. These ranged from pollen counts to historical accounts from government reports and visiting naturalist (Dorn et al. 1984). A more thorough account of the different possible reference condition considered is given in Chapter 4.1.3. For the purposes of this assessment, the pre-settlement condition was chosen as the reference condition. Historical records indicate that FOBU was a sagebrush shrubland prior to European settlement, with the exception of a few trees at higher elevations, much as it is today (Dorn et al. 1984).

4.8.4. Data and Methods

The following discussion of data and methods pertains to the condition assessment for the montane shrubland component. The data and methods for the climate change vulnerability assessment are located in Chapter 2 and Chapter 3.

Vegetation mapping was first completed at FOBU in 1973 with a survey and mapping project completed by Beetle and Marlow (1974). This project identified 12 major vegetation classes and also created a baseline study of range conditions for FOBU (Beetle and Marlow 1974). Dorn et al. (1984) created a vegetation map as part of a study on the impacts of grazing. This mapping was created using available aerial imagery and was considered to be spatially inaccurate (Friesen et al. 20010). A follow-up vegetation mapping project (Jones 1993) verified and refined the mapping created by Dorn et al. (1984). While not a comprehensive vegetation inventory, the Jones (1993) study did contain information on vegetation communities at FOBU that was sufficient and complete enough to provide a baseline against which the current community extent could be evaluated. However, since neither Dorn et al. (1984) nor Jones (1993) were comprehensive vegetation inventories, they cannot be used in determining the full community composition or the changes in composition over time in the montane shrubland community.

Fertig (2000) reviewed and revised the FOBU plant checklist to eliminate synonyms and falsely reported taxa. Fertig and Kyte (2009) further reviewed FOBU voucher specimen plants in 2004 and created an annotated species list. Annotations included park-specific distribution, population size, and flowering periods along with general information on geographic range and nomenclature updates (Fertig and Kyte 2009). Friesen et al. (2010) mapped and described the plant associations occurring in FOBU. This mapping project was conducted from 2005 through 2008 as part of the NCPN Inventory and Monitoring Program and the USGS-NPS National Vegetation Mapping Program (Friesen et al. 2010). Invasive species surveys were conducted in FOBU in 2008, 2009, 2010, 2012, and 2014 (Perkins 2015). This inventory is based on a priority species list that was compiled by FOBU and NCPN staff.

Serviceberry, bitterbrush, chokecherry, snowberry, and mixed mountain shrublands are dominant cover types of montane shrublands (Friesen et al. 2010) and will be used to assess the community extent and composition of montane shrublands within FOBU.

4.8.5. Current Condition and Trend

Community Extent and Change over Time

Montane shrublands comprise 313.6 ha (774.8 ac), or approximately 9% of FOBU’s 3,363.4 ha (8,311.2 ac) (Table 49, Friesen et al. 2010). The location of this community within the park is shown in Figure 34. During the 1992 vegetation project, Jones (1993) verified the location and aerial extent of several small patches of mountain shrub map units that had been delineated by Dorn et al. (1984). These patches accounted for approximately 264 ha (652 ac) of the park.

Table 49. Area and percentage of total area by montane shrubland type (Friesen et al. 2010).

Montane Shrubland Type	Area hectares (acres)	Percent Montane Shrublands	Percent Total Vegetation
Bitterbrush shrubland	1.1 (2.8)	0.4%	0.0%
Chokecherry shrubland	1.6 (3.9)	0.5%	0.0%
Mixed mountain shrubland	104.8 (258.9)	33.4%	3.1%
Mountain snowberry shrubland	0.7 (1.6)	0.2%	0.0%
Sagebrush-serviceberry shrubland	205.4 (507.6)	65.5%	6.1%

Currently, sagebrush-seviceberry shrubland can be found on the high slopes of Fossil Butte, Cundick Ridge, and Rubey Point (Friesen et al. 2010). Mixed mountain shrubland communities are found on steep, exposed slopes and ridges of Rubey Point, Cundick Ridge, Fossil Butte, and near Nature Trail (Friesen et al. 2010). Bitterbrush shrubland communities occur near the rim of Fossil Butte. Chokecherry shrubland communities can be found in a snow-catching depression on the top of Fossil Butte, on a cool, protected slope below a bench on the northeast aspect of Fossil Butte, and along Nature Trail near a spring (Friesen et al. 2010). Mountain snowberry shrubland communities can be found on the north face of Fossil Butte (Friesen et al. 2010). The mountain shrub map units identified by Dorn et al. (1984) and verified by Jones (1993) were located in the same general areas as those located by Friesen et al. (2010).

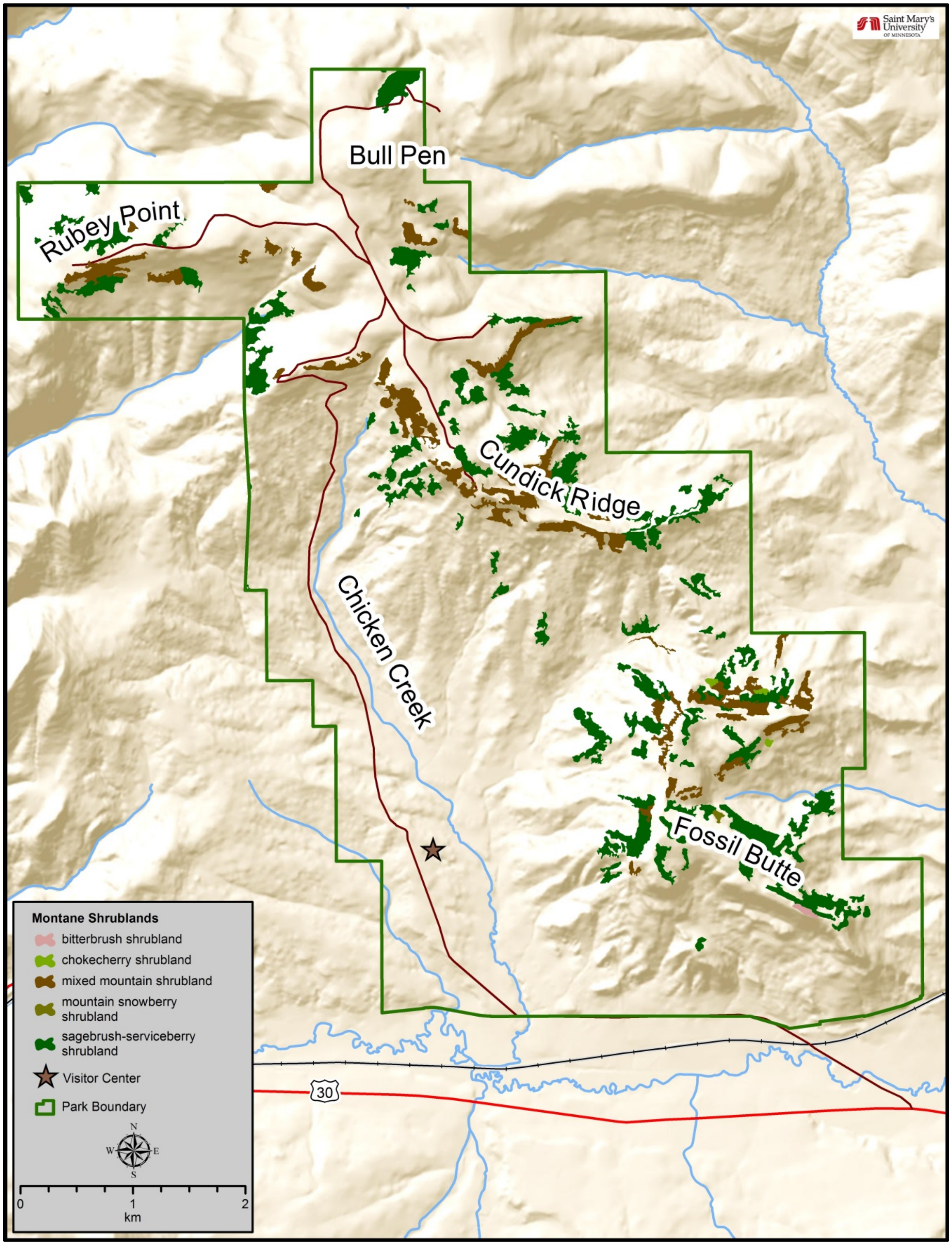

Figure 34. Montane shrubland locations within FOBU (Friesen et al. 2010).

Community Composition

In 1973, Beetle and Marlow (1974) surveyed and mapped vegetation of FOBU. This map included 12 major vegetation types, four of which were "serviceberry complex," "mountain-mahogany and serviceberry complex", "mountain-mahogany complex," and "chokecherry and bitterbrush complex." However, this study did not list the relative abundance of species in each vegetation type (Friesen et al. 2010). Dorn et al. (1984) also developed a vegetation map which was verified with only slight modifications by Jones (1993). This map included 12 vegetation types, one of which was mountain shrub. Vegetation descriptions of this study were incomplete and the data was inaccurate due to the use of unrectified aerial photography (Friesen et al. 2010). Fertig and Kyte (2009) developed a comprehensive list of these plants and classified them by habitat type. The closest classification to the montane habitat type listed in Fertig and Kyte (2009) is "big sagebrush or alkali (longleaf) sagebrush grassland and montane shrub communities." While this classification contains the plants found in the montane shrubland of FOBU, it may also contain plants that are not present in montane shrublands. Friesen et al. (2010) listed 50 plant species that occur within montane shrublands of FOBU. They consisted of two trees, 13 shrubs, 23 forbs, and 12 graminoids (Table 50). The most common species found for each of the plant associations is given in Table 51.

Table 50. Species composition of the montane shrubland communities of FOBU. Abundance level is from NPSpecies (Friesen et al. 2010, NPS 2015). A = Sagebrush-serviceberry shrubland, B = Mixed mountain shrubland, C = Chokecherry shrubland, D = Bitterbrush shrubland, E = Mountain snowberry shrubland

Scientific Name	Common Name	Association	NPSpecies Abundance
Trees			
Pinus flexilis	limber pine	A, B, E	Uncommon
Populus tremuloides	quaking aspen	C	Common
Shrubs			
Amelanchier utahensis	Utah serviceberry	A, B, C, D, E	Common
Arctostaphylos uva-ursi	bearberry	C	Uncommon
Artemisia tridentata ssp. *vaseyana*	mountain big sagebrush	A, B, C, D, E	Abundant
Atriplex confertifolia	spiny saltbush	D	Uncommon
Berberis repens	creeping Oregon-grape	B, C	Uncommon
Cercocarpus montanus	true mountain-mahogany	A, B, E	Common
Chrysothamnus viscidiflorus	green rabbitbrush	A, B, D, E	Common
Holodiscus discolor	oceanspray	B	Uncommon
Prunus virginiana	chokecherry	B, C	Uncommon
Purshia tridentata	antelope bitterbrush	A, B, C, D, E	Common

* Non-native species

Table 50 (continued). Species composition of the montane shrubland communities of FOBU. Abundance level is from NPSpecies (Friesen et al. 2010, NPS 2015). A = Sagebrush-serviceberry shrubland, B = Mixed mountain shrubland, C = Chokecherry shrubland, D = Bitterbrush shrubland, E = Mountain snowberry shrubland

Scientific Name	Common Name	Association	NPSpecies Abundance
Trees			
Ribes cereum	wax currant	A, C	Uncommon
Rosa woodsii	Woods' rose	B, C	Uncommon
Symphoricarpos oreophilus var. *utahensis*	Utah snowberry	A, B, C, E	Common
Graminoids			
Achnatherum hymenoides	Indian ricegrass	B, D	Common
Achnatherum lettermanii	Letterman's needlegrass	A	Uncommon
Achnatherum nelsonii	Nelson's needlegrass	A, C	Uncommon
*Bromus tectorum**	cheatgrass	A, B, D	Uncommon
Carex geyeri	Geyer's sedge	A, B	No data
Elymus lanceolatus ssp. *lanceolatus*	thickspike wheatgrass	A, B, C, D	Uncommon
Leucopoa kingii	spike fescue	A	Common
Leymus cinereus	Great Basin wildrye	B, C, D, E	Common
Pascopyrum smithii	western wheatgrass	A, B	Common
Poa fendleriana	muttongrass	A, B, E	Common
Poa secunda	big bluegrass	A, B	Common
Pseudoroegneria spicata	bluebunch wheatgrass	B	Common
Forbs			
Achillea millefolium	common yarrow	A, B	Common
Balsamorhiza sagittata	arrowleaf balsamroot	A, B, C	Uncommon
Cirsium undulatum	wavy-leaf thistle	A	No data
Comandra umbellata	bastard toadflax	B, C, E	Uncommon
Delphinium nuttallianum	Nuttall's larkspur	C	Uncommon
Descurainia pinnata	western tansymustard	B	Uncommon
Eriogonum brevicaule	shortstem buckwheat	B, D	Uncommon
Eriogonum umbellatum	sulfur buckwheat	A, B, C, E	Uncommon

* Non-native species

Table 50 (continued). Species composition of the montane shrubland communities of FOBU. Abundance level is from NPSpecies (Friesen et al. 2010, NPS 2015). A = Sagebrush-serviceberry shrubland, B = Mixed mountain shrubland, C = Chokecherry shrubland, D = Bitterbrush shrubland, E = Mountain snowberry shrubland

Scientific Name	Common Name	Association	NPSpecies Abundance
Forbs			
Geranium viscosissimum	sticky geranium	C	Uncommon
Helianthella uniflora	oneflower helianthella	B	Uncommon
Linum lewisii	blue flax	E	Uncommon
Lithospermum ruderale	western gromwell	A, B, C, E	Uncommon
Lupinus argenteus	silvery lupine	A	Common
Mertensia oblongifolia	leafy bluebells	A, B, C	Uncommon
Osmorhiza berteroi	sweetcicely	C	Uncommon
Phlox hoodii	Hood's phlox	B	Common
Physaria acutifolia	sharpleaf twinpod	B	Uncommon
Physaria condensata	tufted twinpod	D	Uncommon
Pteryxia terebinthina	turpentine spring-parsley	A, B, D	Uncommon
Senecio integerrimus var. *exaltatus*	Columbia groundsel	A, B	Uncommon
Stenotus acaulis	stemless goldenweed	B	Uncommon
*Taraxacum officinale**	common dandelion	A, B	Uncommon
Trifolium gymnocarpon	hollyleaf clover	A	Uncommon

* Non-native species

Table 51. Common species by strata for the plant associations that make up the montane shrubland community at FOBU (Friesen et al. 2010).

Stratum	Scientific Name	Common Name
Sagebrush-serviceberry shrubland		
Tall shrub/sapling	*Amelanchier utahensis*	Utah serviceberry
Short shrub/sapling	*Symphoricarpos oreophilus* var. *utahensis*	Utah snowberry
	Artemisia tridentata ssp. *vaseyana*	mountain big sagebrush
Herbaceous	*Poa secunda*	big bluegrass

Table 51 (continued). Common species by strata for the plant associations that make up the montane shrubland community at FOBU (Friesen et al. 2010).

Mixed mountain shrubland		
Tall shrub/sapling	*Amelanchier utahensis*	Utah serviceberry
Short shrub/sapling	*Cercocarpus montanus*	true mountain- mahogany
Chokecherry shrubland		
Tall shrub/sapling	*Prunus virginiana*	chokecherry
Short shrub/sapling	*Amelanchier utahensis*	Utah serviceberry
	Symphoricarpos oreophilus var. *utahensis*	Utah snowberry
Herbaceous	*Balsamorhiza sagittata*	arrowleaf balsamroot
	Helianthella uniflora	oneflower helianthella
	Lithospermum ruderale	western gromwell
	Leymus cinereus	Great Basin wildrye
Bitterbrush shrubland		
Short shrub/sapling	*Purshia tridentata*	antelope bitterbrush
	Amelanchier utahensis	Utah serviceberry
Herbaceous	*Pteryxia terebinthina*	turpentine spring-parsley
Mountain snowberry shrubland		
Tall shrub/sapling	*Amelanchier utahensis*	Utah serviceberry
Short shrub/sapling	*Symphoricarpos oreophilus* var. *utahensis*	Utah snowberry

Trends in Invasive Infestation

Extensive IEP surveys were performed within FOBU in 2008, 2009, 2010, 2012, and 2014 (Perkins 2015); refer to Chapter 4.1 of this assessment for details on priority species and survey routes. These efforts were not comprehensive park-wide surveys, but focused on common vectors where IEPs spread such as roads, trails, and waterways. Trends in invasive plants have not been assessed by vegetation association at FOBU. To identify invasive species infestations associated with the montane shrubland communities a spatial query was performed using the data form the 2014 IEP survey and the montane shrubland vegetation communities mapped by Friesen et al. (2010). The result of this analysis is shown in Figure 35 and Table 52. The spatial queries identified just over 27% (157 of 574) of the IEP points that met the selection criteria. Only 17 of the recorded IEP patches were identified as being within a mapped montane shrubland by the spatial queries. Of the five priority species selected as being within the mapped community, cheatgrass was the most common with 7 points selected. Cheatgrass (50 points) and flixweed (4 points) were the most commonly occurring IEPs in proximity to montane shrublands according to the results of the spatial queries.

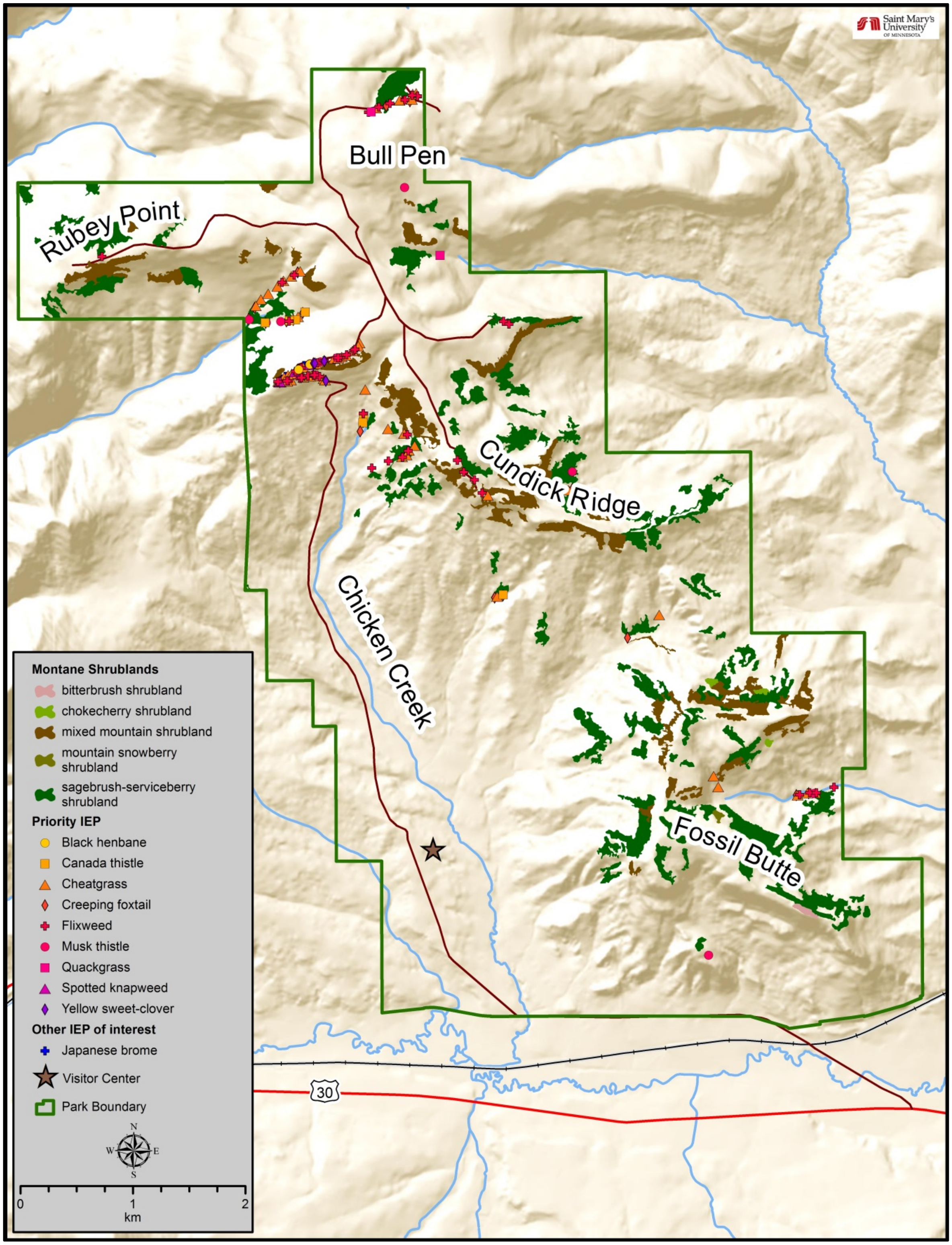

Figure 35. IEP infestations associated with mapped montane shrubland communities.

Table 52. Number of IEP infestation patches from 2014 survey that are within or near a montane shrubland community.

		Number of patches		
Scientific Name	**Common Name**	**Within mapped patch**	**Within 100 m of mapped patch**	**Total**
Priority IEPs				
Alopecurus arundinaceus	creeping foxtail	4	17	**21**
Bromus tectorum	cheatgrass	7	50	**57**
Carduus nutans	musk thistle	2	10	**12**
Centaurea stoebe	spotted knapweed	-	5	**5**
Cirsium arvense	Canada thistle	1	6	**7**
Descurainia sophia	flixweed	3	41	**44**
Elymus repens	quackgrass	-	2	**2**
Hyoscyamus niger	black henbane	-	2	**2**
Melilotus officinalis	yellow sweetclover	-	4	**4**
Other non-native species of interest				
Bromus japonicus	Japanese brome	-	3	**3**
Total		**17**	**140**	**157**

Percent Bare Ground

Percent bare ground is an important measure as it can directly impact soil stability. For more information on the importance of percent bare ground, refer to Chapter 4.1.5. While no quantitative data are available for percent bare ground in FOBU vegetation communities, some insight into potential maximum bare ground values can be inferred from vegetation cover data. Percent bare ground and vegetative cover in montane shrublands varies with community type. In bitterbrush shrubland communities, total vegetation cover is approximately 19% with high exposure of bare soil and sparse cover of small and large rocks in unvegetated areas (Friesen et al. 2010). Chokecherry shrubland communities have total vegetation cover that ranges from 50 to 100% with low to moderate exposure of bare soil, litter, and downed wood in unvegetated areas (Friesen et al. 2010). In mixed mountain shrubland communities, total vegetation cover ranges from 1 to 93% with moderate to high exposure of bare soil, low to moderate cover of small rocks and litter, and low cover of large rocks and downed wood in unvegetated areas (Friesen et al. 2010). Mountain snowberry shrubland communities have a total vegetation cover of approximately 18% with moderate exposure of bare soil and low cover of litter and downed wood in unvegetated areas (Friesen et al. 2010). Refer to the percent bare ground section of the low sagebrush community component for details regarding the percent bare ground measure of FOBU.

Vulnerability to Climate Change

The montane shrublands at FOBU were selected (along with seeps, springs, and slump pond aquatic habitats [Chapter 4.5.5]) for additional analysis of their vulnerability to climate change (See Chapter 3.3.2). The extent and composition of the plant communities that comprise montane shrublands are discussed in detail in the above sections. Based on this discussion, two species were selected to assess the vulnerability of montane shrublands to climate change. By far, the two largest plant associations in this habitat type are the sagebrush-serviceberry shrublands and the mixed mountain shrublands (Table 49). Utah serviceberry and true mountain-mahogany were chosen to represent the montane shrublands, as they are two of the most common species found within this habitat type (Friesen et al. 2010). The vulnerability of Utah serviceberry and true mountain-mahogany will be assessed based on six factors: location within the community's geographic range, sensitivity to extreme climatic events, dependence on hydrologic conditions, the community's adaptive capacity, vulnerability of ecologically influential species, and the potential for climate change to increase the impacts of non-climate stressors. A detailed description of this methodology and definitions of these six variables are presented in Chapter 3.3 of this report.

Both Utah serviceberry and true mountain-mahogany are geographically distributed within the Great Basin and Intermountain Regions of the United States (Figure 36). They can be found on gentle to steep slopes between 2,191 and 2,424 m (7,188 - 7,593 ft) in elevation within FOBU and are oriented at all aspects (Friesen et al. 2010). FOBU is located in the northern and eastern portion of the geographic ranges of Utah serviceberry and true mountain-mahogany. Therefore, location alone would likely not cause them to be significantly vulnerable to an increase in temperature and aridity causing a northern and/or westward shift in their preferred climatic conditions (Figure 36).

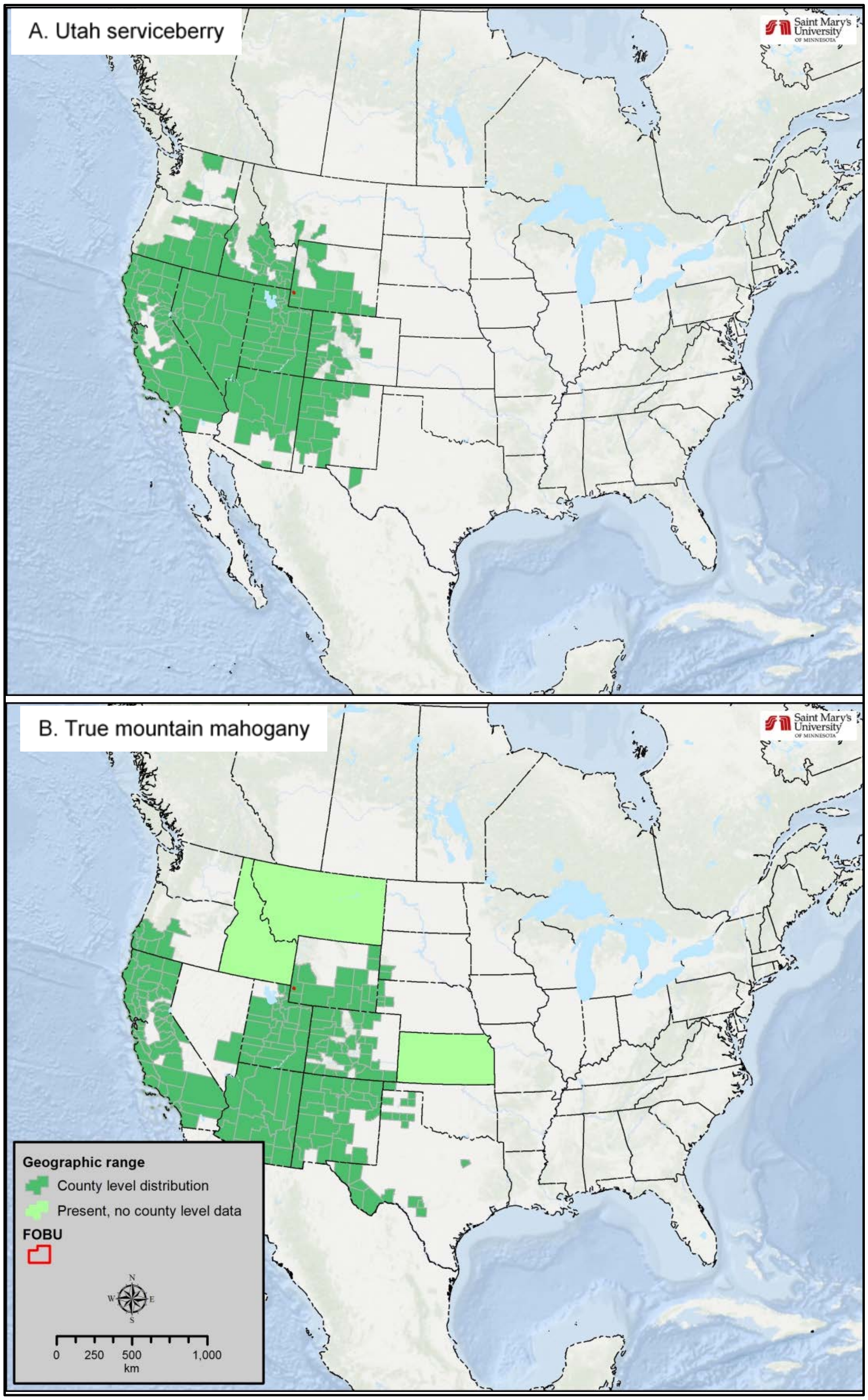

Figure 36. Geographic extent of montane shrubland keystone species (A. Utah serviceberry and B. true mountain-mahogany) used in the climate change vulnerability analysis. The geographic extents are based on county level data from NRCS 2015.

As was discussed in the analysis of seeps, springs, and slump pond habitat's vulnerability to climate change, the climate models project warmer and drier (more arid) conditions for FOBU by 2100 under the RCP 8.5 scenario (Chapter 4.5.5, Figure 23, Figure 24, Figure 25). This is expected to result in longer and hotter summer heat waves along with an increased potential for drought and wildfires (Melillo et al. 2014). Even though the climate models predict an increase in annual precipitation, the higher temperatures will result in greater evapotranspiration rates, leading to an increase in aridity in all seasons (Chapter 4.5.5 - Figure 24). Montane shrublands are well adapted to warm, arid conditions, being both heat and drought tolerant, with seedlings and older stems being the most tolerant (Decker and Rondeau 2014). Most montane shrubland species are also highly fire tolerant and could potentially become established in adjacent forested ecosystems opened up by fires (Decker and Rondeau 2014). Overall, the climate model's predictions of drier conditions, with more frequent and severe droughts and potential for increased wildfires, are not likely to negatively affect these communities.

Montane shrubland species are highly dependent on snow-drifting patterns and the timing of the soil moisture supplied by the winter snows (Fertig, written communication, 7 December 2015). Studies have shown that the many of the species that compose the montane shrubland community can be stressed by cold temperatures and high soil moisture levels (Decker and Rondeau 2014). The projected change to warmer and drier average conditions, especially warmer wintertime temperatures may have adverse impacts on this community. The warmer wintertime temperatures may result in a change from snow dominated precipitation events to rain events. Montane shrublands rely on the winter storms to provide snow-pack that slowly melts providing a slow-release of moisture to the soil (Fertig, written communication, 7 December 2015). Under the projected changes to climate, the presence of snow and the timing and duration of the spring thaws will be affected, possibly to a point that adversely affects the viability of this community within FOBU.

The montane shrublands do exhibit some adaptive capacity. Their geographic range includes a variety of temperature and precipitation regimes (Figure 36). They have also exhibited the ability to survive and thrive under disturbance regimes such as droughts and wildfire (Decker and Rondeau 2014).

The extent to which the hotter and drier conditions expected in FOBU over the next century will exacerbate non-climate stressors of the montane shrubland community is unclear. Researchers believe that drought and warmth across western North America over the past decade have already led to extensive insect outbreaks and increased mortality in many vegetation communities (Miller 2005, Richardson et al. 2012). Higher summer temperatures generally accelerate the development and reproductive rates of insects, while drought stress may increase a plant species' vulnerability to insect attack (Miller 2005). A common defoliator of shrub species is the western tent caterpillar (*Malacosoma californicum*) (Decker and Rondeau 2014). Historically, large infestations of these insects have been infrequent in montane shrublands (USDA 2010). While the montane shrubland species are less likely to exhibit drought stress, it is unknown if conditions favorable to defoliators like the western tent caterpillar will have an impact on overall community health.

It is also difficult to assess how the warmer and drier conditions predicted for FOBU will affect non-native plant incursions into montane shrubland communities. Currently, there are very few instances of non-native species infestations near or within montane shrublands (Figure 35, Table 52). It has been suggested that most aspects of global climate change will favor non-native species over natives (Dukes and Mooney 1999). It is unknown if this pattern will apply to already arid environments such as FOBU. Many of the non-native species already present in FOBU (Table 52) are adapted to disturbed soils and wetter conditions. It is likely that these species would likely be tolerant of warmer conditions, but they may not be adaptable to the predicted drier conditions.

<u>Threats and Stressor Factors</u>
NPS staff identified ungulate browsing and IEPs, particularly cheatgrass, as potential threats and stressors to the montane shrubland community at FOBU. Cheatgrass is one of the most widely distributed non-native grasses in North America (Banks and Baker 2011). It is present in every county in Wyoming (RMCMP 2013). Originally from the sagebrush steppe region of Asia, the sagebrush communities in Wyoming provide similar ecological conditions (RMCMP 2013).

Cheatgrass is successful as an invading species for several reasons. It easily occupies sites that have disturbed soil or vegetation (RMCMP 2013). It also is adapted to a wide range of soil textures (RMCMP 2013). Cheatgrass has long, sharp awns, which make it easily transported by animals, and these same awns defend it from herbivory (RMCMP 2013). Cheatgrass competes with native sagebrush vegetation communities for moisture, sunlight, and nutrients (RMCMP 2013). This is due to the fact that much of its growth occurs in the winter and early spring, when there is less competition from native plants, and it has an extensive and fast-growing root and shoot system (RMCMP 2013). Cheatgrass matures and dries out before other native perennial grasses and as a result, can act as a fuel source for wildfires (RMCMP 2013). In sagebrush communities where cheatgrass is dominant in the understory, it provides a ready source of highly flammable fuel material for wildfire (RMCMP 2013). A more frequent fire regime, fueled by increased cheatgrass accumulations, can lead to a reduction in abundance, or total loss of sagebrush habitat. This is due to the differences in the recovery times for the species. Cheatgrass has a competitive advantage over native perennials following disturbance, due to its faster germination and root growth (RMCMP 2013). Sagebrush is slow-growing and may take 25 to 50 years to recover after a fire (RMCMP 2013).

Ungulate herbivory can influence the structure and function of ecosystems by altering nutrient cycling and competition between species (Hobbs 1996); ungulates also influence fire regimes by altering the available fuel load. In shrublands, ungulates can increase the likelihood of crown fires while decreasing the likelihood of surface fires (Hobbs 1996). According to Kay (1993), montane shrubs browsed by ungulates may have significantly smaller canopy cover, height, size, and volume than those not browsed by ungulates. Excessive browsing can almost entirely stop seed production on shrubs (Kay 1993). Shrubs that are not browsed by ungulates may produce up to 20,000 times more seeds/berries than those that are browsed (Kay 1993). Without seed production, these plants will not be replaced when they die which may lead to a shift in species composition (Kay 1993). Animals such as mule deer, elk, and moose are among those responsible for the over browsing FOBU’s montane shrublands (Evenden et al. 2002). Based on the amount and type of scat in these areas, deer and moose are common in this habitat type (Evenden et al. 2002). These species target mainly true mountain-mahogany and bitterbrush, which can cause the plants to become senescent (Evenden et al. 2002). The number of elk overwintering at FOBU has increased in recent years (Olexa and Garman 2009; see Chapter 4.13) and field observatioins show an increase browsing pressure in montane shrublands (Angela Wetz, FOBU superintendent, written communication, 18 April 2016).

Data Needs/Gaps

At this time, data on the extent of vegetation communities at FOBU is considered a partial data gap. Vegetation mapping conducted by Dorn et al. (1984) and verified by Jones (1993) does have information that could be used to assess community extent and change over time, but it is based on generalized vegetation classifications and not the more specific classifications used by Friesen et al (2010). Neither of these earlier vegetation studies have the comprehensive species lists that are available in Friesen et al. (2010). Although some data exist for the percent bare ground measure, it is insufficient for making an accurate condition assessment. Reference conditions for community composition and percent bare ground measures are needed to determine the overall condition of these measures. Research into the impacts of ungulate grazing, particularly elk, will help managers better understand the threats faced by this community.

Overall Condition

Community Extent and Change over Time

This measure was assigned a *Significance Level* of 3. Data initially collected and mapped by Dorn et al. (1984) and later verified for spatial accuracy by Jones (1993) show that there has been an increase in the aeral extent of the montane shrubland community. The mapping conducted by Friesen et al. (2010) and Jones (1993) are nearly identical in the general locations of where this community is found. Due to the increase in aeral extent, a Condition Level of 0, meaning no concern has been assigned.

Community Composition

The community composition measure was assigned a *Significance Level* of 3. Although Fertig and Kyte (2009) developed a comprehensive list of plants present in FOBU, it did not indicate which of these species were present within montane shrublands. Friesen et al. (2010) listed 47 plant species present within the montane shrublands. While this species richness estimate seems relatively low to moderate, there are little historical data to indicate whether or not this is unusual for montane shrublands within FOBU. Therefore, a *Condition Level* was not assigned to this measure.

Trends in Invasive Infestation

A *Significance Level* of 2 was assigned to this measure. IEP monitoring has shown a decline in the number of infestations from 2008 to 2014 (Perkins 2015). Spatial analysis showed that nearly 30% of the infestation points collected during the 2014 survey were associated with a montane shrubland community, either located within it, or within 100 m (328 ft). Although IEP infestations are declining park-wide, and only a small number of infestations were found within these communities, a

Condition Level of 2 was assigned to this measure, due to proximity of infestations cheatgrass and flixweed. These are two of the more widespread IEPs found within FOBU (Perkins 2015)

Percent Bare Ground

The percent bare ground measure was assigned a *Significance Level* of 2. Information regarding this measure is limited, but percent bare ground appears to be highly variable for some community types present in montane shrublands, making condition assessment difficult. A reference condition is needed to determine appropriate historical conditions for percent bare ground. Therefore, a *Condition Level* was not assigned.

Climate Change Vulnerability Assessment

Analysis of the montane shrublands within FOBU showed that they are within the moderately vulnerable category in terms of vulnerability to the projected climate change, with an overall score of 15 (Table 53). While the certainty scores are in the "high" category with a value of 15, alternative scores were assigned to some of the variables, as the degree of impact is difficult to assess due to uncertainty in the assigned values for some variables.

Table 53. Certainty, vulnerability, and alternative vulnerability scores for montane shrubland community assessment variables. For individual variables, certainty scores are 3 = high, 2 = moderate, and 1 = low.

Variable	Certainty Score[A]	Vulnerability Score[B]	Alternative Scores
Location in geographical range/distribution of plant community	3	3	-
Sensitivity to extreme climatic events (e.g., drought, flash floods, windstorms)	2	2	1
Dependence on specific hydrologic conditions	3	4	-
Intrinsic adaptive capacity	3	2	-
Vulnerability of ecologically influential species to climate change	2	2	1
Potential for climate change to exacerbate impacts of non-climate stressors	2	2	3
Total	**15**	**15**	**13-16**

A = The certainty ranges are 6-10 = low confidence, 11-14 = moderate confidence, 15-18 = high confidence
B = The vulnerability ranges are 6-13 = least vulnerable, 14-19 = moderately vulnerable, 20-25 = highly vulnerable, 26-30 = critically vulnerable

The uncertainty was addressed by identifying alternative scores for those variables in addition to the best estimate scores (Table 53). Alternative scores create a range of likely vulnerability for the plant community. The "sensitivity to extreme climatic events," the "vulnerability of ecologically influential species to climate change," and the "potential for climate change to exacerbate impacts of non-climate stressors" variables were assigned alternative scores for the following reasons. A lower score was assigned to the "sensitivity to extreme climate events" due to the fact that under the right combination of climatic conditions, the montane shrubland community extent could expand into new areas within FOBU. Montane shrubland species, in general, have a high tolerance to most of the aspects of projected change to a warmer drier climate, and the associated environmental changes such as drought. Due to this, a lower alternative score was assigned to the “vulnerability of ecologically influential species to climate change” variable. The “potential for climate change to exacerbate impacts of non-climate stressors” variable was given a higher alternative score due to the overall difficulty in determining how these factors will be impacted by climate change. When factored in, the range of vulnerability scores for montane shrubland is 13 to 16, placing it potentially in the “highly vulnerable” category under a worst-case scenario. The high certainty score suggests that, despite some uncertainty in the degree of impact to the selected species, the classification of montane shrubland in the least vulnerable category is fairly accurate. The scoring worksheet developed for the montane shrublands is included in Appendix F.

Weighted Condition Score
A *Weighted Condition Score* was not calculated for this component due to the unknown *Condition Levels* for two of the four measures. The current condition and trend for this resource at FOBU are unknown.

Montane Shrublands			
Measures	**Significance Level**	**Condition Level**	**WCS = N/A**
Community Extent and Change over Time	3	0	
Community Composition	3	N/A	
Trends in Invasive Infestation	2	2	
Percent Bare Ground	2	N/A	

4.8.6. Sources of Expertise

- Marian Talbert, North Central Climate Science Center Research Statistician
- Nicholas Fisichelli Ph.D., NPS Climate Change Response Program Ecologist

4.8.7. Literature Cited

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4.9. Herptiles

4.9.1. Description

Herptiles include two cold-blooded vertebrate groups: reptiles and amphibians. Amphibians are considered a high priority Vital Sign for monitoring at FOBU (O'Dell et al. 2005). A small variety of herptiles (e.g., snakes, lizards, salamanders, frogs) have been found in the park. A total of three species of reptiles and five species of amphibians are listed as native to the region around FOBU; five of these (two reptiles, three amphibians) are documented in the park (NPS 2014). Though located in an arid climate, the presence of interspersed wet landscape features, such as beaver and slump ponds, small wetlands, seeps and springs, and ephemeral riparian corridors within FOBU, help support a variety of herptiles within the park (Photo 9). Figure 37 shows the locations of some of these wet landscape features. Due to the arid climate, these wet features provide important habitat for amphibians and reptiles found in FOBU. Particularly for amphibians, the water resources and moist soil conditions around these features are necessary for reproduction as well as growth through juvenile stages.

Photo 9. An example of a valuable, wet habitat feature found at FOBU where reproduction of amphibians likely occurs (NPS photo).

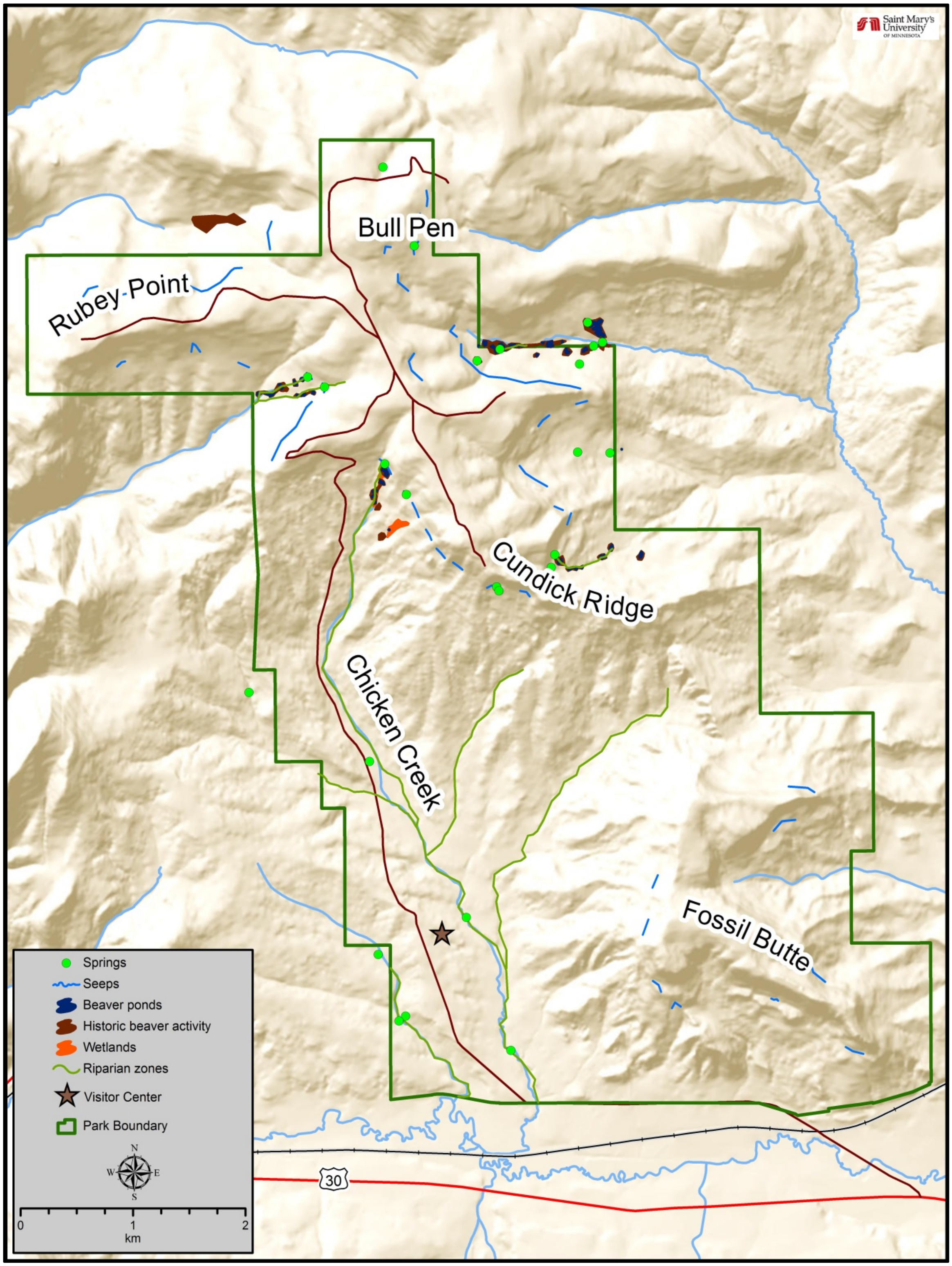

Figure 37. Potential herptile habitat, areas of available surface water, particularly for amphibians that require standing water during the breeding season.

4.9.2. Measures

- Amphibian richness
- Amphibian abundance
- Distribution of amphibians
- Reptile richness
- Reptile abundance
- Distribution of reptiles

4.9.3. Reference Conditions/Values

Ideally, the reference condition would be a historic inventory of herptile presence and abundance within the park or immediate region. However, there is very limited herptile documentation for the area. A study by Dorn et al. (1984) focused on grazing in FOBU, but also recorded presence and relative abundance of herptiles during the short duration of study. As the first documentation of herptile species identified in the park, Dorn et al. (1984) may be used as a reference for herptile presence and relative abundance in FOBU (Table 54).

Table 54. Herptile species list from Dorn et al. (1984).

Scientific Name	Common Name	NPSpecies Abundance
Amphibian		
Ambystoma tigrinum utahensis	Utah tiger salamander	Rare
Pseudacris triseriata	western chorus frog	Common
Lithobates pipiens	leopard frog	Rare
Reptile		
Phrynosoma hernandesi	greater short-horned lizard	No data
Thamnophis elegans vagrans	terrestrial garter snake	No data

4.9.4. Data and Methods

Dorn et al. (1984) conducted a survey of historical and current vegetation communities and the potential impacts livestock grazing has had on vegetation in FOBU. During the course of the survey, researchers also noted the vertebrate occurrences, as well as distribution and relative abundance; a list of herptiles was generated in this effort. The survey was conducted over three days in December 1983 and 19 days in June 1984. Herptile documentation likely occurred during the sampling in June, as herptiles generally hibernate during cold months. The herptiles were surveyed by direct observation or signs of their presence.

Platenberg and Graham (2003) conducted a herpetological inventory for FOBU in 2001 and 2002. Survey methods included diurnal Visual Encounter Surveys (VES), nocturnal spotlight surveys, and night road driving. The 2001 survey also conducted time/area-constrained searches at random locations in addition to the other survey methods. During the second-year surveys, target species were established prior to the field season. For FOBU, this included the western chorus frog; the surveys were timed with spring breeding and summer rain events to optimize encounters. The primary objective was to provide a baseline for FOBU by documenting at least 90% of herptiles in the park. The inventory was also used to identify any species of concern, general abundance, and distribution. Survey tracts and observations were georeferenced with a global positioning system (GPS).

4.9.5. Current Condition and Trend

Amphibian Richness

Overall, documentation of amphibians in FOBU is limited, primarily due to the lack of a comprehensive inventory effort. Dorn et al. (1984) identified the tiger salamander, western chorus frog, and the northern leopard frog as the amphibian species that were present in FOBU. Platenberg and Graham (2003) listed the same three species as occurring in the park (Table 55).

Table 55. Records of amphibian species documented in surveys completed in FOBU. An (X) indicates an actual presence of the species by direct observation and (U) indicates the species is likely to reside in the park due to a species range overlaying the park land and the presence of the species' known optimal habitat, but is currently unconfirmed.

Scientific Name	Common Name	Dorn et al. (1984)	Platenberg and Graham (2003)	NPS (2014)
Ambystoma tigrinum	tiger salamander	X	X	X
Anaxyrus boreas	western toad	-	-	U
Pseudacris triseriata	western chorus frog	X	X	X
Lithobates pipiens	northern leopard frog	X	X	X
Spea intermontana	Great Basin spadefoot	-	-	U

The NPS Certified Species List (NPS 2014) also lists the tiger salamander, northern leopard frog and western chorus frog as present in the park. Two additional species, the western toad (*Anaxyrus boreas*) and the Great Basin spadefoot toad (*Spea intermontana*), are listed as unconfirmed (Table 55).

Amphibian Abundance

Amphibian abundance is considered uncommon for all three species listed in the NPSpecies record (NPS 2014). However, park staff report that chorus frogs can seem abundant in some locations at certain times of year, particularly when environmental conditions are favorable (Aase, written communication, 3 February 2015).

Distribution of Amphibians

Platenberg and Graham (2003) included maps indicating where surveys were conducted and where specimens were observed; the majority of observations occurred during the 2001 survey effort

(Figure 38). Many observations occurred near or within beaver and slump ponds, marshy areas, and aspen groves, which tend to be more mesic than the surrounding arid environments.

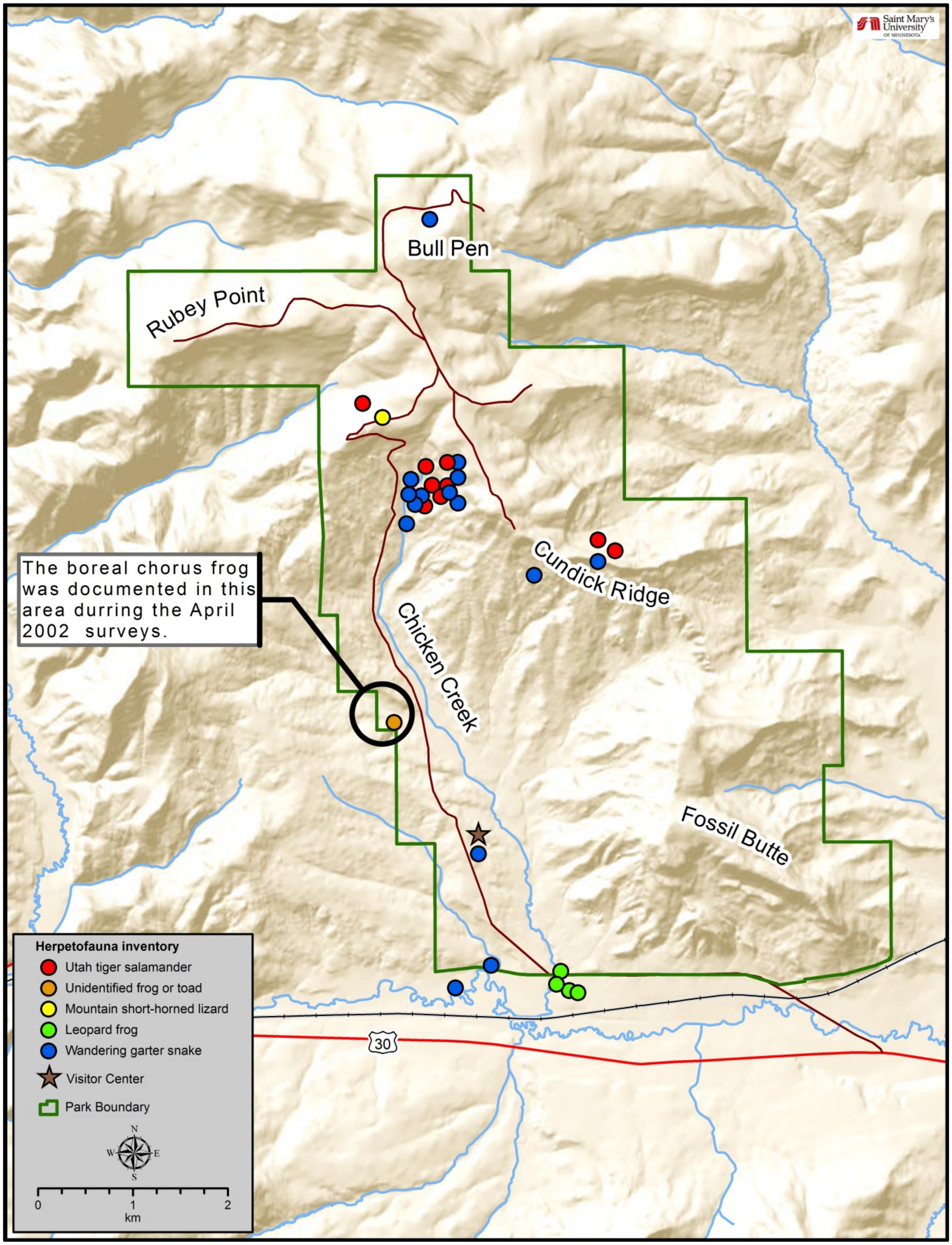

Figure 38. Location of species documented during a 2001 field survey. Approximate location of western chorus frog (*Pseudacris tristeriata*) documented in 2002 is also shown. An offset was applied to data points so that they do not overlap.

Reptile Richness

Dorn et al.'s (1984) grazing study included observations of the terrestrial (or wandering) garter snake (Photo 10) and the greater (or mountain) short-horned lizard in the vertebrate survey section of the study (Table 56).

Photo 10. The terrestrial garter snake is the only snake species documented in FOBU (NPS photo).

Table 56. Records of reptile species documented in surveys completed in FOBU. An (X) indicates an actual presence of the species by direct observation and (U) indicates the species may reside in the park due to a species range overlaying the park land and the presence of the species known optimal habitat, but is unconfirmed.

Scientific Name	Common Name	Dorn et al. (1984)	Platenberg and Graham (2003)	NPS (2014)
Phrynosoma hernandesi	greater short-horned lizard	X	X	X
Sceloporus graciosus	common sagebrush lizard	-	U	U
Thamnophis elegans vagrans	terrestrial garter snake	X	X	X

Platenberg and Graham (2003) also recorded the terrestrial garter snake and the greater short-horned lizard during the 2001 and 2002 survey seasons. The sagebrush lizard (*Sceloporus graciosus*) is also mentioned as likely occurring, since suitable habitats and the species' range are within the park boundaries, although it has not been observed (Platenberg and Graham 2003).

NPSpecies also lists the short-horned lizard and the common sagebrush lizard in addition to the terrestrial garter snake (NPS 2014). NPSpecies (NPS 2014) lists the common sagebrush lizard as unconfirmed, based on Platenberg and Graham's (2003) postulations.

Reptile Abundance

According to NPS (2014), terrestrial garter snake is common at FOBU and the greater short-horned lizard (Photo 11) is uncommon. However, FOBU staff report that short-horned lizards are common on certain slopes in the park (Aase, written communication, 3 February 2015).

Photo 11. The greater short-horned lizard (*Phrynosoma hernandesi*) (NPS photo by Renata Platenberg).

Distribution of Reptiles

Platenberg and Graham (2003) included maps indicating where surveys were conducted and where specimens were observed. A single greater short-horned lizard was observed in 2001; it was an adult female found in an area dominated by sagebrush, serviceberry, and rabbitbrush. The terrestrial garter snake was mostly observed around beaver ponds and other damp areas such as wetlands and aspen groves; thirteen individuals were observed as well as two skin sheds during the 2001 survey (Figure 38, Platenberg and Graham 2003).

Threats and Stressor Factors

Threats to the park's herptiles include non-native species, habitat loss, drought, climate variation/change, erosion, disease, and mercury deposition. Currently, there are no non-native herptiles documented in the park, and it is unknown whether any of the invasive plant species have an impact on the herptile species found in FOBU. Impacts of invasive plants include direct contributions to the decline of threatened and endangered species (USDA 2014). Invasive plants alter the ecology of the ecosystem, often by outcompeting native plants for sunlight, water, nutrients, and space, causing a decrease in biodiversity. This can also impact the insect community composition, which many reptiles and amphibians rely upon for food (USDA 2014).

Periodic drought conditions can impact herpetological survey efforts; this was the case in Platenberg and Graham's (2003) surveys in 2001 and 2002, where drought conditions were extreme and summer rain events were sparse, resulting in major survey reductions in 2002. Droughts can have a particularly significant impact on amphibians, which rely on freshwater for successful reproduction (Walls et al. 2013). Yellowstone National Park in northern Wyoming has experienced sharp declines in amphibian abundance and diversity due to the increased drought events that have desiccated wetlands and altered the hydrologic landscape (McMenamin et al. 2008). The decline is linked to shifting climatic trends (global climate change) in the region that have reduced the amount of suitable amphibian habitat (McMenamin et al. 2008).

Past grazing activities are linked to the accelerated erosion along Chicken Creek and its tributaries, as well as stock water developments in the northeastern area of the park (Dorn et al. 1984, NPS 1991). According to Dorn et al. (1984), any area near water was in poor condition as a result of livestock overgrazing and trampling leading to severe erosion in some areas. Continued erosion along Chicken Creek is mentioned in the NPS (1991) management statement and that photo monitoring of the areas was ongoing at that time.

The aquatic *Batrachochytrium dendrobatidis* (Bd), a type of chytrid fungus, causes chytridiomycosis, a lethal skin disease in amphibians that is linked to significant population declines worldwide, including the Rocky Mountain region (Weldon et al. 2004, Hossack et al. 2009). The fungus parasitizes the host's keratinized skin and mouthparts; it is affecting hundreds of species around the world (Kriger 2006). In several locations within the state of Wyoming, including YELL, GRTE, and the Bridger-Teton National Forest (BTNF), the fungus has been positively identified in amphibians (Olson 2014). Sampling for Bd has not been conducted in FOBU.

Mercury, which occurs both naturally and from human input, becomes most toxic to wildlife when transformation to methylmercury occurs at the bottom of lakes, streams, and in wetlands (EPA 2014a). Atmospheric mercury originates primarily from coal-burning power plants; other known sources are from burning hazardous waste, chlorine production, spills, and improper disposal of mercury-containing products (EPA 2014b). Exposure to methylmercury is cumulative, starting with aquatic organisms at the lowest trophic level; as it reaches higher trophic levels, biomagnification occurs. Biomagnification in wildlife results in mercury levels high enough to cause reduced reproductive success, retardation of growth and development, abnormal behavior, and death (EPA 2014b). There is not a current program for monitoring mercury in FOBU.

<u>Data Needs/Gaps</u>

Although some useful information exists for FOBU's herptiles, it is limited and outdated. This makes it difficult to determine a trend in herptile population dynamics in FOBU. Implementation of long-term monitoring would help managers to assess condition of herptiles and understand any trends in population and distribution that may be occurring in the park.

Overall Condition

Amphibian Richness

The project team defined the *Significance Level* for amphibian richness as a 1. Dorn et al. (1984) and Platenberg and Graham (2003) observed three amphibian species at FOBU. Although no recent surveys have confirmed the continued presence of these species, NPS staff report seeing them in the park (Aase, written communication, 3 February 2015). Therefore, this measure is assigned a *Condition Level* of 1, indicating low concern.

Amphibian Abundance

The project team defined the *Significance Level* for amphibian abundance as a 2. Abundance of amphibians is based on Platenberg and Graham's (2003) herpetological inventory. The three species of amphibians are all considered uncommon in abundance. Since data are limited to this single source, which is now over a decade old, a *Condition Level* was not assigned for this measure.

Distribution of Amphibians

The project team defined the *Significance Level* for amphibian distribution as a 3. The distribution of amphibians is shown in Platenberg and Graham's (2003) herpetological inventory (Figure 38). Given that no more recent information is available for comparison, a *Condition Level* cannot be assigned at this time.

Reptile Richness

The project team defined the *Significance Level* for reptile richness as a 1. There are only two confirmed reptile species in the park (Dorn et al. 1984, Platenberg and Graham 2003). As with amphibians, no recent surveys have confirmed the continued presence of these reptile species, but NPS staff report seeing them in the park (Aase, written communication, 3 February 2015). As a result, this measure is also assigned a *Condition Level* of 1.

Reptile Abundance

The project team defined the *Significance Level* for reptile abundance as a 2. Abundance of reptiles is based on Platenberg and Graham's (2003) herpetological inventory. The terrestrial garter snake is considered common while the greater short-horned lizard is considered uncommon (NPS 2014). Due to limited data, a *Condition Level* has not been assigned.

Distribution of Reptiles

The project team defined the *Significance Level* for reptile distribution as a 3. The distribution of reptiles is addressed in Platenberg and Graham's (2003) herpetological inventory (Figure 38). As with amphibians, a *Condition Level* was not assigned due to a lack of more recent information for comparison.

Weighted Condition Score

At this time, a *Weighted Condition Score* could not be calculated for herptiles, largely due to limited data on abundance and distribution. The condition and trend of herptiles at FOBU are unknown.

Herptiles			
Measures	**Significance Level**	**Condition Level**	**WCS = N/A**
Amphibian Richness	1	1	
Amphibian Abundance	2	N/A	
Distribution of Amphibians	3	N/A	
Reptile Richness	1	1	
Reptile Abundance	2	N/A	
Distribution of Reptiles	3	N/A	

4.9.6. Sources of Expertise

- Arvid Aase, FOBU Museum Specialist

4.9.7. Literature Cited

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4.10. Birds

4.10.1. Description

Bird populations often act as excellent indicators of an ecosystem's health (Morrison 1986, Hutto 1998, NABCI 2009). Birds are often highly visible components of ecosystems, and bird communities often reflect the abundance and distribution of other organisms with which they co-exist (Blakesley et al. 2010). The unique ecosystems and physical formations in FOBU provide bird species with a wealth of habitat types and food sources.

FOBU has confirmed the presence of more than 150 species of birds, and many of these birds are migratory species on their way to breeding grounds in the park or farther north (NPS 2015). Long-distance migratory species are highly informative indicator species, as their overall health depends on several different ecosystems. Global Christmas Bird Count (CBC) data indicate significant declines in migratory bird numbers in recent years (Peterjohn and Sauer 1999, Vickery and Herkert 2001). Nearctic-Neotropic migrants, hereafter Neotropical migrants, are bird species that breed in the temperate latitudes of the U.S. and Canada, but migrate to the tropical latitudes of Central and South America in the winter months (Figure 39). Stotz et al. (1996) estimates that approximately 420 bird species are classified as Neotropical migrants.

Figure 39. Zoogeographic regions of the world; shaded areas represent transition areas between regions (TPWD 2015).

4.10.2. Measures

- Summer breeding bird richness
- Year-round bird richness
- Raptor richness

- Raptor productivity

4.10.3. Reference Conditions/Values

The reference condition for birds in FOBU is currently defined as historic accounts of species present in the region. This is difficult to quantify, as historic reports are sporadic and are often from areas outside of the current FOBU boundaries. While NPS (2015) represents the park's certified species list, it is likely that species not included on that list can be found at times in the park. Continuation of the Rocky Mountain Bird Observatory's (RMBO) monitoring in the park, combined with past records of species in the park (including, but not limited to Johnson et al. 2003 and NPS 2015) could be used in the future as a reference condition for species richness in the park.

4.10.4. Data and Methods

The NPS Certified Bird Species List (NPS 2015) for FOBU was used to both determine the confirmed species in the park and to determine residency of species for this assessment; this list represents all of the confirmed and probably present bird species in the park (Appendix G). In instances where NPS (2015) did not assign residency, the American Ornithologists' Union and the Cornell University Lab of Ornithology's Birds of North America Online Database (http://bna.birds.cornell.edu/bna/) was used to approximate a species' residency as either breeding, migratory, resident, or vagrant. This component's measures separate species richness discussions for breeding birds and for resident (year-round) birds. Species in NPS (2015) that had residency designations of "Breeder" and "Resident" are discussed in the summer breeding bird richness measure, as NPS (2015) defines breeder as a species that reproduces within the park and resident as a species with a year round presence in the park. Only species that had residency designations of "Resident" are discussed in the year-round bird richness measure, as this classification refers only to species that occur in the park at year round. There will be some degree of overlap between these metrics, as resident species will be discussed in both measures. However, this is due to the fact that resident species are often breeding species as well and overlap is ultimately inevitable when using these two metrics as indicators of condition.

Johnson et al. (2003) completed an avian inventory in several Northern Colorado Plateau national parks. Beginning in 2001, random and non-random point count locations were established in FOBU and were surveyed three to four times during the breeding season (mid-May to mid-July); non-random stations were selected in habitats that were not represented in the random selections. Surveys ran in FOBU from 2001-2002. In addition to the surveys completed during the breeding season, Johnson et al. (2003) also completed several other surveys in the park throughout the year. Five (2001) and six (2002) incidental breeding bird surveys were completed in the park, with particular emphasis being placed on habitat zones that were not well represented in the point counts. Eight crepuscular and nighttime surveys were completed in the park in 2001, while only four were completed in 2002. Finally, Johnson et al. (2003) performed area search surveys of the winter bird population of FOBU during the 2000, 2001, and 2002 winters.

The RMBO, in a partnership with the NPS, has conducted annual landbird monitoring across the NCPN since 2005, with McLaren (2014) representing the most recent publication (covering the 2013 field season). The surveys conducted provide park managers with long-term trend data for most regularly occurring landbird species throughout the NCPN, as each year's data are pooled to allow for more accurate estimates of density and abundance. The RMBO monitoring is habitat-based (i.e., only specific habitat types are surveyed), and in FOBU, only the sage shrubland habitat type is surveyed. This habitat type occurs extensively in the NCPN, and often occurs in narrow bands of pure sage, dominated by big sagebrush and mountain sagebrush.

RMBO methodology utilized "…GIS and the Southwest Regional Re-GAP Analysis Project to randomly select sites from a pool of habitat 'stands' that were large enough to accommodate transects (Lowry et al. 2005)" (McLaren 2014, p. 3). Areas with >50% slope were excluded from this pool in order to include only areas that could be safely surveyed by foot. Areas that were determined to be appropriate stands have been surveyed every year since 2005. Surveys consist of 15-minute point counts for each point location on a transect, with each location spaced approximately 250 m (820 ft) apart. Sites were surveyed twice a summer, although beginning in 2013 sites were surveyed only once a summer, and typically occur between one half-hour before sunrise and five hours after sunrise (McLaren 2014). In FOBU, there are two transects (CP-SA14 and CP-SA15); each is located in a sage shrubland habitat, and has been surveyed every year of the study. Data related to the RMBO surveys of FOBU were retrieved from the Rocky Mountain Avian Data Center (http://rmbo.org/v3/avian/ExploretheData.aspx).

4.10.5. Current Condition and Trend

Summer Breeding Bird Richness

Species richness measures represent a total count of the number of species observed in an area or population. For this measure, only the richness of the summer breeding birds in FOBU is discussed. Breeding birds are defined as species identified with a residency of "Breeder" or "Resident" by NPS (2015). As this measure discusses the summer species richness of the park, the CBC data are not discussed in this measure.

NPS Certified Bird Species List (NPS 2015)

The NPS Certified Bird Species List contains 154 species, 69 (45%) of which are "Breeders" and are discussed in this section (Appendix G). An analysis of annual species richness is not possible using these data alone, as no record of when the species was observed is recorded.

NCPN Avian Inventory (Johnson et al. 2003)

Johnson et al. (2003) represents one of the first bird surveys to take place in the park, and utilized different methodologies to document bird species. This measure excludes the winter incidental non-breeding survey that was conducted by Johnson et al. (2003); the breeding bird point count, incidental breeding bird survey, and crepuscular/nighttime surveys are discussed here, however. Using those three survey types, Johnson et al. (2003) documented 91 species, 32 (36%) of which were breeding species. The breeding bird point counts documented 62 total species, with 28 of those species representing breeding species. The incidental breeding bird counts and the nighttime surveys documented comparatively fewer bird species, and only identified four and one breeding species, respectively (Appendix H).

RMBO Landbird Monitoring (2005-present)

The number of breeding species observed in FOBU remained relatively consistent from 2005-2014, with breeding species richness estimates ranging from nine (2009, 2014) to 15 (2013) species (Figure 40). The 10-year average for breeding species richness was 12.4 species (Figure 40). Unlike the NCPN avian inventory in the early 2000s, breeding species made up the majority of species that were observed (23 of the 35 total species observed, 66%). Five breeding species were observed during every year of the monitoring effort: black-billed magpie (*Pica hudsonia*), Brewer's sparrow, common raven (*Corvus corax*), vesper sparrow (*Pooecetes gramineus*), and the western meadowlark (*Sturnella neglecta*).

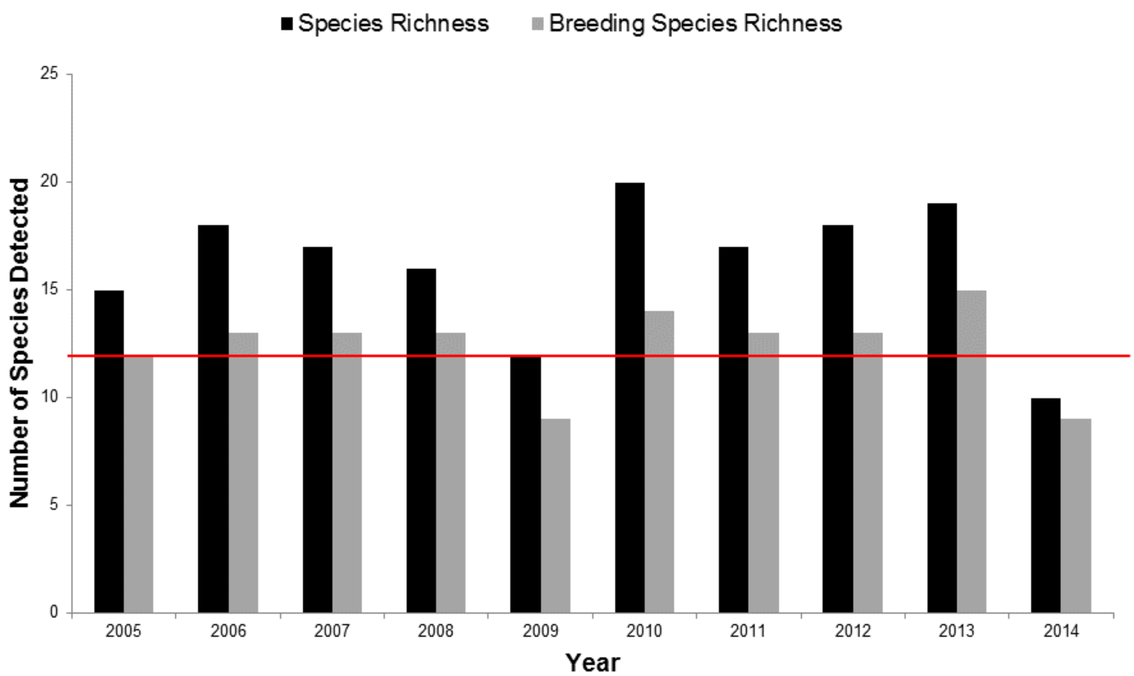

Figure 40. Species richness estimates for FOBU from 2005-2014. Values represent the total number of species observed on both sage shrubland habitat routes in the park. The solid red line indicates the 10-year breeding species richness average for the park (12.4 species/year). Data obtained from http://www.rmbo.org/v3/avian/ExploretheData.aspx.

Year-Round Bird Richness

NPS Certified Bird Species List (NPS 2015)

The NPS Certified Bird Species List contains 154 species, 75 (49%) of which are "Resident" (Appendix G). As previously described, an analysis of annual year-round species richness is not possible using these data alone, as no record of when the species was observed is recorded.

NCPN Avian Inventory (Johnson et al. 2003)

This measure includes survey types utilized by Johnson et al. (2003): breeding season point counts, incidental breeding season surveys, crepuscular/nighttime surveys, and winter incidental non-breeding surveys. In total, these surveys documented 91 species, 85 (93%) of which were year-round species. Of these observations, 53 (58%) were "Resident" species. The bird surveys that took place during the breeding season also yielded the highest numbers of year-round species (60 species), likely due to the higher levels of observer effort when compared to the other survey types (Appendix H).

RMBO Landbird Monitoring (2005-present)

Year-round species richness has fluctuated during RMBO landbird monitoring in FOBU, with richness estimates ranging between 10 species (2014) and 20 species (2010) (Figure 41). Thirty-four year-round species of birds have been documented in FOBU during monitoring efforts. The average species richness estimate for year-round landbird species was 16.2 species. The lowest number of year-round species was observed in 2014, when 10 species were observed.

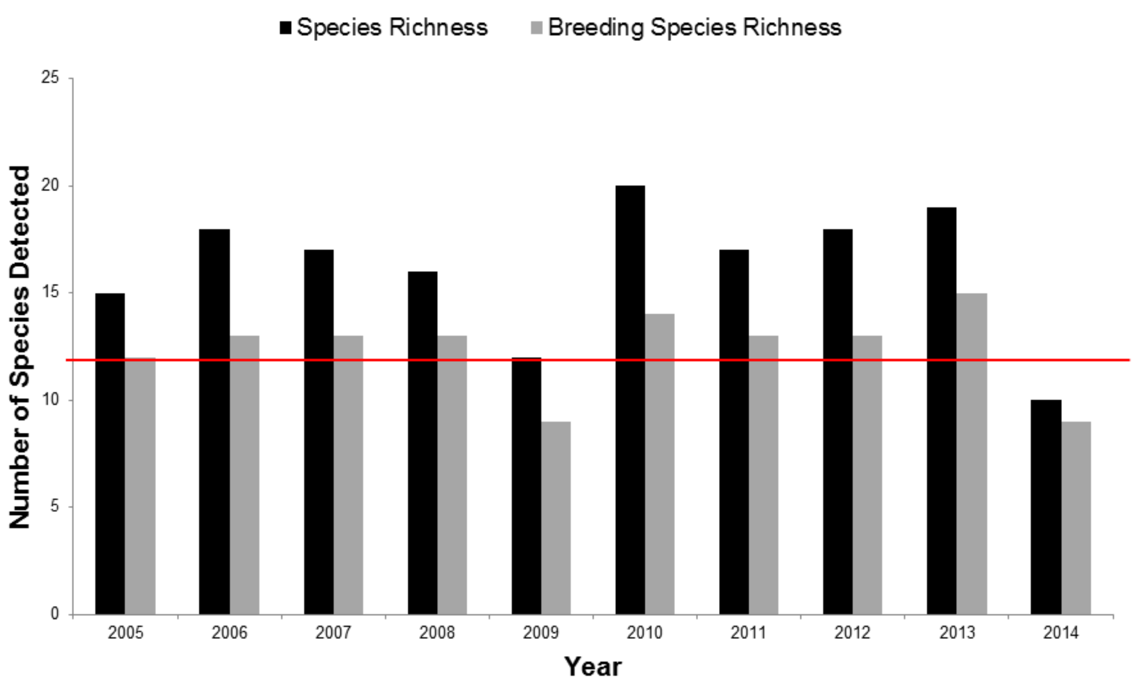

Figure 41. Species richness estimates for FOBU from 2005-2014. Values represent the total number of species observed on both sage shrubland habitat routes in the park. The solid red line indicates the 10-year year-round species richness average for the park (16.2 species/year). Data obtained from http://www.rmbo.org/v3/avian/ExploretheData.aspx.

Raptor Richness

Raptors are top-level predators and are excellent bioindicators of the health of their associated ecosystem (Morrison 1986, Hutto 1998). In the 1940s, raptor populations across North America experienced a population decline due to the use of organophosphates (e.g., dichlorodiphenyltrichloroethane – DDT) as insecticides. Bioaccumulation of these chemicals (particularly DDE, a persistent metabolite of DDT) inhibited calcium metabolism in many raptor species (Fischer 2000). DDT magnified though the food chain, and more chemicals were concentrated within apex predators than in other animals within the same environment (Connell 1999). As a result, affected birds laid eggs that were too thin for successful incubation; eggs that did not break during incubation often contained dead embryos, and mortality rates for hatchlings were high (Ratcliffe 1993, Fischer 2000).

DDT was banned in the United States in December 1972 and reproductive success rates subsequently increased following this ban (Fischer 2000). Species especially affected by the use of organochlorines, such as the peregrine falcon (*Falco peregrinus*), experienced a dramatic population recovery following the ban. The peregrine falcon populations in the continental United States rebounded to over 2,000 breeding pairs in 2002 (White et al. 2002, as cited in USFWS 2003). The peregrine falcon has recovered to population levels that allowed for their removal from the Endangered Species List (the peregrine falcon was delisted in 1999) (USFWS 2003).

The raptor species richness measure represents a total count of the number of species observed in an area or population. For this measure, only the richness of the raptors in FOBU is discussed. Despite the amount of suitable nesting and foraging habitat for raptors in the park, there are limited data relating to both the raptor-specific measures (raptor richness and raptor productivity). Summarized below are the results of avian inventories in the park, with the results isolated to include only raptor species that were observed during the various efforts.

NPS Certified Bird Species List (NPS 2015)
The NPS Certified Bird Species List contains 154 species, 22 (14%) of which are raptors and are discussed in this section (Table 57). This list, however, does not allow for a specific analysis of species richness, as no data are collected other than the presence (or historic presence) of the identified species. It is included, rather, in order to serve as a checklist for comparison when discussing the results of other studies in the park.

Table 57. Raptor species identified as either present or probably present in FOBU.

Common Name	Common Name
American kestrel [A, B, C]	Northern pygmy-owl [A]
Bald eagle [A]	Northern saw-whet owl [A]
Barn owl [A]	Peregrine falcon [A]
Burrowing owl [A]	Prairie falcon [A, B]
Cooper's hawk [A, B]	Red-tailed hawk [A, B]

A = NPS (2015)
B = Johnson et al. (2003)
C = RMBO monitoring effort

Table 57(continued). Raptor species identified as either present or probably present in FOBU.

Common Name	Common Name
Ferruginous hawk [A, B]	Rough-legged hawk [A]
Flammulated owl [A]	Sharp-shinned hawk [A, B]
Golden eagle [A, B]	Short-eared owl [A]
Great horned owl [A, B]	Swainson's hawk [A, B]
Long-eared owl [A, B]	Turkey vulture [A, B]
Northern harrier [A, B, C]	Western screech-owl [A]

A = NPS (2015)

B = Johnson et al. (2003)

C = RMBO monitoring effort

NCPN Avian Inventory (Johnson et al. 2003)

Johnson et al. (2003) documented 12 raptor species in FOBU during an avian inventory of the park from 2001-2003.Of all the survey methodologies utilized by Johnson et al. (2003), the breeding bird point counts documented the highest raptor species richness estimate (seven species), followed by the incidental breeding bird surveys (four species), crepuscular/nighttime surveys (two species, both owls), and the winter incidental survey (one species).

RMBO Landbird Monitoring (2005-present)

RMBO landbird monitoring in FOBU has occurred annually along two transects in the sage shrubland habitat. Raptor richness has been low, with the total number of raptor species observed during the surveys totaling only two (American kestrel [*Falco sparverius*], and northern harrier [*Circus cyaneus*]). These two species were observed in the same survey year only twice (2008, 2012). RMBO monitoring sites are located in only sage shrubland habitat types and are not designed with raptors in mind, and may miss raptor species that occur outside of this habitat zone. Additionally, species such as raptors are not highly vocal species during the breeding season and are less likely to be observed during point counts (McLaren 2014). The terrain of the point counts may make the observation of these non-vocal species difficult, unless the species are flying directly overhead.

Raptor Productivity

Raptor productivity can be reported many ways, often depending upon the species of interest. For example, Ambrose et al. (2008) reported productivity for peregrine falcons as the number of nestlings per total and successful pairs, while Postupalski (1974) defined productivity for bald eagles as the number of fledglings or large young per occupied nest. Similarly, the reference conditions for the minimum productivity levels to support a raptor population are also variable and understudied. According to data collected pre-1955 and post-1985 (Hickey and Anderson 1969, Enderson and Craig 1974. Radcliffe 1993, USFWS 2003), a healthy peregrine falcon population typically has nest success rates of 45-66%. For bald eagles, a nesting success rate of 50% and 0.7 young per occupied nest has been suggested for bald eagle populations to maintain themselves (Tetreau 1998). Because of the variability observed in productivity requirements for different raptor species, a specific reference condition is likely not broadly applicable for this measure. Currently, no data exist in FOBU that document the productivity of the various nesting raptor species in the park. Until these data are collected, an assessment of the current condition of this measure is not possible.

Threats and Stressor Factors

One of the major threats facing bird populations across all habitat types is land cover change (Morrison 1986). Land cover change is not restricted to the breeding habitat; many species depend on specific migratory and wintering habitat types that are also changing. Altered habitats can also compromise the reproductive success or wintering survival rates of species adapted to that habitat.

Migratory bird species face deteriorating habitat conditions along their migratory routes and wintering grounds. Most of the birds that breed in the United States winter in the Neotropics (MacArthur 1959); deforestation has occurred in these wintering grounds at an annual rate up to 3.5% (Lanly 1982). While forest and habitat degradation does occur in the United States, it does not approach the level of degradation seen in the tropics (WRI 1989). Furthermore, Robbins et al. (1989) supported the suggestion that deforestation in the tropics has a more direct impact on Neotropical migrant populations than deforestation and habitat loss in the United States.

According to Postovit and Postovit (1987), human activities impact raptors in at least three ways: 1) by directly harming (physically) or killing eggs, young, or adults; 2) by altering raptor habitats; and 3) by disturbing or disrupting normal raptor behavior. The shouting, yelling, or other disruptive noises produced by visitors may be loud enough to flush nesting raptors from the nest (Call 1979, Ratcliffe 1980); even short periods away from eggs or nestlings could cause nest failure in many species (Suter and Joness 1981, Richardson and Miller 1997). The ferruginous hawk (*Buteo regalis*), a commonly observed species in FOBU, is known to abandon a nest if exposed to nearby rock climbing or human activity (Snow 1972, Olsen and Olsen 1980, White and Thurow 1985). Furthermore, Boeker and Ray (1971) found that human disturbances were the primary cause of 85% of nesting losses for golden eagles. Careful monitoring of the raptor nests in areas of high recreational use will be critical to observe potential trends in occupancy or productivity in nearby nesting raptors.

Wind turbines are suspected to be a direct cause of mortality in raptor species, as the rotating blades on a wind turbine can strike flying raptors. The extent to which mortalities occur in raptor species is likely dependent upon several factors, namely the species of raptors in the area, the height of the turbine (i.e., higher turbines leading to more mortalities), and the elevation of the wind farm above sea level (de Lucas et al. 2008).

Recent efforts to develop alternative energy sources have resulted in more wind farm development across the planet (de Lucas et al. 2008). However, the exact effect that these wind farms have on birds is still poorly understood. Some studies have found that wind farms are responsible for no more mortalities than other human-made structures (e.g., buildings, communication towers) (Osborn et al.

2000), while other studies have found that turbines are responsible for unusually high numbers of raptor mortalities (Smallwood and Thelander 2007).

The development of wind and alternative energy necessitates the creation of high-tension power lines around the developments. The installation of these power lines is often accompanied by high levels of anthropogenic disturbance (e.g., machinery, noise, lights), and once in the ground the power lines may pose a risk for mid-air collision and electrocution in migratory bird species. While likely out of FOBU's control, the installation of cross arms on power poles could increase the distance between energized components on the power pole and reduce the risk of electrocution (Figure 42). Despite representing a mortality threat to raptors, power lines and poles often present ideal perch locations for foraging raptors such as red-tailed hawks (*Buteo jamaicensis*).

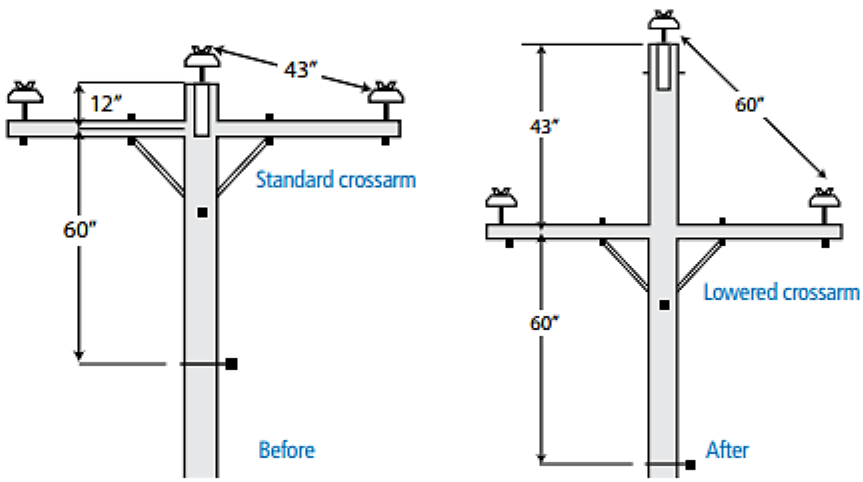

Figure 42. Example of a traditional power line cross arm on the left, and a more raptor/bird specific design on the right (Idaho Power 2011).

<u>Data Needs/Gaps</u>

Continuation of the RMBO's annual landbird monitoring in the park will provide park managers with a valuable long-term data set that will accurately depict trends in abundance, density, and richness in the sage shrubland habitat of FOBU. Expansion of the survey methodology to include a variety of habitat types would provide a more complete picture of the avifauna of the park as a whole. Additionally, the expansion of survey timing would also help managers obtain a better understanding of the trends and status of year-round bird species in the park. Current methodology samples the breeding population of the park, but there has been little to no sampling of the park's overwintering population. Similarly, no survey exists during the spring and fall migration period.

Annual monitoring of the raptor population of FOBU is needed to assess this component's current condition. Currently, no data exist relating specifically to raptor richness, abundance, productivity, or the number of active nest sites in the park. Some bird studies have taken place in the park and have documented raptor presence. However, these studies have not focused on raptors specifically, and monitoring methodology (and timing) may have certain biases that make detecting raptors more difficult. A monitoring program dedicated to the park's raptor population, and that samples during the breeding, migration, and winter seasons, would allow for a more complete assessment of condition for this resource.

Overall Condition

Summer Breeding Bird Richness

The project team defined the *Significance Level* for summer breeding bird richness as a 3. While NPS (2015) classifies a species' residency, there are likely some instances where species are classified incorrectly. This may have resulted in some errors in the metrics used in this document, although this can only be speculated. Johnson et al. (2003) reported 32 breeding species during bird surveys in FOBU from 2001-2003. RMBO monitoring in the park began in 2005 and has reported breeding species richness values ranging from nine (2009, 2014), with 12.4 breeding species observed per year on average. There does not currently appear to be any major cause for concern for the breeding species richness of FOBU, and the species observed in the park during the past two decades are approximately as would be expected for the habitat types found in the park. Continued monitoring of the richness data obtained during the annual RMBO surveys is needed to detect any potential long-term trends in breeding species richness. Additionally, it may be helpful to managers to closely inspect all confirmed species' residency in NPS (2015) to validate which species are breeders and which species are year-round residents. A *Condition Level* of 1 was assigned to this measure, indicating low concern at this time.

Year-Round Bird Richness

Year-round bird species richness was assigned a *Significance Level* of 2 during project scoping. Only two inventories/survey efforts have taken place in FOBU in the past 20 years (although the RMBO monitoring represents an ongoing effort). Both of the survey efforts have focused primarily on the breeding season, and have had limited, if any, survey efforts in the non-breeding seasons. While both Johnson et al. (2003) and the RMBO monitoring program have documented year-round species, it is hard to accurately assess their current condition in the park. Surveys in the park have occurred primarily during the breeding season, which makes it more difficult to observed species that are hunkered down on nests or are non-vocal (such as raptors). Additionally, monitoring efforts have focused on only one habitat type in FOBU, sage shrublands. While this habitat type is likely a highly productive and vital component of FOBU's landscape, it may not accurately reflect the preferred nesting habitat type of all species in the area.

All of this taken into account, it is still possible to determine condition for this resource, understanding that surveys are only capturing a proportion of the population at a time when they are most likely to be easily observed by researchers. Richness estimates for year-round species in 2014 were the lowest reported in any year during RMBO monitoring (Figure 41). The 10-year richness average for the RMBO study was 16.2 species, on 2014 marked only the third year that fell below this mark (Figure 41). Annual variations in richness can happen for a number of reasons, and are not exclusively indicative of declining condition. Numbers could decline due to observation conditions, temporal variations, or the experience or bias of any individual observer. There does not appear to be any major cause for concern in this measure at this time, but the low richness estimate in 2014 does provide something to pay attention to in future analyses. A *Condition Level* of 1 was assigned to this measure.

Raptor Richness
The raptor richness measure was assigned a *Significance Level* of 2. While NPS (2015) documents 22 raptor species as being present or probably present in the park, there has been no raptor-specific survey or inventory to document richness in the park. The two survey and inventory efforts that have taken place in FOBU documented low numbers of raptor species, likely due to survey biases and habitat selection. Until a raptor-specific monitoring program takes place in the park, a *Condition Level* for this measure cannot be assigned.

Raptor Productivity
The raptor productivity measure was assigned a *Significance Level* of 3 during initial project scoping. While this metric can be reported differently depending on the species being studied, there has been no formal study in FOBU that documented the productivity of the various raptor species in the park. Until a study documents the annual productivity of raptor species in the park this measure cannot be assigned a *Condition Level*.

Weighted Condition Score
Due to a lack of data for half of the measures selected for this assessment, a *Weighted Condition Score* cannot be assigned at this time.

Birds			
Measures	**Significance Level**	**Condition Level**	**WCS = N/A**
Summer Breeding Bird Richness	3	1	
Year-Round Bird Richness	2	1	
Raptor Richness	2	N/A	
Raptor Productivity	3	N/A	

4.10.6. Sources of Expertise

- Dusty Perkins, NCPN Program Manager

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4.11. Greater Sage Grouse

4.11.1. Description

Formerly known only as the ‘sage grouse’, this species was recognized as the greater sage grouse (*Centrocercus urophasianus*) in the early 2000s when the Gunnison sage grouse (*Centrocercus minimus*) was classified as a distinct species (Young et al. 2000). The Gunnison sage grouse exhibits unique size, behavior, plumage, and genetic structure when compared to the greater sage grouse (Schroeder et al. 1999). The greater sage grouse is the largest native grouse species in North America and is a sagebrush obligate species, typically found in habitats that are dominated by big sagebrush. The diet of the greater sage grouse consists primarily of sagebrush, but some other plants and small insects are also consumed. Because of the species’ dependence on the sagebrush habitat type, which is among the most vulnerable and at risk ecosystems in the United States (Noss et al. 1995, Knick et al. 2003), the species is often considered an excellent indicator of the overall health of the sagebrush ecosystem (Blomberg et al. 2013).

The greater sage grouse exhibit sexual dimorphism, as the male is typically larger (1.8-3.2 kg [4-7 lbs]) than the female (0.9-1.8 kg [2-4 lbs]), and has a unique plumage (USFWS 2015a, Photo 12).

Photo 12. A male greater sage grouse displaying his breeding plumage on a lek (USFWS photo).

While both sexes share a mottled brown, black, and white plumage, the male has a characteristic white ruff around its neck and has bright yellow air sacs on its breast that inflate during mating displays (USFWS 2015). During mating, male grouse will occupy a ‘lek’ which is a traditional display area that is used annually by the grouse (Harrell 2008). A hierarchy of males typically exists within these leks, with the alpha male occupying the preferred mating location in the center of the lek. Other grouse occupy increasingly smaller zones in the lek, depending upon the status of the male in the lek (i.e., alpha males occupy the largest lek, beta males occupy the next largest, and so on). Females enter the lek as the males display their charismatic plumage, and often preferentially mate with the alpha/beta males. Females typically enter the lek in March, with numbers peaking in April and then declining later in the spring (Harrell 2008).

The current range of the greater sage grouse is estimated to be approximately 67 million ha (165 million ac), which represents a loss of 56% of the species’ home range when compared to historical distribution (Figure 43) (Schroeder et al. 2004). Habitat loss across the species’ range is primarily driven by fragmentation of once continuous sagebrush ecosystems. Agricultural practices, oil/gas/alternative energy developments and exploration, changes in the fire regime, overgrazing, and residential growth all represent substantial threats to the sagebrush community (Crawford et al. 2004, USDA 2014). While greater sage grouse populations experience natural variations, sometimes being cyclical during 8-12 year intervals (Batterson and Morse 1948, Rich 1985), the species has experienced range-wide declines since the mid-1980s (Schroeder et al. 2004, Aldridge et al. 2008) which are likely tied to the loss of continuous habitat. It is estimated that the greater sage grouse population declined an average of 33% since between 1985 and 1995 (Connelly and Braun 1997). Because of this range-wide decline, the species was listed as a candidate species under the United States Endangered Species Act (ESA) in 2010.

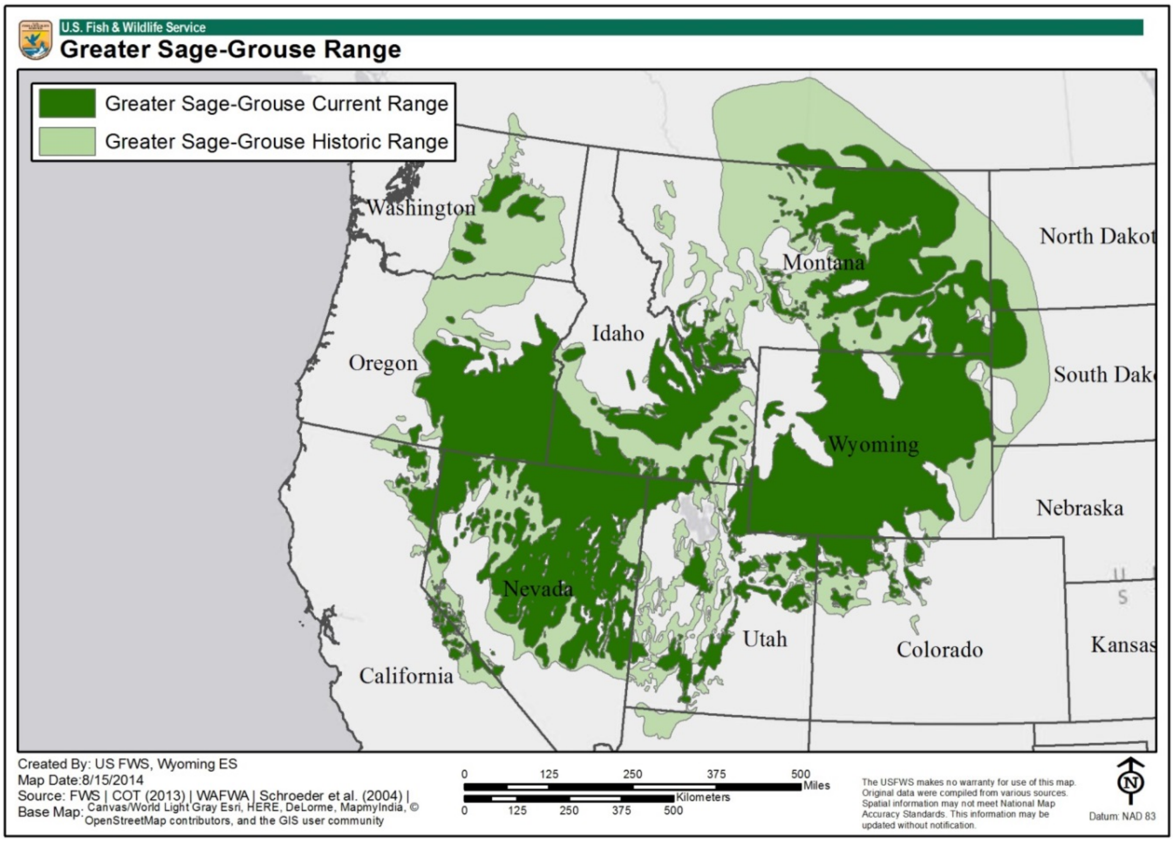

Figure 43. Greater sage grouse historic and current range estimate. Figure is reproduced from http://www.fws.gov/greatersagegrouse/maps.php.

Wyoming is home to the highest number of greater sage grouse in the United States, with an estimated 37% of the population residing in the state (Doherty et al. 2010, USDA 2014). With greater than 70% of sagebrush habitats occurring on public lands in the western United States, many states and agencies have established greater sage grouse management and monitoring plans/protocols. The greater sage grouse core area protection policy was enacted in Wyoming by executive order in 2008, and was updated in 2011 (WY EX Order 2011-5). This policy serves to protect core population areas in the state, and restricts habitat alterations in core areas for a minimum of 5 years, although existing land practices can continue in these areas. FOBU lies within the 'Sage' core area, and has two leks within the park's boundaries: one main lek, and a satellite lek. A third lek lies within close proximity to the park, although it is not within its administrative boundaries. Due to the sensitive nature of this species, lek names and locations will not be discussed in this report.

4.11.2. Measures

- Number of active leks
- Male lek attendance
- Apparent nest success
- Brood size

4.11.3. Reference Conditions/Values

A reference condition for the greater sage grouse is not available at this time. While population accounts and records from historic (pre-settlement) times would be ideal, these sources do not exist and would not be directly comparable to the population in FOBU. Additionally, greater sage grouse populations are marked by a strong cyclical behavior (Batterson and Morse 1948, Rich 1985, Crawford et al. 2004), and averages in a short subset of years may not accurately reflect the true health of the population. There is no single, range-wide survey methodology for the greater sage grouse that is consistently reported on, although male lek attendance and peak attendance dates are commonly utilized metrics (WGFD 2014). The absence of a set metric that defines population health further complicates the establishment of a reference condition for this component. For this assessment, best professional judgment of SMUMN GSS and NPS staff will be used to assess current condition, and when applicable, comparisons will be made to the southwestern Wyoming sage grouse population statistics (obtained from WGFD 2014). Future assessments of condition could consider this document as a baseline or reference condition if applicable.

4.11.4. Data and Methods

The FOBU greater sage grouse population is surveyed annually by two agencies: the Wyoming Game and Fish Department (WGFD) and the NPS. Both agencies utilize similar methodologies, although the timing of the surveys can differ. Both groups utilize lek counts, which consist of three or more visits to a lek during peak male activity. In addition to determining if a lek is active or not, counts are useful to monitor and more precisely estimate the maximum number of males attending a lek in a breeding season (WGFD 2014). Leks are considered active if one or more males are observed displaying during any of the lek visits (WGFD 2014). The two leks in the park can be observed from a single observation point, so observers are able to document male attendance at both leks simultaneously. WGFD surveys the two leks from mid-March until early-May, with surveys typically occurring between 0600-0800 hours. NPS monitoring often begins earlier in the breeding season, and runs from the end of February or beginning of March through the middle of May. NPS observations have been more predictable with observation times, and have traditionally occurred at 0800 hours.

4.11.5. Current Condition and Trend

<u>Number of Active Leks</u>

Greater sage grouse courtship displays occur each spring on a display area referred to as a lek. At these areas, males engage in elaborate mating displays and rituals (often described as a dance) where they display their plumage and yellow air sacs in an effort to attract females. According to the U.S. Fish and Wildlife Service (USFWS) (USFWS 2015a), lek habitat availability is not a limiting factor for the greater sage grouse, as the species will establish leks in a variety of habitat types (bare soil, short-grass steppe, exposed knolls). These areas are typically located near an area of denser cover which is used for escape and foraging (USFWS 2015a). Leks are indicative, however, of the availability of nesting habitat, as the species will only display when appropriate nesting and foraging ecosystems are nearby. Manier et al. (2014) suggests that the majority of female grouse movements (90-95%) are within 8 km (5 mi) of a lek site. Additionally, in Wyoming most females will nest within 5 km (3.1 mi) of a lek site (Holloran and Anderson 2005).

In FOBU, there are currently two lek sites used for greater sage grouse display rituals: one main lek site, and its satellite site located in close proximity to the main site. A third lek site exists in the FOBU area, although it is located on lands not managed by the NPS. The two leks within FOBU have been monitored annually by both NPS-led surveys and WGFD surveys; the lek outside of the park, which was previously surveyed by WGFD, has also been monitored by NPS staff since 2012 (Fagnant, FOBU Chief Naturalist, written communication, April 2016).

The main lek in FOBU has been active during all years of NPS monitoring (2007-2014); WGFD surveyed the lek late in the breeding season in 2014 (late-April, early-May) and did not record any activity. This was the only year that birds were not observed on the site during WGFD monitoring (1997-2014); NPS monitoring early in that year indicated it was active. The satellite lek has been active during every year of NPS monitoring (2007-2014), and every year of WGFD monitoring (2003-2014).

The nearby lek outside of FOBU has been more variable during monitoring. This lek has been monitored since 2003, and was inactive in 2005, and from 2007-2010. This site has not been surveyed for as long as other leks, and the actual status of the lek in a given year may be due more so to the number of visits (i.e., fewer visits means less of a chance to see displaying males). For example, in 2007 only three visits to the lek were made, and 2008 only had one visit. The actual yearly status of this lek is not as definite as the leks within FOBU.

<u>Male Lek Attendance</u>

Estimating the population size of greater sage grouse poses a unique problem, as a statistically valid method does not yet exist (WGFD 2014). One metric that has traditionally been used is annual male lek attendance estimates. According to WGFD (2014, p. 152), monitoring male attendance on a lek "… provides a reasonable index of change in abundance in response to prevailing environmental conditions over time." There are, however, several concerns regarding interpretation of male lek attendance. These cautions include:

- Variation in survey effort and the number of leks surveyed over time;
- The possibility that not all leks in an area/population have been identified (this is unlikely, as WGFD [2014] indicates that the majority of the currently occupied leks in southwest Wyoming have been identified);
- Natural greater sage grouse population cycles;
- The effects of unlocated or unmonitored leks that have become inactive cannot be quantified or qualified;
- Lek locations may change over time (WGFD 2014).

The annual greater sage grouse job completion reports put out by the WGFD summarize this measure as the maximum number of males observed on each lek divided by the number of leks checked (WGFD 2014). For the purpose of this assessment, the male attendance of each lek in the park (main lek and satellite lek) will be reported individually and will be compared to the yearly averages for southwestern Wyoming; data collected by WGFD will be reported separately from the NPS-collected male attendance data and will be based on data collected using the count methodology described in WGFD (2014).

Main Lek Site

NPS (2015)

The most recent data from the main lek site in FOBU are from 2014 (NPS 2015). The 2014 estimates of male attendance at the main lek were the lowest recorded during the 8 years of count data for the lek (NPS 2015). The maximum value of four males observed in 2014 is well below the 2014 southwestern Wyoming average of 20.4 males/occupied lek (Figure 44). The maximum number of males observed at the main lek site in FOBU has averaged 12.25 males during the 8 years of NPS (2015) count efforts (Figure 44). The maximum number of males observed during a lek count has fluctuated from 21 males in 2007 to four males in 2014 (Figure 44). The 8-year average for male attendance at the main lek in FOBU (12.25) is substantially lower than the southwestern Wyoming average over the same time period (35.3 males/occupied lek).

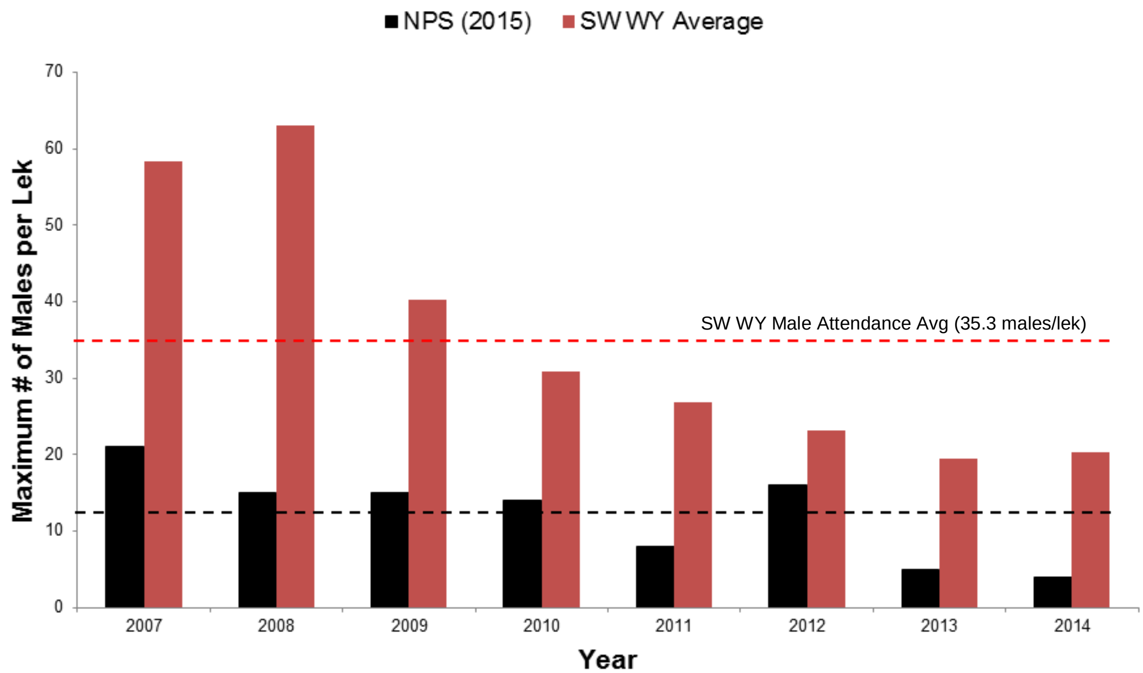

Figure 44. Average maximum male attendance at the main lek site in FOBU from 2007-2014; data are from NPS (2015). The black dashed line represents the 8-year average for maximum male lek attendance (12.25 males).

WGFD Data

The WGFD has monitored the main lek in FOBU annually since 1997. The 2014 count did not record any males at the site and the status of the lek was determined to be unknown (although NPS [2015] did in fact observe males on the lek). The most recent year with males observed on the lek by WGFD was 2013, when a maximum of eight males was observed on the site (Figure 45). This value was below the 2013 southwestern Wyoming average maximum of 19.5 males/occupied lek (WGFD

2014). The maximum number of males observed on the lek has varied during WGFD monitoring, and has ranged from 42 males in 1997 to five males in 2002 and 2003 (Figure 45).

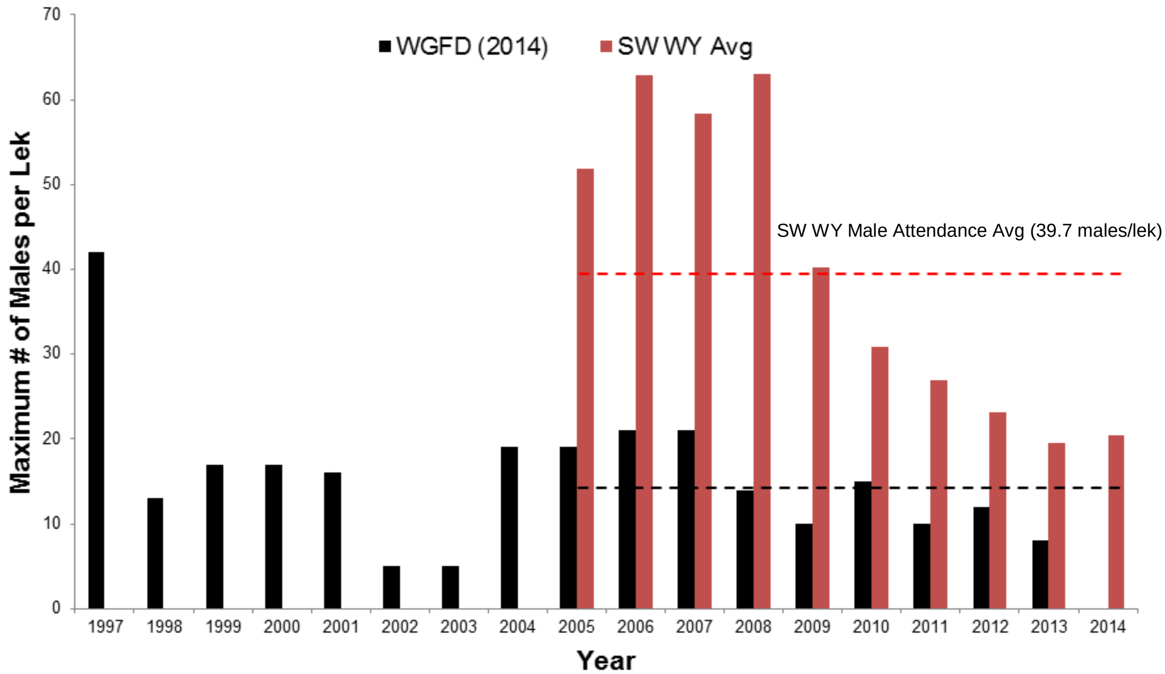

Figure 45. Average maximum male attendance at the main lek site in FOBU from 1997-2014; data are from WGFD monitoring efforts. The black dashed line represents the 10 year average for maximum male lek attendance (14.4 males).

WGFD monitoring has existed at the main lek for a longer period of time than the NPS monitoring (17 years compared to 8 years), and the average maximum number of males observed on the lek during WGFD monitoring is 15.5 males. Looking at only recent data (2005-2014), the 10-year average maximum number of males observed on the lek is 14.4 males. This value is higher than what the NPS monitoring program observed over a similar time period (NPS surveyed only 8 years, not 10; Figure 44, Figure 45), but is still below the southwestern Wyoming 10-year average of 39.71 (Figure 45).

Satellite Lek Male Attendance

<u>*NPS (2015)*</u>

The satellite lek site in FOBU has been monitored by the NPS annually since 2007. In 2014, the maximum male attendance at the satellite lek was 24 males (Figure 46), which was an increase of 11 birds over the previous year, and above the southwestern Wyoming 2014 average of 20.4 males/occupied lek. The maximum number of males observed at the satellite lek has been variable during the 8 years of surveys, with values ranging from 13 males (2013) to 50 males (2009). The male attendance values at the satellite lek exceeded southwestern Wyoming yearly averages in 2009, 2010, 2011, and 2014. When looking at the average maximum male attendance over an 8 year period (the length of NPS monitoring), the satellite lek has averaged 28.1 males/year. This 8-year average is below average when compared to count data from the southwestern portion of Wyoming (35.3 males/lek; Figure 46).

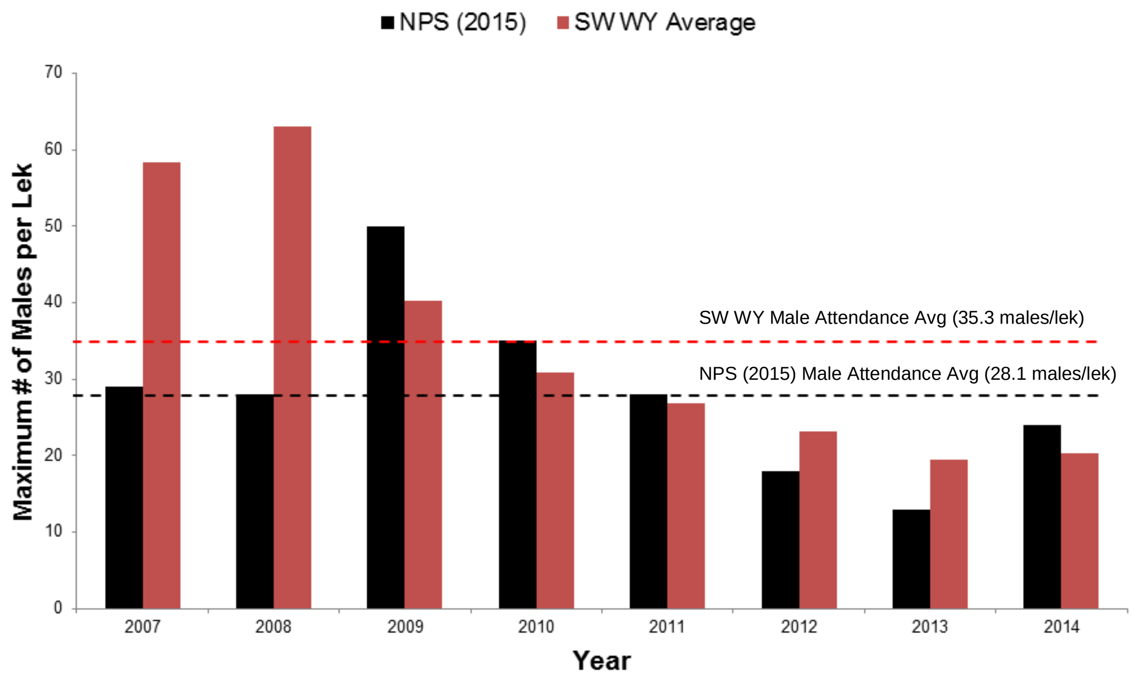

Figure 46. Average maximum male attendance at the satellite lek site in FOBU from 2007-2014; data are from NPS (2015).

WGFD Data

Unlike the main lek in FOBU, which has been surveyed annually since 1997, the satellite lek has only been surveyed annually since 2003. Visits to the lek in 2014 did not identify any males on the lek, and the WGFD classified the status of the lek as unknown. The most recent year with survey data is 2013, when a maximum of 17 males were observed displaying on the lek. This estimate fell just below the 2013 southwestern Wyoming average maximum of 19.5 males/occupied lek (WGFD 2014). The maximum number of males observed on the satellite lek has been variable during WGFD monitoring, and, excluding 2014 results, has ranged from 54 males in 2005 (the highest number of males observed on any lek during any study in the park) to eight males in 2011 (Figure 47).

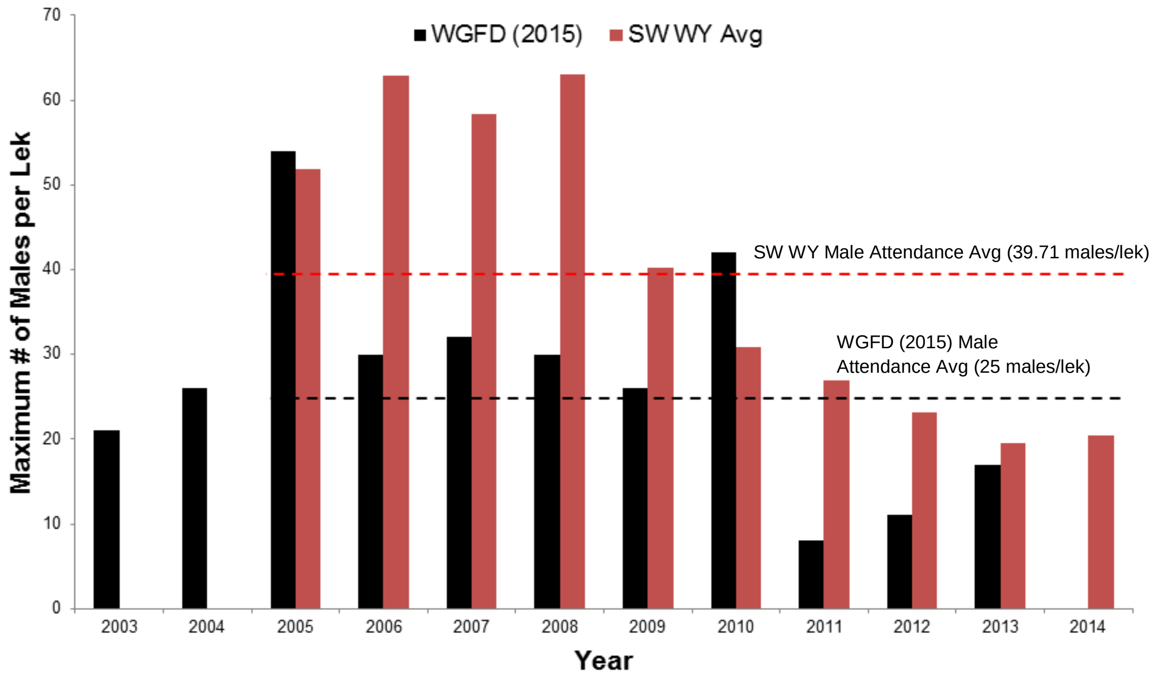

Figure 47. Average maximum male attendance at the satellite lek site in FOBU from 2003-2014; data are from WGFD monitoring efforts.

The average maximum number of males observed on the satellite lek for the duration of WGFD monitoring was 24.75. Looking at only the past 10 years (2005-2014), the average number of males was 25; due to the small difference between the two averages, Figure 47 only displays the 10-year average of the WGFD survey. The 10-year average for the satellite lek was well below the 10-year average of southwestern Wyoming (39.71 males/occupied lek) (Figure 47).

Main and Satellite Lek Data Combined

Because the leks are in close proximity to each other, it is possible, and likely, that grouse move freely between the sites. This makes it difficult to assess the total number of males attending the leks because the males are moving uninterrupted among the different leks. Because of this, this subsection is dedicated to a discussion of the leks together as one large unit, rather than separating them into a main or satellite lek(s). Data collected by Norris Tratnik from 1997-2006 was provided to SMUMN in a format that combined all data into only one value for the maximum number of males observed in the park per year (i.e., a combined count for the main and satellite leks); these data will be included for discussion below under the NPS (2015) section.

NPS (2015)

Peak male attendance in FOBU was observed in 2005 and 2009 when 65 males were observed, while the lowest estimate of male attendance occurred in 2002 when only 14 males were observed (Figure 48). The maximum male attendance estimate for 2014 in FOBU was 28 males (Figure 48). Over the past 10 years (2005-2014), the average maximum male attendance in FOBU was 43.3 males/year (Figure 48).

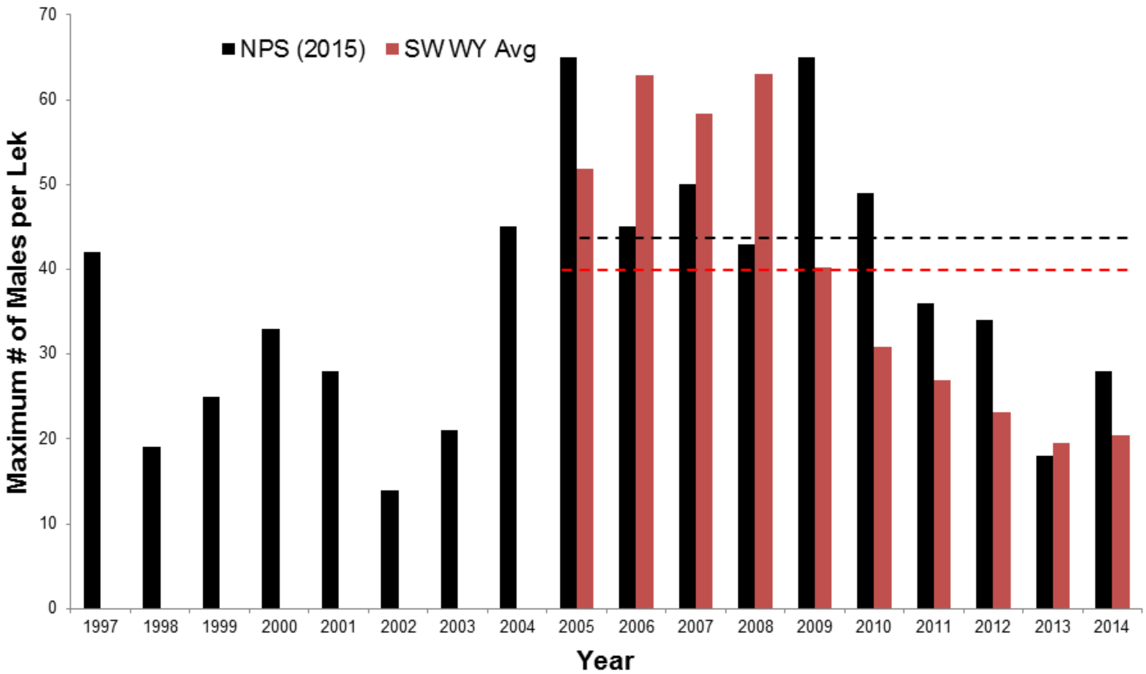

Figure 48. Maximum male lek attendance at both lek sites combined in FOBU from 1997-2014; data are from NPS monitoring efforts. The dashed black line represents the FOBU 10-year average (43.3 males), while the dashed red line represents the southwestern Wyoming average (39.7 males/occupied lek).

WGFD Data

Male attendance estimates in FOBU, using WGFD data, peaked in 2005 when 73 males were observed in the park. The lowest number of males observed in a season occurred in 2014 when no males were observed. Outside of the 2014 value, 2011 had the next lowest male attendance estimate when only 18 males were observed (Figure 49). The four most recent years of study (2011-2014) have produced the lowest estimates of male attendance in FOBU on record using only WGFD data (Figure 49). Over the past 10 years (2005-2014), the average maximum male attendance observed by WGFD was 38 males/year.

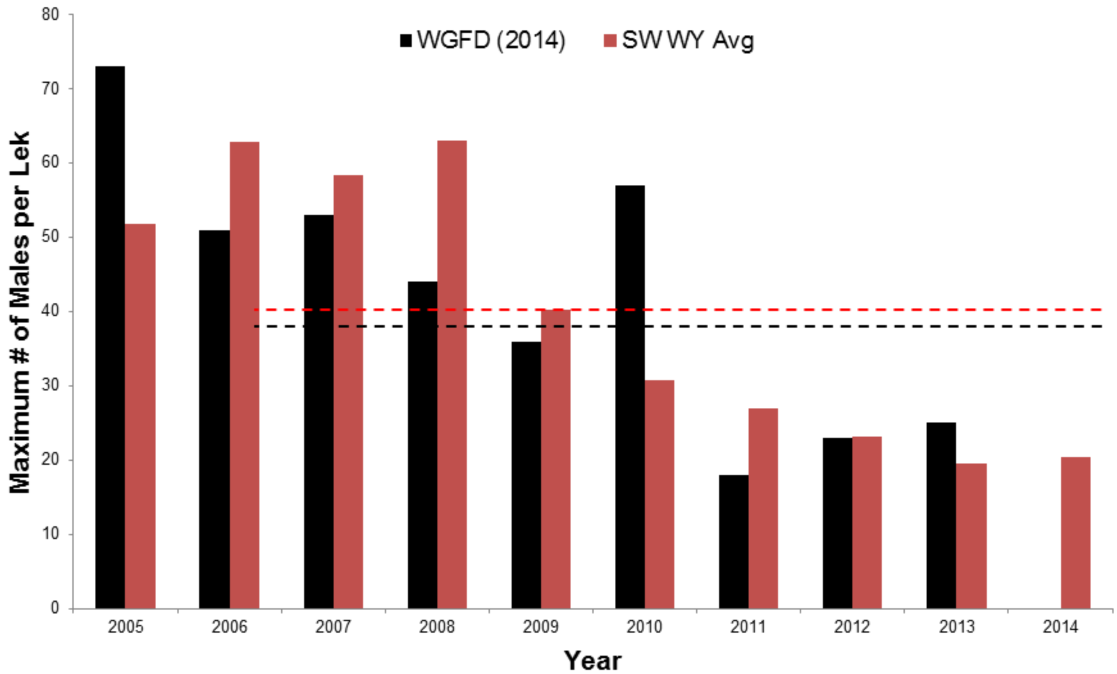

Figure 49. Maximum male lek attendance at both lek sites combined in FOBU from 2003-2014; data are from WGFD monitoring efforts. The dashed black line represents the FOBU 10-year average (38 males/year), while the dashed red line represents the southwestern Wyoming average (39.7 males/occupied lek).

Apparent Nest Success

Nest success for sage grouse is commonly defined as the probability of a single nest hatching at least one egg (Crawford et al. 2004, Holloran et al. 2005). Currently, no data related to nest success exist for the two leks in FOBU; however, several general studies document the average nesting success of the greater sage grouse. Connelly et al. (1991) suggests that sage grouse nest success is likely closely related to a combination of appropriate shrub overstory and herbaceous understory cover at nest sites. Gill (1966) reviewed historic data sources and studies regarding greater sage grouse and found that nesting success ranged from 23.7-60.3%. More recently, Crawford et al. (2004) summarized range-wide population and demographic parameters for the greater sage grouse. The result of this summary was that over the course of 14 studies, the greater sage grouse had an average nest success of 47.4% (Crawford et al. 2004).

While no data exist for this measure in FOBU, Holloran et al. (2005) documented the average annual nest propensity (see note in Table 58), nest success, and adjusted nest success for several sites in Wyoming, one of which (Kemmerer) was in close proximity to FOBU (Table 58). From 2001-2002, the observed nest success in Kemmerer was 33% (±2.2 SE). The overall average nest success for all Holloran et al.'s (2005) sites from 1994-2002 was 49% (±3.7 SE) (Table 58).

Table 58. Greater sage grouse average annual nest propensity and observed success by study area and overall in Wyoming, 1994-2002. Table is reproduced and modified from Holloran et al. (2005).

			Nest Propensity[B]		Observed Success[C]	
Study Area	**Years**	***n*[A]**	**%**	**SE**	**%**	**SE**
Farson	1994-1996	90	86	1.9	38	7.9
Rawlins	1996-1997	53	76	6.3	72	6.9
Casper	1997-1999	120	93	3.9	66	10
Pinedale	1998-1999	-	-	-	-	-
Pinedale	2001-2002	120	74	3.3	41	4.1
Jonah	2000-2002	72	81	9	54	8.4
Lander	2000-2002	75	79	8.6	43	4.4
Kemmerer	2001-2002	67	76	8.6	33	2.2
Overall Average	**1994-2002**	**597**	**81**	**2.4**	**49**	**3.7**

A = number of potentially nesting radiomarked females

B = average annual number of radiomarked females documented incubating a nest relative to number of potentially nesting radiomarked females

C = average annual number of nests that hatched ≥ 1 egg(s) relative to the annual total number of nests Observed nest success estimates include re-nests but do not include researcher-induced abandoned nests.

Brood Size

There are currently no data related to brood size of greater sage grouse in FOBU. Greater sage grouse typically lay between six to eight eggs per nesting season, with the female laying two eggs a day for 3 days (USDOD and USFWS 2006). During a synthesis and analysis of 10 studies of greater sage grouse nesting habits, Crawford et al. (2004) found that greater sage grouse brood sizes averaged 7.5 eggs/nest across their range. While it is unlikely that greater sage grouse in FOBU would substantially deviate from this average, data are needed related to this metric to fully understand any potential trends or relationships.

Despite the species' high reproductive potential, greater sage grouse typically exhibit low productivity and juvenile survival; adults, conversely, exhibit high survival rates and can reach ages of up to 10 years old in the wild (1-2 year life spans are more common; USFWS 2015a). If data were to be collected, this measure should be monitored in harmony with the apparent nest success metric to monitor trends in productivity and survival in the park's grouse population.

Threats and Stressor Factors

Albeit natural, predation represents a major threat to the greater sage grouse population in the FOBU area. While adults are frequently taken as prey, the low survival of chicks in grouse populations suggests that young being taken as prey represents a larger threat. Summarizing data from several studies, Gill (1966) found that predation accounted for 26-76% of nest failures. In FOBU, golden eagles appear to be the primary predator of the species, with several predation attempts being observed each year by NPS staff during lek surveys (Kyte 2004, NPS 2015). During many years, observers have documented dead grouse during lek surveys. It is often presumed that these grouse were killed by golden eagles; in 1998, 11 dead grouse were observed near the lek, in 1999 there were 21 dead grouse, and in 2001 there were three dead grouse (Kyte 2004). Frequently in lek survey notes, observers indicate golden eagles spooking the grouse during displays and causing temporary lek abandonment (NPS 2015). While golden eagles represent the primary predation threat to the species in FOBU, there are other species that may prey upon greater sage grouse. These species include: red-tailed hawk, ferruginous hawk, bobcat (observed killing grouse in 2008; NPS 2015), and coyote.

Every spring and fall, approximately 400 cattle and 5,000 sheep are herded through FOBU. Sheep traverse the park from south to north late every spring, and cattle cross the park from east to west in July (Shattuck, written communication, 25 May 2015). The late-spring drive is of particular concern, as this occurs towards the end of the sage grouse nesting/fledgling season. The potential trampling of the staging grounds, nests, eggs/young, and general cover and habitat in the spring is significant, as this is the species' most critical season. As stated in WGFD (2014, p. 154),

> *Spring habitat conditions are one of the most important factors in determining nesting success and chick survival for sage grouse. Specifically, shrub height and cover, live and residual grass height and cover, and forb production have a large impact on sage-grouse nesting and brood rearing success. The shrubs and grasses provide screening cover from predators and weather while the forbs provide forage and insects that reside in the forbs, which are an important food source for chicks.*

The enabling legislation at FOBU dictates that the monument provides the use and access to the land for these drives. However, careful consideration regarding the timing and location of the stock drives should be made so as to not disturb the greater sage grouse during the critical spring period. Significant loss of habitat or reproductive success could have adverse impacts on the overall health of this population.

Fire represents a concern as well for the greater sage grouse in FOBU. Fire has traditionally been suppressed in FOBU, and the invasion of exotic plant species such as cheatgrass has the potential to increase the fire risk and alter the fire cycle in the sage grouse's endemic habitats. For a detailed discussion regarding the threat of fire in the park, specifically in the sagebrush habitat zones, see Chapters 4.1 and 4.2 of this document.

There is no single causative factor that has led to the sage grouse's decline over the past half-century (Connolly et al. 2000), but human impacts have likely contributed greatly to the greater sage grouse's decline across its range. Vital sagebrush habitat zones have become fragmented due to agriculture, energy exploration/development, and urbanization over the course of the last 100 years (USFWS 2015b). Recent research has shown that sage grouse lek abundance can be affected by noise, as Blickley et al. (2012) found that sage grouse peak male attendance decreased when exposed to experimental noise sources from natural gas drilling and roads. In addition to these indirect sources of mortality, humans are also responsible for direct sources of mortality across the species' range. In

Wyoming, legal harvest of the greater sage grouse is permitted during the species' open hunting season. Hunting is not permitted within FOBU boundaries, but is permitted on lands adjacent to the park. The state hunting season is heavily regulated, and although direct take of animals occurs at relatively high levels each year, the USFWS does not believe that hunting is a threat to the persistence of the species (USFWS 2015a). Controlled management of the harvest must continue to ensure population goals are attained. Road kill strikes are also possible on the roads within and adjacent to FOBU.

Data Needs/Gaps

With lek surveys occurring through two agencies (NPS, WGFD), extensive data sets exist for the male attendance at the two lek sites in FOBU. However, little is known about the average brood size or apparent nesting success of the species in the park. Greater sage grouse nesting sites are often in close proximity to the lek staging grounds, but are frequently under heavy cover and difficult to spot. Until a survey documents the nesting success and brood sizes at the park's two leks, the condition of those measures cannot be assessed.

While the general threats to the greater sage grouse population are recognized in the literature, there has been no formal investigation into how threats such as predation, the annual livestock drives, or hunting on land adjacent to FOBU may be affecting the population within the park's boundaries. Without information specific to the park, the exact impact that these threats may have on the species in FOBU is speculative at best.

Overall Condition

Number of Active Leks

The project team defined the *Significance Level* for the number of active leks as a 3. The number of leks in the park has remained relatively constant since the first lek was discovered in 1997. The main and satellite lek in the park have been active during all years of monitoring. While not discussed in this document, the lek just outside of the park's boundaries has been active infrequently in the past 15 years, as years of inactivity were documented in 2005, and from 2007-2010. Whether or not this is due to limited sample sizes, or true inactivity is uncertain. There does not currently appear to be any significant cause for concern regarding the number of active leks in the park, and this measure was assigned a *Condition Level* of 1, indicating low concern.

Male Lek Attendance

Male lek attendance was assigned a *Significance Level* of 3 during project scoping. Assessing the current condition of male lek attendance in the park is problematic due to several factors. First, greater sage grouse populations are naturally cyclic, and experience temporal variations in size and lek attendance every 8-12 years (Batterson and Morse 1948, Rich 1985). In many instances, data only exists for 8-10 years in the park, which makes it difficult to distinguish between natural cyclical variations. Second, it is difficult to distinguish lek attendance between the main and satellite leks in the park. The leks are in close proximity to each other, and the males frequently move between leks in a given breeding season.

The main lek in FOBU has had consistently lower estimates of male lek attendance during both NPS and WGFD monitoring. The most recent estimates (2014) were well below average during both studies, with no males being observed during WGFD monitoring (which may be due to the timing of surveys). The four males observed during NPS monitoring in 2014 was the lowest estimate of attendance during the course of that survey effort.

FOBU's satellite lek has had higher levels of male attendance than the main lek in recent years, and the peak attendance number of 24 males observed during NPS (2015) represented an increase of 11 males from 2013.

As mentioned previously, it is difficult to determine if recent declining trends in lek attendance (when looking at individual lek sites) are of concern or if they are due to natural variations. There still appears to be a sizeable population of grouse present in the park, as is evident by the combined lek data. However individual lek attendance estimates is enough to warrant a *Condition Level* of 2, indicating a condition of moderate concern.

Apparent Nest Success

The apparent nest success measure was assigned a *Significance Level* of 3. There have not been any data collected in FOBU regarding greater sage grouse nesting success. Until data are collected that directly relate to this measure, a *Condition Level* cannot be assigned.

Brood Size

The project team defined the *Significance Level* for the brood size measure as a 2. While the average brood size for the greater sage grouse in FOBU would likely fall near the species' typical average (7.5 eggs/nest; Crawford et al. 2004), without brood size data specific to FOBU making an assessment regarding the current condition of this measure is not appropriate. No *Condition Level* was assigned to the brood size measure for the greater sage grouse.

Weighted Condition Score

The *Weighted Condition Score* for the greater sage grouse was determined to be 0.50, indicating moderate concern. Due to the species' cyclical nature in population size and lek attendance, a trend arrow was not assigned to this measure.

Greater Sage Grouse			
Measures	Significance Level	Condition Level	WCS = 0.50
Number of Active Leks	3	1	
Male Lek Attendance	3	2	
Apparent Nest Success	3	N/A	
Brood Size	2	N/A	

4.11.6. Sources of Expertise

- Marcia Fagnant, FOBU Chief Naturalist

4.11.7. Literature Cited

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4.12. Pygmy Rabbit

4.12.1. Description

The pygmy rabbit (*Brachylagus idahoensis*) (Photo 13) is a small leporid, or lagomorph, species that inhabits mature basin big sagebrush-dominated vegetation communities in FOBU; they are endemic to western North America (Katzner 1994). Pygmy rabbits differ from other leporid species in that their morphological features are much more petite. They have a small body, short ears, and small hind legs with wide feet; the average adult pygmy rabbit weighs less than one pound (~400 g) (Orr 1940, as cited by Green and Flinders 1980b). Pygmy rabbits have a buff to slate gray overall coat, which becomes silvery gray in winter, and tawny brown fur on their legs, nape, and chest (Keinath and McGee 2004).

Photo 13. Pygmy rabbits are almost entirely reliant on big sagebrush for winter forage and safety from freezing temperatures and predation (NPS photo).

Pygmy rabbits are habitat specialists and are considered a keystone species (Keinath and McGee 2004). They are also the only leporid species to dig their own burrows. The big sagebrush vegetation communities are critical to their success as they rely almost solely on this vegetation for food and cover (Green and Flinders 1980a, Keinath and McGee 2004). Research has shown that, for populations in southern Idaho, big sagebrush comprised 99% of their winter forage and 51% in summer, as supplemental forage with the grasses and forbs that become their primary diet in spring (Green and Flinders 1980a). FOBU has several sage communities that provide suitable habitat for pygmy rabbits. The pygmy rabbit prefers mature stands of the basin big sagebrush. The taller, denser growth provides an adequate subnivean (under the snowpack) environment, which may be required since they are not known to hibernate or store food for the winter (Katzner 1994).

4.12.2. Measures

- Extent of available suitable/preferred sagebrush habitat
- Relative abundance
- Number of burrows and burrow complexes
- Reproductive success
- Annual survival

4.12.3. Reference Conditions/Values

Friesen et al. (2010) mapped the vegetation in FOBU using aerial imagery taken in 2004 (Figure 50, Table 59); the sagebrush community extent serves as the reference condition for suitable habitat for the pygmy rabbit. Green and Flinders (1980b) discussed the historic distribution of the pygmy rabbit with mention of documentation from 1978 that pygmy rabbits were observed in southwestern Wyoming where the park is located (Jensen 1965, as cited by Green and Flinders 1980b). However, Katzner (1994) noted that pygmy rabbits were not present in the park in 1983, when livestock grazing ceased. Although it has been noted that pygmy rabbits prefer basin big sagebrush, there are rabbit occupations within other sagebrush types, as shown in Purcell (2005) survey results.

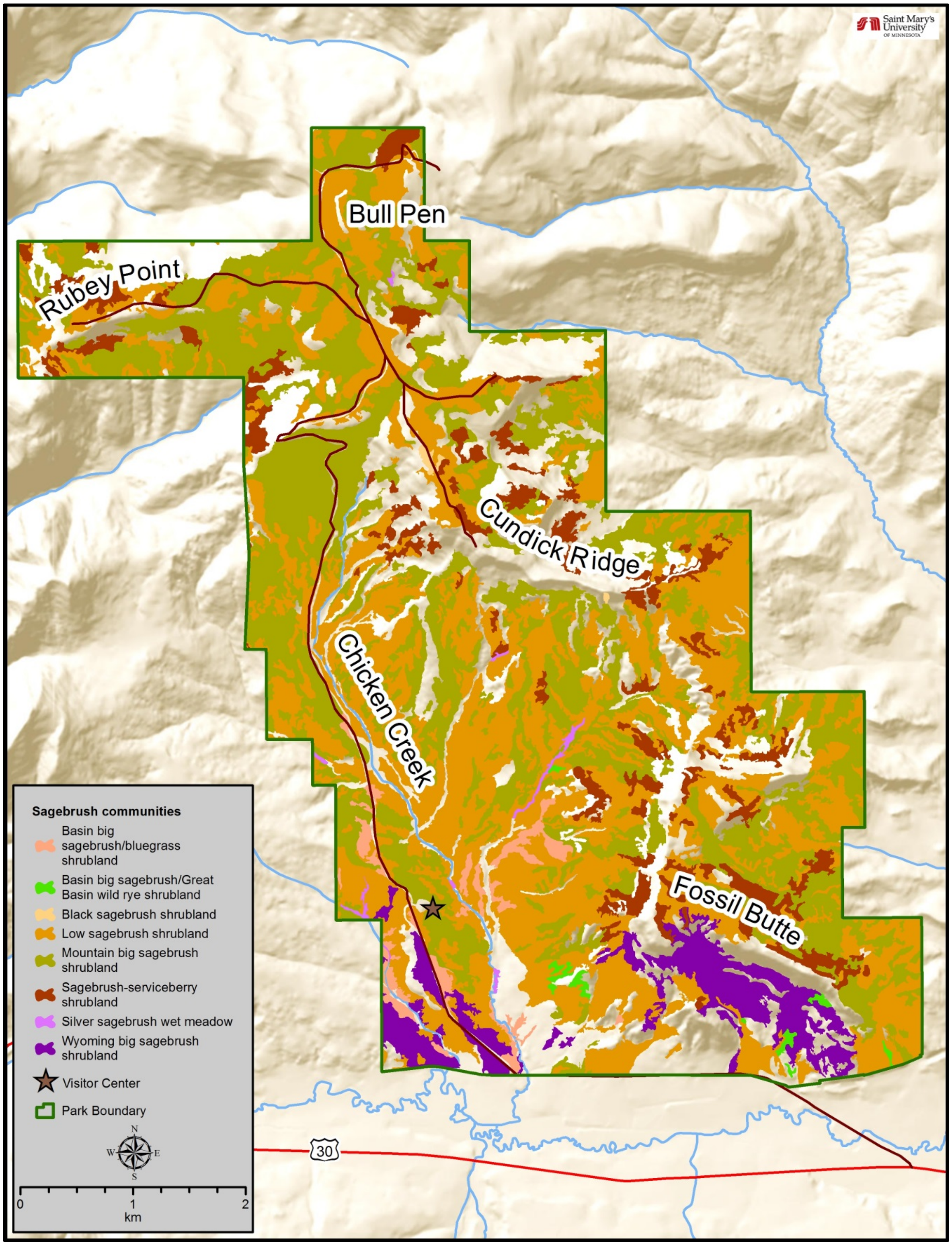

Figure 50. The location and extent of sagebrush communities at FOBU as they were in 2010 (Friesen et al. 2010).

Table 59. The total acreage of sagebrush communities in FOBU (Friesen et al. 2010).

Sagebrush Community Type	Hectares	Acres
Basin big sagebrush/bluegrass shrubland	46	114
Basin big sagebrush/Great Basin wild rye shrubland	9.6	23.8
Black sagebrush shrubland	3	7.7
Low sagebrush shrubland	1,161.2	2,869.3
Mountain big sagebrush shrubland	999.9	2,470.8
Sagebrush-serviceberry	205.4	507.6
Silver sagebrush wet meadow	7.7	19.1
Wyoming big sagebrush shrubland	132.8	328.1

Keinath and McGee (2004) state that fossil records suggest pygmy rabbits were more abundant and widely distributed prior to 7,000 years ago than at any time since. Changes in the distribution and composition of sagebrush communities are thought to have been a factor in the reduction of the geographic range of the pygmy rabbit (USFWS 2001). While this does not provide sufficient data to serve as a reference condition for this measure, it does provide anecdotal evidence of higher abundance and larger range in the past. A FOBU specific population study of pygmy rabbits at FOBU has not been conducted. Keinath and McGee (2004) estimated the population of pygmy rabbits in Wyoming as being relatively low. This estimate was based on the limited number of recorded observations and the limited area of suitable habitat (Keinath and McGee 2004). Numbers on the presence of pygmy rabbits at FOBU is limited to a 2005 survey of a proposed burn area (Purcell 2005). This study recorded the presence of 25 pygmy rabbits while collecting data on their burrow complexes (Purcell 2005). This field inventory was limited to three discrete locations on the western side of the park (Figure 51, Purcell 2005). However, since it was not a population study, it is also not a suitable reference condition for this measure. For the purposes of this analysis the reference condition for relative abundance is considered to be a data gap.

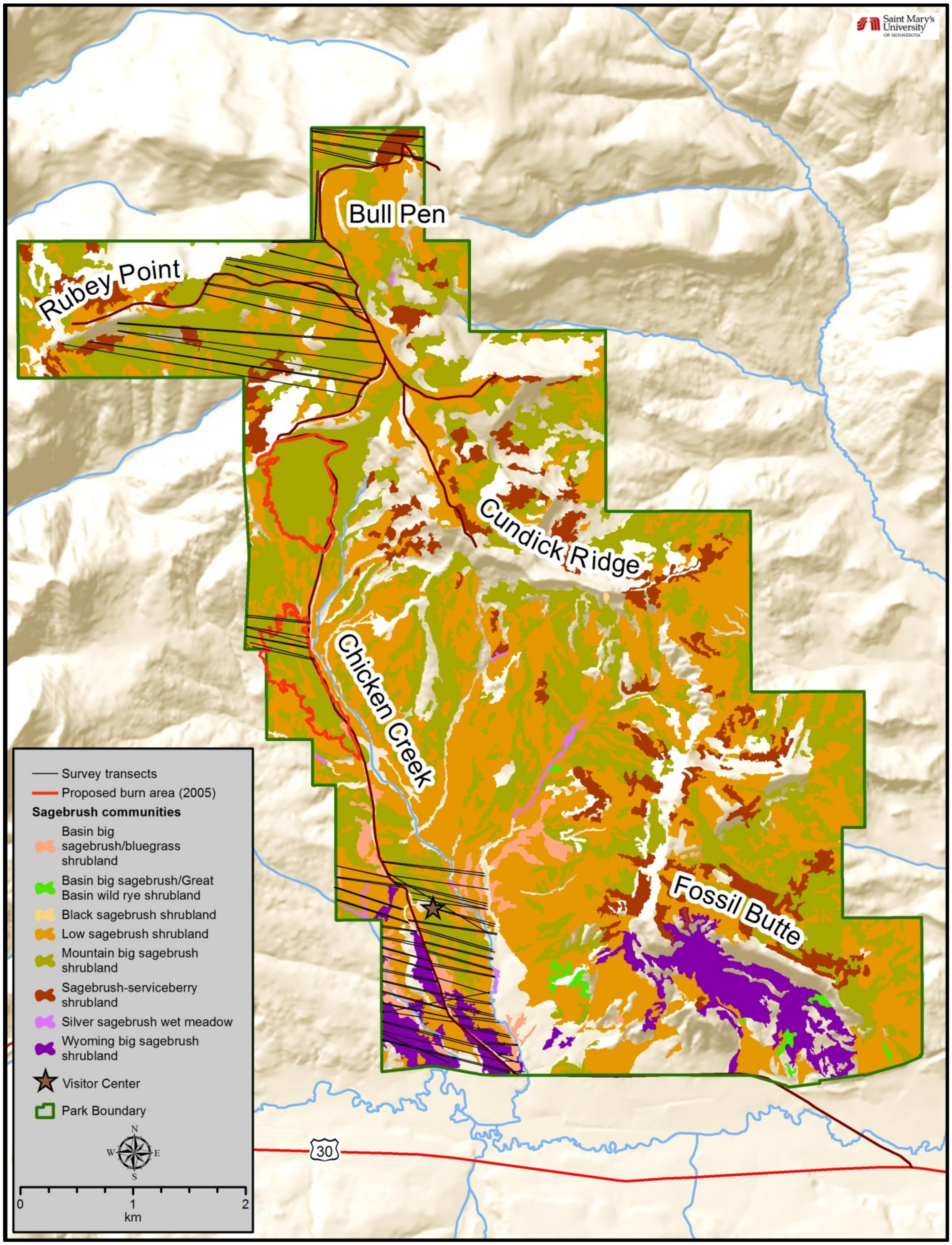

Figure 51. Location of transects surveyed by Purcell (2005) in relation to 2005 proposed burn area and FOBU Visitor Center.

The only data available for number of burrows measure is from the study/survey conducted by Purcell (2005). The surveys were conducted in three discrete locations on the western side of the park (Figure 51, Purcell 2005). This survey data will serve as the reference condition for this assessment.

A reference condition has not been established for reproductive success. There are no reproductive success studies in FOBU regarding the pygmy rabbit population. Collection of baseline data in FOBU is critical for assessing the current condition as well as identifying any trends in the pygmy rabbit population's reproductive success. According to Becker et al. (2011), in the Washington state Columbia Basin where pygmy rabbits have "State Endangered" status, minimum population levels must be achieved in several supportive areas to delist or reclassify the status of pygmy rabbits there. This criterion may be useful in future assessments of the FOBU pygmy rabbit population to determine whether there is need for management adjustments to maintain successful reproduction in the local populations.

A reference condition was also not established for the animal survival measure, as there are no data available regarding annual survival in FOBU. Data for this measure is needed to determine the current status and any trends in the pygmy rabbit population dynamics at FOBU.

4.12.4. Data and Methods

Purcell (2005) conducted pygmy rabbit surveys in FOBU between 23 May and 2 June 2005. Surveys were conducted in an area of the park where a prescribed burn was proposed to take place in the fall of 2005 (Purcell 2005, Figure 51). An unburned area was also chosen as a control site (near the Visitor Center) and surveyed for comparison (Purcell 2005). Within the survey areas, transects were established between boundary lines (roads or FOBU fence-lines) at a minimum of 100 m (328 ft) apart (Purcell 2005). Surveyors walked each transect in an east-west direction from boundary to boundary (Purcell 2005). Signs of pygmy rabbit activity (droppings/fecal pellets color, digging fresh/recent/old, etc.) were observed visually and located with a GPS point (Purcell 2005). Data was collected on the number and condition of burrows, whether the burrows were recently used or not, based on age of fecal pellets (Purcell 2005).

Buskirk and Thimmayya (2010) investigated the impacts of prescribed fire on the pygmy rabbit distribution, abundance, and movement at FOBU following a large prescribed burn in 2005. The perimeters of burned and unburned vegetation in the park were mapped with GPS in June 2008; the total area burned was approximately 56.8 ha (140.4 ac). Cottontails and pygmy rabbits were captured during June 2008-July 2009 with Tomahawk live-traps wrapped in burlap; rabbits were captured inside and outside the park study area. Ten of the captured pygmy rabbits were radio-collared with 5-g radio collars. The collared individuals were then located daily, at various times of the day, for the remainder of the summer of 2008. Vegetation plots, 26 burned and 74 unburned, were placed randomly across the study area with a minimum of 100 m apart to ensure independent occupancy for pygmy rabbits. Several statistical probability methods were used to create occupancy models for pygmy rabbits (see Buskirk and Thimmayya 2010 for detailed descriptions of each variable).

Thimmayya and Buskirk (2012) investigated pygmy rabbit genetic connectivity and diversity in southern Wyoming during a two year project that was conducted in 2008 and 2009. Two other sympatric leporid species, the desert cottontail and mountain cottontail (*Sylvilagus nuttallii*), where also captured and studied for this genetic connectivity assessment. Tomahawk live-traps were used to capture pygmy rabbits in order to collect tissue samples for genetic analysis (Thimmayya and Buskirk 2012). Population differentiation was evaluated using a triad of genetic metrics to determine whether isolation by distance was a statistically significant factor in levels of genetic connectivity (Thimmayya and Buskirk 2012). Detailed methodology for the genetic analysis is available in Thimmayya and Buskirk (2012).

4.12.5. Current Condition and Trend

<u>Extent of Available Suitable/Preferred Sagebrush Habitat</u>
Purcell (2005) surveyed FOBU for pygmy rabbits and their burrows and noted the abundance of suitable habitat; the park has vast expanses of sagebrush communities, which is one of the limiting factors in pygmy rabbit distribution. Figure 50 shows the distribution and extent of the sagebrush communities found within FOBU with data points indicating where pygmy rabbits were observed (Purcell 2005, Friesen et al. 2010). This is the latest available data that describes the extent of sagebrush habitats in FOBU and is considered the reference condition. This serves only as a baseline for future measurements of sagebrush communities in FOBU. More recent assessments of sagebrush distribution would benefit the park for planning and management purposes. The extent of the sagebrush communities encompasses nearly the entire park (Friesen et al. 2010, Figure 50).

Buskirk and Thimmayya (2010) researched the impacts of fire on the distribution, abundance, and movement of pygmy rabbits specifically in the park. The results indicate, and further support, the reliance of pygmy rabbits on older-aged growth sagebrush communities. Management practices, such as prescribed burning, that removes dead standing sagebrush plants and reduce overall cover, negatively impact pygmy rabbits (Buskirk and Thimmayya 2010).

Thimmayya and Buskirk (2012) studied genetic isolation among the local populations dispersed throughout the Wyoming portion of pygmy rabbit range. The main contributing factor to this isolation was habitat fragmentation; the pygmy rabbit is unable to disperse across unfavorable cover conditions since they rely on heavily vegetated sagebrush communities for protection from predation (Buskirk and Thimmayya 2010, Thimmayya and Buskirk 2012). The study results also suggest that the combination of distance and barrier (Interstate 80, which is about 120 km [75 mi] south of FOBU), may have resulted in some has obstructed gene flow (Thimmayya and Buskirk 2012). Low genetic diversity is a conservation concern in that populations with a reduced genetic diversity may also be subject to a lower adaptive capacity (Frankham et al. 2002). Thimmayya and Buskirk (2012) recommended the goals of conservation efforts for pygmy rabbits should be to maintain habitat area and habitat connectivity.

<u>Relative Abundance</u>
Purcell (2005) observed 25 pygmy rabbits in FOBU during the surveys conducted in 2005. As stated previously, this was not a park-wide population study and therefore is not suitable for use as a reference condition. The locations where Purcell observed pygmy rabbits are shown in Figure 52.

Nearly all the sightings were in the southwestern portion of the park in the area around the Visitors Center (control area of the study).

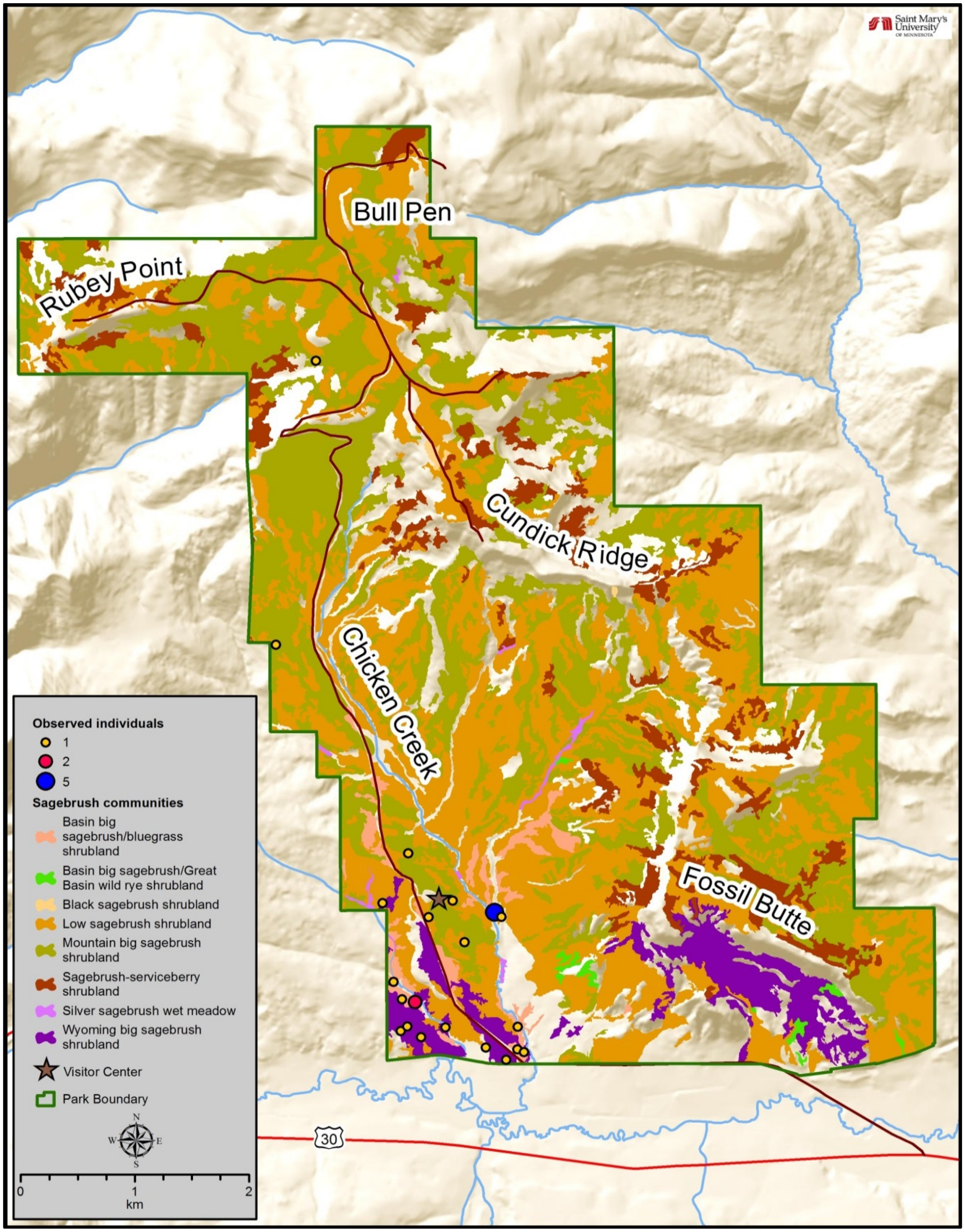

Figure 52. Purcell (2005) pygmy rabbit observations in FOBU.

A more recent study completed by Buskirk and Thimmayya (2010) captured and released 16 pygmy rabbits within FOBU in an effort to develop a habitat occupancy model for pygmy rabbits. As part of this study a number of vegetation plots and transects were surveyed and while the presence of pygmy rabbits was noted in the observations, no count of the number observed was recorded.

Number of Burrows and Burrow Complexes

Purcell (2005) identified a total of 813 burrow complexes along the established transects during foot surveys (Figure 53, Table 60). The observed complexes were in various states of use: old and abandoned, very recent activity, and live pygmy rabbit sightings (Purcell 2005, Figure 53). There were over 4,000 entrances recorded during the foot searches. Table 60 displays the numbers of the various burrows, sorted by condition. As expected based on the locations where pygmy rabbits were observed, the majority of complexes with recent or current activity were in the southwest area of the park near the visitor center, while the complexes further north lacked evidence of recent activity (Figure 53).

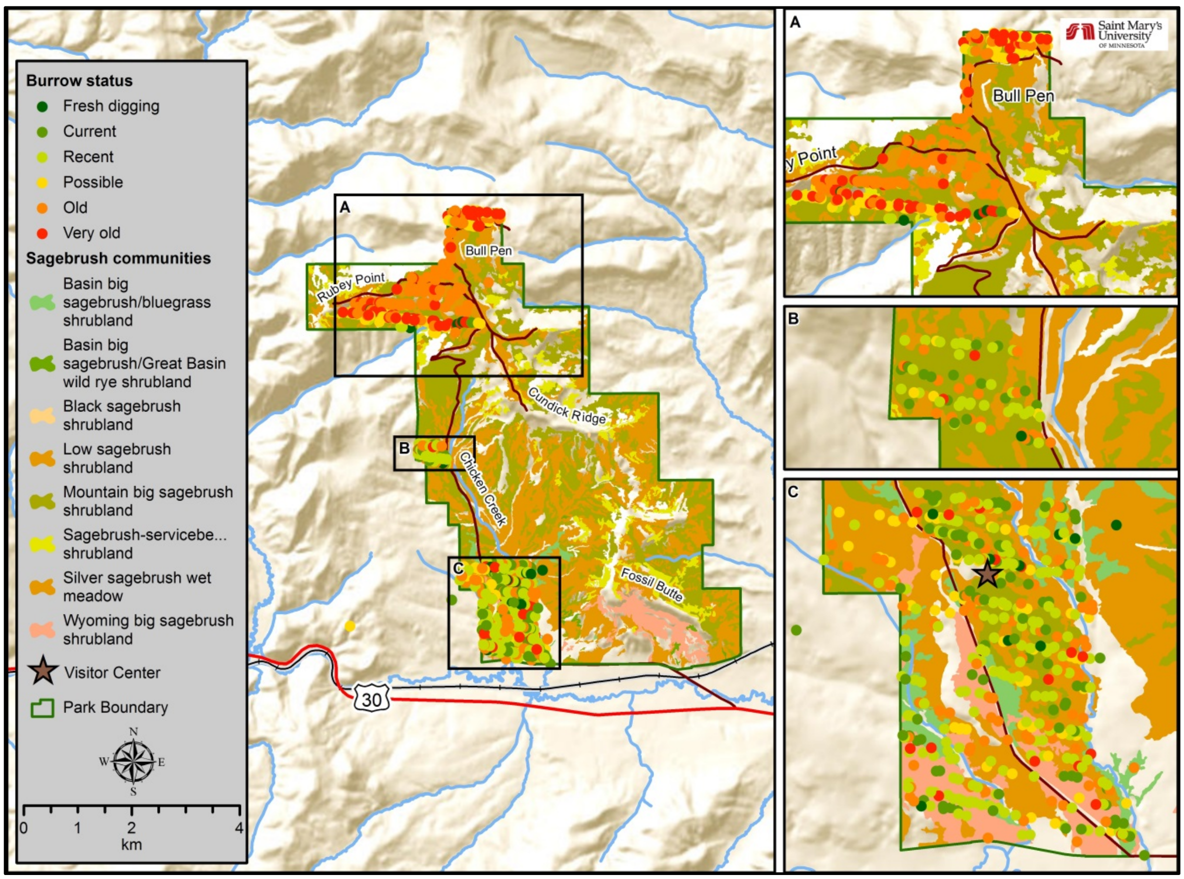

Figure 53. Location and condition of the burrows observed by Purcell (2005).

Table 60. Number of burrows and condition as reported by Purcell (2005).

Burrow Condition	Count
Fresh Digging	14
Current	98
Recent	227
Possible	144
Old	252
Very Old	82
Total number of burrows	817
Total number of entrances	4,293

Reproductive Success

There are no data available that describe the reproductive success of pygmy rabbits in FOBU; therefore this measure is considered a data gap. Reproductive success is measured by a general count of offspring produced by an individual. Keinath and McGee's (2004) species assessment for pygmy rabbits in Wyoming described polyamory in the wild since male home-ranges were observed to overlap with the ranges of several females. The rabbits reach reproductive maturity in their second year and can rear up to three litters during the breeding season; fertility in females occurs for about 2 months in early spring (February through May) and once conception occurs there is a 26 to 28 day gestational period (Wilde 1978, as cited by Keinath and McGee 2004). Newborn pygmy rabbits are maternally dependent for about 8 weeks; during this time they become increasingly self-reliant and at 2 months, will no longer depend on their mother.

Annual Survival

The annual survival of pygmy rabbits has not been assessed at FOBU and is considered a data gap. Generally, annual survival is calculated by an estimated proportion of animals alive from one year to the next and requires a minimum study period of 2 years to assess. Annual survival is useful to managers since it indicates the overall growth rate of the pygmy rabbit population; it determines whether the population is in decline, growing, or static. Pygmy rabbits are the favorite prey item of many animals, such as weasels, coyotes, red foxes, and birds of prey, and are most susceptible during their juvenile stage when their mortality rate is approximated to be around 50% (Wilde 1978, as cited by Keinath and McGee 2004).

Threats and Stressor Factors

Habitat loss and fragmentation is an imminent threat to the pygmy rabbit throughout its range, and negative impacts on the species have been documented (Keinath and McGee 2005, Becker et al. 2011). Suitable habitat for pygmy rabbits has been increasingly altered by grazing, fires, and invasion by exotic species throughout Wyoming; the non-grazed habitats in FOBU are considered critical to the pygmy rabbit (Thimmayya and Buskirk 2012). There is a considerable amount of habitat suited to the pygmy rabbit at FOBU and studies have increased the understanding of the sagebrush-pygmy rabbit relationship (Purcell 2005).

The findings of Buskirk and Thimmayya's (2010) study suggest that burning in areas occupied by pygmy rabbits can be expected to have a negative impact on pygmy rabbits for decades. The prescribed burns severely reduce dead shrub cover and vertical structure present in mature big sagebrush stands that could take more than 35 years to replace (Baker 2006, Buskirk and Thimmayya 2010). Reductions of dead shrub cover may increase pygmy rabbit predation and decrease winter survival capability (Katzner and Parker 1997). Becker et al. (2011) noted dramatic declines post-fire in two pygmy rabbit populations in the Columbia Basin located in the state of Washington; researchers there are currently attempting to reintroduce captive-bred pygmy rabbit populations that were previously extirpated from the Basin.

Data Needs/Gaps

There are several data gaps regarding the status of pygmy rabbits in FOBU. These include data to determine reproductive success and annual survival. Additionally, there are no data available to use as a reference condition in order to determine current condition or trend for the habitat extent and relative abundance measures. Purcell (2005) provides useful information on pygmy rabbit populations and burrows for select areas of the park, but was not a population study and therefore not useful in assessing any trend or the current condition of the pygmy rabbit population at FOBU. Even with the Buskirk and Thimmayya (2010) study, there isn't a solid conclusive trend in pygmy rabbit abundance or the extent of suitable habitat at this time. Neither of these studies provides data on the relative abundance of pygmy rabbits throughout FOBU, therefore data needed to assess the current condition for relative abundance is also a data gap. The reproductive success of pygmy rabbits in FOBU could be studied in various ways, but certainly involves a long-term (several years) study tracking breeding success, fecundity, and offspring mortality of the population in the park.

Overall Condition

Extent of Available Suitable/Preferred Sagebrush Habitat

The extent of available suitable/preferred sagebrush habitat for pygmy rabbits in FOBU was assigned a *Significance Level* of 3. There are only baseline data on this measure from Friesen et al. (2010). This will be useful in comparing subsequent vegetation extent in the coming years to see if there is any change in the extent of preferred pygmy rabbit habitat. At this time, without more recent or older data for comparison, the *Condition Level* cannot be assigned.

Relative Abundance

The relative abundance of pygmy rabbits in FOBU was assigned a *Significance Level* of 3. Purcell (2005) and Buskirk and Thimmayya (2010) both recorded observations of pygmy rabbits at FOBU, however the purposes of the two studies were not targeting data meant to assess abundance at FOBU as a whole. Purcell (2005) assessed the distribution of pygmy rabbits and the number of burrows in a select area prior to a prescribed burn. The Buskirk and Thimmayya (2010) study collected information on only the presence/absence of pygmy rabbits within vegetation plots and along transect surveys within FOBU as part of a study on the impacts of fire to pygmy rabbit habitat and populations. Buskirk and Thimmayya (2010) concluded that prescribed burning of sagebrush areas has a negative impact on abundance and distribution of pygmy rabbits because it destroys suitable habitat. This measure cannot be assigned a *Condition Level* at this time, due to the data gap for both the reference condition and current condition.

Number of Burrows and Burrow Complexes

The number of burrows and burrow complexes was assigned a *Significance Level* of 2. Purcell (2005) is the only study to assess this measure and will be useful for comparison with future studies of pygmy rabbit distribution. However, there are no data from before or after that period of time, and current condition is considered a data gap. Since there are no recent burrow studies, this measure cannot be assigned a *Condition Level* at this time.

Reproductive Success

This measure was assigned a *Significance Level* of 3, but reproductive success is a data gap for FOBU. As a result of this lack of data, a *Condition Level* cannot be assigned.

Annual Survival

Annual survival of pygmy rabbits in FOBU was assigned a *Significance Level* of 2. There are also no data related to annual survival of pygmy rabbits in FOBU. As a result of this data gap, a *Condition Level* cannot be assigned.

Weighted Condition Score

Due to all the measures having substantial data gaps for either a current condition, reference condition, or both, a *Weighted Condition Score* cannot be calculated for the pygmy rabbit at FOBU. The current condition and trend for the population are unknown.

Pygmy Rabbits			
Measures	**Significance Level**	**Condition Level**	**WCS = N/A**
Extent of Available/Preferred Sagebrush Habitat	3	N/A	
Relative Abundance	3	N/A	
Number of Burrows	2	N/A	
Reproductive Success	3	N/A	
Annual Survival	2	N/A	

4.12.6. Sources of Expertise

- Nancy Skinner, FOBU Retired Superintendent
- Dusty Perkins, NCPN Program Manager

4.12.7. Literature Cited

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4.13. Elk

4.13.1. Description

Photo 14. North American elk on Fossil Butte National Monument (NPS photo).

North American elk (*Cervus elaphus*) have been present in the FOBU area since before European settlement (Dorn et al. 1984). Prehistoric archaeological data provide evidence that elk were present as early as 10,000 years ago, although not in large numbers (as reviewed by Dorn et al. 1984). In the FOBU region, elk were mentioned in traveler's journal entries up until the 1850s, but were noted as absent from the area just prior to the time of European settlement (1870s) (Dorn et al. 1984). No precise information is available for when elk returned to the area, only that it was some time after the early 1900s (Dorn et al. 1984).

The elk in the FOBU area belong to the West Green River elk herd, as classified by the WGFD. Since the 1990s, the portion of this herd that utilizes the monument grounds has increased considerably (WGFD 2013). This increase is of particular concern to FOBU staff, as negative effects on the vegetation in the park can be reasonably anticipated. At high population densities, elk can "have substantial localized impacts on some vegetative communities" (NPS 2009, p. 12). Damage is most likely to be noticeable in areas where elk congregate during winter, such as the south side of The Bullpen, Cundick Ridge, and Fossil Butte itself (Fertig 2012).

The primary cause for the recent increased utilization of FOBU lands by elk is Wyoming's elk hunting season (Jeff Short, WGFD Wildlife Biologist, phone communication, 31 July 2014). Area elk seek out the monument grounds as a refuge during the hunting seasons and remain in and around FOBU from September through December or until the heavy snows come, making foraging more difficult (Olexa 2010, Olexa et al. 2014).

4.13.2. Measures

- Regional population estimate
- Extent of browse on preferred food species (primary, secondary, tertiary)
- Male: female ratio
- Reproductive success (measured as cow: juvenile ratio)

4.13.3. Reference Conditions/Values

Establishing a reference condition for the elk utilizing FOBU is made difficult due to a variety of factors. While archaeological records dating back approximately 10,000 years indicate evidence of the consistent presence of various ungulate species, including elk (Dorn et al. 1984), elk were reportedly absent from the area shortly prior to settlement. The elk then returned sometime in the early 20th century (Dorn et al. 1984) as mid-19th century accounts from travelers around the FOBU region mention elk as present on the landscape, though not in abundance (as reviewed by Dorn et al. 1984).

The migratory patterns of elk also influence the presence or absence of elk in the area. Early settlers' accounts (late 1800s) also describe elk migrating or wintering in the Green River Basin immediately to the east of the monument (Cromley 2000). Today, however, the majority of elk utilizing FOBU will winter to the south and west of the park (Short, phone communication, 31 July 2014). Land use activities, hunting patterns, and other factors can all affect elk migration and wintering patterns, which influences the number of elk utilizing the FOBU area.

Because of the lack of specific information concerning elk numbers during prehistoric times and the variability associated with migration, it would be difficult to determine a reference condition for the elk population during that period. A logical reference period would be the late 1800s, just prior to European settlement; however, since no elk were recorded as present during the settlement period, using this time frame as a reference condition would not be accurate. The current and seasonally high elk numbers on FOBU also do not lend themselves to being designated a natural reference condition. Therefore no reference condition regarding population will be set at this time.

4.13.4. Data and Methods

The principal source for quantitative data used in this assessment came from the 2013-JCR Evaluation Form completed by the Wyoming Game and Fish department and from informational sheets prepared by the USGS (Olexa 2010) and the Wyoming Landscape Conservation Initiative (Olexa et al. 2014). Additional information was obtained from personal communications (as documented) or from sources in the literature cited section of this component.

4.13.5. Current Condition and Trend

<u>Regional Population Estimate</u>

The West Green River herd population has decreased since 2008 (Figure 54, WGFD 2013). The population estimate for the herd in 2008 was 7,046 animals, and in 2013 that estimate dropped to 4,619 animals (WGFD 2013). This reduction was by design, as the WGFD has increased the number of elk permits given to hunters in recent years. The increased permits are part of an effort to bring this population down toward the stated goal of 3,100 animals for the area.

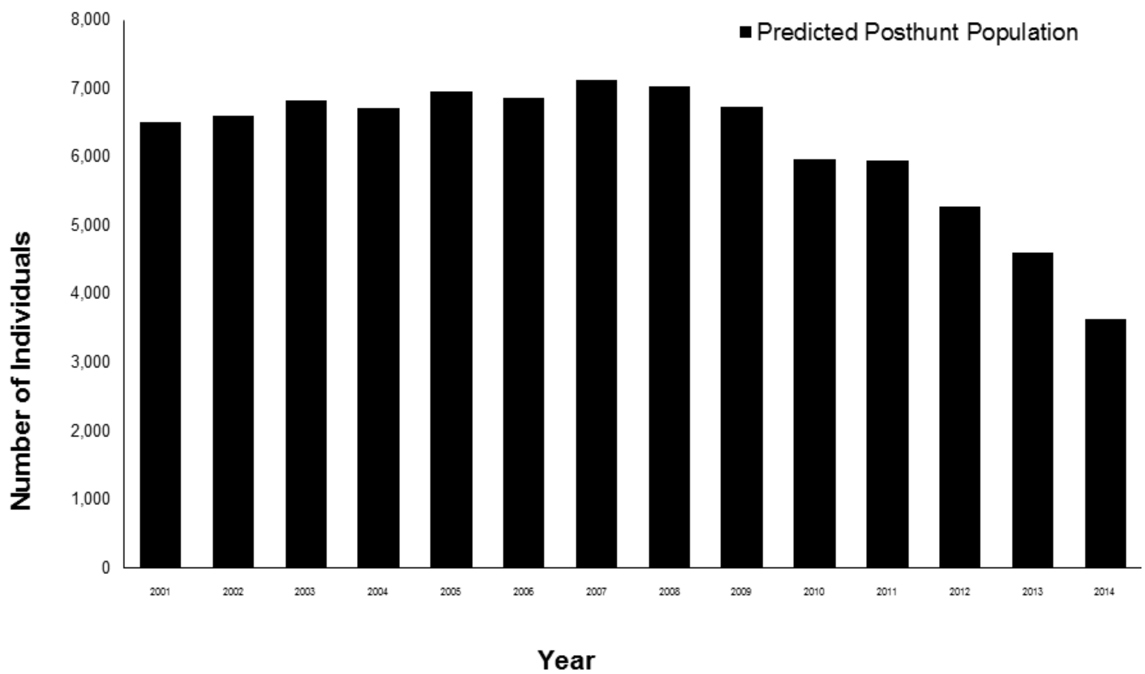


Figure 54.West Green River elk herd population over time (WGFD 2013).

While this downward trend in the regional population is substantial, it is not reflective of the elk population trend within the FOBU boundary. In contrast to the overall trend, the elk population on FOBU has noticeably increased in recent years (Edward Olexa, USGS Wildlife Biologist, verbal communication, 9 July 2014). FOBU park employees have estimated as many as 500-700 elk within the park boundary during the fall (Fagnant, written communication, 6 June 2013). In the early 2000s, the elk inhabiting FOBU seasonally were estimated at just over 100 animals (Evenden et al. 2002).

In 2005, researchers from the USGS Northern Rocky Mountain Science Center (NOROCK) began a long term study to look at “potential resource degradation resulting from a growing elk herd and associated increased use of Fossil Butte National Monument” (Olexa 2010, p. 1). This study involved radio collared elk and the extent and timing of the animals’ presence on the monument. Olexa (2010) observed that the timing of elk movements seemed to be linked to the hunting season. The archery season in the FOBU region typically occurs in September, followed by general seasons in October-

November (WGFD 2015). Elk often move onto the monument when archery season begins in the fall and then leave the park between mid-winter and early spring (Figure 55, Photo 15).

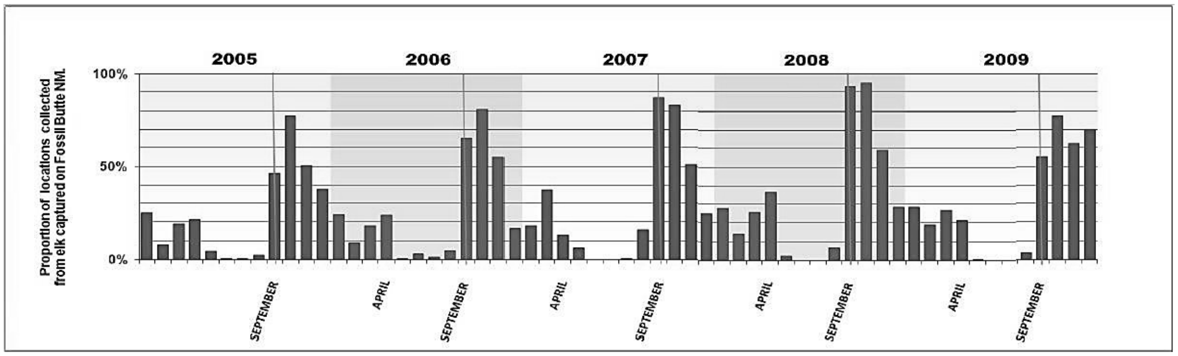


Figure 55. Timing of elk movement onto and off of FOBU (reproduced from Olexa 2010).

<u>Extent of Browse on Preferred Food Species (primary, secondary, tertiary)</u>

In a 2009 letter of support to NOROCK, former FOBU Superintendent David McGinnis wrote: "Our highest resource management priority at Fossil Butte National Monument is to understand the ecological and habitat consequences elk are having on plant communities in our park and surrounding public lands." Despite this, no studies have been completed to date focusing on food selection or browse impact by ungulates on the vegetation communities within FOBU.

Photo 15. Elk at FOBU (NPS photo).

After a recent joint inspection involving WGFD and FOBU staff, WGFD Wildlife Biologist Jeff Short (phone communication, 31 July 2014) observed that the vegetation impacts seen during the field inspection were in line with impacts on lands surrounding the monument. Short commented that there was some observable impact to the aspen trees on the monument, but cautioned that the visit was site-specific and no broad statements concerning the elk's impact on the vegetative communities as a whole could be made from that visit alone.

Male: Female Ratio

The sex ratio is estimated using the number of males/100 females in a herd, with an associated standard error for each ratio. This ratio for this herd is within a normal range given the management objectives (Short, phone communication, 31 July 2014). WGFD provided estimates of sex ratios in the West Green River herd from 2001-2014. The sex ratio in the park has ranged from a low of 19.90 males/100 females (± 0.91) in 2008, to a high of 39.94 males/100 females (±1.89) in 2014 (Figure 56). Data were not collected in 2012.

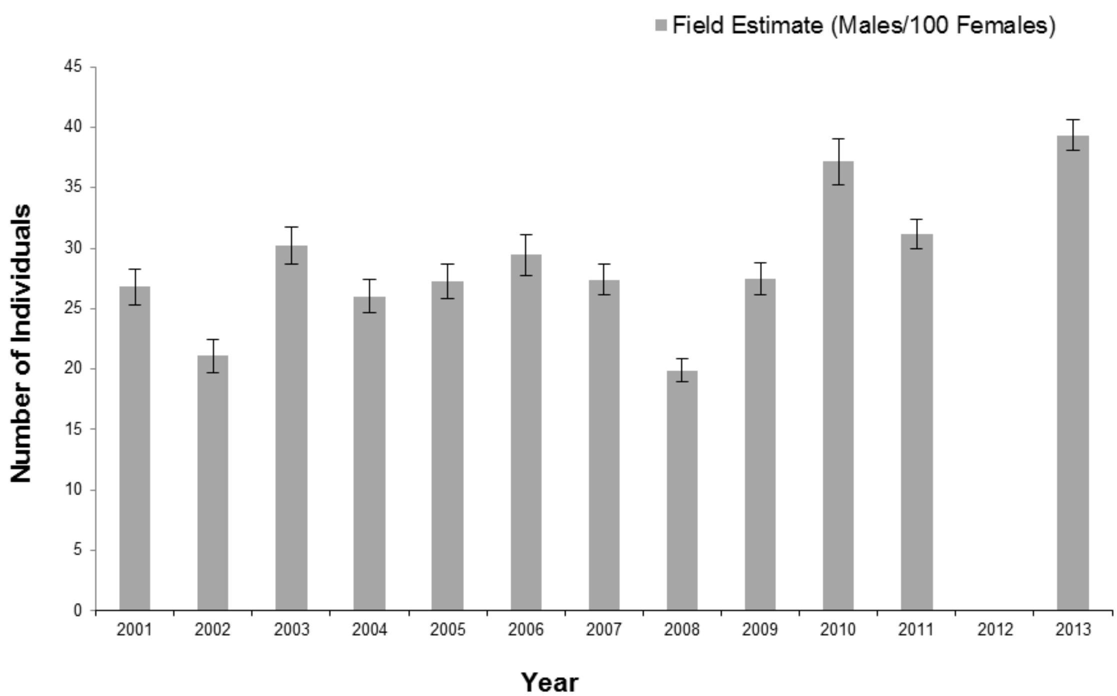


Figure 56. Male: Female ratio trend with standard error bars (West Green River elk herd).

Reproductive Success (measured as juvenile: female ratio)

Reproductive success is evaluated in FOBU using the estimated number of juveniles/100 females, and has been summarized annually since 2001 (WGFD 2013). Juvenile: female ratios ranged from 42.45 juveniles/100 cows (±1.71) in 2007, to 30.0 juveniles/100 cows (± unavailable) in 2014 (Figure 57). Data were not collected in 2012.

According to WGFD biologist Jeff Short (phone communication, 31 July 2014), a juvenile: cow ratio of 30 juveniles to 100 cows would be on the low end of the range for this herd. A concern for the WGFD would be if the ratio drops below this number.

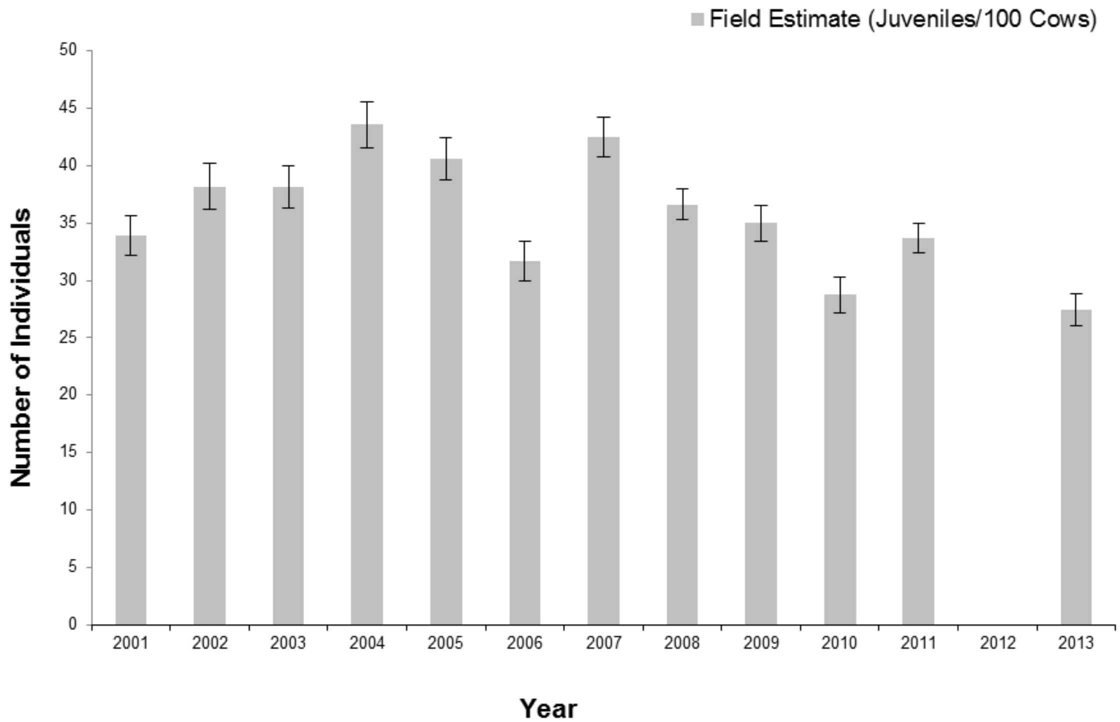


Figure 57. Juvenile: Female ratio with standard error bars (West Green River elk herd).

Threats and Stressor Factors

There are two primary disease concerns for this herd: brucellosis, a bacterial disease, and Chronic Wasting Disease (CWD), a neurological disease. Both diseases can affect animals and humans, and have economic implications for ranchers with domestic livestock.

There are several species of the *Brucella* bacterium. *Brucella abortus* is the species that infects elk, bison and cattle (Wyoming Brucellosis Coordination Team 2014). A brucellosis infection of the female reproductive tract often results in the pregnancy being terminated. The infection usually results in the loss of the first fetus but can also claim the fetuses in a second or even third pregnancy. Fetuses delivered near term may fail to thrive after delivery or be delivered stillborn due to the *Brucella* infection (Wyoming Brucellosis Coordination Team 2014). As of 2014, brucellosis had not been detected in the West Green River elk herd (Olexa et al. 2014).

The monument is also within about 160 km (100 mi) of confirmed CWD cases. Impacts to the West Green River elk herd from CWD could be significant in the long term (Margaret Wild, NPS Chief Wildlife Veterinarian, written communication, 25 June 2014). CWD is a neurological disease that has a 100% mortality rate and affects North American cervids, including white-tailed deer (*Odocoileus virginianus*), 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).

Avoiding or eliminating unnatural concentrations of animals is the best way to prevent these diseases. Disease surveillance by ranchers and hunters is the best way to monitor if/when a disease occurs in the area (Wild, written communication, 25 June 2014).

Other natural stressors include native predators to the area. In the West Green River herd, black bears have minimal impact to the elk population through predation on calves. The mountain lion has slightly greater impacts on the elk population by preying on all ages of elk. Because of the high elk population, the impact from mountain lion and black bear predation on this herd are minimal and are not considered a significant threat at this time (Short, phone communication, 31 July 2014).

Data Needs/Gaps

Although there is considerable general information on elk (e.g., range, habits and food selection), there is very little information concerning elk use specifically in FOBU. Research to provide information regarding elk impact on the monument has been suggested but has not yet been funded. For example, NOROCK has proposed examining the relationship between rare and at risk plants and impacts from the elk population (Olexa and Garman 2009). Elk would be radio-collared and monitored to study the timing and duration of their presence in FOBU vegetative communities with sensitive plant species. This information, along with an estimation of the carrying capacity of the land for elk, could provide the basis for some quantitative analysis of elk impacts. The very unique nature of the monument acting as a refuge for an approximately 4-month period during the dormant stage of most vegetation should also be considered and ultimately combined with vegetative impact estimates to create an informed strategy for managing the elk on FOBU.

While it is likely that some type of elk management may be necessary at FOBU in the future, management planning may be complicated. Viable management options will need to be sensitive to the monument’s enabling legislation, NPS policy, and other constraints, as no hunting is allowed within the monument boundary at present. However, many viable elk management options and tools are available to address these concerns.

Overall Condition

Regional Population Estimate

The project team defined the *Significance Level* for the regional population estimate as a 2. Because the local elk herd population is decreasing while the actual utilization of FOBU by elk is increasing, the regional population estimate may not reflect population conditions in FOBU at this time. The monument has become a refuge for elk during the hunting season. Due to a lack of data specific to the elk population and their transient use of FOBU, a *Condition Level* cannot be assigned.

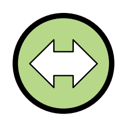
Extent of Browse on Preferred Food Species (primary, secondary, tertiary)

The project team defined the *Significance Level* for this measure as a 2. Due to a lack of data specific to the vegetation communities impacted by elk browse on FOBU a *Condition Level* is difficult to assign. Concerns over the impact from so many elk browsing on the monument during the hunting season have been voiced by monument staff. This concern, along with the impacts to stands of aspen trees noticed by WGFD biologists, warrant moderate concern for this measure. The *Condition Level* was therefore assigned a 2 or of moderate concern.

Male: Female Ratio
The project team defined the *Significance Level* for the male: female ratio measure as a 2.The number of males per one hundred females has risen over the past five years. The increase is due primarily to an increase in elk hunting licenses and the increased harvest of female elk. This ratio is within a normal range for a herd given the management objectives (Short, phone communication, 31 July 2014). A *Condition Level* of 0 or of no concern is assigned for this measure.

Reproductive Success (measured as cow: juvenile ratio)
The project team defined the *Significance Level* for reproductive success as a 2. Within the West Green River herd, this ratio has decreased in recent years. This is due primarily to an increase in elk hunting licenses and the increased harvest of female and juvenile animals. This ratio is at the low end of the normal range for a herd given the management objectives (Short, phone communication, 31 July 2014). A *Condition Level* of 1 or of low concern is assigned for this measure.

Weighted Condition Score
The *Weighted Condition Score* for Elk in FOBU is 0.33 which falls at the top of the good condition range. The high concentration of elk found on FOBU during the hunting seasons is a concern for the park staff and the unknown impact the elk may have on the vegetation within the park.

Elk			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.33**
Regional Population Estimate	2	N/A	
Extent of Browse on Preferred Food Species	2	2	
Male: Female Ratio	2	0	
Reproductive Success	2	1	

4.13.6. Sources of Expertise

- Jeff Short, WGFD Wildlife Biologist and Survey Coordinator
- Margaret Wild, NPS Chief Wildlife Veterinarian
- Edward Olexa, USGS Wildlife Biologist

4.13.7. Literature Cited

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4.14. Dark Night Skies

4.14.1. 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 2014). 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, 2014). Several species require darkness to hunt, hide their location, navigate, or reproduce (NPS 2014). 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.

The resource of a dark night sky is important to the NPS for a variety of reasons. First, the preservation of natural lightscapes (the intensity and distribution of light on the landscape at night) will keep the nocturnal photic environment within the range of natural variability. Excursions outside this natural range may result in a modification to natural ecosystem function, especially to systems involving the behavior and survival of nocturnal animals (NPS 2014). The natural night sky is therefore one of the physical resources under which natural ecosystems have evolved. Second, the "scenery" of national park areas does not just include the daytime hours (NPS 2014). A natural starry sky absent of anthropogenic light is a key scenic resource, especially at large wilderness parks remote from major cities. Third, the history and culture of many civilizations are steeped in interpretations of night sky observations, whether for scientific, religious, or time-keeping purposes (NPS 2014). As such, the natural night sky may be a very important cultural resource, especially in areas where evidence of aboriginal cultures is present. Fourth, the recreational value of dark night skies is important to campers and backpackers, allowing the experience of having a campfire or "sleeping under the stars" (NPS 2014). And lastly, night sky quality is an important wilderness value, contributing to the ability to experience a feeling of solitude in a landscape free from signs of human occupation and technology (NPS 2014).

FOBU is located in a rather remote portion of southwest Wyoming. The closest urban light source is the city of Kemmerer, Wyoming (Figure 58). Kemmerer is approximately 24 km (15 mi) to the east-southeast of FOBU (Moore 2006c). The cities of Evanston, Wyoming, Salt Lake City-Ogden, Utah and Logan, Utah also have an impact on the natural lightscape of FOBU (Moore 2006b). The other local source of artificial light in the vicinity is the Naughton Power Plant. This coal-fired power station is owned by PacifiCorp and is located to the southeast of the park (southwest of Kemmerer).

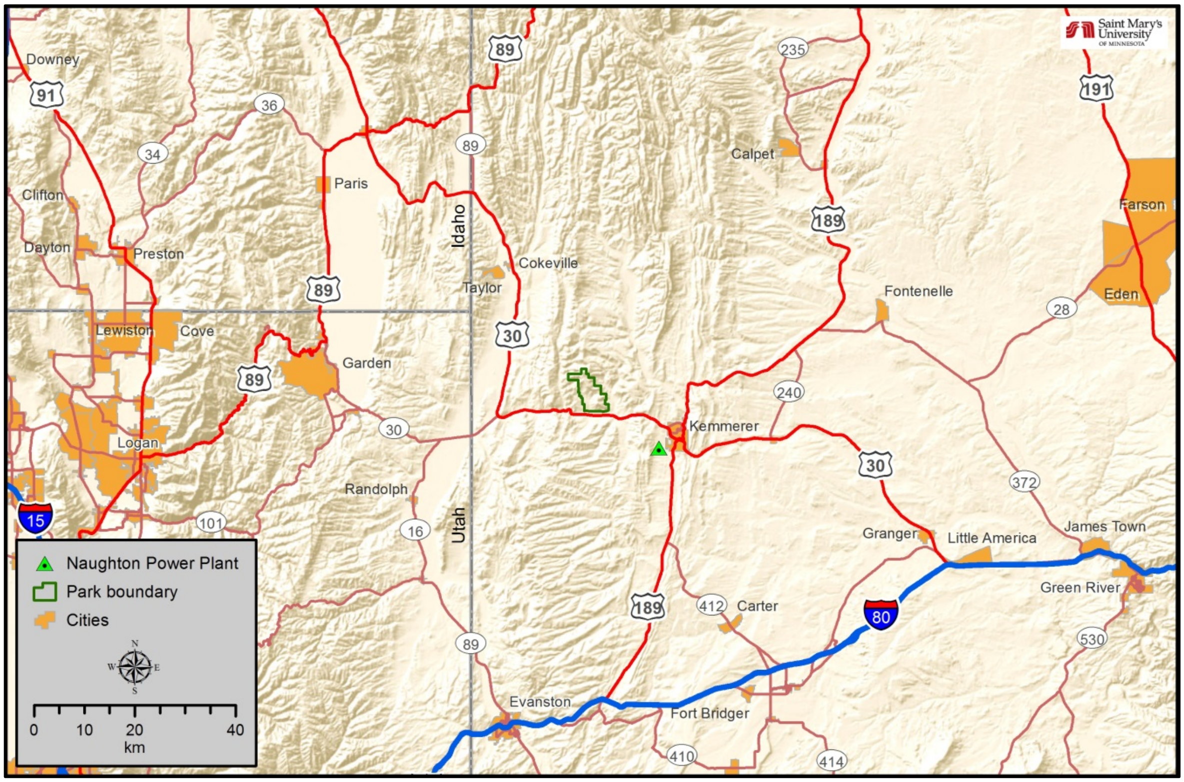


Figure 58. Locations of artificial light in the region surrounding FOBU.

4.14.2. Measures

The dark night sky condition will be assessed using the data collected by the NPS Natural Sounds and Night Sky Division (NSNSD). During field visits the NSNSD collects data for a suite of measures in order to define the current condition of dark night skies in a park unit. These measures typically include:

- Sky luminance over the hemisphere in high resolution (thousands of measurements comprise a data set), reported in photometric luminance units (V magnitudes per square arc second [mag/arcsec^2] or milli-candela per square meter [mcd.m2]) or relative to natural conditions, often shown as a sky brightness contour map of the entire sky. V magnitude (mags) is a broadband photometric term in astronomy, meaning the total flux from a source striking a detector after passing through a “Johnson-Cousins V” filter. It is similar to the “CIE photopic” broadband function for wavelengths of light to which the human eye is sensitive (Bessell 1990);
- Integrated measures of anthropogenic sky glow from selected areas of sky that may be attributed to individual cities or towns (known as city light domes), reported in milli-Lux of hemispheric illuminance or vertical illuminance;
- Integration of the entire sky illuminance measures, reported either in milli-Lux of total hemispheric (or horizontal) illuminance, milli-Lux of anthropogenic hemispheric (or horizontal) illuminance, V-magnitudes of the integrated hemisphere, or ratio of anthropogenic illuminance to natural illuminance;

- Vertical illuminance from individual (or groups of) outdoor lighting fixtures at a given observing location (such as the Wilderness boundary), in milli-Lux;
- Visual observations by a human observer, such as Bortle Class and Zenith limiting magnitude (ZLM);
- Integrated synthesized measure of the luminance of the sky within 50 degrees of the Zenith, as reported by the Unihedron Sky Quality Meter, in mag/arcsec^2.

4.14.3. Reference Conditions/Values

Park staff selected the appearance of the night sky prior to settlement as the desired reference condition. This condition can be defined as the absence of artificial light in terms of sky luminance and illuminance at the observer's location from anthropogenic sources as follows:

> *No portion of the sky background brightness exceeds natural levels by more than 200 percent, and the sky brightness at the Zenith does not exceed natural Zenith sky brightness by more than 10 percent. The ratio of anthropogenic hemispheric illuminance to natural hemispheric illuminance from the entire night sky does not exceed 20 percent. The observed light from a single visible anthropogenic source (light trespass) is not observed as brighter than the planet Venus (0.1 milli-Lux) when viewed from within any area of the park designated the naturally dark zone* (Dan Duriscoe, NSNSD, pers. comm., 2011).

Achieving this reference condition for preserving natural night skies is well summarized in the NPS Management Policies (NPS 2006) as follows in section 4.10:

> *The Service will preserve, to the greatest extent possible, the natural lightscapes of parks, which are natural resources and values that exist in the absence of human-caused light.*

Implementing this directive in FOBU requires that facilities within the park and local communities around the park meet outdoor lighting standards that provide for the maximum amount of environmental protection while meeting human needs for safety, security, and convenience. This means that outdoor lights within the park:

- produce zero light trespass beyond the boundary of their intended use;
- be of an intensity that meets the minimum requirement for the task, but does not excessively exceed that requirement;
- be of a color that is toward the yellow or orange end of the spectrum to minimize sky glow;
- be controlled intelligently, preventing unnecessary dusk to dawn bright illumination of areas.

4.14.4. Data and Methods

The NSNSD conducted field visits to FOBU in 2004 and 2006 to collect data on the night sky brightness in order to establish a baseline of light pollution (Moore 2005, 2006a, and 2006b). A second objective of these field visits was to identify the light pollution sources and to establish their relative contributions (Moore 2005). Data were collected from atop Rubey Point on the nights of 9-

11 September, 13-14 October, and 5-7 November 2004 (Moore 2005). Due to weather conditions and equipment malfunctions only the data for the nights of 13-14 October were determined as usable by the NSNSD (Moore 2005). Further examination of the data showed the need for at least 1-2 more datasets in order to accurately capture night sky brightness during standard atmospheric conditions (Moore 2005). The NSNSD supplemented the initial dataset with data collected from Rubey Point on 18 August and 26 September 2006 (Moore 2006a and 2006b). During these visits, location information and weather conditions were documented, which include: coordinates, elevation, date of monitoring, start time, data quality, equipment used, air temperature, humidity, wind speed, and exposure, in addition to the suite of photometric indicators. It should be noted that the full suite of data is not available for each of the four datasets. The Bortle Class, ZML, and illuminance from city light domes were only available for the 26 September 2006 dataset. Important statistics from the four field visits are presented in Appendix I-Appendix L.

Anthropogenic light in the night environment can be very significant, especially on moonless nights. Unshielded lamps mounted on tall poles have the greatest potential to cause light pollution, since light directly emitted by the lamp has the potential to follow an unobstructed path into the sky or the distant landscape. This type of light spill has been called glare, intrusive light, or light trespass (Narisada and Schreuder 2004). The dark-adapted human eye will see these individual light sources as extremely bright points in a natural environment. These sources also have the potential to illuminate the landscape, especially vertical surfaces aligned perpendicular to them, often to a level that approaches or surpasses moonlight. The brightness of such objects may be measured as the amount of light per unit area striking a “detector” or a measuring device, or entering the observer’s pupil. This type of measure is called illuminance (Ryer 1997).

Illuminance is measured in lux (metric) or foot-candles (English), and is usually defined as luminous flux per unit area of a flat surface (1 lux = 1 lumen/m^2). However, different surface geometries may be employed, such as a cylindrical surface or a hemispheric surface. Integrated illuminance of a hemisphere (summed flux per unit area from all angles above the horizon) is a useful, unbiased metric for determining the brightness of the entire night sky. Horizontal and vertical illuminance are also used; horizontal illuminance weights areas near the Zenith much greater than areas near the horizon, while vertical illuminance preferentially weights areas near the horizon, and an azimuth of orientation must be specified.

Direct vertical illuminance from a nearby anthropogenic source will vary considerably with the location of the observer, since this value varies as the inverse of the square of the distance from light source to observer (Ryer 1997). Therefore, measures of light trespass are usually made in sensitive areas (such as public campgrounds).

Anthropogenic light which results in an upward component will be visible to an observer as “sky glow.” This is because the atmosphere effectively scatters light passing through it. The sky is blue in daytime because of Rayleigh scattering by air molecules, which is more effective for light of shorter wavelengths. For this reason, bluish light from outdoor fixtures will produce more sky glow than reddish light. Larger particles in the atmosphere (aerosols and water vapor droplets) cause Mie scattering and absorption of light, which is not as wavelength-dependent and is more directional.

When the air is full of larger particles, this process gives clouds their white appearance and produces a whitish glow around bright objects (e.g., the sun and moon). The pattern of sky glow as seen by a distant observer will appear as a dome of light of decreasing intensity from the center of the city on the horizon. As the observer moves closer to the source, the dome gets larger until the entire sky appears to be luminous (Garstang 1989).

Light propagated at an angle near the horizon will be effectively scattered and the sky glow produced will be highly visible to an observer located in the direction of propagation. Predictions of the apparent light dome produced by a sky glow model demonstrate this (Luginbuhl et al. 2009). Light reflected off surfaces (e.g., a concrete road or parking area) becomes visible light pollution when it is scattered by the atmosphere above it, even if the light fixture has a "full cutoff" design and is not visible as glare or light trespass to a distant observer. For this reason, the intensity and color of outdoor lights must be carefully considered, especially if light-colored surfaces are present near the light source.

Light domes from many cities, as they appear from a location within Joshua Tree National Park, are shown in Figure 59 and Figure 60, as a grayscale and in false color. This graphic demonstrates that the core of the light dome may be tens or hundreds of times brighter than the extremities. A logarithmic scale for sky luminance and false color are commonly used to display monochromatic images or data with a very large dynamic range, and are used extensively in reports of sky brightness by the NSNSD.

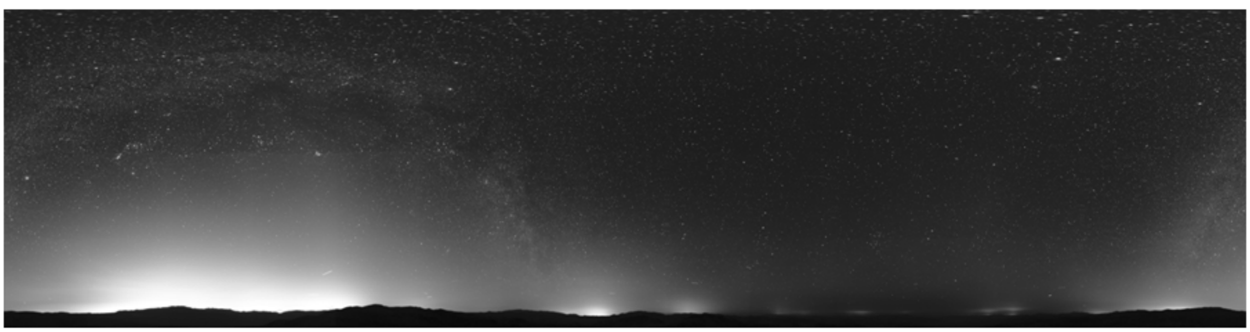


Figure 59. Grayscale representation of sky luminance from a location in Joshua Tree National Park (Dan Duriscoe, NPS NSNSD).

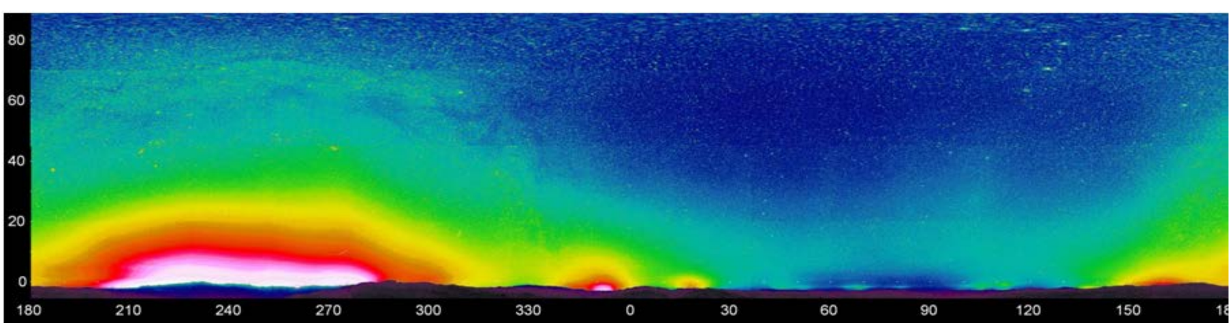


Figure 60. False color representation of Figure 59 after a logarithmic stretch of pixel values (Dan Duriscoe, NPS NSNSD).

The brightness (or luminance) of the sky in the region of the light domes may be measured as the number of photons per second reaching the observer for a given viewing angle, or area of the sky (such as a square degree, square arc minute, or square arc second). The NSNSD utilizes a digital camera with a large, dynamic range, monochromatic charge-coupled device (CCD) detector and an extensive system of data collection, calibration, and analysis procedures (Duriscoe et al. 2007). This system allows for the accurate measurement of both luminance and illuminance, since it is calibrated on standard stars that appear in the same images as the data and the image scale in arc seconds per pixel is accurately known. Sky luminance is reported in astronomical units of V-magnitudes per square arc second, and in engineering units of milli-candela per square meter. High resolution imagery of the entire night sky reveals details of individual light domes that may be attributed to anthropogenic light from distant cities or nearby individual sources. These data sets may be used for both resource condition assessment and long-term monitoring.

Figure 59 and Figure 60 contain information on natural sources of light in the night sky as well as anthropogenic sources. The appearance of the natural night sky may be modeled and predicted in terms of sky luminance and illuminance over the hemisphere, given the location, date, time, and the relative brightness of the natural airglow (the so-called “permanent aurora” which varies in intensity over time) (Roach and Gordon 1973). The NSNSD has constructed such a model, and uses it in analysis of data sets to remove the natural components. This results in a more accurate measure of anthropogenic sky glow (Figure 61). Figure 60 represents “total sky brightness” while Figure 61 displays “anthropogenic sky glow” or “net light pollution.” This is an important distinction, especially in areas where anthropogenic sky glow is of relatively low intensity.

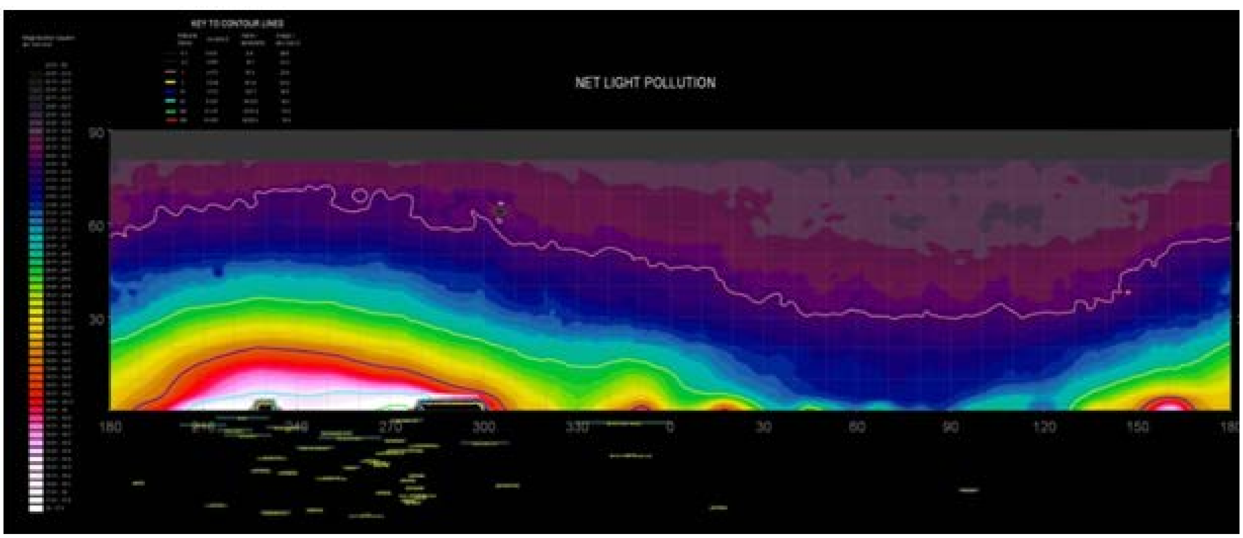


Figure 61. Contour map of anthropogenic sky glow at a location in Joshua Tree National Park, analogous to Figure 60 with natural sources of light subtracted (Figure provided by Dan Duriscoe, NPS Night Sky Team).

The accurate measurement of both anthropogenic light in the night sky and the accurate prediction of the brightness and distribution of natural sources of light allows for the use of a very intuitive metric of the resource condition - a ratio of anthropogenic to natural light. Both luminance and illuminance for the entire sky or a given area of the sky may be described in this manner (Hollan 2010). This so-called "light pollution ratio" is unitless and is always referenced to the brightness of a natural moonless sky under average atmospheric conditions, or, in the case of the NSNSD data, the atmospheric conditions determined from each individual data set.

The reference conditions for anthropogenic sky luminance were identified as no more than 200 percent brighter than natural conditions in *any* area of the sky and no more than 10 percent brighter at the Zenith. These values correspond to light pollution ratios of 2.0 and 0.1, respectively. The NSNSD has obtained values of 50-100 for this measure at the core of city light domes seen from several areas administered by the NPS, including Lake Mead National Recreation Area, Saguaro National Park, and Colorado National Monument (NPS Night Sky Team, unpublished data). This is because these NPS areas are very close to the cities of Las Vegas, Nevada; Tucson, Arizona; and Grand Junction, Colorado, respectively. FOBU is in a fortunate location of being distant from large cities. As such, the park provides a refuge from bright light domes, which can significantly impair sky quality at distances of 160 km (100 mi) or more from the center of the city.

A quick and moderately accurate method of quantifying sky brightness near the Zenith is the use of a Unihedron Sky Quality Meter. The Unihedron Sky Quality Meter is a single-channeled hand-held photometric device. A single number in magnitudes per square arc second is read from the front of the device after its photodiode and associated electronics are pointed at the Zenith and the processor completes its integration of photon detection. Because the meter is relatively inexpensive and easy to use, a database of measures has grown since its introduction (see http://unihedron.com/projects/darksky/database/index.php). The NSNSD produces values from each data set as both a synthesized value derived from the high-resolution images and by hand held measures with a Unihedron Sky Quality Meter. The performance of the Sky Quality Meter was tested and reviewed by Cinzano (2005). While fairly accurate and easy to use, the value it produces is biased toward the Zenith. Therefore, the robustness of data collected in this manner is limited to areas with relatively bright sky glow near the Zenith, corresponding to severely light polluted areas. While not included in the reference condition, a value of about 21.85 would be considered "pristine," providing the Milky Way is not overhead and/or the natural airglow is not unusually bright when the reading is taken.

Visual observations are important in defining sky quality, especially in defining the aesthetic character of night sky features. A published attempt at a semi-quantitative method of visual observations is described in the Bortle Dark Sky Scale (Bortle 2001). Observations of several features of the night sky and anthropogenic sky glow are synthesized into a 1-9 integer interval scale, where class 1 represents a "pristine sky" filled with easily observable features and class 9 represents an "inner city sky" where anthropogenic sky glow obliterates all the features except a few bright stars. Bortle Class 1 and 2 skies possess virtually no observable anthropogenic sky glow (Bortle 2001).

Another visual method for assessing sky quality is ZLM, which is the apparent brightness or magnitude of the faintest star observable to the unaided human eye, which usually occurs near the

Zenith. This method involves many factors, the most important of which is variability from observer to observer. A ZLM of 7.0-7.2 is usually considered “pristine” or representing what should be observed under natural conditions; observation of ZLM is one of the factors included in the Bortle Dark Sky Scale. Zenith Limiting Magnitude is often referenced in literature on the quality of the night sky, and is the basis for the international “Globe at Night” citizen-scientist program (see http://www.globeatnight.org/index.html). The NSNSD has experimented with the use of this observation in predicting sky quality, and has found that it is a much coarser measure and prone to much greater error than accurate photometric measures over the entire sky. For these reasons, it is not included in the reference conditions section.

4.14.5. Current Condition and Trend

As stated earlier, the NSNSD documented baseline dark night sky conditions based on data collected during field visits in 2004 and 2006. Data was collected from atop Rubey Point located in the northwest corner of FOBU at an elevation of 2,451 m (8,041 ft). Sky conditions for the sample dates were relatively clear, with a few high cirrus clouds present on the nights of 13 October 2004 and 18 August 2006. During these visits, the extinction coefficients (measure of air opacity) ranged from 0.14 - 0.29 (Moore 2004a, 2004b, 2006a, and 2006b). Values between 0.14 and 0.2 suggests that the sky is relatively clear, however the 0.29 value is a moderately high extinction given FOBU’s location and elevation (Jeremy White, NPS Night Skies Program Physical Science Technician, written communication, 21 September 2015).

Table 61 shows the observed and light pollution ratio values for select sky luminance measures from the four NSNSD field visits at FOBU. A complete listing of all the sky luminance data can be found in Appendix I-Appendix L. The “observed” result corresponds to what an observer on the ground would see, and the light pollution ratio (LPR) expresses the amount of artificial light above the natural condition (NPS 2015). The LPR is expressed as a percentage, for example a value of 0.10 = 10% above natural conditions (NPS 2015). The zenith value is one of the more widely reported sky quality indicators. This measure is calculated based on a one degree diameter circle centered on the zenith (NPS 2015). Values lower than 21.3 mag/arcsec^2 generally indicate a degraded sky quality (NPS 2015). The mean all-sky indicator is an unbiased measure of the amount of light reaching the observer from sky luminance (NPS 2015). The natural moonless reference condition for this indicator is 21.6 mag/arcsec^2 (NPS 2015). The median value is the middle sky brightness value for the entire sky; a view of the entire sky will reveal most areas to be near this value (NPS 2015). The median value can also be referenced to the natural moonless condition (NPS 2015). The measured values for each of these indicators was near or below the reference condition value and the LPR ranged from a low of <10% to 74% (Table 61). These values indicate that there was some degradation to the quality of the night sky at FOBU at the time of the field visits.

Table 61. Select sky luminance measures in mag/arcsec² for the four NSNSD field visits to FOBU.

	13 October 2004		14 October 2004		18 August 2006		26 September 2006	
	Observed	**LPR**	**Observed**	**LPR**	**Observed**	**LPR**	**Observed**	**LPR**
	(mag/arcsec²)		**(mag/arcsec²)**		**(mag/arcsec²)**		**(mag/arcsec²)**	
Zenith	21.40	0.31	21.36	< 0.10	21.8	< 0.10	21.73	< 0.10
Mean all-sky	20.84	0.74	20.86	0.27	21.57	0.25	21.21	0.25
Median	20.97	0.52	20.93	0.16	21.65	0.10	21.29	0.11

Results for the illuminance from city light domes measure for each night is shown graphically in the false color estimated artificial sky glow mosaics (Figure 62). These graphics represent the sky luminance from artificial sky glow. Land features and individual light trespass sources have been removed, leaving an at-a-glance representation of the amount of light pollution from sky glow observed at Rubey Point (NPS 2015). In these figures, light intrusions from local light sources can be seen. The sky glow from Kemmerer, Wyoming appears between bearings 100°-120° and the Naughton Power Plant is found at the bearing of 90°. Other communities visible are Evanston, Wyoming (bearing 190°) and Logan, Utah (bearing 260°).

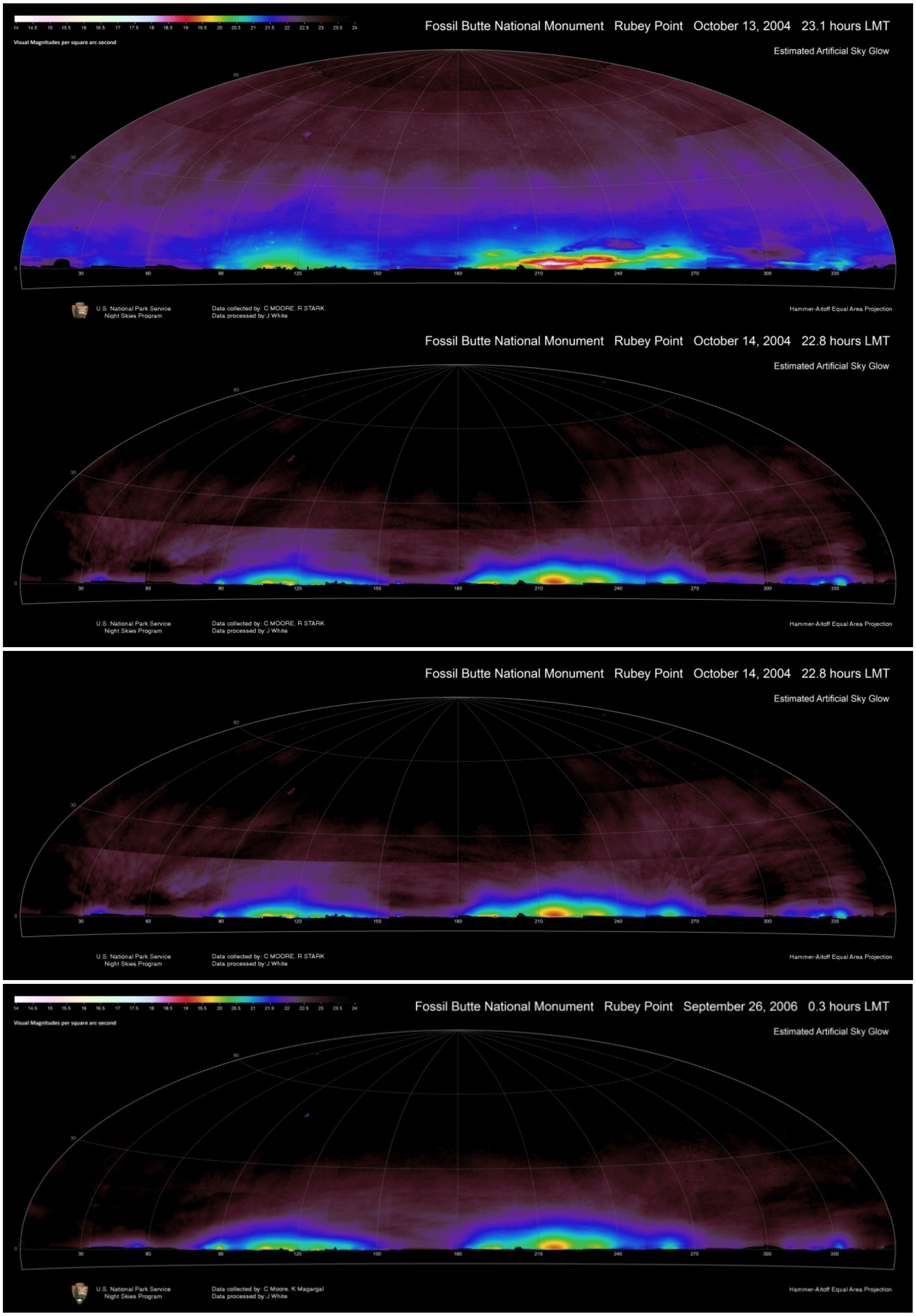


Figure 62. False color mosaic images of the FOBU night sky on (A) 13 October 2004, (B) 14 October 2004, (C) 18 August 2006, and (D) 26 September 2006. Images are taken from the top of Rubey Point. Images were taken from Moore 2004a, 2004b, 2006a, and 2006b.

In Figure 62 the bearings range from 0° on the left, 180° in the center, and 360° on the left-hand side of each image. The most dominant feature is the sky glow from the Salt Lake City/Ogden, Utah area centered at bearing 218°. In comparing the false color mosaics for the four nights, although there is some slight variation in the images due to atmospheric conditions the images are fairly consistent. Specific data on the brightness of these light domes were available for the 26 September 2006 field visit and are given in Table 62. Values for these observations are given in mags; the lower the value (smaller or more negative), the brighter the object (Moore 2006b).

Table 62. Light dome data from 26 September 2006 night visit. Units in magnitudes (Moore 2006c).

City	Brightness (mags)
Naughton Power Plant	-0.79
Kemmerer and south	-2.70
Evanston	-1.38
Salt Lake-Ogden	-3.07
Logan	-0.27
Total	**-4.02**

The illuminance measures are an indication of the amount of light that is striking the ground (horizontal) or a vertical plane (vertical) (NPS 2015). The natural reference condition for moonless nights for the horizontal is 0.8 milli-Lux and 0.4 milli-Lux for the vertical (NPS 2015). The horizontal values for the four NSNSD visits to FOBU ranged from a minimum of 0.69 milli-Lux to a maximum of 1.30 milli-Lux (Moore 2004a, 2004b, 2006a, and 2006b). The vertical value ranged from a minimum of 0.53 milli-Lux to a maximum of 0.96 milli-Lux (Moore 2004a, 2004b, 2006a, and 2006b). The LPR for the horizontal ranged from 0.09 to 0.45 and the vertical values ranged from 0.44 to 1.12 (Moore 2004a, 2004b, 2006a, 2006b).

The Sky Quality Meter (SQM) values for the four NSNSD field visits ranged from a minimum value of 21.20 mag/arcsec^2 to a maximum value of 21.81 mag/arcsec^2 (Moore 2004a, 2004b, 2006a, and 2006b). The Bortle Class and ZLM values were available only for the 26 September 2006 field visit. The Bortle Class recorded for that night was three with a ZLM of seven (Moore 2006c). SQM values of 21.3 (Bortle Class 1-3) and greater are within the range of natural skies, 19.5-21.3 (Bortle Class 4-6) could be considered significantly degraded, while values less than 19.5 (Bortle Class 7-9) are considered severely degraded (NPS 2015). As was the case with the sky luminance values, the night sky at FOBU are near the break point between natural and significantly degraded skies, suggesting some degradation of the night sky has taken place.

<u>Threats and Stressor Factors</u>

FOBU is subjected to low levels of anthropogenic light pollution. This light pollution comes from oil and gas drilling operations and urban areas southwest and east of the park (see Figure 58). Currently there are few to no light fixtures within the park and it is particularly important that within-park sources of light be contained, eliminating light trespass and minimizing anthropogenic sky glow. Lorenz (2006) and Danko (2014) re-created a light pollution map that displays the level of light pollution occurring in FOBU and surrounding areas (Figure 63). The park is located in two levels of light pollution ranging from two to three on the Bortle Scale, which means the dark night sky is slightly impaired. The PacifiCorp Naughton Plant was the nearest oil and gas drilling operation (Figure 58); however, the light pollution map displays higher light pollution from Salt Lake City and Kemmerer than from the plant. Further the NPS NSNSD has developed a GIS model derived from data from the 2001 World Atlas of Night Sky Brightness (Cinzano 2001), which depicts zenith sky brightness (the brightness of the sky directly above the observer). A neighborhood analysis is then applied to the World Atlas to determine the anthropogenic sky brightness over the entire sky. Finally, the modeled anthropogenic light over the entire sky is presented as a ratio (ALR) over the natural sky brightness (Duriscoe in preparation). Based on this GIS model, the all-sky anthropogenic ratio ranges from 0.44 to 0.66 within the park boundary, indicating a sky 44% to 66% brighter than average natural conditions, based primarily on the proximity to Kemmerer and the PacifiCorp Naughton plant (Figure 64). The median value for the park is 0.53 or 53% brighter than average natural conditions. According to NPS (2010), the park's location was slightly isolated from artificial light from industrial plants and city lights.

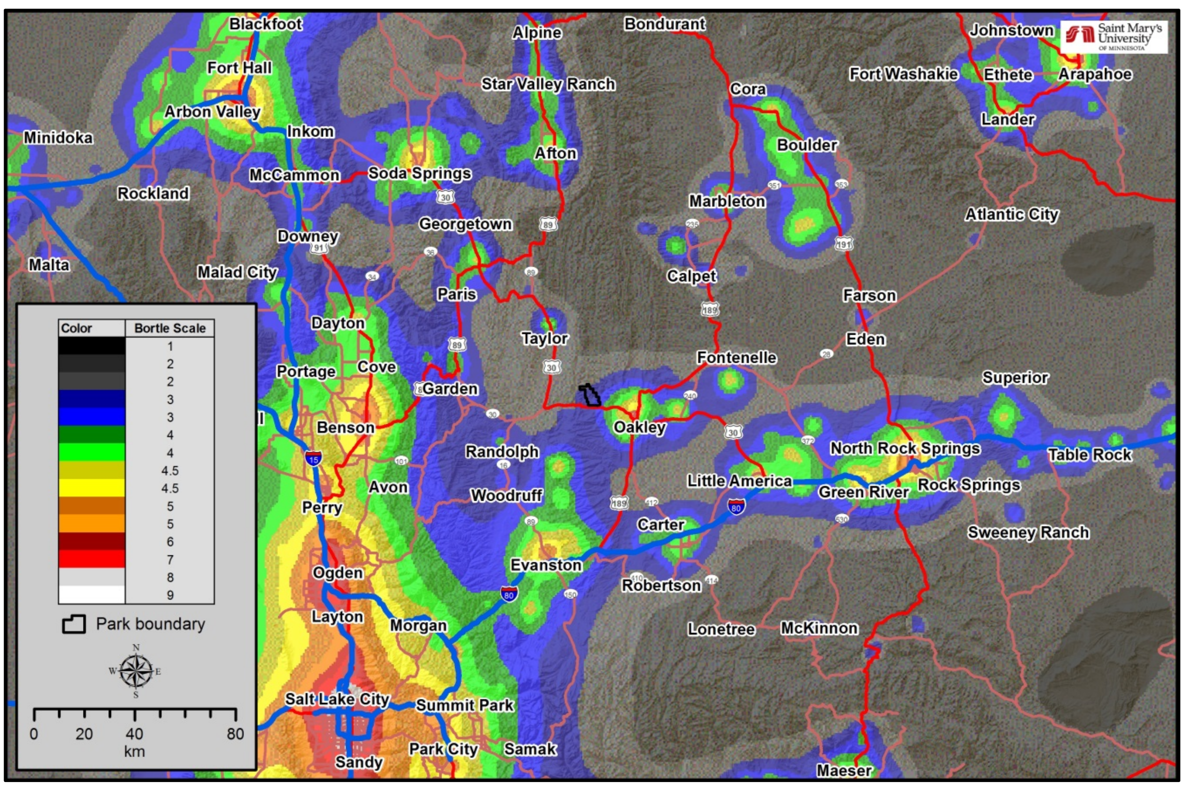
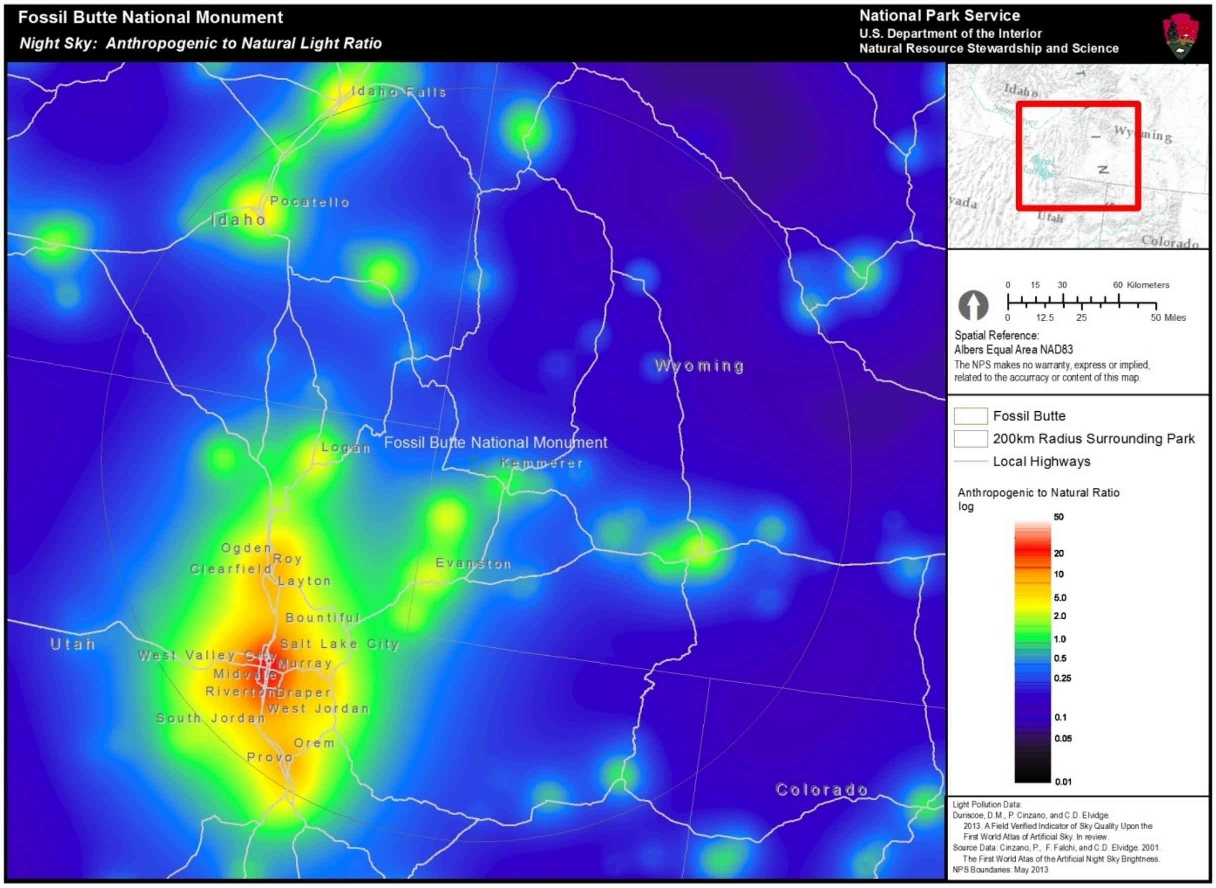


Figure 63. Levels of light pollution occurring in FOBU, and in surrounding areas (Lorenz 2006; Danko 2014).



Created by NPS Natural Sounds & Night Skies Division and NPS Inventory and Monitoring Program MAS Group on 20150921

Figure 64. Regional view of anthropogenic light near FOBU expressed as an all-sly anthropogenic light pollution ratio. Fossil Butte has an LPR range of 0.44 to 0.66 with a median value of 0.56.

Data Needs/Gaps

A draft plan for natural lightscape management in FOBU, which could include zoning the park area to indicate where outdoor lighting is required and where the naturally dark zone occurs, would greatly benefit park managers and researchers. Continued measurement of the entire sky brightness condition should occur on a periodic basis, about once every 5 years, with Rubey Point as the preferred observation site, in order to track external threats. This would provide data that could determine if the light intrusion has stabilized or continues to degrade.

Overall Condition

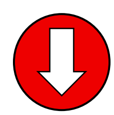
NPS Night Sky Team's Suite of Measures

During scoping meetings, the FOBU NRCA team assigned the NPS Night Sky Team's suite of measures a *Significance Level* of 3. Based on the interpretation of the data available from the NSNSD's 2004 and 2006 field visits, all of the measures were determined to be either in the "degraded" range or right on the border between "natural" and "degraded." The data clearly indicate that the dark night skies are negatively impacted by the oil and gas drilling operations and urbanization of the areas to the east and west of FOBU. Based on these factors, a *Condition Level* of

2, meaning moderate concern was assigned to this component. While a population study was not conducted as part of this analysis, it can be assumed that the impact from the urban light domes, especially the Salt Lake City/Ogden area, will increase as these urban areas continue to grow. Based on this assumption, a downward or continuing degradation trend was assigned. It should be noted that the scoring and trends analysis for this component represents the conditions of the dark night sky at FOBU as of 2006, and may or may not accurately reflect the current conditions. This analysis does provide a baseline reference condition to be used in conjunction with data from a NSNSD visit that reflects the current condition, to more accurately interpret the current condition of the night sky at FOBU.

Weighted Condition Score

The dark night sky component was assigned a *Weighted Condition* Score of 0.67, indicating that the condition warrants significant concern. The downward trend was assigned based on the expected population growth in the Salt Lake City/Ogden areas. Further, no known light pollution mitigation measures have been taken by local communities or industrial or commercial facilities adjacent to the park. A moderate confidence level was assigned, primarily due to the fact that the data used was from 2004 and 2006 and it is unknown if this represents the current condition of dark night skies at FOBU.

Dark Night Skies			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.67**
NPS Night Sky Team Suite of Measures	3	2	

4.14.6. Sources of Expertise

- National Park Service Night Sky Team members Dan Duriscoe, Chad Moore, Teresa Jiles, Jeremy White, and Robert Meadows

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4.15. Viewscape

4.15.1. Description

A viewscape is the area that is visible from a particular location or set of locations, often developed using GIS analysis tools. Two datasets are required to calculate a viewscape using GIS: a digital elevation model (DEM) and point or polyline data defining points in which a person would be viewing a landscape. With the defined data, GIS software determines visibility to and from a particular cell or set of cells in a DEM resulting in a viewscape layer. This viewscape layer is a raster that defines the visible area on the landscape from the point or set of points contained within an outline of a polygon. Combining viewscape layers with layers that identify areas of undesirable impacts on the landscape creates a quantitative description of visual stress on a viewscape; repeating this process for multiple viewscape layers in a pre-defined landscape, such as a National Park, provides a quantitative description of stress across the viewscape in the area.

Multiple studies indicate that people prefer natural views over-developed landscapes (Sheppard and Sheppard 2001, Kearney et al. 2008, Han 2010). The National Park Service Organic Act (16 U.S.C. l) implies the need to protect the viewscapes of National Parks, Monuments, and Reservations. However, FOBU’s small size makes it difficult to maintain views that are natural and unaffected by outside land uses (NPS 1980, Photo 16, Photo 17).

Photo 16. South-facing panoramic view from Cundick Ridge (Shannon Amberg, SMUMN GSS).

Photo 17. View of Fossil Butte (Tyra Olstad, NPS).

During initial project scoping, project stakeholders identified viewscape as a placeholder component. These components are recognized in the assessment as an important resource for the park, but little or no data exist to examine its current condition. Available data will be summarized; however, condition will not be assessed. A description of the component, available data, and potential threats and stressors are provided for the primary purpose of inclusion in a future assessment when appropriate data are available.

4.15.2. Measures

- Current viewscape
- Change in viewscape since 1850s

4.15.3. Reference Conditions/Values

The reference condition for the park's viewscape was not defined during project scoping. A potential reference condition could be the viewscape prior to European settlement (~1850s).

4.15.4. Data and Methods

Chicken Creek Road, Cundick Ridge, and the Historic Quarry Trail were chosen by SMUMN GSS as vistas within the park for this analysis. Chicken Creek Road vista consists of five point shapefiles (including the Visitor Center); Cundick Ridge vista consists of one point shapefile; and the Historic Quarry Trail vista consists of one line shapefile (Figure 65). Visitors frequently observe the landscape in the park from theses defined observation points. At each of these points, a viewshed was calculated using ESRI's Spatial Analyst Viewshed Tool in ArcGIS 10.0, which requires point or polyline GIS data (representing the viewing location) and a DEM. For each of the observation points, a point shapefile was created for use with the Viewshed tool and the DEM used for each observation point was mosaicked from the National Elevation Dataset (NED), which has a resolution of approximately 10 m (33 ft). A 1.7-m (5.5-ft) offset was applied to each observation point shapefile to account for average human height. The result of the operation is a theoretical viewshed layer that represents the visible area from a point without correcting for visibility factors (e.g., vegetation, smoke, humidity, heat shimmer, or curvature of the earth).

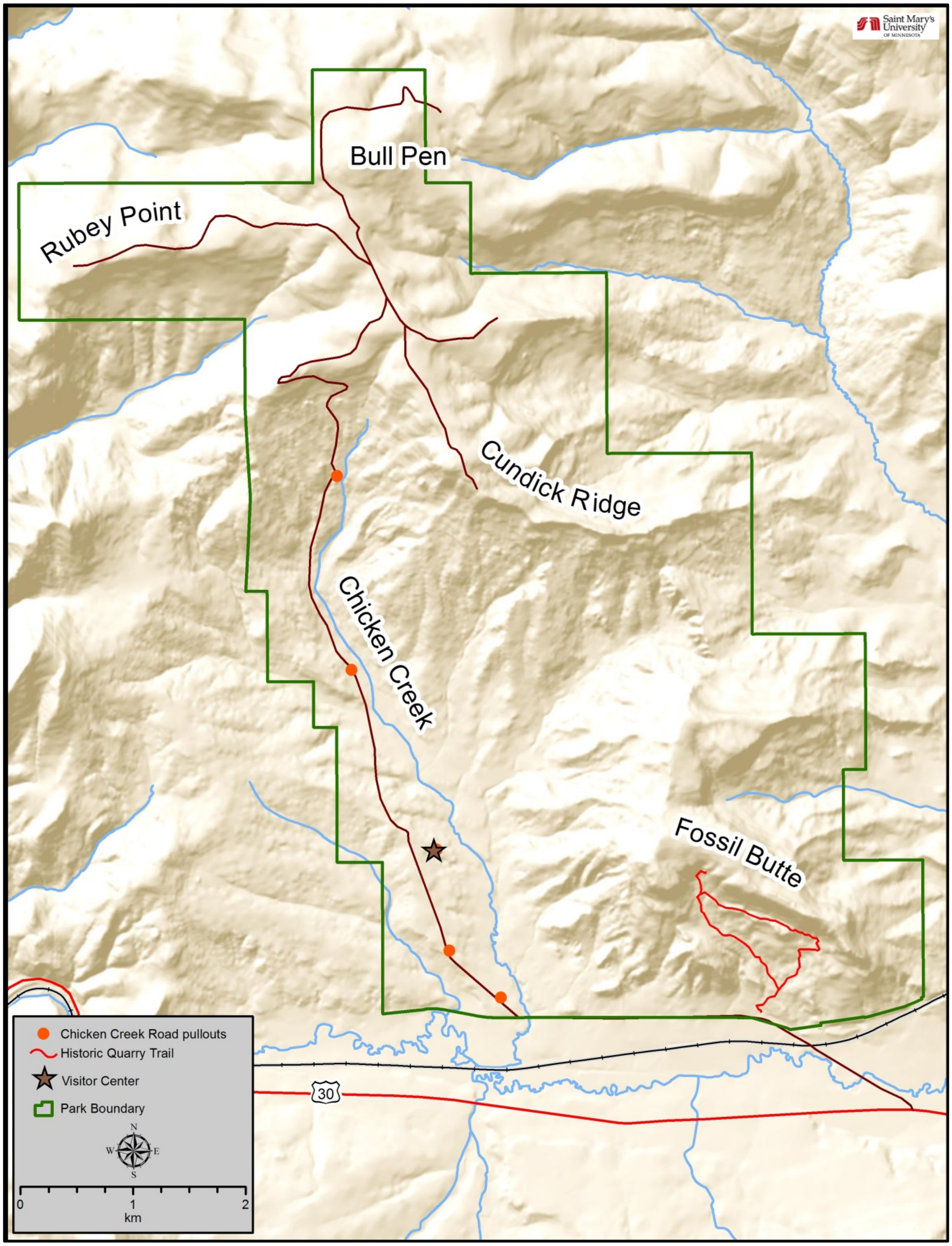

Figure 65. Vista locations in FOBU.

4.15.5. Current Condition and Trend

Current Viewscape

The composite visible area from all of the vistas (hereafter, composite viewshed) is 352 km^2 (135.9 mi^2) (Figure 66). Approximately 1,640 ha (4,053 ac) of FOBU is visible from all of the vistas. That is approximately 49% of the park. Natural landscapes dominate the viewshed from the select vistas. Although the road is visible from Chicken Creek Road pullouts and Cundick Ridge, there are few other non-contributing features inside the park. Visibility of development features at vistas located toward the park's northern boundary may be lower, due to the distance from the main highway. The few development features toward the northern portion of the park include parking lots, paved and unpaved trails, and fencing. Visibility of development (powerlines, Highway 30, buildings) on surrounding land is higher at vistas near the southern boundary of the park. Most of the development features that are in the park provide safety and are of interpretive value to visitors, such as the viewing parking lots, trails, fencing, and the Visitor Center.

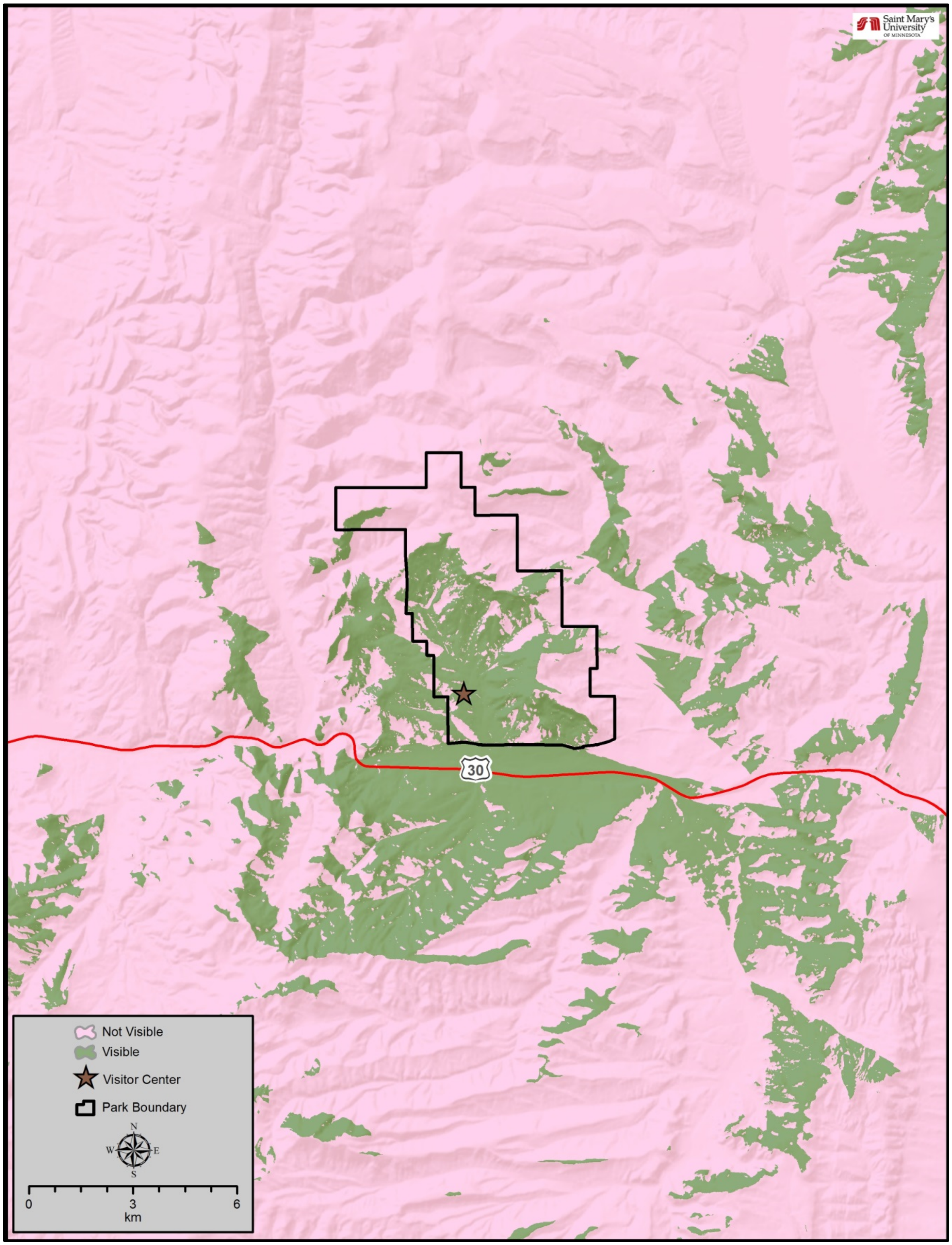

Figure 66. Composite viewshed for select vistas in FOBU.

Change in Viewscape Since 1850s

There are no available data on the viewscape in the park between 1985 and 2000. There are also little available data on the change in viewscape between 2000 and 2015. The National Land Cover Dataset (NLCD) contains changes in landcover classes between 2001 and 2011 (Jin et al. 2013, Figure 67). The NLCD does not summarize changes in viewscape, but may aid in displaying areas that have been developed (urban) in recent years. Annual aerial photos of the park and surrounding areas would provide a more detailed picture of change.

According to the NLCD (Jin et al. 2013), there was little change in FOBU landcover between 2001 and 2011. A majority of visible landcover in the park is considered Shrub Scrub (Figure 68). The Shrub Scrub landcover class (referred to as shrub steppe by park managers) includes, "areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation." This class includes "true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions" (MRLC 2014, p. 1). A majority of the landcover changes in the park from 2001 to 2011 were to the Shrub Scrub classification. Other smaller areas in the park were converted to Deciduous Forest, Evergreen Forest, and Grassland/Herbaceous classifications (Figure 68). There were no significant changes (e.g., large areal conversions, number of areas changed) in the park or in surrounding areas regarding urban development between 2001 and 2011. It should be noted that there may have been more recent changes in landcover since the publication of this NRCA document.

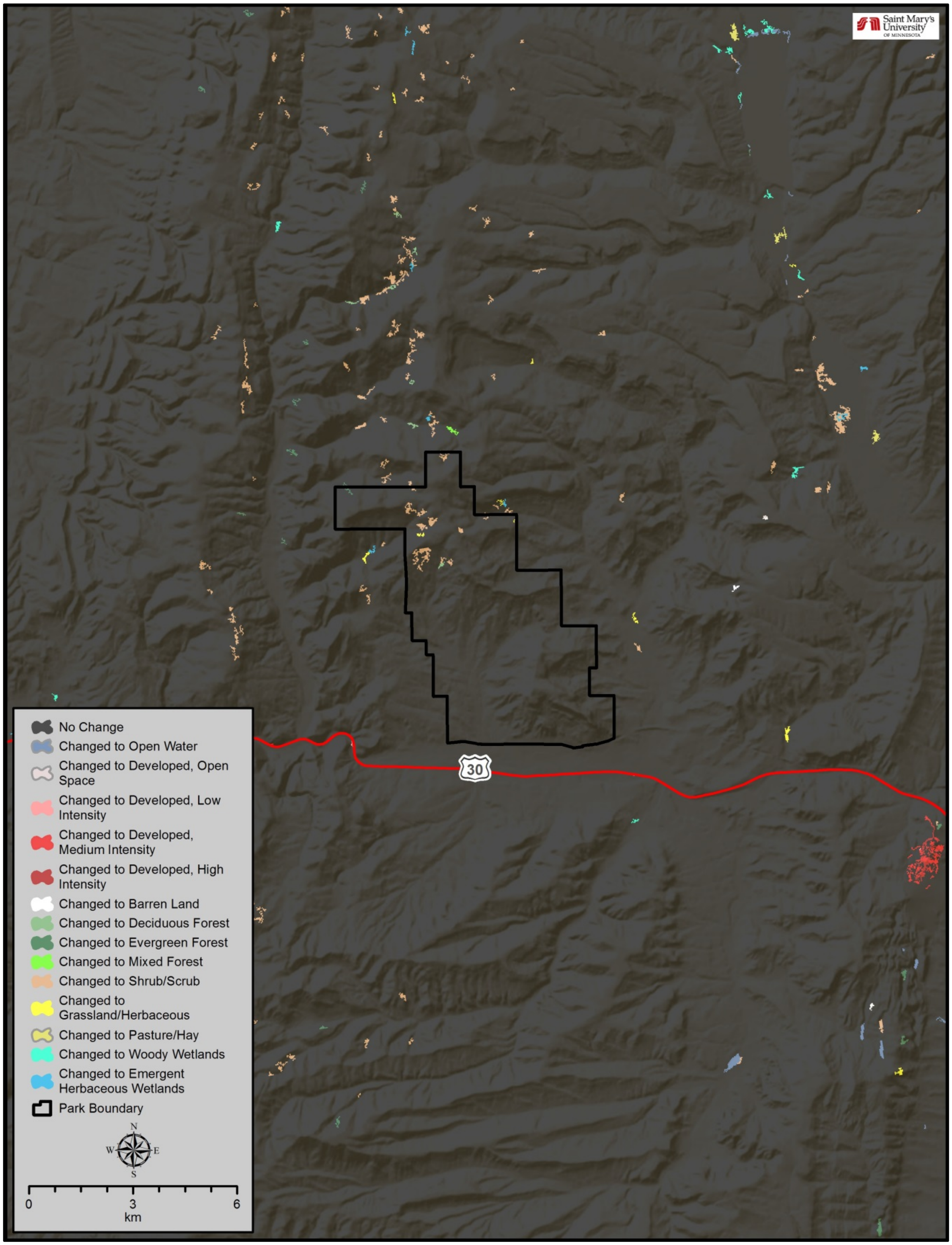

Figure 67. Landcover change in and around FOBU between 2001 and 2011 (Jin et al. 2013, MRLC 2014)

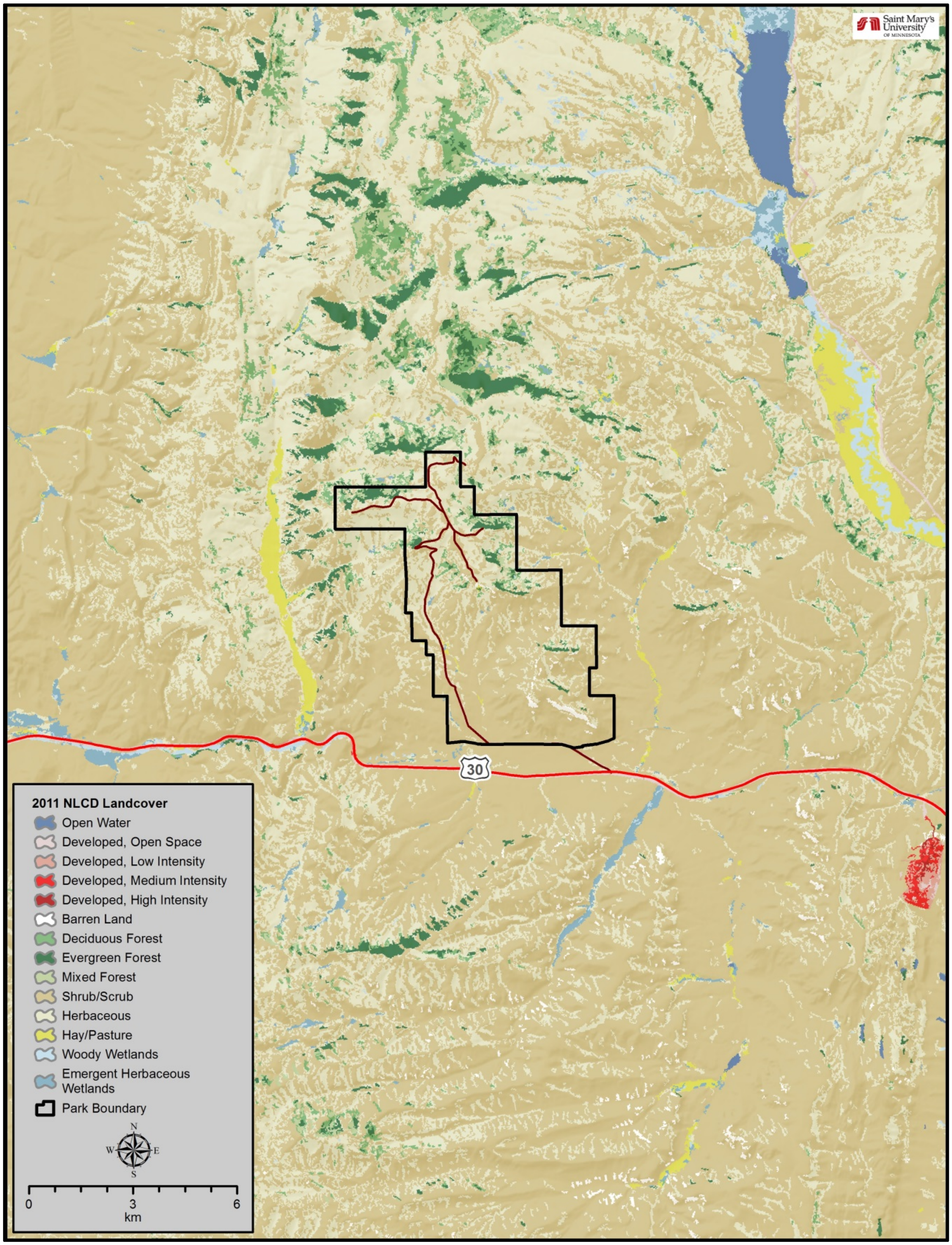

Figure 68. The 2011 landcover that is visible from vistas in FOBU (Jin et al. 2013, MRLC 2014).

Threats and Stressor Factors

The FOBU park staff identified several existent and potential threats to viewscape in the park. A major concern to park managers is development on lands surrounding the park. These threats include wind energy development, natural gas and oil development, potential development of the Highway 30 corridor, and power transmission lines.

Wind energy development is a major threat to the viewscape in the park. According to DIP et al. (2006) and NPS (2012), there was a proposal to construct more than 100, 91 m (300 ft) tall wind turbines on Fossil Ridge (Figure 69), which is located less than 8 km (5 mi) south of the park boundary. No permits for this development were issued as of 2012; however, future development is still a possibility. The closest wind farms are located near Evanston in Uinta County, which is more than 48 km (30 mi) to the south of the park. These wind farms are active but not visible from the park.

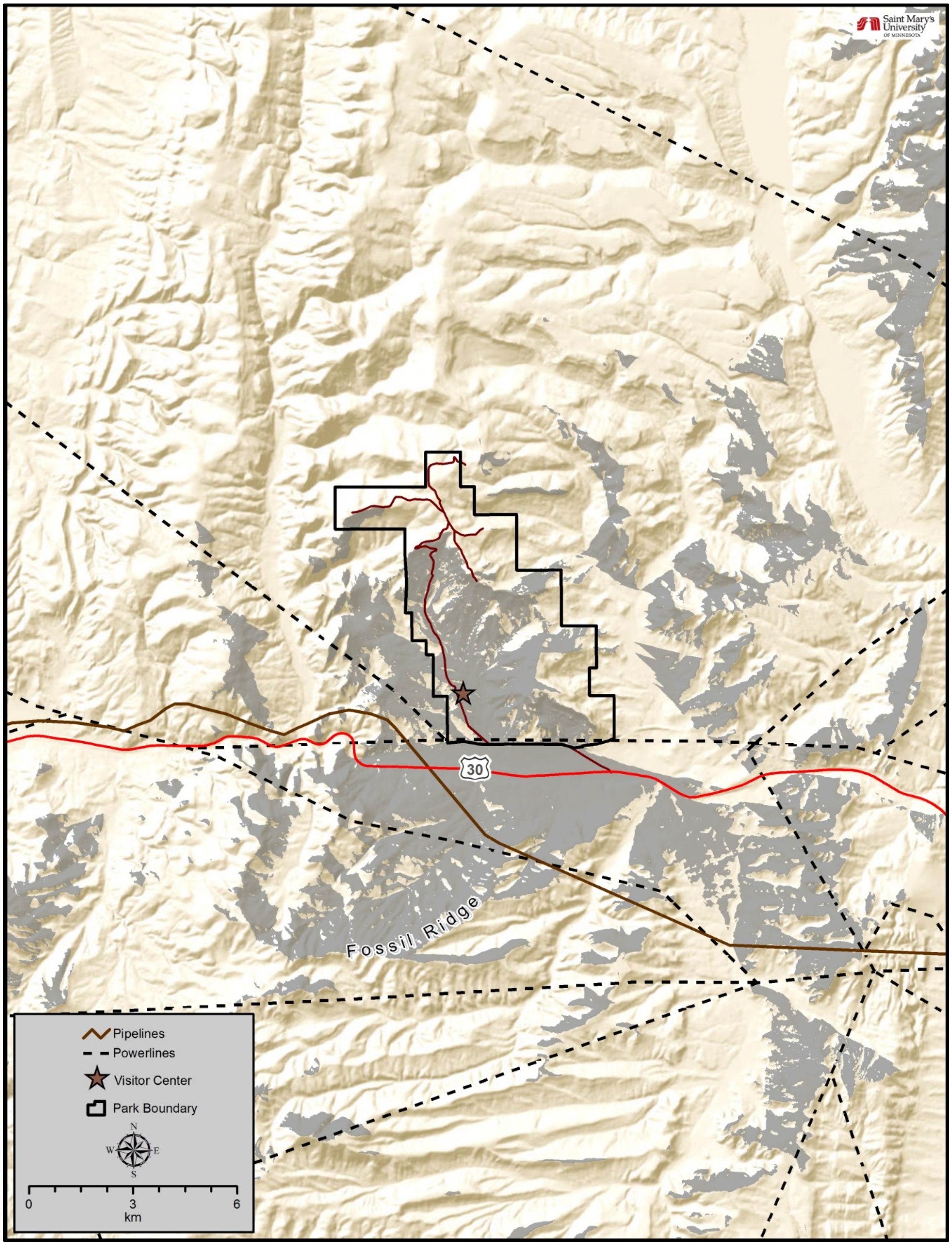

Figure 69. Location of powerlines, pipelines, US Highway 30, and proposed wind farm on Fossil Ridge in relation to FOBU. The gray areas represent areas visible from the selected vistas in the park.

Natural gas and oil development is another threat to the park's viewscape. A major gas pipeline runs just south of the park (NPS 2012, Figure 69). Any future maintenance or expansion of this pipeline may threaten the natural viewscape. There are 38 oil and gas fields in Lincoln County, and 95 permits to drill in the county have been granted. However, none of the fields or permits are located in township 21 north and range 117 west (land located just east of the park; NPS 2012).

Power transmission lines are also a threat to the viewscape at FOBU. Several power lines run just south and west of the park boundary (NPS 2014, Figure 69). Transmission lines are over 30 m (100 ft) tall, which makes it difficult for visitors to overlook their presence among the natural viewscape.

Any potential development of the Hwy 30 corridor would also be a threat to the FOBU viewscape, due to its close proximity to the park. Actual road and/or building construction activity and its results would impact the natural views from the park (Figure 69).

Data Needs/Gaps

There are no historic data on the natural viewscape in the park. Aerial photos or historic ground condition photos documenting any change over the years would be useful to park managers in assessing the condition in the future. While this assessment provides some baseline information regarding the park's visual resources, it should not be considered all-inclusive. Incorporation of different and new GIS data sets, such as a higher resolution DEM, additional non-natural feature layers, or land ownership data with more coverage, would enhance any future analysis. Continued development of spatial data that explain landscape change will enable accurate and up-to-date viewshed assessments of the metrics examined in this analysis.

Overall Condition

An evaluation of the parks veiwscape was not conducted as part of the NRCA. The park resource staff recognized the importance of this measure, but realized that historical data needed to complete an assessment was limited if available. This analysis was conducted to provide a baseline for comparison of future viewscape analyses.

4.15.6. Sources of Expertise

- This assessment relied on available spatial data and published literature as the primary sources of expertise, with review by FOBU staff.

4.15.7. Literature Cited

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4.16. Paleontological Resources

4.16.1. Description

FOBU was established precisely for its wealth of paleontological resources, the vitality of which is reflected in the park's enabling legislation to "preserve outstanding paleontological sites and related geological phenomena, and to provide for the display and interpretation of scientific specimens" (NPS 1991, p. 5). The Hayden Survey of the 1870s and 1880s represents the initial paleontological work within Fossil Basin, with Fossil Butte first appearing in literature in 1879 when the area was described by Peale (1879) (Tweet et al. 2012). The Fossil Butte region has long been preserved as public lands, with commercial fossil collecting occurring in the Fossil Basin's Green River Formation beginning in the late 19th century and greatly expanding after the 1960s (Tweet et al. 2012). It is estimated that possibly half a million fish fossils were removed between 1965 and 1990 (Tweet et al. 2012). Today there are several former commercial sites within FOBU, including the Haddenhams site and the Larson Fish Quarry, while the park continues to cooperate with local commercial quarries to raise awareness of fossils within the basin (Tweet et al. 2012).

Photo 18. Wyoming's state fossil, *Knightia eocaena* (NPS photo)

FOBU protects a unique fresh-water fossilized assemblage of organisms that once lived in or around an ancient lake of the Eocene epoch known as Fossil Lake (Tweet et al. 2012). Millions of fish fossils are present at FOBU along with the fossilized remains of insects, plants, and other animals, allowing for interpretations of an entire ecosystem and the evolutionary study of modern groups (NPS 1991, Graham 2012). Perhaps the most significant aspect of this assemblage is the exceptional preservation of complete skeletons and rarely preserved organisms, referred to as "Lagerstätte" (Graham 2012). The quality of this preservation is rarely seen in the fossil record and is the result of water conditions and fine-grained lake sediments that combined to preserve articulated skeletons and delicate fossils (NPS 2014a). As a whole, the fossil beds of FOBU allow for the reconstruction of the Earth's major transition from a greenhouse to an icehouse climate, including preserving a detailed history of complex Eocene paleoenvironments, paleoclimates, and ancient organisms associated with Fossil Lake (Graham 2012).

The exposed geologic record at FOBU includes an episode of marine and marginal marine deposition during the Early Triassic, floodplain and lake deposition during the Eocene, as well as more recent surficial processes (Tweet et al. 2012). These stratigraphic units, including their associated depositional environment and paleontological resources within FOBU, are presented in Table 63. Triassic rocks, the oldest within the park, were deposited between 250 and 245 million years ago and include the Woodside Redbeds and overlying Thaynes Limestone (Tweet et al. 2012). These two formations represent a series of marine advances and retreats during the Early Triassic, with the Woodside Redbeds deposited during a marine regression and the Thaynes Limestone deposited during a rapid transgression from the west (Tweet et al. 2012). Fossils are very rare in the Woodside Redbeds, while the Thaynes Limestone is known to be very fossiliferous and dominated by shelled marine invertebrates such as mollusks (Tweet et al. 2012). Neither formation is known to be fossiliferous within FOBU, although the Thaynes Limestone presents high potential for containing fossils in the park.

Table 63. Stratigraphy, fossils, and depositional setting of FOBU (table recreated from Tweet et al. 2012). Formations are listed in order of age, from oldest (Woodside Redbeds) to youngest (Quaternary sediments).

Formation	Age	Fossils Within FOBU	Depositional Environment
Woodside Redbeds	Early Triassic	None to date; fossils are very rare in this formation in general	Terrestrial coastal settings
Thaynes Limestone	Early Triassic	None to date; marine invertebrates are most likely, and brachiopods, bivalves, ammonites, gastropods, and crinoids have been found in Fossil Basin	Outer shelf to inner shelf marine settings
Wasatch Formation	Early Eocene	Invertebrate trace fossils and locally abundant fragmentary fossils of turtles, lizards, crocodilians, and mammals	Fluvial and floodplain systems, associated with Fossil Lake for much of the formation's history
Green River Formation	Early Eocene	Stromatolites and other microbialites, plant fossils, freshwater invertebrates, insects, rays, bony fish, rare tetrapods, and abundant vertebrate coprolites	Freshwater to evaporative lacustrine settings (Fossil Lake)
Quaternary sediments	Pleistocene-Holocene	Bison bones	Fluvial and landslide deposits

Following the Thaynes Limestone formation, a nearly 200 million year geological gap exists until the Late Cretaceous when a major mountain-building event known as the Laramide Orogeny began forming Fossil Basin as a result of compressional stresses (Tweet et al. 2012). The subsidence of Fossil Basin immediately followed and persisted into the Eocene, allowing for the creation of Fossil Lake and the deposition of the Wasatch and Green River formations (Tweet et al. 2012). This deposition dates to between 54 and 50 million years ago, when an abrupt increase in global temperatures formed an extensive great-lake system in the warm-temperate climate of Wyoming, Utah, and Colorado during the late Paleocene and Eocene (Graham 2012, Tweet et al. 2012). This included Lake Gosiute to the east on the opposite side of Oyster Ridge, Lake Uinta to the south on the other side of the Uinta Mountains, and Fossil Lake of Fossil Basin, the smallest and shortest-lived of the three lakes (Tweet et al. 2012). Fossil Lake dates to the early part of the Green River

Formation, and three major phases are present in the lake's history (Tweet et al. 2012). The earliest phase of Fossil Lake was concentrated in the southern part of Fossil Basin, where the lake was largely freshwater and shallow (Tweet et al. 2012). The middle phase featured a period of greater precipitation that fed the growing freshwater lake (Tweet et al. 2012). The lake was populated with a myriad of fish species and the surrounding environments were composed of lush habitats, home to ancestral rodents, dog-sized horses, bats, carnivorous mammals, and a wide variety of insects and snakes (Graham 2012, Tweet et al. 2012). Fossil Lake's final phase was largely hypersaline as the basin became closed and was filled by the encroaching rivers of the Wasatch Formation (Tweet et al. 2012). These three phases can be identified from the sedimentary strata of the Green River Formation (Graham 2012, Tweet et al. 2012). These strata are the Road Hollow Member (phase 1), the Fossil Butte Member (phase 2), and the Angelo Member (phase 3) (Graham 2012, Tweet et al. 2012).

As can be seen from Table 63, the Wasatch Formation, the Green River Formation, and the Quaternary sediments are the geologic formations that are known to be fossiliferous at FOBU (Tweet et al. 2012). The highly erosive Wasatch Formation underlies, overlies, and intermingles with the Green River Formation and is comprised of fluvial, floodplain, deltaic, and shoreline deposits that once surrounded Fossil Lake (Graham 2012). The Wasatch Formation represents the terrestrial environment that surrounded Fossil Lake, and produces primarily fragmented fossils from a variety of early mammals and reptiles (Evenden et al. 2002, NPS 2014b). Four members of the Wasatch Formation are present at FOBU (Tweet et al. 2012). From oldest to youngest they are the lower member, the main body, the mudstone tongue, and the Bullpen Member (Tweet et al. 2012). The majority of fossils in the Wasatch Formation come from the main body and it is the only member of the formation that is known to be fossiliferous at FOBU (Graham 2012, Tweet et al. 2012). Fossils found within the main body include wood, seeds, invertebrate trace fossils, reptiles, birds, eggshell fragments, and mammals such as multituberculates (rodent-like early mammals), dinoceratans (rhinoceros-like mammals), marsupials, and enigmatic mammals (Tweet et al. 2012). The Wasatch Formation also contains fossils reworked from older Jurassic layers such as bivalves, Cretaceous-age fish, and dinosaur teeth (Graham 2012). Fossils as old as the Paleozoic have also been found in rocks of the Wasatch Formation (Tweet et al. 2012). Table 64 contains a list of the fossilized mammals and reptiles found within the Wasatch Formation at FOBU.

Table 64. Mammal and reptile fossils of the Wasatch Formation, FOBU. The table is recreated from a list of species compiled by Arvid Aase, FOBU curator, and originally published in Graham (2012).

Mammals (39 Genera)	
Lemur-like primates	**Arboreal and climbing insectivores**
Coepelemur australotutus	*Anemorhysis* sp.(arboreal)
Notharctus nunienus	*Omomys carteri* (arboreal)
Notharctus robinsoni	*Apheliscus insidiosus* (climbing)

Table 64 (continued). Mammal and reptile fossils of the Wasatch Formation, FOBU. The table is recreated from a list of species compiled by Arvid Aase, FOBU curator, and originally published in Graham (2012).

Mammals (39 Genera)	
Arboreal omnivores	*Haplomylus scottianus* (climbing)
Microsyops latidens	*Palaeanodon* sp. (climbing)
Microsyops scottianus	**Ground-dwelling herbivores**
Cantius frugivorous	*Ectocion superstes*
Smilodectes mcgrewi	*Phenacodus trilobatus*
Arboreal herbivores	*Esthonyx spatularius*
Apatemys chardini	**Brontotheres**
Rodents	*Lambdotherium popoagicum*
Leptotomus parvus	*Palaeosyops frontinalis*
Microparamys sp.	**Artiodactyls**
Paramys copei	*Hexacodus uintensis*
Paramys excavates	*Bunophorus macroptemus*
Knightomys depressus	*Diacodexis metsiacus*
Carnivores	*Diacodexis secans*
Uintacyon sp.	*Hyopsodus wortmani* (elongate, dachshund-shaped)
Miacis sp.	**Others**
Vulpavus canavus	*Hyracotherium vasacciense* (horse)
Viverravus sp.	*Peratherium marsupium* (possum)
Prolimnocyon sp. (climbing)	*Homogalax protapirinus* (tapir)
Palaeosinopa lutreola (amphibious fish-eater)	*Diacodon alticuspis* (leptictid)
	Coryphodon sp. (hippo-like pantodont)
	Didymictis protenus (viverravid)
	Meniscotherium chamense (phenacodontid condylarth)
	Ectoganus sp.(burrowing stylinodontid taeniodont)
	Prototomus secundaria
Reptiles (8 Genera)	
Lizards	**Turtles**
Glyptosaurus sylvestris (armored)	*Baptemys wyomingensis*

Table 64 (continued). Mammal and reptile fossils of the Wasatch Formation, FOBU. The table is recreated from a list of species compiled by Arvid Aase, FOBU curator, and originally published in Graham (2012).

Reptiles (8 Genera) (continued)	
Lizards (continued)	**Turtles (continued)**
Melanosaurus sp.	*Echmatemys cibollensis*
Xestops vagans	*Amyda* sp. (soft-shelled)
Alligator	**Crocodile**
Procaimanoidea sp.	Crocodylid (indeterminate)

Having been formed from ancient lake sediments, the Green River Formation represents the most important rock unit of Fossil Butte (NPS 1991). The Green River Formation is world-renowned for the preservation quality and remarkable diversity (Photo 19) of its fossil fish and other lake-dwelling organisms (NPS 2014a). Commercial fossil collection in areas surrounding FOBU produces tens-of-thousands to hundreds-of-thousands of fossil fish each year (NPS 2014a). The oldest portion of the Green River Formation is the Road Hollow Member (Graham 2012). This member developed on a floodplain in the southern part of the basin and as yet, remains to be thoroughly investigated (Graham 2012). Fossils from this member include leaves, plant debris, bivalves, gastropods, ostracodes, turtles, birds, crocodile teeth, mammals, and fish (Tweet et al. 2012). The overlying Fossil Butte Member contains most of the known fossils from FOBU, with fish and their associated coprolites the most well-known component of the fossil assemblage (Tweet et al. 2012). This member represents a period of greater precipitation that led to Fossil Lake being much larger in size with a myriad of fish species in addition to microbialites, spores/pollen, leaves, bivalves, gastropods, insects, birds, amphibians, reptiles, and mammals (Graham 2012, Tweet et al. 2012). Fossils from the Fossil Butte Member are designated in terms of F-1 and F-2, with F-1 including those sites from the “18-inch layer” of the center of the basin, and F-2 including those sites from the “split-fish” layers largely found in the northeast part of the basin (Tweet et al. 2012). The youngest member of the Green River Formation, the Angelo Member, represents a climatic stage in Fossil Lake when temperatures began to fall with the onset of global cooling at the end of the early Eocene (Tweet et al. 2012). This climate shift resulted in decreased precipitation and surface runoff (Graham 2012). The cooler, more arid climates coupled with fluctuating lake salinity resulted in the Angelo Member exhibiting a decrease in fossil preservation, diversity, and abundance (Graham 2012). Table 65 contains a listing of representative fossils found within the Fossil Butte Member, Green River Formation, Fossil Basin.

Photo 19. A fully articulated horse, the only specimen found in the Green River Formation to date (NPS photo).

Table 65. Representative fossils from the Fossil Butte Member, Green River Formation, Fossil Basin. The table is recreated from a list of species compiled by Arvid Aase, FOBU curator, and Tweet et al. (2012) originally published in Graham (2012).

Birds (14 Genera)	
Frigatebird	**Others**
Limnofregata azygosternon	*Presbyornis pervetus* (waterbird)
Limnofregata. hasegawai	*Gallinuloides wyomingensis* (land fowl)
Parrot relative	*Messelornis nearctica* (bittern-like)
Cyrilavis colburnorum	*Fluvioviridavis platyrhamphus* (oilbird)
Avolatavis tenens	*Prefica nivea* (goatsucker)
Ground dwelling bird	*Primobucco mcgrewi* (perching bird)
P. kistneri	*Tynskya eocaena* (raptor-like bird)
Pulchrapollia olsoni	*Cons schucherti* (small, arboreal bird)
	Foro panarium
	Diatryma feather (giant ground bird)

Table 65 (continued). Representative fossils from the Fossil Butte Member, Green River Formation, Fossil Basin. The table is recreated from a list of species compiled by Arvid Aase, FOBU curator, and Tweet et al. (2012) originally published in Graham (2012).

Fish (23 Genera)	**Amphibians and reptiles (19 Genera)**	**Mammals (26 Genera)**
Stingrays	**Alligators**	**Bat**
Asterotrygon maloneyi	*Alligator* sp.	*Icaronycteris index*
Heliobatis radians	*Allognathosuchus* sp.	*Onychonyctris finneyi*
Gar	*Procaimanoidea* sp.	**Condylarths**
Lepisosteus bemisi	**Crocodilian**	*Hyopsodus minusculus*
Atractosteus simplex	*Borealosuchus wilsoni*	*Hyopsodus vicarious*
Atractosteus atrox	*Leidyosuchus wilsoni*	**Carnivores**
Bowfin	*Crocodylus acer*	*Miacis gracilis*
Amia pattersoni	*Crocodylus affinis*	*Vulpavus profectus*
Cyclurus gurleyi	*Pristichampsus vorax*	*Vulpavus australis*
Bonytongue	**Turtles**	*Viverravus minutes*
Phareodus encaustus	*Baaena arenosa*	*Viverravus eucristadens*
Phareodus testis	*Echmatemys septaria*	*Mesonyx* sp. (wolf-like)
	Echmatemys wyomingensis	*Metacheiromy* sp.
Herring and herring-like	*Chisternon*	*Sinopa minor*
Diplomystus dentatus	*Platypeltis* sp. (soft-shelled)	**Climbing insectivores**
Knightia eocaena	*Trionyx* sp. (soft-shelled)	*Talpavus nitidus*
Knightia alta	**Alcids**	*Nyctitherium* sp.
Gosiutichthys parvus	*Nautilornis avus*	**Arboreal insectivores**
Perch-like	*Nautilornis proavitus*	*Omomys pucillus*
Mioplosus labracoides	**Lizards**	*Washakius insignis*
Priscacara serrata	*Afairiguana avius* (anole)	**Arboreal omnivores**
Priscacara liops	*Bahndwivici ammoskius*	*Uintasorex parvulus*
Priscacara hypsacantha	*Saniwa ensidens* (monitor)	*Microsyops elegans*
Trout-perch	**Others**	**Ground-dwelling herbivores**
Amphiplaga brachyptera	*Boavus idelmani* (boa snake)	*Pseudotomus robustus*

Table 65 (continued). Representative fossils from the Fossil Butte Member, Green River Formation, Fossil Basin. The table is recreated from a list of species compiled by Arvid Aase, FOBU curator, and Tweet et al. (2012) originally published in Graham (2012).

Fish (23 Genera)	**Amphibians and reptiles (19 Genera)**	**Mammals (26 Genera)**
Trout-perch (continued)	**Others (continued)**	**Ground-dwelling herbivores**
Erismatopterus levatus	*Paleoamphiuma tetradactylum* (salamander)	*Paramys delicatus*
Catfish	*Eopeolobates grandis* (frog)	*Thisbemys* sp.
Hypsidoris farsonensis		**Primates**
Astephus antizuus		*Notharctus matthewi* (lemurlike)
Others		*Tetonius* sp.
Crossopholis magnicaudatus		**Others**
Eohiodon falcatus (mooneye)		*Orohippus pumilus* (horse)
Notogoneus osculus (salmon)		*Hyrachyus* sp. (tapir-like)
Amyzon gosiutensis (suckerfish)		*Tetrapassaius* sp.
Esox kronneri (pickerel)		*Sciuravis nitidus*
Asineops squamifrons (extinct)		*Tellotherium* sp.
Masillosteus janeae		
Unnamed *Asineops*-like form		
Invertebrates (23 Genera)	**Insects (30 Genera)**	**Plants (103 Genera) Representatives include:**
Shrimp	**Beetles**	**Horsetail**
Bechleja rostrata	*Eugnamptus* sp. (snout beetle)	*Equisetum winchesteri*
Crayfish	*Lebia protospiloptera*	**Palm**
Procambarus primaevus	*Sciabregma tenuicornis*	*Palmites* sp.
Clams	*Adclocera perantiqua*	*Sabalites* sp.
Plesielliptio priscus	*Syntomostylus fortis*	**Cattail**
P. n. sp. A	**Flies**	*Typha lesquereuxi*
Sphaerium sp.	*Eomyza holoptera*	**Lillypad**
Snails	*Sackenia gibbosa*	*Nelumbo* sp.
Goniobasis tenera	*Plecia pealei*	**Sumac**
Hydrobia utaensis	*Lithophypoderma* sp.	*Rhus mixta*

Table 65 (continued). Representative fossils from the Fossil Butte Member, Green River Formation, Fossil Basin. The table is recreated from a list of species compiled by Arvid Aase, FOBU curator, and Tweet et al. (2012) originally published in Graham (2012).

Invertebrates (23 Genera)	Insects (30 Genera)	Plants (103 Genera) Representatives include:
Snails (continued)	**Flies (continued)**	**Sumac (continued)**
Hydrobia sp. A	*Chilosia scudderi*	*Rhus nigricans*
Valvata subumbilicata	*Cyttaromyia obdurescens*	**Sycamore**
Valvata filosa	*Pronophlebia rediviva*	*Platanus wyomingensis*
Viviparus trochiformis	**Mosquito**	**Tree of heaven**
Viviparus paludinaeformis	*Culex sp.*	*Ailanthus lesquereuxi*
Physa bridgerensis	**Water strider**	**Poplar**
Physa longiuscula	*Telmatrechus parallelus*	*Populus cinnamomoides*
Physa pleromatis	**Planthopper**	*Populus wilmattae*
Physa sp. A	*Thaumastocladius simplex*	**Maple**
Biomphalaria aequalis	**Wasp**	*Acer lesquereuxi*
Biomphalaria storchi	*Plectiscidea lanhami*	**Balloon vine**
Biomphalaria pseudoammonius	*Tylocomnus creedensis*	*Cardiospermum coloradensis*
Drepanotrema sp.	*Tryphoa amasidis*	**Soapberry**
Gyraulus militaris	*Pepsis avitula*	*Sapindus dentoni*
Omalodiscus cirrus	*Hoplisus archoryctes*	
Lymnaea sp. B	**Dragonfly**	**Pine**
Lymnaea similis	*Eolestes synthetica*	*Picea pinifructus*
Pleurolimnaea tenuicosta	*Stenogomphus scudderi*	*Picea balli*
Oreoconus n. sp. A	*Zacallites balli*	*Picea florissanti*
	Swallowtail butterfly	**Fern**
	Praepapilio colorado	*Cladaphlebis septula*
	Moth	*Marsilea* sp.
	Hexerites primalis	*Regnellidium* sp.
	Ant	
	Archimyrmex sp.	

Table 65 (continued). Representative fossils from the Fossil Butte Member, Green River Formation, Fossil Basin. The table is recreated from a list of species compiled by Arvid Aase, FOBU curator, and Tweet et al. (2012) originally published in Graham (2012).

Invertebrates (23 Genera)	Insects (30 Genera)	Plants (103 Genera) Representatives include:
	Liometopum sp.	
	Eoformica eocenica	
	Protoazteca hendersoni	
	Cricket	
	Pronemoblus smithii	

Quaternary sediments of FOBU include a variety of gravel-sized sediments mostly deposited by fluvial processes or small local landslides (Tweet et al. 2012). The majority of these deposits are thought to be of Holocene-age, although there is potential for some gravel in the vicinity to date to the late Pliocene or early Pleistocene (Tweet et al. 2012). Quaternary sediments within the park have produced bison bones (Table 63, Tweet et al. 2012).

4.16.2. Measures

- Documentation and inventory of paleontological sites within the park
- Changes in specimen abundance at paleontological localities
- Rates of erosion exposing paleontological resources

4.16.3. Reference Conditions/Values

A reference condition/value for paleontological resources was not defined by park staff. Ideally, the 100% documentation of all paleontological sites within the park would provide the best baseline data for reference conditions/values. However, this is not practical, since complete identification and inventory of FOBU paleontological resources is not available, particularly given that new features and sites are constantly exposed by natural processes. FOBU reports annually to the GPRA Goal Ia9 (Paleontological Localities Condition) concerning 95 localities, all of which were reported to be in good condition as of 2010 (Tweet et al. 2012). Additionally, FOBU works to maintain "good working relationships with commercial collectors focused on shared information so both parties benefit" (Tweet et al. 2012, p. 378-379). New geological and paleontological data for Fossil Lake is continually brought to light by FOBU park staff, as well as by various commercial fossil concerns in the vicinity (Tweet et al. 2012).

4.16.4. Data and Methods

Paleontological and geological research at FOBU has been extensive, with fossil documentation, inventory, monitoring, and protection being the primary management responsibilities at the park (Graham 2012). Research in the vicinity of FOBU began during the late 19th century, with the park established to protect areas of notable fossil resources derived primarily from the Green River Formation, one of the best-known fossil lake deposits in the world (Tweet et al. 2012). Much of the park's fossil collections are specific to the park's research quarry, where over 2,500 specimens of Green River Formation plants, insects, and fish were documented between 1998 and 2007 (Tweet et al. 2012). Graham (2012) prepared one of the more recent and comprehensive Geologic Resources Inventory (GRI) reports for FOBU. This project provided a geologic map and pertinent geologic information to support resource management and science-based decisions in accordance with GRI objectives (Graham 2012). This report is intended to assist park managers in the use of digital geologic map data in accordance with their data model, and provides an overview of park geology, including geologic resource management issues, geologic features and process, and the geologic history leading to the park's present-day landscape (Graham 2012). Graphics and tables are also utilized to summarize the main features, characteristics, and potential management issues for all rocks and unconsolidated deposits in the immediate area of the park (Graham 2012).

Additional sources providing geological and paleontological overviews useful for this assessment include Evenden et al. (2002) and Tweet et al. (2012). Evenden et al. (2002) is a Phase I natural resources monitoring report that summarizes existing information on NPS and related natural resource monitoring programs within the NCPN, presenting overviews of biological and physical resources of network parks, including describing monitoring goals and needs, and presents a theoretical framework with conceptual models for guiding future efforts. Tweet et al. (2012) substantially updated, revised, and expanded the 2002 paleontological resource summary completed for FOBU and other NCPN parks (Koch and Santucci 2002). Tweet et al. (2012) presents paleontological resource summaries for the parks of the NCPN compiled through extensive literature reviews and interviews with park staff and professionals, including preliminary paleontological resource management recommendations for each park.

4.16.5. Current Condition and Trend

Documentation and Inventory of Paleontological Sites

FOBU has one of the world's premiere fish fossil deposits, with the park established to protect a portion of an extremely fossiliferous Eocene lake deposit and the geologic landmark of Fossil Butte (Tweet et al. 2012). FOBU reports annually on 95 paleontological localities, in addition to providing a publically-available list of over 2,500 fossil specimens documented from the park's research and interpretation quarry from 1998-2007 (Tweet et al. 2012). Between 200 and 500 specimens are collected from the quarry each year where the fossils are evaluated, catalogued, and stored by park staff for inclusion in the park's museum or interpretive collection (Graham 2012). Given the abundance, diversity, and scientific importance of FOBU's paleontological resources, documentation and inventory is critical to their monitoring and protection.

Documentation provides baseline data that is needed for the development of an effective inventory and monitoring program for the park (Graham 2012). Inventories typically include data on scope, significance, and distribution of fossils at each locality, including a description of the associated strata (Graham 2012). Accurate documentation of historical collections can be imprecise due to vague locality information provided by early workers (Tweet et al. 2012). An additional issue regarding accurate documentation and inventory of the paleontological sites in and around FOBU is nearly a century of commercial collecting from sites now near or within the park (Tweet et al. 2012).

Changes in Specimen Abundance at Paleontological Localities

New fossil species continue to be discovered in the Eocene lake sediments of Fossil Basin, even after 100 years of collecting (Graham 2012). Unfortunately, specimen cataloguing lags behind collection, since half of the research quarry fossils are covered with matrix and are only visible in cross-section, requiring them to be x-rayed in order to gather data pertaining to the species, size, orientation, and articulation of the specimens (Graham 2012). Monitoring frequency in relation to changes in specimen abundance can be determined by repeatedly surveying areas for new fossil exposures. Utilizing overlying GIS data for repeated surveys is beneficial in identifying those sites containing paleontological resources and those with few to none, making apparent those locations with the highest potential for new specimens (Graham 2012).

Rates of Erosion Exposing Paleontological Resources

Erosion processes continually expose fossil resources and can lead to eventual fossil loss. Both the Wasatch and Green River formations have the potential to erode quickly, requiring scientifically important fossils to be collected before detrimental impact (Graham 2012). Temperature fluctuations and mass wasting are other natural elements that contribute to erosion and weathering within the park (Graham 2012). Temperature fluctuations can lead to the expansion and contraction of water in the spaces between rock fractures, promoting increased weathering and erosion. The shrink-swell process, particularly in mudstone of the Wasatch Formation, destabilizes slopes and increases the potential for rockfalls, landslides, slumps, and other mass movements (Graham 2012).

In 2002, FOBU initiated a monitoring program to study erosion rates and in situ fossil stability in the highly erosive Wasatch Formation (Graham 2012). A freeze-thaw index allows the park staff to determine how often fossil sites should be monitored; a higher freeze-thaw index suggests higher weathering and erosion rates (Graham 2012). Sites where fossils are eroding from the formation are continually prospected and located using GPS techniques. Erosion stakes have been installed at the park and located with GPS, allowing park staff to monitor and document any change in ground surface (Graham 2012). The monitoring will also providing quantitative erosional data. In regards to mass wasting, documented impacts to fossil resources are rare at FOBU, except for rockfalls occurring in the Green River Formation (Graham 2012). Fossils have not been discovered in mass-wasting deposits of the Wasatch and Green River formations, suggesting landslides have not yet exposed nor buried fossil sites (Graham 2012). The Green River Formation is not subjected to the same systematic evaluation and monitoring as the Wasatch Formation where slow-moving earthflows continue to disturb the formation, but sites in both formations are evaluated after mass movement events when new fossils may be exposed or previous localities damaged (Graham 2012).

Threats and Stressor Factors

Park staff identified climate change, extreme weather, visitor impact, and theft as potential threats or stressors to the paleontological resources at FOBU. These potential threats/stressors make up a small part of the various environmental and anthropogenic factors and processes that can affect paleontological resources. Figure 70 is a conceptual diagram illustrating some of the various potential threats or stressors to paleontological resources and how they interact.

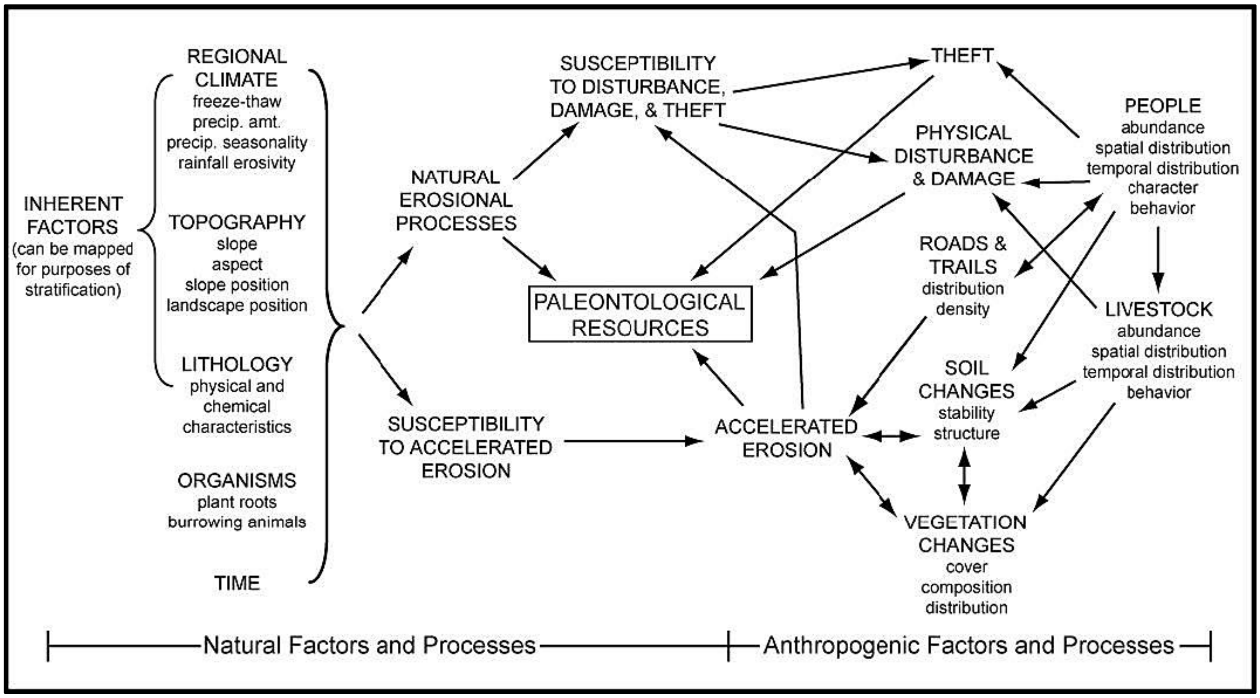

Figure 70. Conceptual diagram illustrating various environmental and anthropogenic factors and processes that might affect the stability of in situ paleontological resources. The graphic is an NPS diagram Graham (2012) reproduced from Santucci and Koch (2003).

Changes to the timing, frequency, and duration of precipitation events associated with climate change, coupled with the highly erodible landscape within FOBU, has the potential to influence the erosional and weathering rates of geological formations containing paleontological resources at the park (Wei et al. 2009). Climate change and extreme weather events could also lead to changes in other erosional factors such as freeze-thaw events and wind erosion. Changes in climate could contribute to loss of vegetation, opening up new areas to wind and water erosion (Wei et al. 2009), potentially exposing more paleontological sites.

Fossil resources at FOBU are at an increased risk for theft and vandalism given their abundance and accessibility to the public. An expanding market for vertebrate fossils increases the pressure to adequately protect these non-renewable resources, with the ability to assess and control this complicated by a limited park staff and high number of exposures (Graham 2012). A 2002 study by Hockett and Roggenbuck (2002) determined that a great majority of FOBU visitors agreed with NPS policies to protect fossil resources, with 87% of on-site visitors feeling it was unacceptable to remove a small piece of fossil, while 81% felt it was wrong to remove a fossil from a rock layer (Graham 2012). The management statement for FOBU (NPS 1991) indicated that the theft of fossils from the park was assumed to be occurring with some regularity, although no actual evidence of this existed at the time. In the summer of 2003, five separate visitors were observed chipping at layers in the park’s research quarry or searching through waste piles; four of these visitors damaged quarry layers, but whether any actual fossil theft had occurred could not be determined due to the damage (Graham 2012). Despite this, Graham (2012) indicated that fossil theft is not thought to be a major issue at the park. Park resource managers have undertaken efforts to minimize visitor impact from physical disturbance (e.g., trampling), trespassing, and theft from the park's research and interpretation quarry (Graham 2012). Efforts include improved trail signage, improved training of Quarry Program interpreters, increased levels of interpretive information, and improved self-guided Nature Trail interpretation (Graham 2012). Both the environment and park visitors possess the ability to impact fossil resources at FOBU, as reflected in Figure 70, necessitating continued monitoring to limit and prevent their occurrence.

Data Needs/Gaps

Continued research on the paleontological resources at FOBU can provide a better understanding of past as well as potential future conditions (Graham 2012, Tweet et al. 2012). The geological and paleontological resources provide researchers the opportunity to study an entire historic ecosystem, including not only the individual plant and animal species present, but also how they interacted (Graham 2012). Paleoclimate research on the Green River and Wasatch formations could also provide information on the effects of climate change (Graham 2012).

Park resource managers have indicated a variety of research needs including: a comprehensive study of fossil insects, determination of mass mortality causes, and study of the Road Hollow Member faunal assemblage (Graham 2012). Other geologic resource management issues identified by park staff include: determination of depositional rates, fish growth studies, and exploration of the mechanisms of lamina (a fine sedimentary rock layer) deposition (Graham 2012).

Overall Condition

Documentation and Inventory of Paleontological Sites within the Park

The project team defined the *Significance Level* for this measure as a 2. FOBU submits annual reports for 95 paleontological localities and provides a publicly available listing of over 2,500 fossil specimens. Documentation continues as new specimens are collected each year and are evaluated, catalogued, and stored by park staff. Given the fact that new resources are constantly exposed in the quarry and by natural processes, complete documentation of every site is highly unlikely. Therefore, this measure is assigned a *Condition Level* of 1, meaning low concern.

Changes in Specimen Abundance at Paleontological Localities

The project team also assigned this measure a *Significance Level* of 2. New specimens continue to be discovered. The geologic formations within FOBU contain significant fossil resources and there is a potential for new discoveries. Visitor impacts through vandalism and theft can impact the abundance of specimens at the various paleontological sites within FOBU. Due to the implementation of management actions to minimize this impact, the measure has also been assigned a *Condition Level* of 1, meaning low concern.

Rates of Erosion Exposing Paleontological Resources
This measure was assigned a *Significance Level* of 2 by the project team. Resource managers at FOBU have implemented data collection and monitoring programs to study erosion rates in areas that are more susceptible to erosion and erosional factors. Data from these studies can be used as baseline information for assessing the impact of erosion and the analysis of future trends. Due to the potential for increased erosion due to climate change and related extreme weather events, this measure is assigned a *Condition Level* of 2, indicating moderate concern.

Weighted Condition Score
The *Weighted Condition Score* for FOBU's paleontological resources is 0.44, indicating moderate concern. This is primarily driven by the potential for impact to this resource from potentially changing climate conditions. Continued monitoring efforts will provide information that could be used to identify any trends in erosion rates. Continued efforts by resource staff to minimize the potential impacts from park visitors should ensure that these significant physical resources are available for study and visitor enjoyment for many years to come.

Paleontological Resources (Fossils)			
Measures	**Significance Level**	**Condition Level**	**WCS = 0.44**
Documentation and Inventory of Paleontological Sites Within the Park	2	1	
Changes in Specimen Abundance at Paleontological Localities	2	1	
Rates of Erosion Exposing Paleontological Resources	2	2	

4.16.6. Sources of Expertise

- Vincent Santucci, NPS Geological Resources Division Senior Geologist/Paleontology Program Coordinator
- Arvid Aase, FOBU Museum Specialist

4.16.7. Literature Cited

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Chapter 5. Discussion

Chapter 5 provides an opportunity to summarize assessment findings and discuss the overarching themes or common threads that have emerged for the featured components. The data gaps and needs identified for each component are summarized and the role these play in the designation of current condition is discussed. Also addressed is how condition analysis relates to the overall natural resource management issues of the park.

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 are needed to help inform the status or overall condition of a key resource component in the park. Data gaps exist for nearly all the resource components assessed in this NRCA. Only dark night skies and paleontological resources had adequate information available to assign a condition level to all of the identified measures for these components. The remaining components had varying degrees of data needs, ranging from one to all of the identified measures. Table 66 provides a detailed list of the key data gaps by component. Each data gap or need is discussed in further detail in the individual component assessments (Chapter 4).

Table 66. Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Low sagebrush community	➢ Population surveys for abundance and location of *Lomatium* populations. ➢ Field surveys to accurately map and describe the composition of ground cover (e.g., litter, soil crust, rock, bare ground). ➢ Future comprehensive vegetation mapping/monitoring studies to collect data that can be used in association with Friesen et al. (2010) to determine changes in vegetation cover. ➢ IEP surveys focused on the specific composition and abundance of priority IEP species within the low sagebrush communities.
Big sagebrush community	➢ Further research on the species composition of big sagebrush communities, specifically on the dominant sagebrush species and shifts in dominant species. ➢ Future comprehensive vegetation mapping/monitoring studies to collect data that can be used in association with Friesen et al. (2010) to determine changes in vegetation cover. ➢ IEP surveys focused on the specific composition and abundance of priority IEP species within the big sagebrush communities.
Aspen woodlands	➢ Research on the regeneration rates of aspen woodlands. ➢ Future comprehensive vegetation mapping/monitoring studies to collect data that can be used in association with Friesen et al. (2010) to determine changes in vegetation cover. ➢ IEP surveys focused on the specific composition and abundance of priority IEP species within aspen woodlands.

Table 66 (continued). Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Mixed conifer woodlands	➢ Research focused on the age class distribution, community composition, and regeneration conditions in mixed conifer woodlands. ➢ Future comprehensive vegetation mapping/monitoring studies to collect data that can be used in association with Friesen et al. (2010) to determine changes in vegetation cover. ➢ IEP surveys focused on the specific composition and abundance of priority IEP species within mixed conifer woodlands.
Seeps, springs, and slump pond aquatic habitat	➢ Comprehensive inventory of vegetation community composition of the parks seep- and spring-associated habitats. ➢ Inventory of the aquatic macroinvertebrate populations within the parks seeps and springs. ➢ Long-term monitoring of the water quality and discharge of the parks seeps and springs. ➢ Future comprehensive vegetation mapping/monitoring studies to collect data that can be used in association with Friesen et al. (2010) to determine changes in vegetation cover. ➢ IEP surveys focused on the specific composition and abundance of priority IEP species within seep, spring, and slump pond aquatic habitats.
Cushion plant communities	➢ Further research and population studies on tufted twinpod. ➢ Future comprehensive vegetation mapping/monitoring studies to collect data that can be used in association with the Friesen et al. (2010) to determine changes in vegetation cover. ➢ IEP surveys focused on the specific composition and abundance of priority IEP species within the cushion plant communities.
Alkali flats community	➢ Field surveys to accurately map and describe the composition of ground cover. ➢ Future comprehensive vegetation mapping/monitoring studies to collect data that can be used in association with Friesen et al. (2010) to determine changes in vegetation cover. ➢ IEP surveys focused on the specific composition and abundance of priority IEP species within the alkali flats communities.
Montane shrublands	➢ Field surveys to accurately map and describe the composition of ground cover. ➢ Future comprehensive vegetation mapping/monitoring studies to collect data that can be used in association with Friesen et al. (2010) to determine changes in vegetation cover. ➢ IEP surveys focused on the specific composition and abundance of priority IEP species within montane shrublands. ➢ Research into the impacts of ungulate herbivory, particularly elk, to help managers better understand the threats faced by this community.

Table 66 (continued). Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Herptiles	➢ Population inventories and studies to update the composition and distribution of the herpetofauna community at FOBU. ➢ Development and implementation of a long-term monitoring program that would assist park resource managers in assessing the condition of the park's herptiles and to understand trends in population and distribution.
Birds	➢ Continuation of the RMBO's annual land bird monitoring program will provide park resource managers with a long-term data set that can be used to identify trends in abundance, density, and species richness within the sagebrush communities. ➢ Expansion of the survey methodology to include a variety of vegetation communities and habitat types would provide a more complete picture of the avifauna across the park as a whole. ➢ Addition of bird surveys during the spring and fall migration period and in winter would provide resource managers with a better understanding of the trends and status of year-round bird species in the park. ➢ Annual studies specifically for raptors are needed in order to assess this resource. Previous bird studies have not focused on raptors specifically, and monitoring methodology (and timing) may have certain biases that make detecting raptors more difficult.
Greater sage grouse	➢ Further research on the average brood size and nesting success within the park. ➢ Research on how hunting pressures on lands adjacent to the park are impacting the sage grouse population within the park. ➢ Research on the impact the annual stock drives have on the park's sage grouse population. ➢ Research on the effects of predators on the park's sage grouse population.
Pygmy rabbit	➢ Completion of a comprehensive population study of the park's pygmy rabbit population. ➢ Long-term research projects focused on the breeding success, fecundity, and offspring mortality of the parks pygmy rabbit population.
Elk	➢ Research studies that focus specifically on the impact of the elk population on the various vegetation communities. ➢ Research to determine the park's carrying capacity for elk. ➢ Development of a long-term elk management plan.
Dark night skies	➢ The last visit by the NPS NSNSD was approximately 10 years ago. Given the analysis of that data and current conditions, another visit by the NPS NSNSD is recommended. ➢ Continued monitoring by the NPS NSNSD on a regular basis is recommended given the degraded quality of the night skies. This would provide data that could determine if the light intrusion has stabilized or continues to degrade. ➢ Development of a natural lightscape management plan for the park.

Table 66 (continued). Identified data gaps or needs for the featured components.

Component	Data Gaps/Needs
Viewscape	➢ Archival research to identify and locate historical photographs that depict the views from the park, or the landcover/land use conditions of the areas within the park's viewscape. ➢ Continued development of spatial data that explain landscape change as it relates to viewscape analysis is recommended. Additional attributes such as height above surface would improve the results of this line of sight analysis.
Paleontological resources	➢ Continued research of the paleontological resources at FOBU is recommended. ➢ Research of the paleoclimate of the Green River and Wasatch formations could provide insights into the effects of climate change. ➢ Several research needs were identified by park resource managers, including a comprehensive study of fossil insects, determination of mass mortality causes, study of the Road Hollow Member faunal assemblage, determination of depositional rates, fish growth studies, and exploration of the mechanisms of lamina (a fine sedimentary rock layer) deposition (Graham 2012).

Several of the park's data gaps involve the need for comprehensive inventories and continued monitoring to accumulate data to assess and evaluate the condition and trends over time for many of the resources included in this analysis. This is evident by the high number of measures that could not have a current condition assigned due to either recent data gaps or lack of historic data to quantify the identified reference condition. The majority of the park's vegetation communities would benefit from research on the occurance of invasive species by vegetation community and percent ground and canopy cover for each of the parks vegetation communities. Other components, such as birds and herptiles, would benefit from more consistent sampling efforts (both timing and methodology).

5.2. Component Condition Designations

Table 67 displays the conditions assigned to each resource component presented in Chapter 4 (definitions of condition graphics are located in Figure 71 following Table 67). It is important to remember that the graphics represented are simple symbols for the overall condition and trend assigned to each component. Because the assigned condition of a component (as represented by the symbols in Table 67) is based on a number of factors and an assessment of multiple literature and data sources, it is strongly recommended that the reader refer back to each specific component assessment in Chapter 4 for a detailed explanation and justification of the assigned condition. Condition designations for some components are supported by existing datasets and monitoring information and/or the expertise of NPS staff, while other components lack historic data, a clear understanding of reference conditions (i.e., what is considered desirable or natural), or even current information. Condition could not be determined for seven of the 15 selected components: low sagebrush, mixed conifer woodlands, cushion plant communities, montane shrublands, herptiles, birds, and pygmy rabbits.

For featured components with available data and fewer information gaps, assigned conditions varied. Only one component, elk, was considered to be in good condition. However, the score was at the upper limit of the good condition range, and any small decline in the population could shift it into the moderate concern range. Six components (big sagebrush, aspen woodlands, seeps, springs, and slump pond aquatic habitats, alkali flats community, and greater sage grouse) were of moderate concern, and one component (dark night skies) was considered to be of significant concern. This level was assigned based on the fact that available information is outdated and more than likely does not represent current conditions and also due to the amount of anthropogenic light in the parks sky dome.

Table 67. Summary of current condition and condition trend for featured NRCA components.

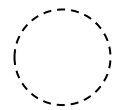
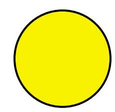
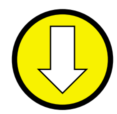
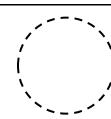
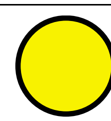
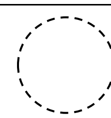
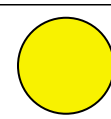
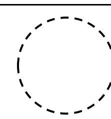
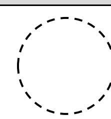
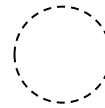
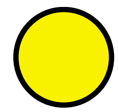
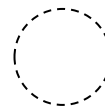
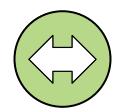
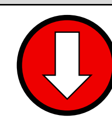
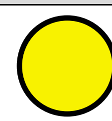
Component	WCS	Condition
Biological Composition		
Ecological communities		
Low sagebrush community	N/A	
Big sagebrush community	0.42	
Aspen woodlands	0.58	
Mixed conifer woodlands	N/A	
Seep, spring, and slump pond aquatic habitat	0.37	
Cushion plant communities	N/A	
Alkali flats community	0.44	
Montane shrublands	N/A	
Herptiles		
Herptiles	N/A	

Table 67 (continued). Summary of current condition and condition trend for featured NRCA components.

Component	WCS	Condition
Biological Composition		
Birds		
Birds	N/A	
Greater sage grouse	0.50	
Mammals		
Pygmy rabbits	N/A	
Elk	0.33	
Environmental Quality		
Dark night skies	0.67	
Viewscape	N/A*	N/A*
Physical Characteristics		
Geology		
Paleontological resources	0.44	

*The viewscape measure was included as a non-evaluated component per the project stakeholders' request. No assessment of condition was conducted.

5.3. Park-wide Condition Observations

5.3.1. Vegetation Communities

The vegetation communities of FOBU are typical of semi-desert upland climates. Two more ecologically unique communities (cushion plant communities and alkali flats communities) are present within the park. Additionally, riparian communities have established in areas where seeps, springs, and slump ponds provide the perennial water and soil moisture necessary for these habitats. Given a lack of data for several key measures, a condition assessment could not be completed for four of the eight vegetation communities. Data were available to assess the condition of the big sagebrush community, aspen woodlands, alkali flats communites, and the seeps, springs and slump pond aquatic habitats. While all four were determined to be of moderate concern, there was a wide disparity within this range. The seeps, springs, and slump pond aquatic habitats were scored just above the upper limit for being considered in good condition. Improvement in any of the measures could cause the score to shift to good condition. Conversely, the condition score for aspen woodlands was near the upper limit of the moderate concern level. In addition, a declining trend was assigned to this measure. This resource should be closely monitored as the trend indicates the likelihood this resource will become a significant concern. This community should be closely monitored so that management actions could be put into place if the condition continues to deteriorate. The condition value assigned to big sagebrush was in the middle of the moderate concern range.

5.3.2. Other Biotics

Other biotic components included in the NRCA were herptiles, birds, greater sage grouse, pygmy rabbits, and elk. Due to data gaps in the identified measures or in defining the reference condition, an assignment of condition could only be made for the greater sage grouse and elk. Elk were considered in good condition with a stable trend; however, more research is needed to quantify the impact this species has on the vegetation communities within the park. The greater sage grouse was considered to warrant moderate concern. However, this is more a reflection of the difficulty of determining lek attendance. Overall, there appears to be a sizeable population within the park.

5.3.3. Environmental Quality

Environmental quality is important in maintaining healthy functioning ecosystems. The health of terrestrial and aquatic organisms in parks can be affected substantially by air and water quality conditions. Visitor experience may be diminished by the impact the surrounding land use has on the views from the park during both the day and night. The data collected by the NPS NSNSD for FOBU is approximately 10 years old. In reality, this data does not reflect the current impacts on the night skies at the park. The analysis of the data collected in 2004 and 2006 shows that there was some degradation to the night sky at that time. Another visit by the NPS NSNSD is recommended to assess the current condition of the night skies at the park.

The condition of the park’s viewscape was not assessed for the NRCA. This assessment does include a review of the potential for impact from several threats that were identified by park resource managers. The intent of the analysis conducted as part of this NRCA was to create a baseline condition for the park’s viewscape for use in future studies.

5.3.4. Physical Characteristics

FOBU was established due to its wealth of paleontological resources and as a means to protect those resources. This analysis concluded that, in general, these resources are being protected. The assignment of moderate condition was mainly a reflection of the potential for impact from the changing climate of the region, although there is the need to continue regular monitoring and minimize visitor impact on these resources.

5.3.5. Park-wide Threats and Stressors

Several threats and stressors influence the condition of multiple resources within FOBU. These include invasive plant species, adjacent land uses, climate change, and the impacts associated with visitor use. Exotic plant species are a threat to all of the park's vegetation communities, as they can out-compete native plants and alter ecological processes such as fire regime and nutrient cycling (Scott and Wilcove 1998, Perkins 2014). Climate change may exacerbate existing threats to the park's resources, such as drought and insect and disease outbreaks (Saunders et al. 2008).

5.3.6. Climate Change Vulnerability Assessment

The objectives of the climate change pilot were threefold: 1) assess the vulnerability of key resources; 2) to provide an understanding of why these resources are vulnerable, including providing insights on the interactions of climate change with existing threats and stressors to resources; and 3) to serve as a pilot project for integrating climate change vulnerability assessments (in particular a landscape scale community-based assessment) into the existing NRCA process and report template.

Using a framework for vulnerability assessment initially developed by Galbraith (2011) and modified by Amberg et al. (2012), the climate change assessment methodology employed is a multi-scale analysis that focuses on the vulnerability of select ecological communities in FOBU (defined by vegetation types). A focus on the overall vulnerability of ecological communities in the park provides an umbrella under which vulnerability may be examined and inferred for key species inhabiting those communities; the degree of vulnerability for a plant community would presumably directly influence the sensitivity and vulnerability of individual animal species residing in that community. For instance, if a specific plant community is expected to change very little despite projected climate shifts (i.e., low vulnerability), it is probable that many of the animal species that rely on the community would also be less vulnerable to many of the potential stresses of climate change. Likewise, if a plant community is expected to experience dramatic changes in composition or distribution due to climate change, it is highly probable that species dependent upon that community for habitat would also be greatly affected.

This assessment presents a summary of projected climate changes for the FOBU region and analysis of the vulnerability of select park natural resources to these changes. As the methodology employed in this pilot was to be a landscape scale community-based assessment, two vegetation communities from the FOBU NRCA framework were selected for inclusion in this pilot study. By selecting communities from this framework, the climate change integration pilot study was a park-centric approach and built on the established NRCA process. Several considerations were taken into account during the discussions to select the components for inclusion in the pilot study. A specific set of selection criteria was not established; however, FOBU resource managers were asked to consider their long-term management as part of the selection process. With guidance from SMUMN GSS and the NPS climate change integration team, FOBU resource managers selected montane shrublands, an iconic and important park plant community, and seeps, springs, and slump pond aquatic habitats, which depend upon unique physical resources, as the two communities to include in the pilot study. Each assessment considers the exposure of the resource to projected climate changes, the degree of sensitivity to such changes, and the ability to cope with and adapt to these changes.

<u>Historical conditions</u>

Analysis of historical (1895-2010) PRISM data indicates a warming trend for both maximum and minimum average annual temperatures in the FOBU region. Maximum average annual temperatures have increased 0.8 ºC (1.4 ºF) and minimum average annual temperature increased 0.4 ºC (0.7 ºF) over the past century. The monthly precipitation exhibited a -1.2% per century increase, though it was determined to not be statistically significant (PRISM 2015).

Projected future conditions

Average annual temperatures in the FOBU region are projected to increase by 2.2 °C (4 °F) by 2030 and by 5.3 °C (8 °F) or higher by the end of the century under RCP 8.5 (Cowell and Urban 2010, HPRCC 2013). By 2100, it is estimated that average summer and fall temperatures will increase more than average winter and spring temperatures (ClimateWizard 2014). In general, precipitation is projected to increase by the end of the century, but there is considerable variation in projections and confidence in precipitation projections is much lower than for temperature projections (Shafer et al. 2014). Overall, even with an increase in precipitation, the projected climate by 2050–2100 at FOBU is estimated to become much drier, as higher temperatures will drive increased evapotranspiration rates. The projected increase in evapotranspiration is estimated to exceed (substantially) the projected increase in precipitation, which would result in significantly reduced soil moisture. General predictions for the region also suggest an increase in extreme temperature (number of excessively hot days) and weather events (increase in strong convective storms).

Vegetation community assessment

Two of the eight ecological communities identified in the NRCA framework were assessed for vulnerability to climate change (montane shrubland and the seeps, springs, and slump pond aquatic habitats). Vulnerability was determined by examining six variables: current location of the plant community in its known geographical range, sensitivity to extreme climatic events, dependence on specific hydrologic conditions, intrinsic adaptive capacity, vulnerability of ecologically influential species in the community, and potential for climate change to exacerbate the influence of non-climate stressors. The plant communities ranged in vulnerability to climate change from moderately vulnerable to highly vulnerable. Table 68 summarizes the vulnerability of the plant communities examined and the confidence in these vulnerability scores based on current available science.

Table 68. Summary of plant community vulnerability to projected climate change (2050–2100) at FOBU.

Community	Climate Change Vulnerability[A]	Confidence[B]	Alternative Vulnerability Scores
Montane shrubland	Moderate (15)	Moderate (15)	13-16
Seeps, springs, and slump pond aquatic habitats	High (23)	High (15)	22-25

A = 6-13 = least vulnerable, 14-19 = moderately vulnerable, 20-25 = highly vulnerable, 26-30 = critically vulnerable

B = 6-10 = low confidence, 11-14 = moderate confidence, 15-18 = high confidence.

Seeps, springs, and slump pond aquatic habitats at FOBU were determined to be highly vulnerable to climate change. The projected warmer, drier climate conditions and increased variability in precipitation for the region will likely impact the amount of available surface and ground water that supply these habitats. This in turn will have a detrimental impact on the vegetation communities that rely on the moist soil conditions these areas provide. More research is needed to understand the dynamics of these features with regard to available water to better determine overall vulnerability to climate change. The montane shrublands were determined to be moderately vulnerable to climate change. Montane shrubland species, in general, have a good tolerance to most of the aspects of projected change to a warmer drier climate, and the associated environmental changes such as drought. However the reliance on the winter snows and moisture supplied by the slow release of during the spring thaw period makes them highly dependent on a specific hydrologic regime (Fertig, written communication, 7 December 2015).

Uncertainty in assessing vulnerability

Uncertainty is inherent at every stage of this type of assessment. The future scenarios for climate change do not cover the entire range of plausible future conditions and, thus, do not capture the full range of potential resource vulnerability. Uncertainty is also present in the analysis of vulnerability conducted by SMUMN GSS, resulting from a lack of definitive literature and scientific knowledge that characterizes the relationship of many natural resources to climate shifts and/or non-climate stressors and how these resources will respond to climate change. While it is possible to reduce some uncertainties by building better models or by gathering additional data, many are unavoidable and irreducible, and managers must make decisions in the face of uncertainty.

Overall conclusions

FOBU is an extremely diverse park, supporting a range of unique features, from internationally significant paleontological features to a protected and recovering sagebrush steppe ecosystem and views that encompass both historic and prehistoric landscapes, along with a variety of wildlife species (NPS 1980, DIP HFC 2006). This assessment serves as a review and summary of available data and literature for featured natural resources in the park. The information presented here may serve as a baseline against which any changes in condition of components in the future may be compared. Current condition could not be determined for many components due to data gaps. For resources where condition could be assessed, the majority warranted moderate concern. Trends could not be established for the majority of the components, mainly due to the lack of data to quantify the desired reference condition.

Understanding the condition of these resources can help managers prioritize management objectives and better focus conservation strategies to maintain the health and integrity of these ecosystems. The changing climate will have impacts on all of these resources to some degree. Many conservation strategies were developed before climate change became a major consideration for natural resource managers. However, recent science has increased our awareness of the ecological consequences of climate change, and managers now are tasked with adapting and refining conservation approaches to best protect natural resources from the influences of changing climate. Essential to the adaptation effort is identifying and, when possible, quantifying the comparative vulnerabilities of important ecological resources, such as through a vulnerability assessment. This provides natural resource managers with greater understanding of which climate influences or resources require the most immediate attention.

This report incorporates a community-based process for a qualitative assessment of climate change vulnerability for select natural resources in FOBU. These resources are characterized using the projected regional downscaled climate changes and the best estimates of resource vulnerabilities based on available literature and professional judgment. The project team believes the statistical downscaling approach to developing regional climate change projections is both appropriate and applicable for vulnerability assessment and the results of the assessment provides resource managers with a credible way of estimating resource vulnerabilities in FOBU.

The results of the climate change assessment show that the ecological resources in FOBU can exhibit wide ranging levels of vulnerability to climate change and, consequently, it is likely that managers can expect to see substantial changes in the distribution of many of these resources in the next several decades. This type of assessment is a very important first step in understanding how park resources may change with ongoing and future climate change. It will also provide managers a starting point from which to begin identifying the resources that may not cope well with climate change and those that may be resilient to projected changes.

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Appendices

Appendix A. Overview of Climate Change Vulnerability Assessments

Climate change has been linked in large part to the long-term and accelerating release of carbon into the atmosphere. The Special Report on Emissions Scenarios (SRES) A1B and A2 family of carbon emissions scenarios are often used to estimate potential future changes in climate; these scenarios are commonly referred to as 'moderate' and 'high' carbon emissions scenarios (Nakicenovic et al. 2000). The difference between these two scenarios can be summarized by differences in the projected emissions of CO_2, the atmospheric component that is primarily responsible for global warming (IPCC 2007). These A1B and A2 emissions scenarios have very similar rates of atmospheric CO_2 increases until about 2050, when the A2 (high) scenario diverges with higher projected emissions of greenhouse gases than the A1B (moderate) scenario. Since these emissions scenarios were published (Nakicenovic et al. 2000), the rate of increase in atmospheric CO_2 has equaled or exceeded the highest projected emissions scenarios examined by the IPCC (Rahmstorf et al. 2007).

Moss et al. (2010) identified the need for new scenarios for the research community. This was due to several factors: the current generation of climate models need more detailed information than what was provided by previous emission scenarios, an increase in interest for scenarios that incorporate the impacts of different climate policies in addition to the no-climate-policy scenarios explored previously (e.g., SRES), and increasing interest in exploring the role of adaptation (van Vuuren 2011). Rather than incorporating this into their process, the IPCC asked the research community to develop a new set of scenarios (IPCC 2007, van Vuuren 2011). This development process was guided by a set of design criteria (Moss et al. 2008, 2010). In order to evaluate how climate might change in the future, the IPCC requested the research community develop a set of scenarios based on the following criteria: provide the current generation of climate models with more detailed information than what was provided by previous emissions scenarios, address an increased interest for scenarios that incorporate the impacts of different climate policies in addition to the no-climate-policy scenarios explored in earlier scenarios, and increase interest in exploring the role of adaptation (Moss et al. 2008, 2010, van Vuuren 2011). The research community developed a new set of scenarios, each referred to as a RCP. The term "representative" signifies that each of the RCPs is representative of a larger set of scenarios already defined in the literature (van Vuuren 2011).

As a whole, the RCPs are meant to be compatible with the full range of emissions scenarios available in the current scientific literature, both with and without climate policy (van Vuuren 2011). The term "concentration pathway" emphasizes that these RCPs are not final new, fully integrated scenarios, but rather an internally consistent set of projections of the components of radiative forcing (the change in energy in the atmosphere due to GHG emissions) that are to be used in subsequent phases of new or updated scenarios (van Vuuren 2011). The use of "concentration" instead of "emissions" also emphasizes that concentrations are used as the primary product of the RCPs, and they are designed as input to climate models (van Vuuren 2011). Coupled carbon-cycle climate models can then calculate associated emission levels (van Vuuren 2011). A set of four pathways were produced that lead to radiative forcing levels of 8.5, 6, 4.5 and 2.6 W/m^2 by 2100 (van Vuuren 2011). Each of the RCPs covers the 1850–2100 period, and extensions have also been formulated for modeling climate change up to the year 2300 (van Vuuren 2011). Since they were developed with the current emission levels in mind, they can be related to the emissions scenarios produced by the IPCC. They represent different possible futures determined in complex ways by demographic development, socio-economic development, and technological change (Nakicenovic et al. 2000, van Vuuren 2011). For the purposes of this report, the main differences in the RCPs can be summarized by differences in greenhouse gas emissions (Figure 72).

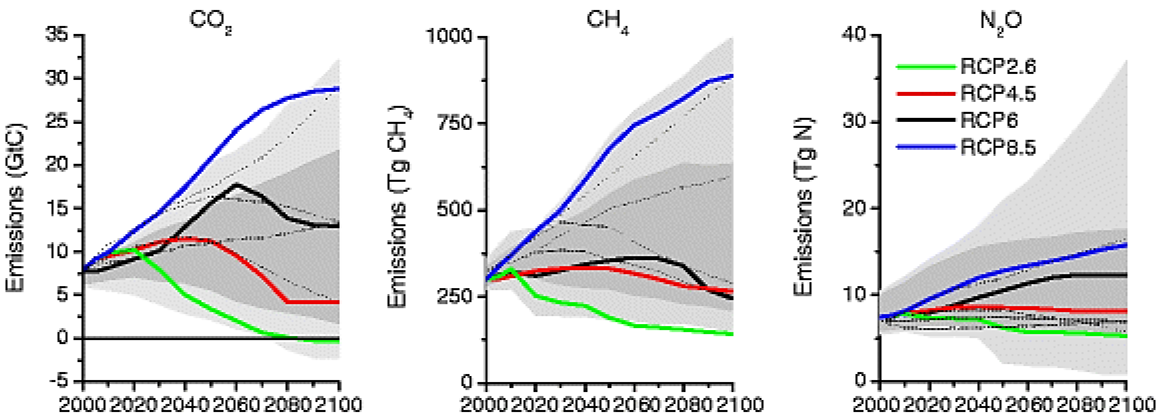

Figure 71. Emission levels of main greenhouse gases by RCPs. The grey areas indicate the 98th and 90th percentiles (light/dark grey) of the literature. The dotted lines indicate four of the SRES marker scenarios (from van Vuuren 2011).

Climate change can impair the natural and cultural resources that the NPS was established to preserve. Jonathan Jarvis, director of the NPS, has referred to climate change as the greatest challenge to maintaining “America’s natural and cultural heritage unimpaired for future generations” (Jarvis 2009, p. 2). The NPS recognizes the importance of understanding the impacts and influences of climate change on national park resources and developing adaptation strategies to best conserve species and ecosystems in light of rapidly shifting climate. A recent initiative in the NPS CCRP focuses on building a greater understanding of the effects and influences that projected climate shifts may have on natural and cultural resources across the National Park System. This initiative encourages the use of CCVAs as part of a strategy to determine and better understand natural and cultural resource vulnerability to climate change and the synergistic relationships these changes may have with existing threats and stressors to those resources.

A CCVA is an assessment of the likelihood and extent to which projected climatic shifts (including such variables as precipitation and temperature) will have adverse or beneficial influences on a given natural or cultural resource (e.g., species, plant community, or ecosystem; sacred sites, archeological artifacts) (IPCC 2007, Stein and Glick 2011). As a result, CCVAs are increasingly viewed as a key tool for providing resource managers with information that can be used to aid adaptation planning efforts for vulnerable natural and cultural resources. Specifically, a CCVA makes three main contributions to resource management. First, a vulnerability assessment helps identify *which* resources are most or least vulnerable to estimated climate changes, a determination that better enables managers to prioritize resources for enhanced conservation (Stein and Glick 2011). Second, a CCVA can uncover why resources are vulnerable or resilient (Stein and Glick 2011). The assessment process helps to determine the characteristics of a resource that make it more vulnerable to or better able to cope with climatic shifts and the associated environmental changes; this information can better equip resource managers with the understanding necessary to develop the most appropriate and practical management responses to climatic shifts in their region. Finally, a CCVA can help elucidate gaps in knowledge that exist for certain cultural and natural resources in general, so that these gaps can be filled and the vulnerability of these resources more accurately assessed.

Assessing the vulnerability of natural systems to climate change is a relatively new science and, where completed, assessments have exhibited a wide range of project approaches, primarily in regard to the scale at which analysis occurs. Some projects have focused on the vulnerability of certain ecologically influential species in a natural system, particularly those listed as threatened or endangered (Galbraith and Price 2011). Others have focused on the vulnerability of specifically defined ecosystems within a region (e.g., vulnerability of Massachusetts fish and wildlife habitats [Galbraith and O'Leary 2011]; species vulnerability assessment for the Middle Rio Grande, New Mexico [Finch et al. 2011]) and, based on the vulnerability of the ecosystem as a whole, make inferences about the subsequent effect on the species that primarily use those ecosystems.

The NPS is considering several strategies to integrate climate change resource vulnerability into the park NRCAs. In March 2014, NPS partnered with Colorado State University and SMUMN GSS to implement a pilot project to assess the feasibility of slightly modifying existing NRCA project scopes to accommodate an assessment of resource vulnerability to climate change. The pilot project's goal is to seek creative approaches to considering climate change vulnerabilities in the context of the park's NRCA project.

As part of this effort, SMUMN GSS employed a landscape scale community-based assessment for select resource components of the FOBU NRCA. The type of assessment focuses on ecological communities. This type of evaluation casts a broader net in the examination of resources, rather than looking at a list of individual species. By focusing on the community scale it is possible to infer that the degree of vulnerability for a community would directly influence the sensitivity and vulnerability of key species residing in that community. For example, if a community has low vulnerability to climate change and is expected to change very little despite projected climate shifts, it is likely that the diversity of key species residing in that community would also not experience much change or stress due to climate change. Likewise, if a community is estimated to be highly vulnerable to climate change and is expected to experience dramatic changes in composition or distribution, it is likely that the key species dependent upon that community for habitat would also be affected. Thus, a focus on the vulnerability of ecological communities within a landscape (i.e., the ecosystem or community scale) can provide a larger umbrella under which vulnerability may be examined and inferred for species inhabiting those communities. These are also typically priority resources that park managers express concern over when looking at ongoing park threats and long-term park resource sustainability.

SMUMN GSS worked collaboratively with FOBU resource staff and the NPS climate change integration pilot team to incorporate climate change analysis into the NRCA. After evaluating the ecological communities represented in the FOBU NRCA framework (Chapter 3, Figure 7), the montane shrublands and seeps, springs and slump pond aquatic habitats were selected to be evaluated in terms of their vulnerability to climate change. For the purpose of this analysis, vulnerability is defined as "the extent to which a species, habitat, or ecosystem is susceptible to harm from climate change impacts" (Schneider et al. 2007, as cited by Stein and Glick 2011, p. 9). Vulnerability consists of three key components: 1) sensitivity of a system to climate changes; 2) exposure of a system to climate changes; and 3) adaptive capacity to respond to those changes (IPCC 2007, as cited by Stein et al. 2011). Sensitivity is a measure of the degree to which a system is affected, either adversely or beneficially, by a given change in climate. Exposure is a measure of the amount of climatic and environmental change that a species or system is likely to experience. Adaptive capacity is the ability of a species or system to accommodate or cope with climatic and environmental change impacts with minimal disruption. Figure 73 illustrates the theoretical relationship among the three components and how they interact to determine overall vulnerability.

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Appendix B. Plant species documented in FOBU's aspen woodlands during various vegetation surveys of the park.

Note that NPS (2015) does not identify species by community type; this final column represents all species documented in aspen woodlands by earlier surveys that are currently included on the FOBU certified species list. Also, Friesen et al. (2010) was not a species inventory.

Scientific Name	Common Name	Dorn et al. (1984)	Fertig and Kyte (2009)	Friesen et al. (2010)	NPS (2015)
Acer glabrum	Rocky Mountain maple		X		X
Achillea millefolium	common yarrow			X	X
Actaea rubra	western red baneberry	X	X		X
Agastache urticifolia	nettle-leaf giant-hyssop	X	X		X
Allium brevistylum	short-style onion		X		X
Allium geyeri var. tenerum	Geyer's onion	X	X		X
Amelanchier alnifolia var. *alnifolia*	western serviceberry	X	X		PP*
Amelanchier alnifolia var. *pumila*	western serviceberry		X		X
Amelanchier utahensis	Utah serviceberry			X	X
Angelica argute	sharptooth angelica	X	X		X
Apocynum androsaemifolium	spreading dogbane		X	X	X
Arabis glabra	tower-mustard		X		X
Arctostaphylos uva-ursi var. *uva-ursi*	bearberry		X		X
Arnica cordifolia	heartleaf arnica	X	X		X
Artemisia cana ssp. *viscidula*	silver sagebrush	X	X	X	X
Artemisia dracunculus	tarragon		X		X

A = non-native; *PP = probably present

Appendix B (continued). Plant species documented in FOBU's aspen woodlands during various vegetation surveys of the park.

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Scientific Name	Common Name	Dorn et al. (1984)	Fertig and Kyte (2009)	Friesen et al. (2010)	NPS (2015)
Artemisia tridentata ssp. *vaseyana*	mountain big sagebrush			X	X
Aster sp.	aster	X		X	
Astragalus agrestis	field milkvetch			X	X
Astragalus canadensis var. *brevidens*	Canada milkvetch		X		X
Barbarea orthoceras	American wintercress		X		X
Boechera angustifolia	Drummond's rockcress		X		X
Boechera brachycarpa	spreadingpod rockcress		X		X
Bromus anomalus	nodding brome		X		X
Bromus inermis var. *inermis*[A]	smooth brome		X		X
Bromus sp.	brome grasses			X	
Camassia quamash	common camas	X	X		X
Carex geyeri	elk sedge			X	X
Carex hoodii	Hood's sedge		X		X
Carex microptera	ovalhead sedge			X	X
Carex nebrascensis	Nebraska sedge			X	X
Cercocarpus montanus	true mountain-mahogany	X	X	X	X

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Appendix B (continued). Plant species documented in FOBU's aspen woodlands during various vegetation surveys of the park.

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Scientific Name	Common Name	Dorn et al. (1984)	Fertig and Kyte (2009)	Friesen et al. (2010)	NPS (2015)
Chamerion angustifolium	fireweed		X	X	X
Chenopodium leptophyllum	narrow-leaf goosefoot		X		X
Cirsium scariosum	meadow thistle		X		X
Cirsium subniveum	snowy thistle		X		X
Cirsium undulatum	wavy-leaf thistle			X	X
Claytonia lanceolata	western springbeauty	X	X		X
Collinsia parviflora	small flowered blue-eyed Mary	X	X		X
Collomia linearis	narrowleaf collomia		X		X
Corallorhiza maculata var. *maculata*	spotted coral-root		X		X
Corallorhiza striata var. *striata*	striped coral-root		X		X
Cornus sericea	redosier dogwood			X	X
Danthonia californica	California oatgrass	X	X		X
Danthonia intermedia	timber oatgrass		X		PP*
Delphinium glaucum	tower larkspur		X		X
Deschampsia cespitosa	tufted hairgrass		X	X	X
Descurainia incana var. *macrosperma*	mountain tansymustard		X		X

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Appendix B (continued). Plant species documented in FOBU's aspen woodlands during various vegetation surveys of the park.

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Scientific Name	Common Name	Dorn et al. (1984)	Fertig and Kyte (2009)	Friesen et al. (2010)	NPS (2015)
Descurainia sophia[A]	flixweed; herb sophia		X		X
Dodecatheon pulchellum	dark-throat shooting-star	X	X		X
Draba albertina	slender draba		X		X
Elymus cinereus	Great Basin wildrye		X		X
Elymus glaucus	blue wildrye	X	X		X
Elymus lanceolatus	thickspike wheatgrass			X	X
Elymus x saundersii	Saunders' wild-rye		X		X
Epilobium ciliatum var. *ciliatum*	American willow-herb		X		X
Epilobium ciliatum var. *glandulosum*	American willow-herb		X		X
Equisetum arvense	field horsetail		X		X
Erigeron corymbosus	foothill daisy		X		X
Erigeron speciosus	showy fleabane		X		X
Eucephalus glaucus	blueleaf aster		X		X
Festuca idahoensis	Idaho fescue		X		X
Floerkea proserpinacoides	false mermaid	X	X		X
Fragaria virginiana	Virginia strawberry	X	X		X

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Appendix B (continued). Plant species documented in FOBU's aspen woodlands during various vegetation surveys of the park.

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Scientific Name	Common Name	Dorn et al. (1984)	Fertig and Kyte (2009)	Friesen et al. (2010)	NPS (2015)
Galium bifolium	twin-leaf bedstraw	X	X		X
Galium boreale	northern bedstraw	X	X	X	X
Galium trifidum	small bedstraw	X	X		X
Gentianella amarella var. *amarella*	northern gentian	X	X		X
Geranium richardsonii	white geranium			X	X
Geranium viscosissimum var. *incisum*	sticky geranium		X		X
Geranium viscosissimum var. *viscosissimum*	sticky geranium	X	X		X
Geum macrophyllum var. *perincisum*	large-leaf avens	X	X		X
Hieracium cynoglossoides	houndtongue hawkweed		X		X
Hydrophyllum capitatum	ballhead waterleaf	X	X		X
Hymenoxys hoopesii	orange sneezeweed	X	X		X
Juncus balticus	Baltic rush			X	X
Juncus confusus	Colorado rush	X	X		X
Juncus longistylus	longstyle rush	X	X		X
Juniperus scopulorum	Rocky Mountain juniper	X	X	X	X
Leymus cinereus	basin wildrye			X	

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Scientific Name	Common Name	Dorn et al. (1984)	Fertig and Kyte (2009)	Friesen et al. (2010)	NPS (2015)
Ligusticum filicinum	fern-leaf lovage	X		X	X
Lithophragma glabrum var. *ramulosum*	bulbiferous fringecup	X	X		X
Lithophragma parviflorum	small-flowered prairiestar		X		X
Lithophragma tenellum	slender flowered prairiestar		X		X
Lomatium dissectum var. *multifidum*	fern-leaved biscuitroot	X	X		X
Lonicera involucrata	bearberry honeysuckle	X	X		X
Lupinus argenteus var. *rubricaulis*	silvery lupine	X	X		X
Lupinus leucophyllus	velvet lupine			X	PP*
Lupinus sericeus	silky lupine			X	X
Mahonia repens	creeping barberry	X	X	X	X
Maianthemum stellatum	spikenard	X	X	X	X
Melica bulbosa	oniongrass			X	X
Mertensia oblongifolia	leafy bluebells	X	X	X	X
Nemophila breviflora	Great Basin nemophila	X	X		X
Osmorhiza chilensis (Osmorhiza berteroi)	mountain sweet cicely	X	X	X	X
Oxypolis fendleri	Fendler's cowbane			X	

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Scientific Name	Common Name	Dorn et al. (1984)	Fertig and Kyte (2009)	Friesen et al. (2010)	NPS (2015)
Oxytropis deflexa var. *sericea*	nodding locoweed		X		X
Packera paupercula	balsam groundsel		X		PP*
Packera streptanthifolia var. *streptanthifolia*	cleft-leaved groundsel		X		X
Paxistima myrsinites	mountain box	X	X		X
Penstemon procerus	small-flower beardtongue		X		X
Pentaphylloides floribunda	shrubby cinquefoil		X		X
Phacelia sericea var. *ciliosa*	silky phacelia	X	X		X
Pinus flexilis	limber pine	X	X	X	X
Poa arida	plains bluegrass			X	X
Poa bulbosa	bulbous bluegrass		X		X
Poa fendleriana	muttongrass			X	X
Poa interior	interior bluegrass		X		X
Poa pratensis[A]	Kentucky bluegrass		X	X	X
Poa secunda	Sandberg bluegrass			X	X
Polygonum bistortoides	American bistort	X	X		X
Polygonum douglasii var. *douglasii*	Douglas' knotweed		X		X

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Scientific Name	Common Name	Dorn et al. (1984)	Fertig and Kyte (2009)	Friesen et al. (2010)	NPS (2015)
Populus tremuloides	quaking aspen	X	X	X	X
Potentilla arguta	tall cinquefoil	X	X		X
Potentilla gracilis var. *fastigiata*	slender cinquefoil	X	X		X
Potentilla gracilis var. *pulcherrima*	soft cinquefoil		X		X
Potentilla pensylvanica	prairie cinquefoil	X	X		X
Prunus virginiana	chokecherry	X	X	X	X
Pseudocymopterus montanus	alpine false springparsley			X	
Pseudotsuga menziesii var. *glauca*	Douglas-fir	X	X	X	X
Ranunculus acriformis var. *montanensis*	sharp buttercup	X	X		X
Ranunculus acris[A]	tall buttercup		X		X
Ribes cereum	wax currant			X	X
Ribes inermis	whitestem gooseberry	X	X		X
Ribes viscosissimum	sticky currant	X	X		PP*
Rorippa curvipes var. *curvipes*	common yellowcress		X		X
Rosa nutkana var. *hispida*	Nootka rose		X		X
Rosa woodsii	Wood's rose	X	X	X	X

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Scientific Name	Common Name	Dorn et al. (1984)	Fertig and Kyte (2009)	Friesen et al. (2010)	NPS (2015)
Rudbeckia occidentalis	western coneflower	X	X		X
Salix bebbiana	Bebb's willow	X	X		X
Salix exigua	coyote willow			X	X
Salix lutea (Salix eriocephala var. *watsonii)*	yellow willow			X	X
Salix scouleriana	Scouler willow	X	X		X
Sambucus racemosa var. *melanocarpa*	black elderberry	X	X		X
Scrophularia lanceolata	lance-leaf figwort		X		X
Senecio integerrimus var. *exaltatus*	Columbia groundsel			X	X
Senecio serra var. *serra*	butterweed groundsel	X	X		X
Shepherdia canadensis	russet buffalo-berry	X	X	X	X
Sidalcea oregana	Oregon checker-mallow	X	X		X
Silene menziesii var. *menziesii*	Menzies' campion	X	X		X
Sium suave	hemlock water-parsnip		X		X
Solidago canadensis var. *salebrosa*	Canada goldenrod		X		X
Solidago velutina	alcove goldenrod		X		X
Stellaria longipes	long-stalk starwort		X		X

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Scientific Name	Common Name	Dorn et al. (1984)	Fertig and Kyte (2009)	Friesen et al. (2010)	NPS (2015)
Symphoricarpos oreophilus	moutain snowberry	X	X	X	X
Symphyotrichum foliaceum var. *parryi*	leafy aster		X		X
Symphyotrichum spathulatum	western mountain aster		X		X
Taraxacum officinale[A]	common dandelion			X	X
Thalictrum fendleri	Fendler's meadow-rue			X	
Thalictrum occidentale	western meadow-rue		X		X
Thalictrum venulosum	veiny meadow-rue	X		X	PP*
Trifolium hybridum[A]	alsike clover		X		X
Valeriana occidentalis	western valerian	X	X		X
Veronica biloba	twolobe speedwell		X		X
Viola adunca	hookedspur (blue) violet	X	X		X
Viola canadensis	Canadian violet	X	X		PP*

A = non-native; *PP = probably present

Appendix C. Plant species documented in FOBU's mixed conifer woodlands.

Mixed Conifer Habitat Species	**Common Name**	**Fertig (2000)**	**Fertig and Kyte (2009)**	**Friesen et al. (2010)**
Acer glabrum	Rocky Mountain maple	X	X	
Achillea millefolium	common yarrow	X		X
Achnatherum hymenoides	Indian ricegrass			X
Amelanchier alnifolia var. *alnifolia*	western serviceberry	X	R	
Amelanchier alnifolia var. *pumila*	dwarf serviceberry	X	X	
Amelanchier utahensis	Utah serviceberry	X	X	X
Aquilegia coerulea	Colorado columbine	X	X	
Arctostaphylos uva-ursi var. *uva-ursi*	bearberry	X	X	
Arnica cordifolia	heart-leaf arnica	X		X
Artemisia tridentata ssp. *vaseyana*	mountain big sagebrush	X		X
Balsamorhiza sagittata	arrowleaf balsamroot	X	X	
Carex rossii	Ross' sedge	X	X	
Castilleja sulphurea	sulphur paintbrush	X	X	
Ceanothus martini	Utah mountain-lilac	X	X	
Ceanothus velutinus	deer-brush	X	X	
Cercocarpus montanus	true mountain-mahogany	X	X	X
Chenopodium leptophyllum	narrow-leaf goosefoot		X	
Chrysothamnus viscidiflorus	green rabbitbrush	X		X
*Cirsium arvense**	Canada thistle	X		X

X = confirmed, R = reported, but not confirmed; *Invasive species

Appendix C (continued). Plant species documented in FOBU's mixed conifer woodlands.

Mixed Conifer Habitat Species	Common Name	Fertig (2000)	Fertig and Kyte (2009)	Friesen et al. (2010)
Collinsia parviflora	blue-eyed Mary	X	X	
Corydalis aurea var. *aurea*	golden smoke	X	X	
Danthonia intermedia	timber oatgrass	X	R	
Delphinium nuttallianum	Nuttall's larkspur	X		X
Dodecatheon pulchellum	dark-throat shooting-star	X	X	
Elymus lanceolatus	streambank wheatgrass	X		X
Eriogonum brevicaule	shortstem buckwheat	X		X
Eriogonum umbellatum	sulfur buckwheat	X		X
Eriogonum umbellatum var. *majus*	sulphur-flower buckwheat	X	X	
Eucephalus elegans (Aster elegans)	elegant aster	X	X	
Eucephalus engelmannii (Aster engelmannii)	Engelmann's aster	X	X	
Frasera speciosa (Swertia radiata)	elkweed (green gentian)	X	X	
Galium boreale	northern bedstraw	X	X	
Gayophytum diffusum var. *strictipes*	spreading groundsmoke	X	X	
Geranium viscosissimum var. *incisum*	sticky geranium	X	X	
Geranium viscosissimum var. *viscosissimum*	sticky geranium		X	
Helianthella uniflora	oneflower helianthella	X	X	
Heuchera parvifolia	little-leaf alumroot	X	X	
Holodiscus discolor var. *dumosis*	oceanspray			X

X = confirmed, R = reported, but not confirmed; *Invasive species

Appendix C (continued). Plant species documented in FOBU's mixed conifer woodlands.

Mixed Conifer Habitat Species	Common Name	Fertig (2000)	Fertig and Kyte (2009)	Friesen et al. (2010)
Juniperus communis var. *depressa*	common juniper	X	X	
Juniperus scopulorum	Rocky Mountain juniper	X		X
Lappula occidentalis	western stickseed	X		X
Leucopoa kingii	spike fescue	X	X	
Leymus cinereus	Great Basin wildrye	X		X
Lithospermum ruderale	western gromwell	X		X
Lomatium bicolor	Wasatch biscuitroot	X	X	
Berberis (Mahonia) repens	creeping Oregon-grape	X	X	X
Maianthemum racemosum var. *amplexicaule*	false Solomon's-seal		X	
Maianthemum stellatum	spikenard	X	X	
Mertensia oblongifolia	leafy bluebells	X		X
Mertensia viridis	green bluebells	Potential	X	
Pascopyrum smithii	western wheatgrass	X		X
Paxistima myrsinites	mountain box	X	X	
Penstemon procerus	small-flower beardtongue	X		X
Penstemon radicosus	matroot beardtongue	X	X	
Pentaphylloides floribunda	shrubby cinquefoil	X	X	
Phacelia sericea var. *ciliosa*	silky phacelia	X	X	
Phlox hoodii	Hood's phlox	X		X
Pinus flexilis	limber pine	X	X	X

X = confirmed, R = reported, but not confirmed; *Invasive species

Appendix C (continued). Plant species documented in FOBU's mixed conifer woodlands.

Mixed Conifer Habitat Species	Common Name	Fertig (2000)	Fertig and Kyte (2009)	Friesen et al. (2010)
Poa compressa	Canada bluegrass	X	X	
Poa fendleriana	muttongrass	X	X	X
*Poa pratensis**	Kentucky bluegrass	X		X
Poa secunda	Sandberg bluegrass	X		X
Poa secunda var. *elongata*	Canby bluegrass	X	X	
Populus tremuloides	quaking aspen	X	X	
Prunus virginiana	chokecherry	X		X
Pseudostellaria jamesiana (Stellaria jamesiana)	James' (sticky) chickweed	X	X	
Pseudotsuga menziesii var. glauca	Douglas-fir	X	X	X
Pteryxia terebinthina	turpentine spring-parsley	X		X
Purshia tridentata	antelope bitterbrush	X		X
Ribes cereum	wax currant	X	X	X
Ribes viscosissimum	sticky currant	X	R	
Rosa woodsii	Wood's rose	X		X
Shepherdia canadensis	russet buffalo-berry	X	X	X
Streptanthus cordatus	Heart-leaved streptanthus	X	X	
Symphoricarpos oreophilus var. *utahensis*	Utah snowberry	X	X	X
Trifolium gymnocarpon	hollyleaf clover	X		X
Trisetum spicatum	spike trisetum	X	R	
Viola purpurea var. *venosa*	goose-foot violet	X	X	

X = confirmed, R = reported, but not confirmed; *Invasive species

Appendix D. Plant species documented at four FOBU springs by Springer et al. (2006).

Scientific Name	Common Name	Spring #1	Millet Spring	Moosebones Spring	Cundick Spring
Achillea millefolium	common yarrow	X	X	X	X
Achnatherum nelsonii	Columbia needlegrass		X		
Agastache urticifolia	nettle-leaf giant-hyssop	X	X		
Agoseris glauca	short-beaked agoseris	X	X	X	X
Allium acuminatum	taper-tip onion				X
Allium geyeri	Geyer's onion			X	X
*Alopecurus arundinaceus**	creeping foxtail		X		X
Amelanchier alnifolia	western serviceberry	X			X
Amelanchier utahensis	Utah serviceberry			X	
Angelica arguta	sharptooth angelica	X			
Arabis glabra	tower-mustard	X	X		X
Arabis hirsuta	hairy rockcress			X	
Artemisia cana	silver sagebrush		X		X
Artemisia ludoviciana ssp. *ludoviciana*	Louisiana sagebrush				X
Artemisia tridentate	big sagebrush	X	X		X
Astragalus agrestis	field milkvetch	X	X	X	X
*Barbarea vulgaris**	garden yellowrocket		X		
Bromus carinatus	California brome	X	X	X	
*Bromus tectorum**	cheatgrass	X		X	
Calamagrostis stricta ssp. *Inexpansa*	northern reedgrass			X	
Camassia quamash	common camas				X
Carex aquatilis	water sedge	X			
Carex aurea	golden sedge	X			
Carex microptera	ovalhead sedge	X	X		X
Carex nebrascensis	Nebraska sedge			X	

*Invasive species

Appendix D (continued). Plant species documented at four FOBU springs by Springer et al. (2006).

Scientific Name	Common Name	Spring #1	Millet Spring	Moosebones Spring	Cundick Spring
Carex pellita	wooly sedge	X			
Carex praegracilis	clustered field sedge		X	X	
Carex sp.	sedge				X
Carex utriculata	Northwest Territory sedge	X	X	X	X
Chamerion angustifolium	fireweed	X			
Chenopodium atrovirens	pinyon goosefoot	X			
Chenopodium capitatum	blite goosefoot	X			
*Cirsium arvense**	Canada thistle	X	X		X
Cirsium scariosum	meadow thistle			X	X
Cirsium sp.			X		
*Cirsium vulgare**	bull thistle	X		X	X
Collinsia parviflora	blue-eyed Mary		X	X	X
Collomia linearis	narrowleaf collomia	X		X	X
Cornus sericea	redosier dogwood			X	X
Cymopterus longipes	longstalk springparsley				X
*Cynoglossum officinale**	common hound's tongue	X			
Delphinium nuttallianum	Nuttall's larkspur				X
Deschampsia cespitosa	tufted hairgrass		X	X	X
Descurainia incana	mountain tansymustard	X		X	
*Descurainia sophia**	flixweed	X		X	
Dodecatheon pulchellum	dark-throat shootingstar			X	X
Eleocharis palustris	common spikerush	X	X	X	X
Elymus cinereus	Great Basin wildrye	X	X	X	
Elymus trachycaulus ssp. *trachycaulus*	slender wheatgrass			X	X
Epilobium halleanum	Hall's willowherb				X
Epilobium hornemannii	Hornemann's willowherb	X			
Equisetum laevigatum	smooth horsetail			X	

*Invasive species

Appendix D (continued). Plant species documented at four FOBU springs by Springer et al. (2006).

Scientific Name	Common Name	Spring #1	Millet Spring	Moosebones Spring	Cundick Spring
Ericameria nauseosa	rubber rabbitbrush	X			
Erigeron glabellus	smooth fleabane	X	X		
Eriogonum umbellatum	sulfur buckwheat				X
Erysimum inconspicuum	shy wallflower			X	
Eurybia glauca	gray aster	X			
Fragaria virginiana	Virginia strawberry			X	
Galium boreale	northern bedstraw			X	
Geranium viscosissimum	sticky geranium	X	X	X	X
Geum macrophyllum	large-leaf avens	X	X	X	X
Glyceria striata	fowl mannagrass	X	X		
Hackelia floribunda	manyflower stickseed	X	X		
Hackelia patens	common stickseed	X			
Holodiscus discolor var. *dumosus*	oceanspray			X	
Hordeum brachyantherum	meadow barley		X	X	
Hymenoxys hoopesii	orange sneezeweed	X		X	
Juncus balticus	Baltic rush	X		X	X
Juncus ensifolius	swordleaf rush	X	X	X	X
Juncus tenuis	slender rush				X
*Lactuca serriola**	prickly lettuce	X	X	X	
Lemna turionifera	turion duckweed	X			
Lomatium bicolor	Wasatch biscuitroot				X
Lonicera involucrate	bearberry honeysuckle				X
Lupinus argenteus	silvery lupine				X
Lupinus sericeus	Pursh's silky lupine		X		
Maianthemum stellatum	starry false lily of the valley	X	X	X	X
Melica bulbosa	oniongrass		X		
Mertensia oblongifolia	leafy bluebells		X		X

*Invasive species

Appendix D (continued). Plant species documented at four FOBU springs by Springer et al. (2006).

Scientific Name	Common Name	Spring #1	Millet Spring	Moosebones Spring	Cundick Spring
Mertensia sp.	bluebells				X
Mimulus guttatus	common monkeyflower	X	X	X	
Monolepis nuttalliana	Nuttall's povertyweed			X	
Mulgedium oblongifolium (Lactuca tatarica var. *pulchella)*	blue lettuce	X			
Osmorhiza occidentalis	western sweetroot	X			
Phacelia hastata	silverleaf phacelia	X	X		
Phlox longifolia	long-leaf phlox				X
Platanthera hyperborea	northern green orchid	X			
Platanthera sp.	orchid			X	
Poa fendleriana	muttongrass				X
*Poa pratensis**	Kentucky bluegrass	X	X	X	X
Poa secunda ssp. *juncifolia (P. nevadensis)*	rush (Nevada) bluegrass				X
*Polygonum navicular**	prostrate knotweed		X	X	
Polygonum bistortoides	American bistort				X
Polygonum douglasii	Douglas' knotweed		X		
Polygonum sawatchense	Sawatch knotweed			X	
Populus tremuloides	quaking aspen	X	X		X
Potentilla anserina	silverweed cinquefoil			X	
Potentilla gracilis	slender cinquefoil		X	X	X
Prunus virginiana	chokecherry	X	X		
Pseudostellaria jamesiana	James' chickweed		X		
Ranunculus aquatilis	water buttercup	X	X	X	
Ranunculus cymbalaria	alkali buttercup		X	X	X
Ribes cereum	wax currant			X	X
Ribes inerme	whitestem gooseberry	X	X	X	X
Rosa woodsii	Woods' rose	X	X	X	X

*Invasive species

Appendix D (continued). Plant species documented at four FOBU springs by Springer et al. (2006).

Scientific Name	Common Name	Spring #1	Millet Spring	Moosebones Spring	Cundick Spring
Rudbeckia occidentalis	western coneflower	X		X	
*Rumex crispus**	curly dock		X		X
Rumex salicifolius	willow dock		X		
Salix sp.	willow	X			X
Scrophularia lanceolata	lance-leaf figwort		X		
Senecio integerrimus var. *exaltatus*	Columbia groundsel				X
Senecio serra	butterweed groundsel	X	X	X	
Shepherdia canadensis	russet buffalo-berry				X
Sidalcea oregana	Oregon checkerbloom		X	X	X
Silene menziesii	Menzies' campion	X			
Sisyrinchium idahoense	Idaho blue-eyed grass			X	
Sonchus arvensis ssp. *uliginosus**	moist sowthistle			X	
Stellaria longipes	long-stalk starwort	X		X	X
Symphoricarpos oreophilus	mountain snowberry	X		X	X
Symphyotrichum sp.	aster	X		X	
*Taraxacum officinale**	common dandelion	X	X	X	X
Thalictrum occidentale	western meadow-rue	X	X		
Thelypodium paniculatum	northwestern thelypody			X	
*Thlaspi arvense**	field pennycress		X	X	
Toxicoscordion venenosum (Zigadenus venenosus)	meadow death camas				X
Tragopogon dubius	yellow salsify				X
Triglochin maritima	seaside arrowgrass			X	
Typha latifolia	broadleaf cattail	X			
unidentified *algae*	algae		X		
unknown *Fabaceae*	legume				X
Urtica dioica	stinging nettle	X	X	X	

*Invasive species

Appendix D (continued). Plant species documented at four FOBU springs by Springer et al. (2006).

Scientific Name	Common Name	Spring #1	Millet Spring	Moosebones Spring	Cundick Spring
Veronica americana	American speedwell	X	X	X	X
Viola sororia var. *affinis*	bog violet	X		X	
Viola sp.	violet	X			
	Total	**66**	**56**	**65**	**63**

Appendix E. Seep, spring, slump pond habitats climate vulnerability scoring worksheet.

		Vulnerability Score		Confidence Score		Alternative Score	Notes:
1. Location in geographical range/distribution	Close to (<200 kms) southern limit of community distribution	5		High	3		FOBU is centrally located within
of community	More distant from southern limit of community distribution	1		Medium	2		geographic range of both species
				Low	1		
		Score	**3**	**Score**	**3**	**-1**	
2. Sensitivity to extreme climatic events	Highly vulnerable to extreme climatic events	5		High	3		Juncus can tolerate periods of drought
(e.g., drought, floods, windstorms, ice storms)	Less vulnerable to extreme climatic events	3		Medium	2		Narrowleaf cottonwood not as
	Not vulnerable to extreme climatic events	1		Low	1		drought tolerant
		Score	**4**	**Score**	**3**		
5. Dependence on specific hydrologic conditions	community is dependent on specific hydrologic conditions	5		High	3		Dependent of soil moisture from
	community is less dependent on specific hydrologic conditions	1		Medium	2		precipitation events, runoff,
				Low	1		groundwater or surface flow, or
		Score	**4**	**Score**	**3**		seeps and springs
4. Intrinsic adaptive capacity	Unlikely to be significant (low adaptive capacity)	5		High	3		Low adaptive capacity due to
	Likely to be significant (high adaptive capacity)	1		Medium	2		specific soil moisture requirements
				Low	1		
		Score	**4**	**Score**	**2**	**1**	
6. Vulnerability of Foundation/Keystone species	Foundation/keystone spp. likely to be particularly vulnerable to climate change	5		High	3		Narrowleaf cottonwood only
to climate change	Foundation/keystone spp. unlikely to be vulnerable to climate change	1		Medium	2		found in 2 locations, present
				Low	1		only due to presence of spring
		Score	**4**	**Score**	**2**		
7. Potential for climate change to exacerbate impacts	Potential for large increase in stressor impacts	5		High	3		*Juncus* fairly resistant to insects/disease
of non-climate stressors	Potential low	1		Medium	2		Invasives likely better adapted
				Low	1		to hotter, drier conditions.
		Score	**4**	**Score**	**2**	**1**	Water demand from outside park
		Totals	23		15	22-25	

	Total score	Vulnerability category	Confidence scores	
Range of 7-35	7 to 16	Less Vulnerable	7 to 11	Low
	17 to 23	Vulnerable	12 to 16	Moderate
	24 to 30	Highly Vulnerable	17 to 21	High
	31 to 35	Critically Vulnerable		

Appendix F. Montane shrubland climate vulnerability scoring worksheet.

		Vulnerability Score		Confidence Score		Alternative Score	Notes:
1. Location in geographical range/distribution	Close to (<200 kms) southern limit of community distribution	5		High	3		Located at the northeastern extent of
of community	More distant from southern limit of community distribution	1		Medium	2		geographic range
				Low	1		
		Score	**3**	**Score**	**3**		
2. Sensitivity to extreme climatic events	Highly vulnerable to extreme climatic events	5		High	3		Highly tolerant of drought and
(e.g., drought, floods, windstorms, ice storms)	Less vulnerable to extreme climatic events	3		Medium	2		low soil moisture conditions.
	Not vulnerable to extreme climatic events	1		Low	1		Community composition has some
		Score	**2**	**Score**	**2**	**1**	dependence on temperature and soil moisture
5. Dependence on specific hydrologic conditions	community is dependent on specific hydrologic conditions	5		High	3		Low dependency on soil moisture. Studies have
	community is less dependent on specific hydrologic conditions	1		Medium	2		shown community composition has dependence
				Low	1		on temperature and soil moisture, specifically
		Score	**4**	**Score**	**3**		snow-pack and timing and duration of spring thaws
4. Intrinsic adaptive capacity	Unlikely to be significant (low adaptive capacity)	5		High	3		Sprouting ability enhances
	Likely to be significant (high adaptive capacity)	1		Medium	2		species recovery from disturbance
				Low	1		Likely to become dominant
		Score	**2**	**Score**	**3**		where it is subdominant, especially after fire
6. Vulnerability of Foundation/Keystone species	Foundation/keystone spp. likely to be particularly vulnerable to climate change	5		High	3		Montane shrublands are tolerant
to climate change	Foundation/keystone spp. unlikely to be vulnerable to climate change	1		Medium	2		to most aspects associated with
				Low	1		projected climate change
		Score	**2**	**Score**	**2**	**1**	
7. Potential for climate change to exacerbate impacts	Potential for large increase in stressor impacts	5		High	3		Increased potential for insect
of non-climate stressors	Potential low	1		Medium	2		infestations and non-native plants
				Low	1		
		Score	**2**	**Score**	**2**	**3**	
		Totals	15		15	13-16	

	Total score	Vulnerability category	Confidence scores	
Range of 7-35	7 to 16	Less Vulnerable	7 to 11	Low
	17 to 23	Vulnerable	12 to 16	Moderate
	24 to 30	Highly Vulnerable	17 to 21	High
	31 to 35	Critically Vulnerable		

Appendix G. Bird species present in FOBU according to the NPS Certified Species List (NPS 2015).

R = resident, B = breeder, M = migratory, V = vagrant.

Common Name	Occurrence	Residency
American Coot	Present	R
American Crow	Present	R
American Goldfinch	Present	B
American Kestrel	Present	B
American Robin	Present	B
American Three-toed Woodpecker	Probably Present	B
American Wigeon	Present	B
Ash-throated Flycatcher	Probably Present	B
Bald Eagle	Present	B
Bank Swallow	Probably Present	B
Barn Swallow	Present	R
Barn-Owl	Probably Present	B
Black Rosy-finch	Present	B
Black-billed Magpie	Present	B
Black-capped Chickadee	Present	R
Black-chinned Hummingbird	Probably Present	B
Black-headed Grosbeak	Present	R
Black-throated Gray Warbler	Probably Present	B
Black-throated Sparrow	Unconfirmed	B
Blue Grouse	Present	R
Blue-gray Gnatcatcher	Present	V
Blue-winged Teal	Present	R
Bobolink	Unconfirmed	B
Brewer's Blackbird	Present	R
Brewer's Sparrow	Present	B
Broad-tailed Hummingbird	Present	B
Brown Creeper	Present	R

Appendix G (continued). Bird species present in FOBU according to the NPS Certified Species List (NPS 2015).

R = resident, B = breeder, M = migratory, V = vagrant.

Common Name	Occurrence	Residency
Brown-headed Cowbird	Present	B
Burrowing Owl	Present	R
California Gull	Present	M
Canada goose	Present	B
Canyon Wren	Probably Present	B
Cassin's Finch	Present	R
Cedar Waxwing	Present	M
Chipping Sparrow	Present	R
Chukar	Present	R
Clark's Nutcracker	Present	B
Cliff Swallow	Present	B
Common Nighthawk	Present	R
Common Poorwill	Present	R
Common Raven	Present	B
Common Snipe	Present	R
Common Yellowthroat	Unconfirmed	B
Cooper's Hawk	Present	R
Dark-eyed Junco	Present	R
Downy Woodpecker	Present	R
Dusky Flycatcher	Present	R
European Starling	Present	B
Evening Grosbeak	Present	R
Ferruginous Hawk	Present	B
Flammulated Owl	Probably Present	B
Fox Sparrow	Present	R
Franklin's Gull	Present	M
Gadwall	Present	B
Golden Eagle	Present	B

Appendix G (continued). Bird species present in FOBU according to the NPS Certified Species List (NPS 2015).

R = resident, B = breeder, M = migratory, V = vagrant.

Common Name	Occurrence	Residency
Golden-crowned Kinglet	Present	R
Grasshopper Sparrow	Probably Present	B
Gray Catbird	Present	R
Gray Flycatcher	Present	R
Gray Jay	Present	B
Gray-crowned Rosy-finch	Probably Present	M
Great Horned Owl	Present	R
Green-tailed Towhee	Present	B
Green-winged Teal	Present	B
Hairy Woodpecker	Present	R
Hammond's Flycatcher	Present	R
Hermit Thrush	Present	R
Hooded Warbler	Present	M
Horned Lark	Present	B
House Finch	Present	R
House Wren	Present	B
Killdeer	Present	R
Lark Bunting	Probably Present	B
Lark Sparrow	Present	B
Lazuli Bunting	Present	R
Lesser Goldfinch	Probably Present	B
Lewis' Woodpecker	Present	R
Lincoln's Sparrow	Present	R
Loggerhead Shrike	Present	R
Long-eared Owl	Present	B
MacGillvray's Warbler	Present	R
Mallard	Present	B
Mountain Bluebird	Present	B

Appendix G (continued). Bird species present in FOBU according to the NPS Certified Species List (NPS 2015).

R = resident, B = breeder, M = migratory, V = vagrant.

Common Name	Occurrence	Residency
Mountain Chickadee	Present	R
Mourning Dove	Present	B
Northern Flicker	Present	B
Northern Harrier	Present	R
Northern Pintail	Present	B
Northern Pygmy-owl	Probably Present	B
Northern Rough-winged Swallow	Present	R
Northern Saw-whet Owl	Probably Present	B
Northern Shrike	Present	R
Olive-sided Flycatcher	Present	R
Orange-crowned Warbler	Present	B
Peregrine Falcon	Present	B
Pine Grosbeak	Present	B
Pine Siskin	Present	R
Pinyon Jay	Present	R
Plumbeous Vireo	Present	R
Prairie Falcon	Present	B
Pygmy Nuthatch	Present	R
Red Crossbill	Present	R
Red-breasted Nuthatch	Present	R
Red-naped Sapsucker	Present	R
Red-necked Phalarope	Present	M
Red-tailed Hawk	Present	B
Red-winged Blackbird	Present	B
Ring-billed Gull	Present	M
Rock Dove	Present	R
Rock Wren	Present	B
Rough-legged Hawk	Present	R

Appendix G (continued). Bird species present in FOBU according to the NPS Certified Species List (NPS 2015).

R = resident, B = breeder, M = migratory, V = vagrant.

Common Name	Occurrence	Residency
Ruby-crowned Kinglet	Present	B
Ruffed Grouse	Present	R
Rufous Hummingbird	Present	M
Sage Grouse	Present	B
Sage Sparrow	Present	R
Sage Thrasher	Present	R
Sandhill Crane	Present	B
Savannah Sparrow	Present	R
Say's Phoebe	Present	B
Scott's Oriole	Probably Present	B
Sharp-shinned Hawk	Present	R
Short-eared Owl	Present	R
Snow Bunting	Probably Present	M
Song Sparrow	Present	R
Sora	Present	B
Spotted Sandpiper	Present	R
Spotted Towhee	Present	R
Steller's Jay	Present	R
Swainson's Hawk	Present	R
Swainson's Thrush	Present	R
Townsend's Solitaire	Present	R
Tree Swallow	Present	R
Turkey Vulture	Present	R
Veery	Probably Present	B
Vesper Sparrow	Present	B
Violet-green Swallow	Present	R
Virginia's Warbler	Probably Present	B
Warbling Vireo	Present	B

Appendix G (continued). Bird species present in FOBU according to the NPS Certified Species List (NPS 2015).

R = resident, B = breeder, M = migratory, V = vagrant.

Common Name	Occurrence	Residency
Western Bluebird	Present	B
Western Cordilleran Flycatcher	Present	R
Western Kingbird	Present	R
Western Meadowlark	Present	B
Western Screech-owl	Probably Present	B
Western Scrub-jay	Present	R
Western Tanager	Present	R
Western Wood-Pewee	Present	B
White-breasted Nuthatch	Present	R
White-crowned Sparrow	Present	R
White-faced Ibis	Present	B
White-throated Swift	Present	B
Willet	Probably Present	B
Williamson's Sapsucker	Probably Present	B
Wilson's Warbler	Present	R
Yellow Warbler	Present	R
Yellow-bellied Sapsucker	Not in Park	
Yellow-breasted Chat	Unconfirmed	B
Yellow-rumped Warbler	Present	R
Total Species Richness		**154**
Breeders		**69**
Resident		**75**
Migratory		**9**
Vagrant		**1**

Appendix H. Bird species observed during the Johnson (2003) inventory of FOBU.

Note that migratory and vagrant species have been removed from this appendix to align with the measures found in this assessment.

Common Name	Residency	Breeding Point Count (2001-2002)	Incidental Breeding Survey (2001-2002)	Crepuscular/ Nighttime Survey (2001-2002)	Winter Incidental Non-breeding Survey (2001-2003)
American Kestrel	B	X			
American Robin	B	X			
Barn Swallow	R		X		
Black-billed Magpie	B	X			X
Black-capped Chickadee	R	X			X
Black-headed Grosbeak	R	X			
Blue Grouse	R		X		
Brewer's Blackbird	R	X			
Brewer's Sparrow	B	X			
Broad-tailed Hummingbird	B	X			
Brown Creeper	R	X			
Brown-headed Cowbird	B	X			
Cassin's Finch	R	X			
Chipping Sparrow	R	X			
Chuker	R		X		
Clark's Nutcracker	B	X			
Cliff Swallow	B	X			
Common Nighthawk	R			X	
Common Poorwill	R			X	
Common Raven	B	X			X
Cooper's Hawk	R	X			
Cordilleran Flycatcher	R	X			
Dark-eyed Junco	R	X			X
Downy Woodpecker	R		X		

Appendix H (continued). Bird species observed during the Johnson (2003) inventory of FOBU.

Note that migratory and vagrant species have been removed from this appendix to align with the measures found in this assessment.

Common Name	Residency	Breeding Point Count (2001-2002)	Incidental Breeding Survey (2001-2002)	Crepuscular/ Nighttime Survey (2001-2002)	Winter Incidental Non-breeding Survey (2001-2003)
Dusky Flycatcher	R	X			
Ferruginous Hawk	B		X		
Golden Eagle	B	X	X		X
Golden-crowned Kinglet	R	X			
Gray Flycatcher	R	X			
Great Horned Owl	R			X	
Great-tailed Grackle	B	X			
Green-tailed Towhee	B	X			
Hairy Woodpecker	R		X		
Hammond's Flycatcher	R	X			
Hermit Thrush	R		X		
Horned Lark	B	X			
House Wren	B	X			
Killdeer	R		X		
Lazuli Bunting	R	X			
Loggerhead Shrike	R		X		
Long-eared Owl	B			X	
MacGillivray's Warbler	R	X			
Mallard	B		X		
Mountain Bluebird	B	X			
Mountain Chickadee	R	X			X
Mourning Dove	B	X			
Northern Flicker	B	X			
Northern Harrier	R	X			
Northern Rough-winged Swallow	R		X		

Appendix H (continued). Bird species observed during the Johnson (2003) inventory of FOBU.

Note that migratory and vagrant species have been removed from this appendix to align with the measures found in this assessment.

Common Name	Residency	Breeding Point Count (2001-2002)	Incidental Breeding Survey (2001-2002)	Crepuscular/ Nighttime Survey (2001-2002)	Winter Incidental Non-breeding Survey (2001-2003)
Orange-crowned Warbler	B	X			
Pine Siskin	R		X		
Plumbeous Vireo	R		X		
Prairie Falcon	B		X		
Pygmy Nuthatch	R		X		
Red-breasted Nuthatch	R	X			
Red-naped Sapsucker	R	X			
Red-tailed Hawk	B	X			
Rock Wren	B	X			X
Ruby-crowned Kinglet	B	X			
Sage Grouse	B	X			
Sage Sparrow	R		X		
Sage Thrasher	R	X			
Sandhill Crane	B	X			
Say's Phoebe	B	X			
Sharp-shined Hawk	R		X		
Song Sparrow	R		X		
Spotted Sandpiper	R		X		
Spotted Towhee	R	X			
Steller's Jay	R	X			
Swainson's Hawk	R	X			
Swainson's Thrush	R	X			
Townsend’s Solitaire	R		X		
Tree Swallow	R	X			
Turkey Vulture	R	X			

Appendix H (continued). Bird species observed during the Johnson (2003) inventory of FOBU.

Note that migratory and vagrant species have been removed from this appendix to align with the measures found in this assessment.

Common Name	Residency	Breeding Point Count (2001-2002)	Incidental Breeding Survey (2001-2002)	Crepuscular/ Nighttime Survey (2001-2002)	Winter Incidental Non-breeding Survey (2001-2003)
Vesper Sparrow	B	X			
Violet-green Swallow	R	X			
Warbling Vireo	B	X			
Western Meadowlark	B	X			
Western Scrub-Jay	R		X		
Western Wood-Pewee	B	X			
White-breasted Nuthatch	R	X			
White-crowned Sparrow	R	X			
Yellow Warbler	R	X			
Yellow-rumped Warbler	R	X			
Total Species Richness		**60**	**22**	**4**	**7**
Breeding Richness		**28**	**4**	**1**	**4**
Year-round Richness		**33**	**19**	**4**	**4**
Raptor Richness		**7**	**4**	**1**	**1**

Appendix I. Night sky quality monitoring report for Rubey Point, Fossil Butte National Monument for night of 13 October 2004.

NPS NIGHT SKIES PROGRAM DATA NIGHT REPORT

FOBU041014 Fossil Butte National Monument **Rubey Point** **14-Oct-04**

Data Night Attributes

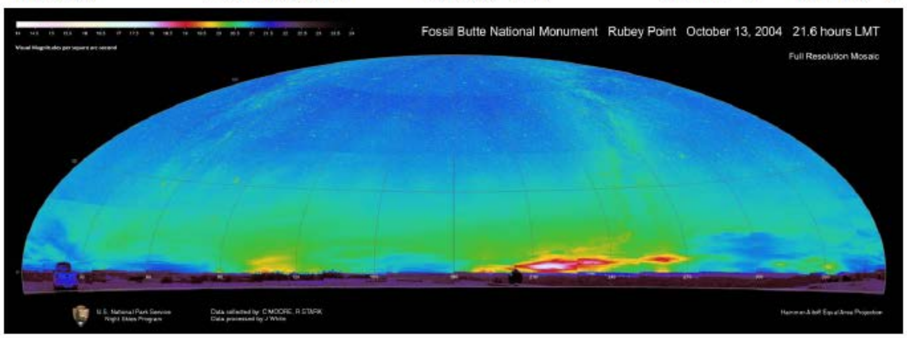
Longitude:	-110.80990	Camera:	IMG 1	Air temp. (C):	4.4	ZLM:	OBS_1: C Moore
Latitude:	41.88250	# of sets:	4	R. H. (%):		BORTLE:	OBS_2: R Stark
Elevation (m):	2451	Exposure (secs):	15	Wind Speed (mph):	6	SQM:	OBS_3:

NARRATIVE: Clouds starting to clear some. High cirrus throughout remains persistant

Data Set Attributes

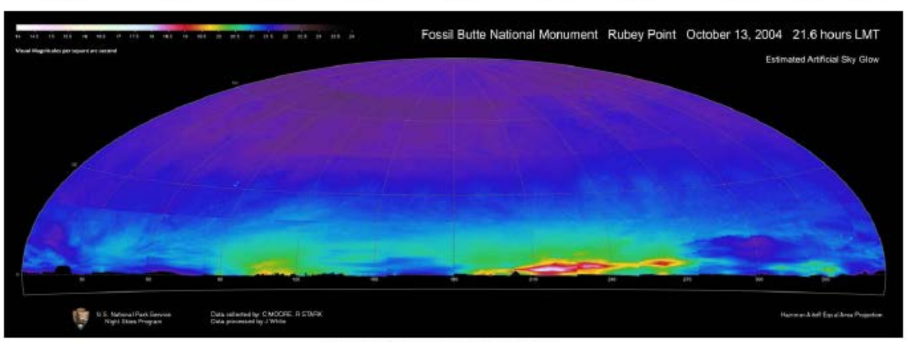
	Quality Flags				Natural Sky Model			Extinction				Collection Properties			
Data Set	Use-able	Col-lection	Pro-cessing	Atmo-sphere:	Zenith airglow (μcd/m²)	Fit quality	Natural sky model fit notes	Ext. coeff. (mag/airmass)	Std err Y	# stars used	# stars reject	% Clouds	Ave. Point Error	Max Point Error	total bias drift
1	N	3	3	3	95	2	High cirrus and poor extinction	0.373	0.33	52	28	6	0.21	0.40	8.5
2	N	3	3	3	127	2	High cirrus and poor extinction	0.347	0.33	39	29	6	0.22	0.41	8.5
3	Y	3	3	3	127	3	Lowest extinction of night, best set	0.235	0.11	66	26	4	0.34	0.52	7.1
4	Y	3	3	3	127	3	High cirrus and poor extinction	0.444	0.26	53	35	4	0.53	0.88	9.0

FOBU041014 Date (LMT) 13-Oct-04 Time (LMT): 21.64 Reference: N Data Set: **1**



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec⁻²)	Average Sky Luminance (μcd/m²)	Zenith Luminance (mag arcsec⁻²)	Zenith Luminance (μcd/m²)	Brightest luminance (mag arcsec⁻²)	Brightest lumininance	Synthetic SQM (mag arcsec⁻²)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
20.76	539	21.11	391	17.62	9,719	21.07	-7.83	1.450	1.086

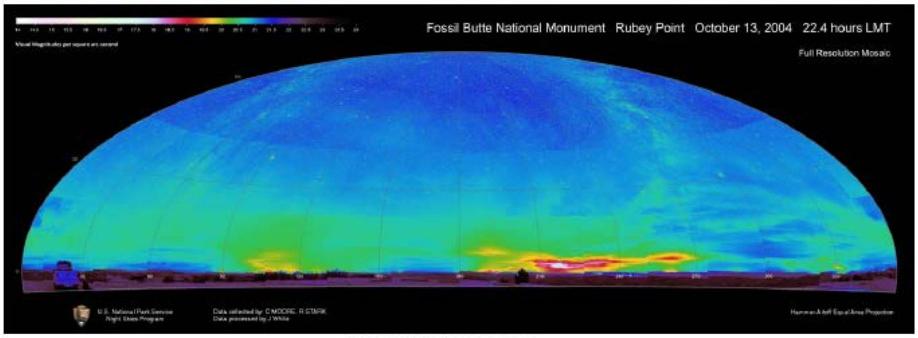


PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance (μcd/m²)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest lumininance (μcd/m²)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
53.1	324	264.5	228.3	175	9,585	1.31	-7.25	0.756	0.719

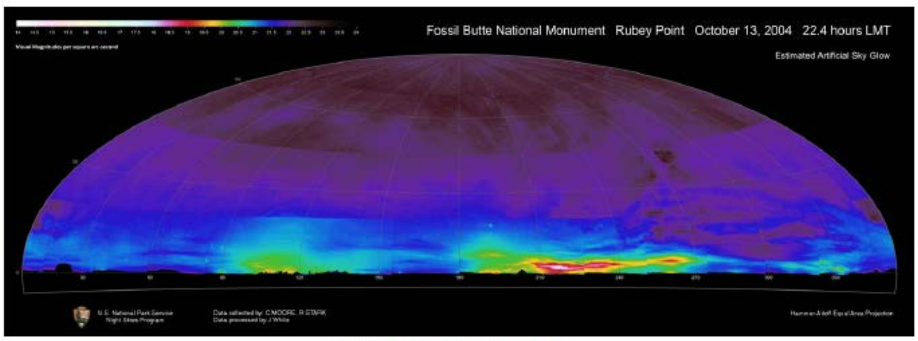
Appendix I (continued). Night sky quality monitoring report for Rubey Point, Fossil Butte National Monument for night of 13 October 2004.

FOBU041014 | Date (LMT) 13-Oct-04 | Time (LMT): 22.38 | Reference: N | Data Set: 2



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec^{-2})	Average Sky Luminance (μcd/m^2)	Zenith Luminance (mag arcsec^{-2})	Zenith Luminance (μcd/m^2)	Brightest luminance (mag arcsec^{-2})	Brightest lumininance	Synthetic SQM (mag arcsec^{-2})	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
20.85	494	21.31	326	17.57	10,162	21.17	-7.73	1.316	0.951

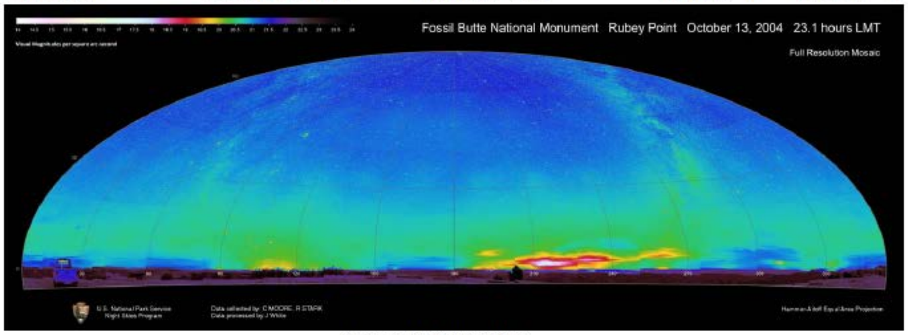


PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance (μcd/m^2)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest lumininance (μcd/m^2)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
59.9	237	173.9	145.7	112	10,020	0.95	-6.91	0.495	0.522

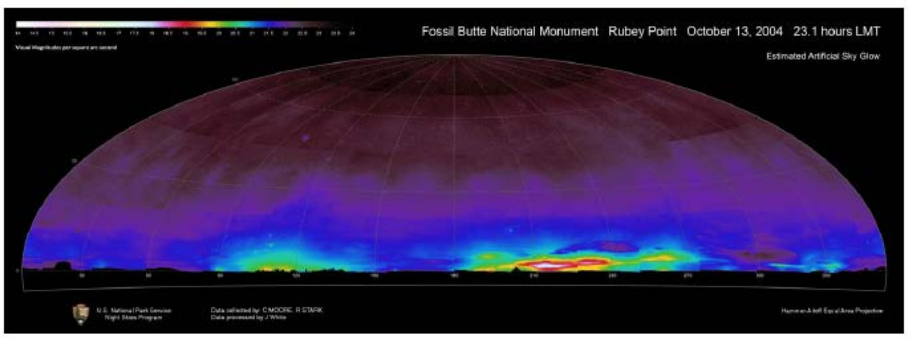
Appendix I (continued). Night sky quality monitoring report for Rubey Point, Fossil Butte National Monument for night of 13 October 2004.

FOBU041014 | Date (LMT) 13-Oct-04 | Time (LMT): 23.13 | Reference: Y | Data Set: 3



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec^{-2})	Average Sky Luminance (μcd/m^2)	Zenith Luminance (mag arcsec^{-2})	Zenith Luminance (μcd/m^2)	Brightest luminance (mag arcsec^{-2})	Brightest lumininance	Synthetic SQM (mag arcsec^{-2})	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
20.87	487	21.40	298	17.39	12,012	21.21	-7.71	1.282	0.956

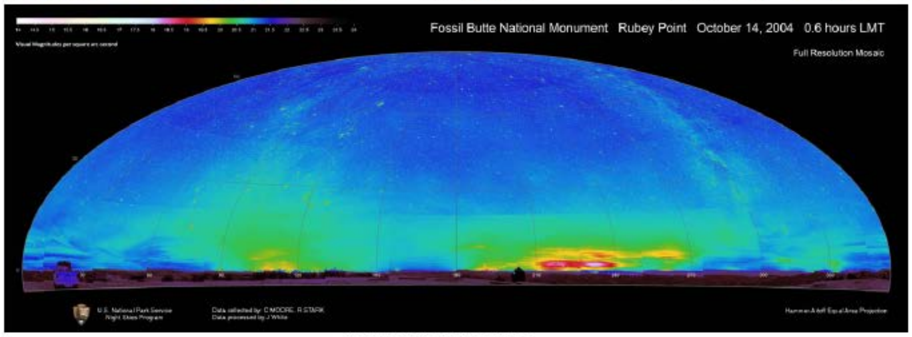


PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance (μcd/m^2)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest lumininance (μcd/m^2)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
66.1	184	128.1	104.8	52	11,831	0.74	-6.64	0.357	0.449

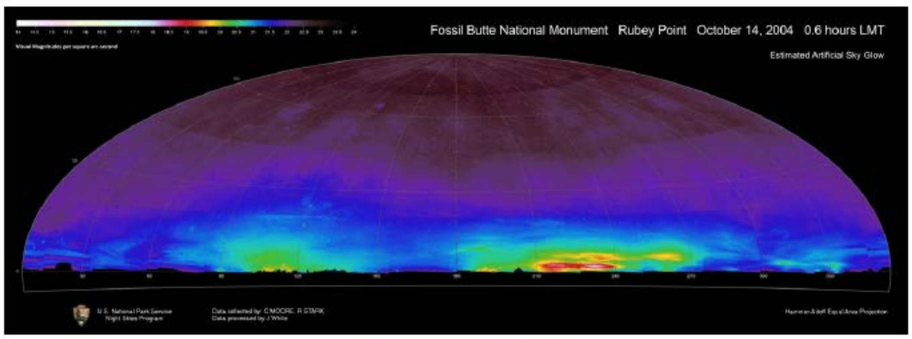
Appendix I (continued). Night sky quality monitoring report for Rubey Point, Fossil Butte National Monument for night of 13 October 2004.

FOBU041014 Date (LMT) 14-Oct-04 Time (LMT): 0.57 Reference: N Data Set: 4



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec^{-2})	Average Sky Luminance (μcd/m^2)	Zenith Luminance (mag arcsec^{-2})	Zenith Luminance (μcd/m^2)	Brightest luminance (mag arcsec^{-2})	Brightest lumininance	Synthetic SQM (mag arcsec^{-2})	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
20.94	456	21.36	309	18.06	6,502	21.26	-7.64	1.217	0.874



PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance (μcd/m^2)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest lumininance (μcd/m^2)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
61.8	229	168.9	135.8	88	6,373	0.92	-6.87	0.469	0.510

Appendix J. Night sky quality monitoring report for Rubey Point, Fossil Butte National Monument for night of 14 October 2004.

NPS NIGHT SKIES PROGRAM DATA NIGHT REPORT

FOBU041015 Fossil Butte National Monument **Rubey Point** **15-Oct-04**

Data Night Attributes

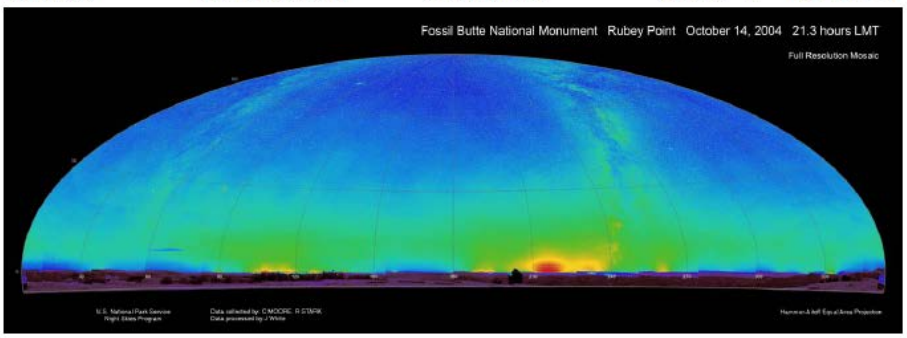
Longitude:	-110.81000	Camera:	IMG 1	Air temp. (C):	5.6	ZLM:		OBS_1:	C Moore
Latitude:	41.88300	# of sets:	4	R. H. (%):		BORTLE:		OBS_2:	R Stark
Elevation (m):	2450	Exposure (secs):	15	Wind Speed (mph):	7	SQM:		OBS_3:	

NARRATIVE: Clear skies

Data Set Attributes

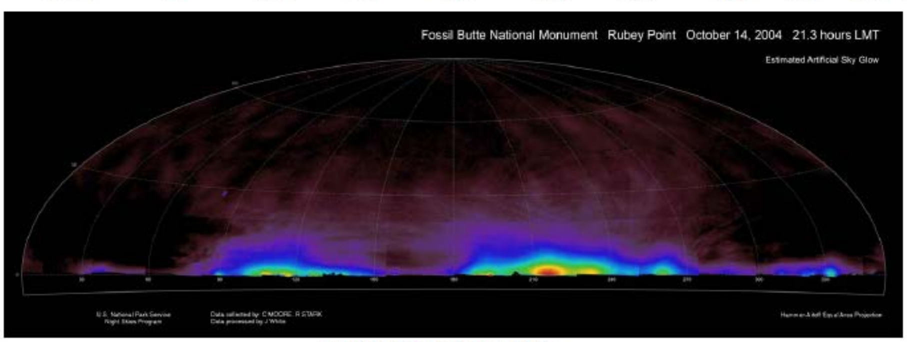
	Quality Flags				Natural Sky Model			Extinction			Collection Properties				
Data Set	Use-able	Col-lection	Pro-cessing	Atmo-sphere:	Zenith airglow ($\mu cd/m^2$)	Fit quality	Natural sky model fit notes	Ext. coeff. (mag/airmass)	Std err Y	# stars used	# stars reject	% Clouds	Ave. Point Error	Max Point Error	total bias drift
1	Y	4	4	4	162	3	High cirrus or haze causing subtraction issues. Extinction coeff is	0.137	0.04	82	3	1	0.31	0.49	8.7
2	Y	4	4	4	175	3	High cirrus or haze causing subtraction issues. Extinction coeff is	0.138	0.04	83	3	0	0.32	0.49	6.4
3	Y	4	4	4	175	3	High cirrus or haze causing subtraction issues. Extinction coeff is	0.135	0.04	85	1	0	0.35	0.52	7.2
4	Y	4	4	4	166	3	High cirrus or haze causing subtraction issues. Extinction coeff is	0.139	0.04	95	4	0	0.40	0.56	5.1

FOBU041015 Date (LMT) 14-Oct-04 Time (LMT): 21.30 Reference: N Data Set: **1**



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec⁻²)	Average Sky Luminance ($\mu cd/m^2$)	Zenith Luminance (mag arcsec⁻²)	Zenith Luminance ($\mu cd/m^2$)	Brightest luminance (mag arcsec⁻²)	Brightest luminance	Synthetic SQM (mag arcsec⁻²)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
20.84	500	21.29	330	18.67	3,701	21.15	-7.74	1.343	0.970

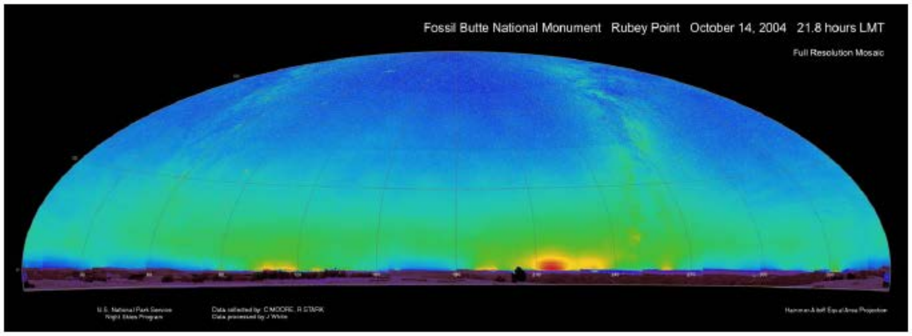


PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance ($\mu cd/m^2$)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest lumininance ($\mu cd/m^2$)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
84.7	78	50.0	45.4	31	3,482	0.31	-5.70	0.149	0.232

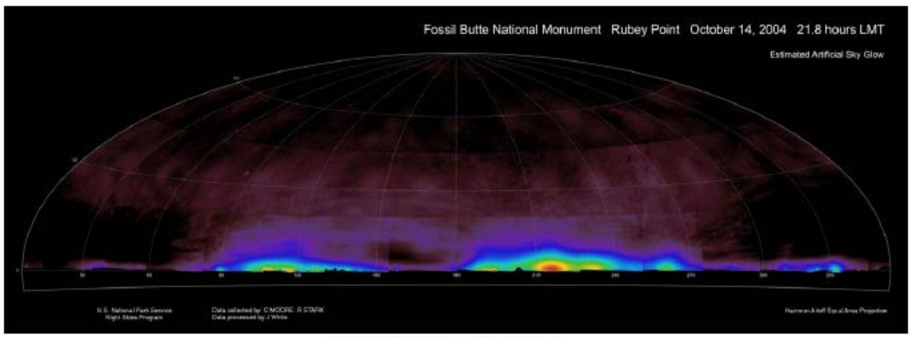
Appendix J (continued). Night sky quality monitoring report for Rubey Point, Fossil Butte National Monument for night of 14 October 2004.

FOBU041015 Date (LMT) 14-Oct-04 Time (LMT): 21.78 Reference: N Data Set: 2



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec⁻²)	Average Sky Luminance (μcd/m²)	Zenith Luminance (mag arcsec⁻²)	Zenith Luminance (μcd/m²)	Brightest luminance (mag arcsec⁻²)	Brightest lumininance	Synthetic SQM (mag arcsec⁻²)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Max Vert
20.80	517	21.29	330	18.61	3,888	21.11	-7.78	1.396	0.975

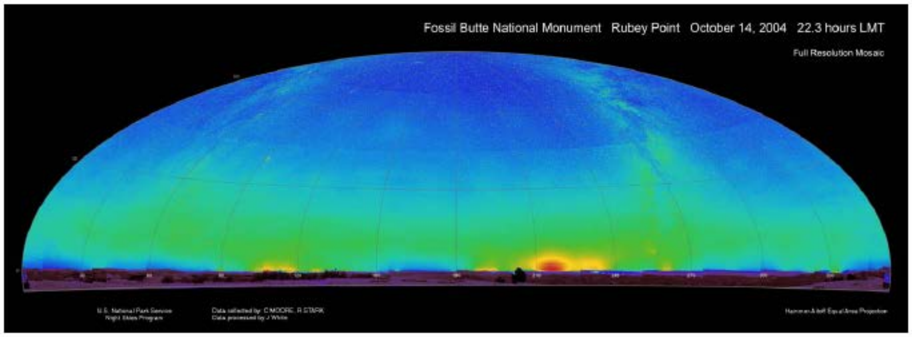


PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance (μcd/m²)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest lumininance (μcd/m²)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Max Vert
84.8	75	51.2	47.0	28	3,665	0.30	-5.66	0.148	0.212

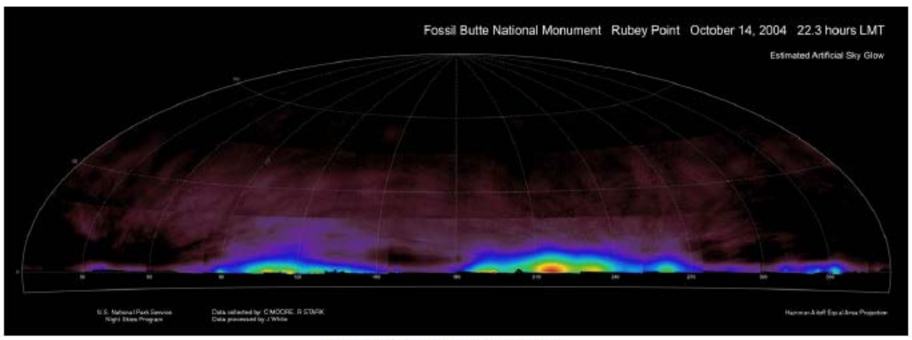
Appendix J (continued). Night sky quality monitoring report for Rubey Point, Fossil Butte National Monument for night of 14 October 2004.

FOBU041015 Date (LMT) 14-Oct-04 Time (LMT): 22.27 Reference: N Data Set: 3



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec^{-2})	Average Sky Luminance (μcd/m^2)	Zenith Luminance (mag arcsec^{-2})	Zenith Luminance (μcd/m^2)	Brightest luminance (mag arcsec^{-2})	Brightest lumininance	Synthetic SQM (mag arcsec^{-2})	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
20.82	508	21.36	310	18.64	3,780	21.16	-7.76	1.356	0.940

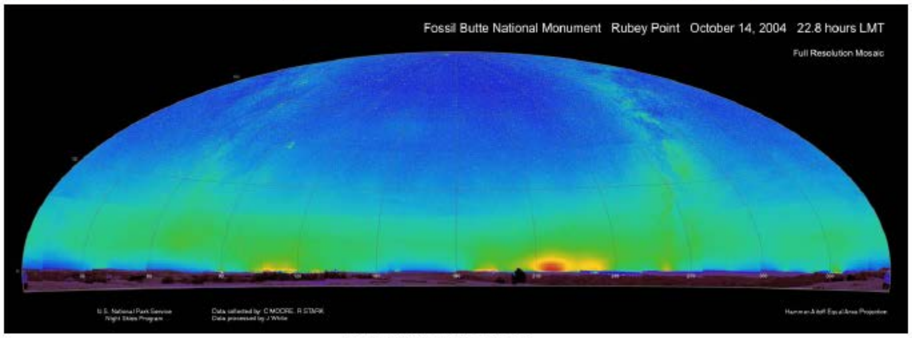


PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance (μcd/m^2)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest lumininance (μcd/m^2)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
87.8	65	40.3	32.3	11	3,554	0.26	-5.50	0.106	0.182

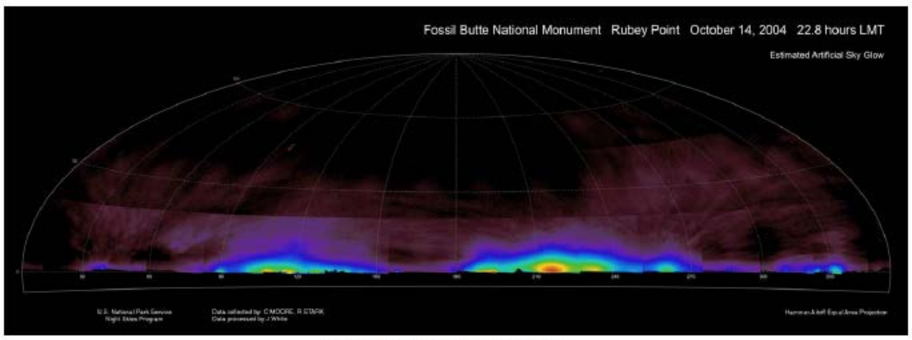
Appendix J (continued). Night sky quality monitoring report for Rubey Point, Fossil Butte National Monument for night of 14 October 2004.

FOBU041015 | Date (LMT) 14-Oct-04 | Time (LMT): 22.75 | Reference: Y | Data Set: 4



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec^{-2})	Average Sky Luminance ($\mu cd/m^2$)	Zenith Luminance (mag arcsec^{-2})	Zenith Luminance ($\mu cd/m^2$)	Brightest luminance (mag arcsec^{-2})	Brightest lumininance	Synthetic SQM (mag arcsec^{-2})	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Max Vert
20.86	490	21.36	309	18.57	4,063	21.20	-7.72	1.304	0.899



PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance ($\mu cd/m^2$)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest lumininance ($\mu cd/m^2$)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Max Vert
87.3	68	39.7	29.3	12	3,845	0.27	-5.55	0.103	0.174

Appendix K. Night sky quality monitoring report for Rubey Point, Fossil Butte National Monument for night of 18 August 2006.

NPS NIGHT SKIES PROGRAM DATA NIGHT REPORT

FOBU060819 Fossil Butte National Monument **Rubey Point** **19-Aug-06**

Data Night Attributes

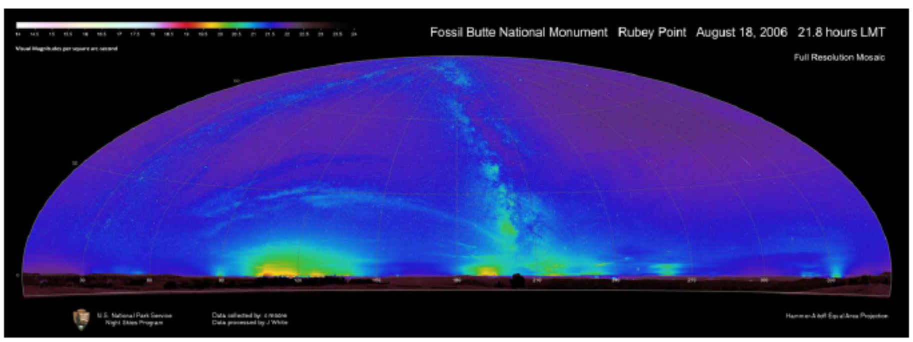
Longitude:	-110.80988	Camera:	IMG 1	Air temp. (C):	13.9	ZLM:	OBS_1: C Moore
Latitude:	41.88248	# of sets:	3	R. H. (%):	22.0	BORTLE:	OBS_2:
Elevation (m):	2442	Exposure (secs):	12	Wind Speed (mph):	3	SQM:	OBS_3:

NARRATIVE: Smoke plume to west, some high cirrus, transparency fair. Second set best of night

Data Set Attributes

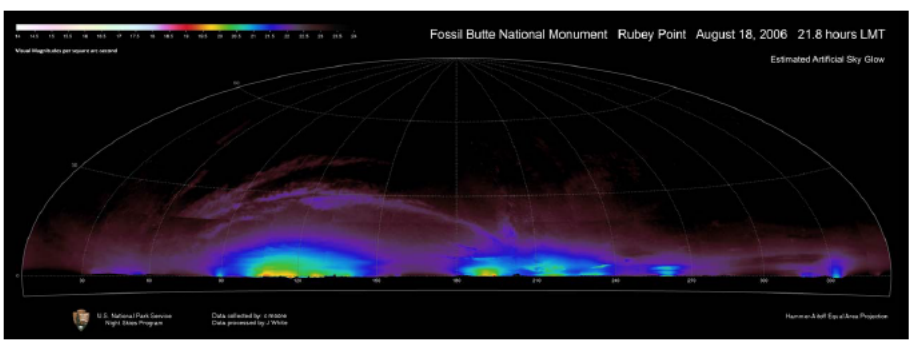
	Quality Flags				Natural Sky Model			Extinction			Collection Properties				
Data Set	Use-able	Col-lection	Pro-cessing	Atmo-sphere:	Zenith airglow (μcd/m²)	Fit quality	Natural sky model fit notes	Ext. coeff. (mag/airmass)	Std err Y	# stars used	# stars reject	% Clouds	Ave. Point Error	Max Point Error	total bias drift
1	Y	3	4	3	64	4	Fairly good subtraction, haze and clouds	0.334	0.31	41	26	5	0.39	0.64	13.6
2	Y	4	4	3	54	4	Fairly good subtraction, haze and clouds	0.286	0.12	63	19	5	0.41	0.66	9.5
3	Y	4	4	3	54	4	Fairly good subtraction, haze and clouds	0.329	0.23	49	20	6	0.44	0.69	4.9

FOBU060819 Date (LMT) 18-Aug-06 Time (LMT): 21.84 Reference: N Data Set: **1**



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec⁻²)	Average Sky Luminance (μcd/m²)	Zenith Luminance (mag arcsec⁻²)	Zenith Luminance (μcd/m²)	Brightest luminance (mag arcsec⁻²)	Brightest lumininance	Synthetic SQM (mag arcsec⁻²)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
21.54	262	21.58	254	18.68	3,669	21.79	-7.05	0.708	0.543

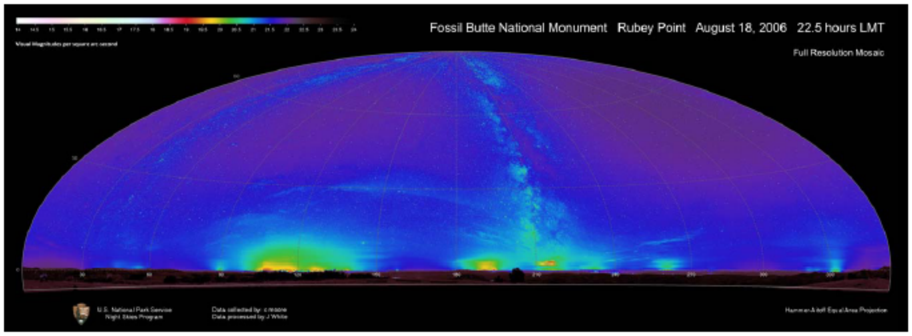


PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance (μcd/m²)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest lumininance (μcd/m²)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
88.0	68	35.5	23.7	7	3,513	0.27	-5.56	0.093	0.207

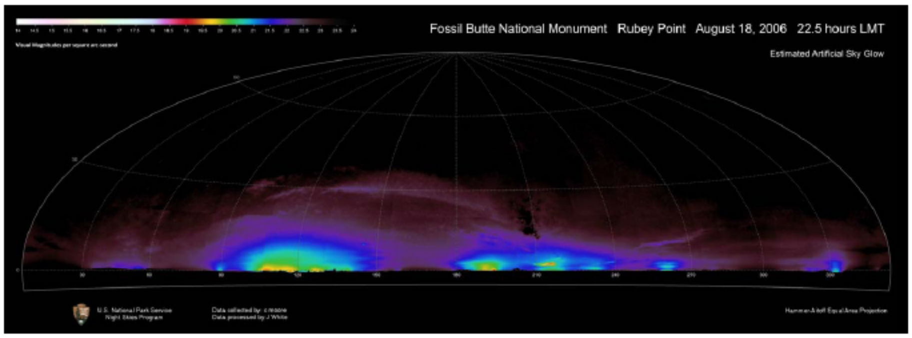
Appendix K (continued). Night sky quality monitoring report for Rubey Point, Fossil Butte National Monument for night of 18 August 2006.

FOBU060819 Date (LMT) 18-Aug-06 Time (LMT): 22.52 Reference: Y Data Set: **2**



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec-²)	Average Sky Luminance (μcd/m²)	Zenith Luminance (mag arcsec-²)	Zenith Luminance (μcd/m²)	Brightest luminance (mag arcsec-²)	Brightest lumininance	Synthetic SQM (mag arcsec-²)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
21.57	256	21.80	206	18.70	3,587	21.81	-7.02	0.692	0.527

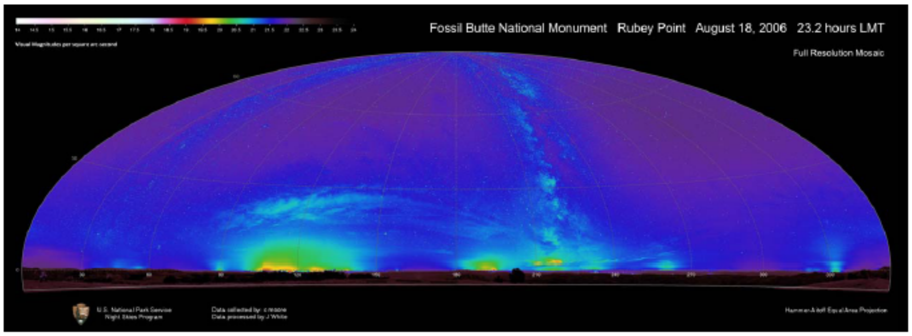


PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance (μcd/m²)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest lumininance (μcd/m²)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
89.0	62	31.9	20.6	-4	3,430	0.25	-5.46	0.082	0.195

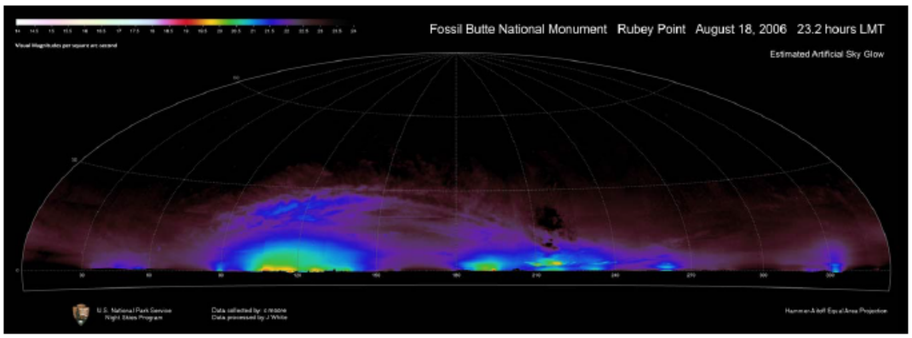
Appendix K (continued). Night sky quality monitoring report for Rubey Point, Fossil Butte National Monument for night of 18 August 2006.

FOBU060819 Date (LMT) 18-Aug-06 Time (LMT): 23.20 Reference: N Data Set: **3**



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec⁻²)	Average Sky Luminance (μcd/m²)	Zenith Luminance (mag arcsec⁻²)	Zenith Luminance (μcd/m²)	Brightest luminance (mag arcsec⁻²)	Brightest lumininance	Synthetic SQM (mag arcsec⁻²)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
21.58	252	21.70	226	18.69	3,614	21.84	-7.01	0.682	0.518



PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance (μcd/m²)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest lumininance (μcd/m²)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
87.1	70	40.4	26.6	-7	3,458	0.28	-5.60	0.099	0.217

Appendix L. Night sky quality monitoring report for Rubey Point, Fossil Butte National Monument for night of 26 September 2006.

NPS NIGHT SKIES PROGRAM DATA NIGHT REPORT

FOBU060926 Fossil Butte National Monument **Rubey Point** **26-Sep-06**

Data Night Attributes

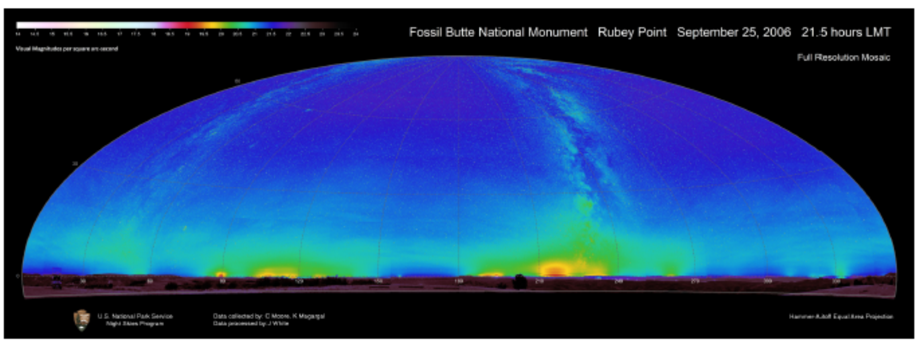
Longitude:	-110.80991	Camera:	IMG 1	Air temp. (C):	7.2	ZLM:		OBS_1:	C Moore
Latitude:	41.88248	# of sets:	4	R. H. (%):	54.0	BORTLE:		OBS_2:	
Elevation (m):	2450	Exposure (secs):	15	Wind Speed (mph):	6	SQM:		OBS_3:	

NARRATIVE: Thin haze layer SW, otherwise clear.

Data Set Attributes

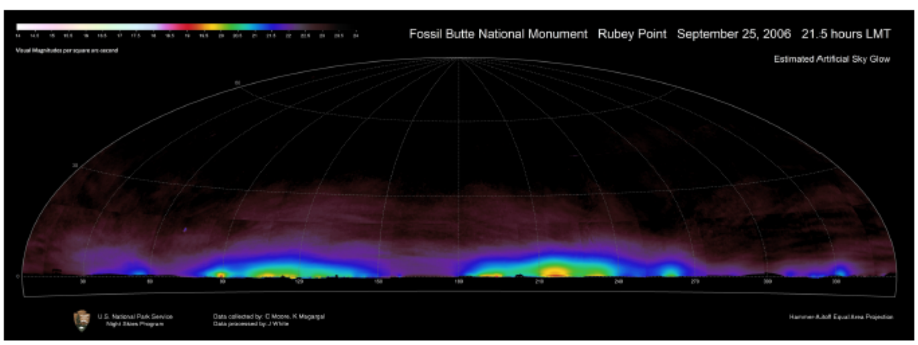
	Quality Flags				Natural Sky Model			Extinction				Collection Properties			
Data Set	Use-able	Col-lection	Pro-cessing	Atmo-sphere	Zenith airglow (μcd/m²)	Fit quality	Natural sky model fit notes	Ext. coeff. (mag/airmass)	Std err Y	# stars used	# stars reject	% Clouds	Ave. Point Error	Max Point Error	total bias drift
1	Y	4	4	4	102	4	Good subtraction through all sets	0.157	0.03	75	1	0	0.24	0.41	8.9
2	Y	4	4	4	108	4	Good subtraction through all sets	0.155	0.03	87	1	0	0.27	0.44	9.2
3	Y	4	4	4	108	4	Good subtraction through all sets	0.155	0.04	83	2	0	0.31	0.46	6.2
4	Y	4	4	4	95	4	Good subtraction through all sets	0.157	0.04	92	2	0	0.35	0.49	6.8

FOBU060926 Date (LMT) 25-Sep-06 Time (LMT): 21.54 Reference: N **Data Set: 1**



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec⁻²)	Average Sky Luminance (μcd/m²)	Zenith Luminance (mag arcsec⁻²)	Zenith Luminance (μcd/m²)	Brightest luminance (mag arcsec⁻²)	Brightest lumininance	Synthetic SQM (mag arcsec⁻²)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Max Vert
21.15	376	21.55	260	18.61	3,892	21.48	-7.43	0.984	0.716

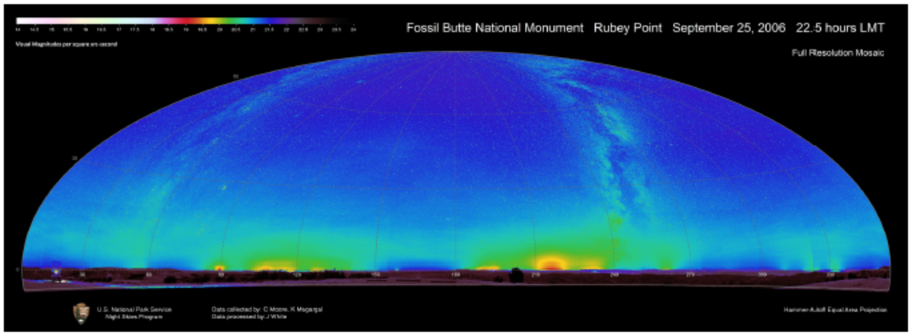


PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance (μcd/m²)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest lumininance (μcd/m²)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Max Vert
88.6	65	29.9	20.6	-10	3,709	0.26	-5.51	0.077	0.174

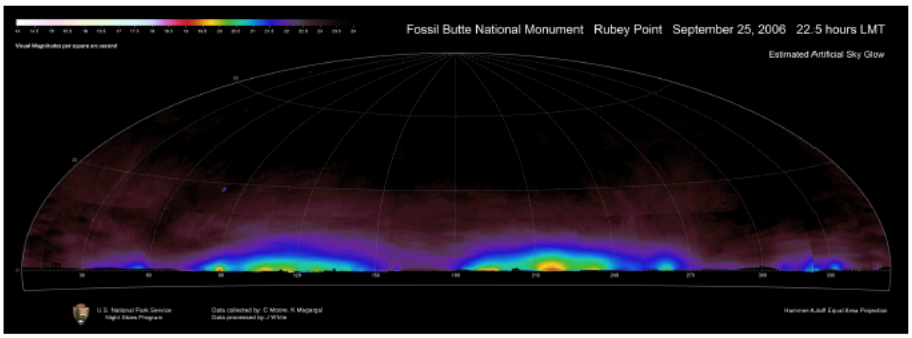
Appendix L (continued). Night sky quality monitoring report for Rubey Point, Fossil Butte National Monument for night of 26 September 2006.

FOBU060926 Date (LMT) 25-Sep-06 Time (LMT): 22.50 Reference: N Data Set: 2



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec⁻²)	Average Sky Luminance (μcd/m²)	Zenith Luminance (mag arcsec⁻²)	Zenith Luminance (μcd/m²)	Brightest luminance (mag arcsec⁻²)	Brightest lumininance	Synthetic SQM (mag arcsec⁻²)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
21.12	387	21.60	248	15.55	65,385	21.43	-7.47	1.024	0.722

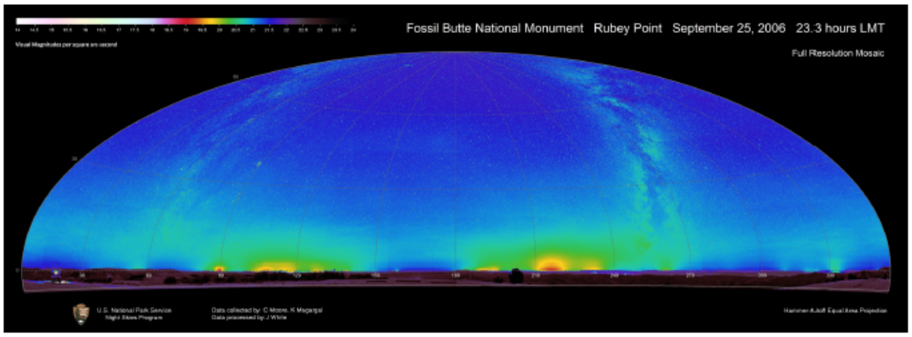


PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance (μcd/m²)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest lumininance (μcd/m²)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
88.0	68	34.7	25.3	-1	3,537	0.28	-5.56	0.092	0.178

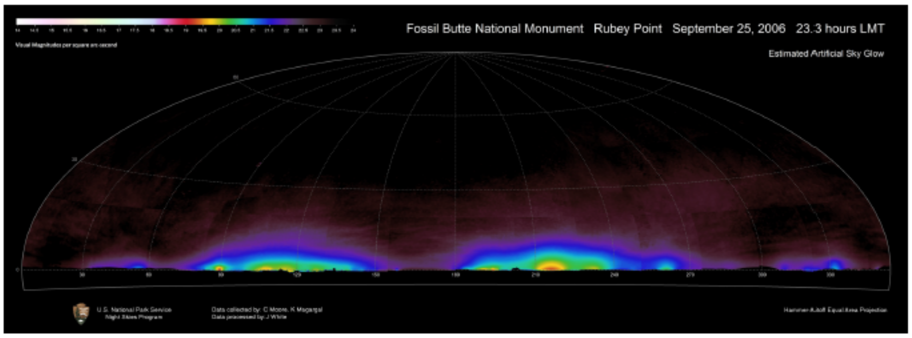
Appendix L (continued). Night sky quality monitoring report for Rubey Point, Fossil Butte National Monument for night of 26 September 2006.

FOBU060926 Date (LMT) 25-Sep-06 Time (LMT): 23.35 Reference: N Data Set: **3**



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec^{-2})	Average Sky Luminance (μcd/m^2)	Zenith Luminance (mag arcsec^{-2})	Zenith Luminance (μcd/m^2)	Brightest luminance (mag arcsec^{-2})	Brightest lumininance	Synthetic SQM (mag arcsec^{-2})	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
21.13	382	21.64	240	15.55	65,241	21.43	-7.46	1.018	0.710

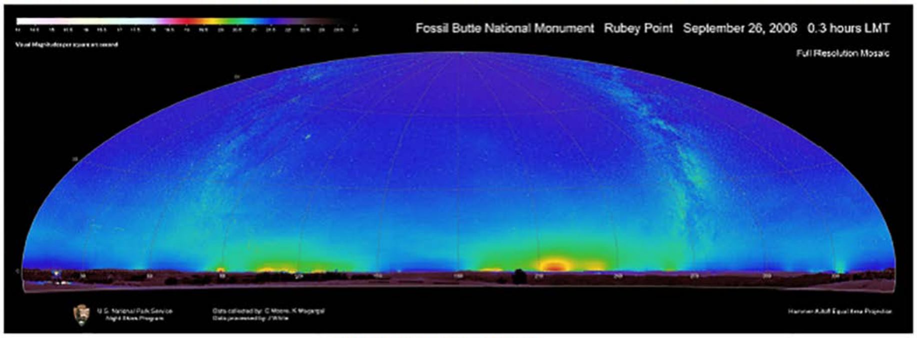


PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance (μcd/m^2)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest lumininance (μcd/m^2)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
88.6	65	33.3	24.9	5	2,720	0.26	-5.50	0.088	0.170

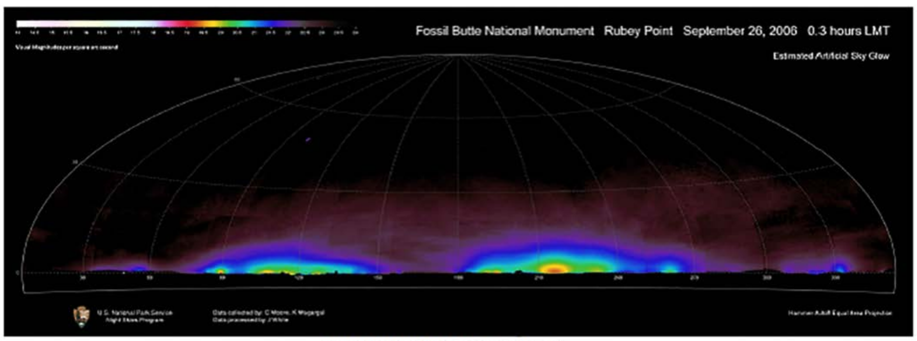
Appendix L (continued). Night sky quality monitoring report for Rubey Point, Fossil Butte National Monument for night of 26 September 2006.

FOBU060926	Date (LMT) 26-Sep-06	Time (LMT): 0.30	Reference: Y	Data Set: 4



PHOTOMETRY OF ALL SOURCES

Average Sky Luminance (mag arcsec⁻²)	Average Sky Luminance (μcd/m²)	Zenith Luminance (mag arcsec⁻²)	Zenith Luminance (μcd/m²)	Brightest luminance (mag arcsec⁻²)	Brightest lumininance	Synthetic SQM (mag arcsec⁻²)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
21.21	357	21.73	220	15.55	65,148	21.51	-7.39	0.945	0.674



PHOTOMETRY OF ARTIFICIAL SKYGLOW

Sky Quality Index (SQI)	Average Sky Luminance (μcd/m²)	Average Sky Luminance to zenith angle 80°	Average Sky Luminance to zenith angle 70°	Zenith Luminance	Brightest lumininance (μcd/m²)	All-sky light pollution ratio (ALR)	Total luminous emittance (mags)	Illuminance (mlux) Horizontal	Illuminance (mlux) Max Vert
89.4	61	29.4	19.7	-5	2,997	0.25	-5.44	0.072	0.183

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National Park Service
U.S. Department of the Interior

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