Betsey York
Devan Allen McGranahan

Identifying existing knowledge and necessary data on grassland resources to support resilient grazing ecosystems

Status of—and recommendations for—data, knowledge, and management in the NPS Midwest Region

A final report to the
National Park Service
Midwest Region

NDSU RANGE SCIENCE

Executive Summary

The purpose of this project was to contribute to an understanding of the current state of grassland resource management in five units of the National Park Service's Midwest Region. Our specific project goals were to

1. Identify multi–species management goals and ecological objectives for each Midwest Region National Park Service unit to enhance grassland ecosystem function
2. Recommend changes to existing strategies and/or specific actions to improve achievement of management goals
3. Identify key uncertainties and data gaps that might act as barriers to managing for resilient grassland ecosystems, and prioritize research needs to address high priority data gaps

We used a three-part approach consisting of on-site interviews with NPS management, on-site and online audits of available documents and data for each unit, and a follow-up survey to determine how broadly interview responses applied across all participants.

In our analysis and discussion we focus on the *grazing ecosystem*, which Frank *et al.* (1998) distinguish from other habitats "by its prominent herbivore-based food web and by the extent to which ecological processes are regulated by dynamics within that food web." Our primary finding is that sustainable management of grazing ecosystems in the NPS Midwest Region would benefit from coördinated management of fire and grazing regimes.

In grazing ecosystems around the world, the fire-grazing interaction creates a unique ecological disturbance referred to as *pyric-herbivory*, which supports and stabilizes a breadth of grassland ecological services and functions. Successfully coupling fire and grazing regimes in a management context requires an integrated perspective that is often substantially different from the species-specific focus we found to predominate natural resource management within each NPS unit studied here.

In addition to the unit-specific assessments and recommendations given in the Appendices, this report discusses the science behind fire-grazing interactions in grazing ecosystem management, principal considerations for successfully coupling fire and grazing regimes in conservation areas of the North American Great Plains, and addresses potential cultural and logistical barriers to the adoption of necessary management perspectives and practices. We also describe steps that can be taken to facilitate the successful coupling of fire and grazing regimes in the NPS Midwest Region. Briefly, these steps include:

- Use ecological site descriptions to identify soils-based disturbance response groups as a means to understand patterns of plant community composition and productivity dynamics at a landscape level.
- Add primary productivity measurements to existing plant community sampling protocols, extend the application of those protocols, and incorporate productivity data with disturbance response groups to delineate burn units that maximize the stability of grazing resources within and across years.
- Maximize opportunities to use domestic livestock in grazing ecosystem management as a flexible means to track stocking rate with rainfall and primary productivity.

Contents

List of Figures

List of Tables

List of Abbreviations

CESU — Cooperative Ecosystem Studies Units. A consortium of federal and non-federal partners that facilitates contributions by researchers and other experts to the mission of the National Park Service.
EPMT — Exotic Plant Management Team
IRMA — Integrated Resource Management Application. Online access to NPS statistics and data.
MWR — The National Park Service's Midwest Region
NDSU — North Dakota State University
NPS — National Park Service. Units in this study include:

- AGFO — Agate Fossil Beds National Monument
- BADL — Badlands National Park
- TAPR — Tallgrass Prairie National Preserve
- THRO — Theodore Roosevelt National Park
- WICA — Wind Cave National Park

Identifying existing knowledge and necessary data on grassland resources to support resilient grazing ecosystems

Status of—and recommendations for—data, knowledge, and management in the NPS Midwest Region

Betsey York, MSc[1,2]
Devan Allen McGranahan, PhD[1]

[1] *Range Science Program, School of Natural Resource Sciences, North Dakota State University*
[2] *Oklahoma Department of Conservation*

July 13, 2019

This project contributes to an understanding of the current state of grassland resource management in five units of the National Park Service's Midwest Region. We focus on the grazing ecosystem, which Frank *et al.* (1998) distinguish as a "prominent herbivore-based food web and by the extent to which ecological processes are regulated by dynamics within that food web." Our primary finding is that sustainable management of grazing ecosystems in the NPS Midwest Region would benefit from integrated management of fire and grazing regimes.

Introduction

Review of Project Objectives

Primary project goals:

1. Identify multi–species management goals and ecological objectives for each Midwest Region National Park Service unit that are expected to result in improved grassland ecosystem function
2. Recommend changes to existing strategies and/or specific actions to improve achievement of management goals
3. Identify key uncertainties and data gaps that might act as barriers to managing for resilient grassland ecosystems, and prioritize research needs to address high priority data gaps

Across the United States, each unit of the National Park Service (NPS) has a mandate to "conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations (Organic Act 1916)". Whether a postage stamp size unit or a large multi-site park, the managers must interpret this federal directive. We focus on five NPS units in the Midwest Region: Agate Fossil Beds National Monument (AGFO), Badlands National Park (BADL), Tallgrass Prairie National Preserve (TAPR), Theodore Roosevelt National Park

(THRO) and Wind Cave National Park (WICA). The size and specific mandate of each Unit differs substantially, making their management practices and needs diverse. Thus, we worked with each Unit individually to understand their management goals and motivations. Identifying goals and ecological objectives at the outset allowed us to determine if current management strategies use the latest science to achieve their goals.

The purpose of this report is to communicate strategies that enhance the resilience of grassland resources for NPS units that both rely upon, and are required to conserve, functional native prairie ecosystems. We focus on ensuring highly-functional ecosystem processes through the restoration and maintenance of natural ecological disturbance regimes. The rationale for this management approach follows in this report, and we highlight areas where units in the region lack information or plans to work towards these management goals.

Grassland ecology and management

Primary drivers of species composition and ecological structure and function in grasslands are fire, herbivory, and climate (Blair *et al.* 2014). Grasslands are ecologically adapted to thrive under ecological disturbances (Samson *et al.* 2004). Considered together, intensity, frequency, spatial extent, and temporal characteristics (e.g., seasonality and duration) of an ecological disturbance comprise the *disturbance regime*. Most issues and resulting recommendations addressed in this report focus on the suppression, removal, or alteration of historic disturbance regimes. In this report, we describe management actions that seek to restore or mimic, as best as possible, the disturbance regimes that characterized the grasslands of the Northern Great Plains prior to European settlement. Here we review the scientific literature that forms our basis for natural or ecologically-analogous disturbance regimes.

Fire

Fire has been an intrinsic component of grasslands and other rangeland ecosystems since these biomes developed and spread around the world. Grasslands as we know them today—including both the vegetation and characteristic animal communities—emerged after the last Ice Age, and have burned regularly and naturally since. Many grass-dominated landscapes owe their existence to fire, especially in the US Great Plains (Axelrod 1985), where precipitation is substantial enough to support woody plant species capable of converting these landscapes to shrublands, woodlands, or even forests without regular burning.

As Europeans established colonies and new nations around the world, they radically altered natural fire regimes. Settlers on the North American prairies especially saw fire as an existential threat to homesteads and towns made of flammable materials with little capacity for defense against fires. It is possible that the fires Europeans encountered were extraordinarily intense due to unnaturally high fuel loads following the extirpation of both bison and indigenous peoples—which prevented large fires by grazing and intentionally burning, respectively—prior to settlement; see Courtwright (2011). As natural resource management became institutionalized in the 20th century, the perspective that fire was a force of destruction that needed to be stopped to protect valuable natural resources became central to federal management policy, including the National Park Service (Bachelet *et al.* 2000; Umbanhowar Jr 1996). If fires began naturally, or were started via a human act, they were extinguished as quickly as possible presumably to protect both humans and resources the unit protects. Due to continued suppression, fuels built up across the landscape. This led to wildfires breaking out across the plains much harder to suppress due to higher fuel loads causing fires to burn more intensely and across a larger extent.

The view of fire as a destructive force was—and in many parts of the US, remains—a tenet of rangeland management aimed at maximizing livestock production. The analogies between fire and grazing animals as consumers of vegetation are obvious (Bond & Keeley 2005), and many livestock producers view combustion as a competitor to rumination, literally vaporizing—and thus wasting—plant biomass that could be turned into marketable animal products. Meanwhile the historical association between fire and loss of life and property persists in the psyche of residents throughout the Great Plains (Courtwright 2007), which perpetuates the narrative that fire not only consumes forage but has an overall negative effect (e.g., Wright & Bailey 1982).

Early ecologists struggled to reconcile the destructive nature of fire with the persistence of fire-dependent grassland ecosystems in areas that should otherwise support trees (Clements 1916; Transeau 1935). The current perspective is that rangelands are dynamic, *non-equilibrium* systems that require periodic disturbances like fire to maintain optimal ecological function (Westoby *et al.* 1989). Meanwhile conventional rangeland management aimed at maximizing livestock production has been implicated in the degradation of habitat for many of the species that contribute to grassland biodiversity (Fuhlendorf & Engle 2001). Fire is now widely recognized as critical to balancing rangeland ecology and productivity (Fuhlendorf *et al.* 2012; Toombs *et al.* 2010).

Rangeland managers in the Great Plains are increasingly adopting fire (Twidwell *et al.* 2013), although today's fire looks different than those of previous centuries. Wildfires—whether the result of a natural or human-caused ignition—are still suppressed, and managers implement prescribed fires to ensure land burns under conditions that provide as much safety and control over fire behavior and fire effects as possible. In most rangelands, the effects of having been burned are no longer apparent approximately two years after a prescribed fire (Limb *et al.* 2016).

Grazing

Grazing is a general type of herbivory in which consumers non-selectively procure mouthfuls of vegetation, and is contrasted with browsing, in which consumers carefully select individual tissues from individual plants. As a result, grazers typically focus on finer plant material such as grasses, other graminoids, and herbaceous flowering plants (forbs), and have wide mouths and tongues to facilitate large bites; browsers can select leaves from woody plants with narrow mouths and nimble tongues. Bison, cattle, and sheep are grazers, while deer and goats are browsers. (Pronghorn antelope and elk, meanwhile, are versatile herbivores, switching between grazing and browsing depending on season and nutritive demands.) Evolutionary interactions between grazer morphology, behavior, forage preferences, and plant-soil dynamics have created a global pattern of "grazing ecosystems" as diverse as Yellowstone National Park and the Serengeti (Frank *et al.* 1998).

The ecological integrity of many grazing ecosystems worldwide has been threatened by the introduction of commercial agricultural grazing regimes. Ranchers and pastoralists often manage domestic livestock with high stocking rates and rely on infrastructure and other inputs to increase productivity, frequently with negative impacts to biodiversity and ecosystem function (Watkinson & Ormerod 2001). In the western United States, livestock grazing has been implicated in the degradation of substantial public land area (Fleischner 1994). In its emphasis on spatially-even forage utilization in pursuit of maximum livestock production, commercial range management in the Great Plains has failed to support critical habitat and other ecosystem services for rangeland biodiversity (Fuhlendorf & Engle 2001). At the same time, herbivory is a defining ecological component of grazing ecosystems and in many grasslands is essential to maintain biodiversity and productivity (e.g., Collins *et al.* 1998; Patton *et al.* 2007). With the extirpation of native grazers from most of North America's grasslands—and many Midwestern NPS units—a balance must be struck between sustainability and biodiversity conservation (Watkinson & Ormerod 2001).

A critical distinction between management and grazer identity must be made when describing and planning a grazing regime. While intensive livestock management can effect environmental damage to soil, slopes, and water quality (Bilotta *et al.* 2007), well-managed grazing systems are "a forgotten hero of conservation" (Franzluebbers *et al.* 2012). In the Great Plains, how grazers are managed tends to matter more for conservation outcomes than whether the species is native (bison) or introduced (cattle) (Allred *et al.* 2011a). Cattle grazing, specifically, was identified as having a positive influence on some grassland-obligate birds on public grassland in the Northern

Great Plains (Ahlering & Merkord 2016).

Climate

Climate zones defined by precipitation, latitude, and elevation divide grasslands of the North American Great Plains into four major biomes—the eastern tallgrass prairie; western shortgrass prairie, or shortgrass steppe; and two central mixed-grass prairie types, divided into southern mixed-grass and northern mixed-grass. With the exception of Tallgrass Prairie National Preserve, in eastern Kansas, the NPS units of the Midwest Region are situated in the northern mixed-grass prairie. The western side of the biome is relatively higher elevation than other prairie in the region, which combined with the latitude creates a cool temperate climate characterized by long cold winters, short, potentially hot summers with long days bookended by wide cool growing seasons, and considerable variability in rainfall among years and among seasons with years. This climate facilitates perennial grasslands co-dominated by cool-season (C_3) and warm-season (C_4) grasses, and a diversity of forbs.

Within local climate zones (sub-types of the broader northern mixed-grass prairie), precipitation is the main driver of short-term primary productivity and a major influence on plant community composition. In fact, despite the importance of fire and grazing on the composition of grassland communities in the Northern Great Plains, precipitation is a moderating influence on disturbance-driven effects on composition (Ahlering & Merkord 2016). Primary productivity generally increases with light-moderate grazing, but ultimately tracks with annual precipitation (Patton *et al.* 2007). Variability in primary productivity and vegetation composition among burned and unburned sites in the northern mixed-grass prairie is negligible compared to the effects of precipitation (Erichsen-Arychuk *et al.* 2002; Whisenant & Uresk 1989).

There is considerable uncertainty about how grassland communities in the northern Great Plains will respond to potential alterations to climate regimes under projected global change (Chamaillé-Jammes & Bond 2010; McGranahan & Yurkonis 2018). Shifts in the dynamics of the characteristic co-dominance between C_3 cool-season and C_4 warm-season grasses could be driven by any combination of the following:

- Temperature changes— Hotter summers should favor the drought-tolerant C_4 photosynthetic pathway, but longer frost-free cool-season growing periods would favor C_3 grasses, especially cool-season invasive species such as Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*).
- Precipitation changes— Even among the drought-tolerant C_4 grasses in the region, shifts among C_4 species following sustained deviations from normal precipitation alter forage production and palatability. And even if community composition remains stable, precipitation variability can have substantial impacts on grazers (Craine *et al.* 2013).
- Atmospheric carbon fertilization— Atmospheric carbon dioxide concentrations ([CO_2]) have nearly doubled in the last 250 years. The effects on plant community dynamics are not entirely clear. Generally, the C_3 pathway should be more likely to take advantage of excess carbon in the atmosphere (Temme *et al.* 2013), but there are apparently no overarching differences among C_3 and C_4 grasses, specifically (Wand *et al.* 1999). Changes in soil moisture and water use efficiency are confounding (Chamaillé-Jammes & Bond 2010). Other responses to altered [CO_2] include changes in the nutritional value of plant material (Craine *et al.* 2010; Taub *et al.* 2008).

Ecological Site Descriptions

Fire, grazing, and climate variability are incorporated into working understandings of non-equilibrium rangeland dynamics through *state-and-transition models* (Westoby *et al.* 1989), adopted widely by the US Natural Resource Conservation Service (see an example in Fig. 1).

In this system, rangeland landscapes are divided into *ecological sites* defined primarily by soil type (the relative amount of clay, silt, and loam) and landscape position (uplands, bottomlands,

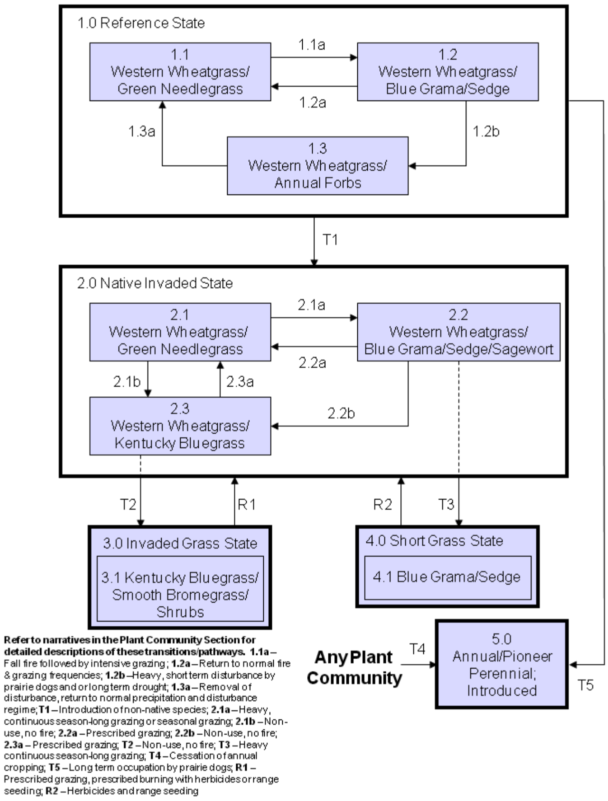


Figure 1: An example of a state-and-transition model from the Ecological Site Description (ESD) for loamy sites in MLRA 54 (NW South Dakota and SW North Dakota). All NRCS ESD information is available online.

or some position along a slope). Each ecological site has several potential plant communities; which one is observed depends on management history and environmental factors. The potential communities are divided into *states*, or broad condition categories ranging from relatively pristine prairie to rangeland heavily degraded by invasive species or excessive stocking.

Within each state are variations of the community that might shift slightly (described by *transitions*) depending on precipitation or time since a non-degrading disturbance like moderate grazing or prescribed fire. Large transitions between states occur in response to intense and/or persistent disturbances, and require substantial management intervention to reverse. In this way managers can predict vegetation responses to disturbance and plan management based on expected productivity under various management and climate scenarios.

Grassland resilience

While grasslands are one of the most abundant ecosystems worldwide, in developed countries grasslands are also one of the most imperiled ecosystems (Blair *et al.* 2014; Newbold *et al.* 2016). This is especially the case in the U.S. Great Plains, where 30–85% of native tallgrass and mixed-grass prairie has been lost since the mid-1800's, mostly to cultivation (Samson & Knopf 1994); the conversion to row-crop agriculture has continued into the 21st century (Wright & Wimberly 2013). Most National Park Service units in the Midwest are charged with the conservation of the natural and cultural histories of the North American prairie. Ensuring an attractive visitor experience in open grassland can be a challenge without mountains, forests, and the exciting geology of Western parks, thus four of the five units in the Midwest Region currently have bison (*Bison bison*)[1].

Overall, current grassland management practices in Midwest Region NPS units follow a species-specific approach reminiscent more of wildlife population management rather than ecosystem ecology. The focus on individual species was common in park planning throughout the 20th century (Lebel *et al.* 2006). We found both vegetation and wildlife management in Midwest region NPS units to be species oriented. In particular, invasive species management depends on the specific invasive species units must manage (Bestelmeyer & Briske 2012).

In contrast to species-specific wildlife management, the ecosystem perspective considers interactions between communities, the abiotic environment, ecosystem function rather than emphasizing the population status of individual species. The importance of dynamic ecosystems to grassland resilience is one of the most important scientific acknowledgments in recent history (Thomas 1996). As used here, *resilience* refers to

> The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (Walker *et al.* 2004).

[1] It is our understanding that the fifth unit, AGFO, had plans for a bison herd but these have since been shelved.

Resilience is important to the NPS if it is to successfully follow its mandate to preserve natural or cultural histories for the education and enjoyment of future generations. While this might sound like a static mission—the conservation of a stable state—it ironically requires substantial flexibility in management to maintain a constant state despite multiple variable environmental factors. The diversity of pressures on protected lands is increasing. Ecosystems must be able to receive threats and bounce back to continue to provide ecosystem services (i.e., carbon sequestration, wildlife habitat, erosion control, viewscapes, etc.). Recommendations in this report communicate how specific management practices can enhance the resilience of grassland ecosystems and maintain ecosystem service delivery in the Midwestern NPS units.

> Fire management and ungulate management are influenced by spatial and political factors at least as much as by scientific factors and choices are partially informed by science but ultimately driven by human value (Cole & Yung 2012).

While this report leans heavily on the published scientific literature to determine how to enhance the function and stability of grazing ecosystems in the NPS Midwest Region, the project has had an inherent human dimensions component from the beginning. Site visits included not only data audits but semi-structured interviews with park managers at the units to better understand management priorities within existing bounds of social, cultural, and political constraints. The enabling legislation of units guides the focus of management, budget, and staffing needs for NPS units throughout the country. Prorities and activities are also affected by external and internal forces. Considering our broad recommendations within the social contexts of specific units will better enable implementation of scientific suggestions. Thus our approach consisted of both qualitative and quantitative methods to achieve the outlined goals. These methodologies allowed us to develop unit-specific and region-wide perspectives on current management and management needs.

Methods

Research Design

This research study was accomplished under the Midwest Cooperative Ecosystems Study Unit (CESU). The CESU commissioned North Dakota State University to complete this work and respond to the objectives set forth in the Scope of Work. To accomplish these objectives fully, the NDSU research team applied a mixed method approach to fully understand management goals, current data gaps and desired outcomes for grassland management in these Midwest region NPS units. This approach included both qualitative and quantitative data collection methods. Interviews, surveys, and data audits collectively inform the recommendations communicated at the conclusion of this report.

Study Area

The CESU Scope of Work named five NPS units spanning four states under the jurisdiction of the NPS Midwest Region office in Omaha, Nebraska (Fig. 2):

- Agate Fossil Beds National Monument (Nebraska)
- Badlands National Park (South Dakota)
- Tallgrass Prairie National Preserve (Kansas)
- Theodore Roosevelt National Park (North Dakota)
- Wind Cave National Park (South Dakota)

These NPS units all contain substantial grassland area, although they are also geomorphologically and hydrologically variable (Gitzen *et al.* 2010).

Researchers visited the units in late spring 2018. Data audits and interviews of management staff were conducted at each site to understand management goals and availability of data.

Data Collection

Interviews and Surveys

Interviews were in-person and semi-structured. This format allowed us to cover similar topics in

Figure 2: Geographic location of NPS units included in this study.

each interview while allowing managers to discuss Unit-specific issues in detail (Creswell 2003; Montello & Sutton 2012). Items in the interview guide are included as Appendix F. Interview questions were developed by using an established framework (Fig. 3) created under previous social-ecological describing rangeland manager decision making (Lubell *et al.* 2013). The framework focuses on factors influencing management decisions and how they evolve in response to dynamic social- ecological system characteristics.

We adapted the decision making framework to describe the process in terms of NPS decision making (Fig. 3). In early 2018, we attended a MWR Bison Strategic Meeting and conducted a focus group to aid in formation of the altered framework. The social system influencing decision making varies considerably between the two. NPS managers must take into account other opinions at their unit, visitor wants and needs, legislative mandate, and budgetary constraints.

B. York conducted 18 interviews, recording them for later transcription. Interviews were coded using the RQDA package for Qualitative Analysis in the R statistical environment (Huang 2018; R Core Team 2017) to identify common themes and inform the survey instrument. Interviews helped us better understand sources of current uncertainties and overall management goals.

We created items on the survey to understand goals, management plans, data availability, and knowledge gaps in grassland management. We tailored the survey to inform the three objectives of this study. We sent out the survey with an invitation to participate and an invitation to disseminate the survey to others at their unit. It was developed

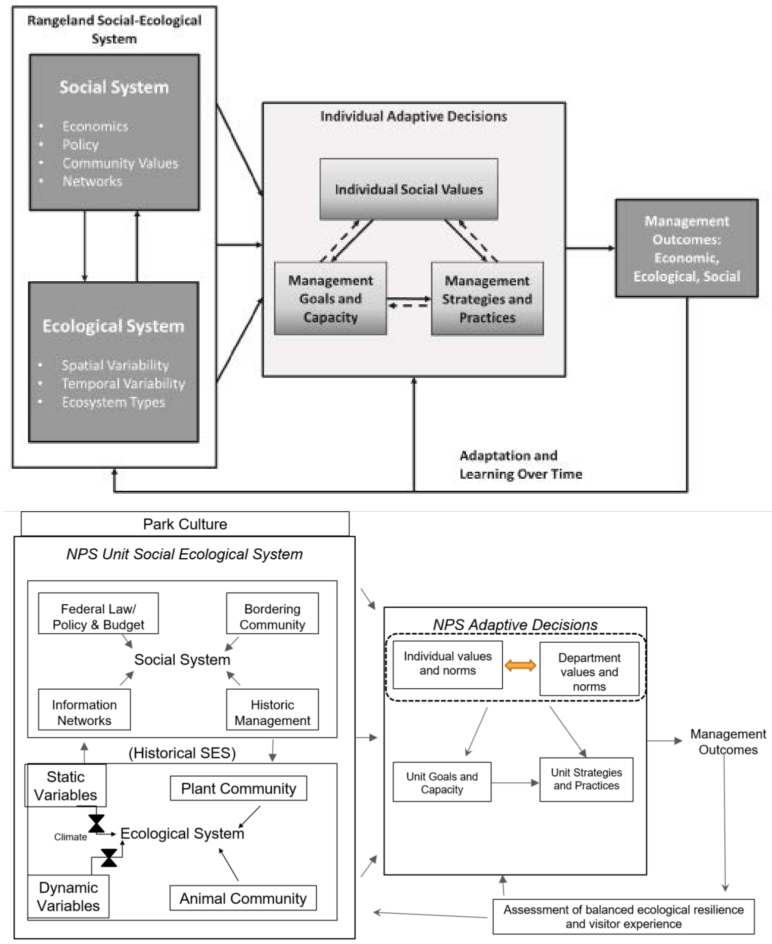


Figure 3: A general and an NPS-specific framework for adaptive rangeland management.
Top: The general adaptive management decision-making framework from Lubell *et al.* (2013).
Bottom: An NPS-specific framework for adaptive management modified from the adaptive rangeland management decision-making framework by Lubell *et al.* (2013).
Although not an explicit component of the analysis in this report, these frameworks helped us identify relevant topics to address in interviews and provided a means to contextualize responses.

in Google Forms and questions can be seen in Appendix G. We used responses to support our final management recommendations.

Data Audits

Three sources of information informed data audits of each park service unit. Ahead of site visits, the Integrated Resource Management Applications (IRMA) portal provided a large amount of information. B. York reviewed publicly available data and management plans housed within IRMA, and discussed data and management plans with unit staff that may have been not available to the public.

On-site visits revealed the second source of information. B. York searched file cabinets for paper copies of management plans, data files, and research studies conducted in the park, and flagged topics related to grassland management and scanned these documents for later analysis at NDSU. This included but was not limited to: wildlife, vegetation, hydrology, geology, and fire. We also searched digital copies on NPS site servers in the same manner.

Finally, the data audit was completed with a literature search for academic studies accomplished in the units. We found studies conducted in the parks by using academic search engines as well as looking into Investigator Annual Reports (IAR) for each unit. The records found during the data audits can be seen in detail in the Unit-specific appendices starting on page 26.

Discussion

The **principal objective** for natural resource management in Midwest Region NPS units is to emphasize the *grazing ecosystem*, "which is distinguished from other habitats by its prominent herbivore-based food web and by the extent to which ecological processes are regulated by dynamics within that food web. (Frank *et al.* 1998)"

Management objectives that focus on the food web and dynamic trophic interactions between grazers and vegetation as a community contrast with current perspectives, which we found to be overly species-specific (e.g.,the population biology of charismatic and endangered species), and often reactive (e.g., invasive plant species management).

To be clear, we understand the historical and institutional reasons for these perspectives, and appreciate that continued compliance with federal policy will require much of the species-specific monitoring and reporting to continue. But this does not preclude individual NPS units from developing strategies aimed at enhancing the resilience of the grazing ecosystem.

The **main strategy** by which we suggest management might better reflect focus on the grazing ecosystem is the *coupling of fire and grazing disturbance regimes* within each unit. Our research indicates that compartmentalized management within the region—e.g., species-specific emphasis on bison population biology and endangered and invasive species, lack of coördination between fire management and vegetation management and monitoring—currently results in discrete management of fire and grazing, which impedes a multi-trophic grazing ecosystem management strategy. Considerable scholarship in rangeland ecology and management describes how the pre-settlement condition of interactive fire and regimes—a unique ecological disturbance Fuhlendorf *et al.* (2009) described as *pyric herbivory*—has been largely decoupled in modern rangeland landscapes; we review this material in greater detail below.

Two **essential tactics** that support the strategic coupling of fire and grazing include (1) designing prescribed fire management programs based on requirements of healthy grazing ecosystems, beginning with supporting an adequate forage base for large herbivores; and (2) ensuring robust information on the spatial variability in plant community composition and productivity under various successional stages within each potential community phase to make sound decisions on burn unit delineation and stocking with respect to forage availability. Below, we focus on these two tactics generally, while individual NPS units are addressed in their own Appendices.

Fire in the grazing ecosystem

We conclude that prescribed fire will constitute a major component of grazing ecosystem management in Midwest Region NPS units—its use should be expanded, and instead of being a management objective in and of itself, the successful completion of frequent prescribed burns should be seen as the foundation of a multi-trophic management strategy.

Thus it is important that biotic and abiotic responses to fire at each level of the grazing ecosystem in NPS units be understood. Fire ecology should be a high priority in species management plans and the design of data collection protocols. To advance a strategy of grazing ecosystem management built around coupled fire-grazing disturbances, management plans must consider—and draw from robust data on—three key areas of knowledge for fire use in ecosystem management (Driscoll *et al.* 2010):

- Species responses to fire regimes
- Spatial and temporal characteristics of fire effects on biota
- Interactions between fire regime and other ecological processes

Species and fire: Responses and interactions

It is critical to understand species dependence on specific habitat resources and how disturbance influences the availability of limiting resources. Variability in species response can be driven by several variable components of disturbance regimes:

- For *fire-tolerant species* expected to recover in place, managers must understand
  - Severity thresholds in fire intensity
  - Variability in fire sensitivity by season
- For *fire-sensitive species* that recolonize burned areas, managers must understand
  - Spatial extent of fire in relation to resource connectivity
  - Proximity to source populations and potential barriers to dispersal

- For *species affected by grazing*, managers must understand
  - Relative role of seeds vs. vegetative tissue in persistence and spread
  - Impacts of grazing duration
  - Potential legacy and lag effects
- Finally, *for all species*, managers must understand elasticity in these responses across variable precipitation. Adaptive management requires knowledge on how quickly species respond to disturbance under various climate scenarios, as well as the duration and permanence of these responses, to ensure that observations used to trigger management actions reflect meaningful ecological conditions and ecosystem status.

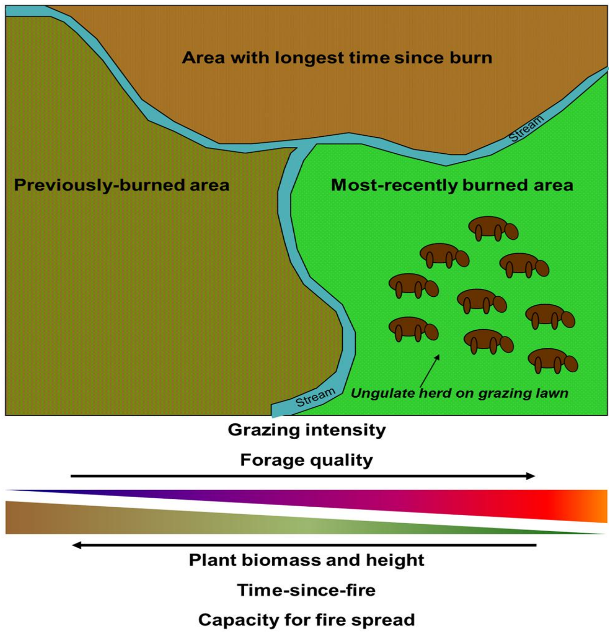


Figure 4: A stylized representation of landscape-level patterns associated with coupled fire and grazing regimes originally presented by McGranahan & Kirkman (2013).

The fire-grazing interaction

Theory & concept Recoupling fire and grazing disturbance regimes is the first step in restoring the patterns and processes that characterized pre-settlement grazing ecosystems—i.e., the ecological aesthetic and condition that we believe is central to the conservation mission of the National Park Service as we interpret its mandate in the Midwest Region. The fire-grazing interaction—a unique, pre-settlement disturbance process known as pyric-herbivory (Fuhlendorf *et al.* 2009)—is based on the concept that grazers respond to the pattern of fire in grassland landscapes, and thus shape emergent patterns of vegetation and ecological processes in space and time.

Vegetation responses, especially, are key to conservation of rangeland biodiversity. The broad suite of rangeland wildlife—and grassland-obligate species, especially—have an equally wide breadth of habitat requirements, many of which depend on vegetation directly (e.g, for breeding habitat, forage resources, or host plant specificity) or indirectly (e.g., prey associations with vegetation types).

Much of the science on the fire-grazing interaction has developed from livestock grazing on conservation areas and commercial rangelands. Rangeland ecologists have criticized conventional management practices for maintaining a specific type of vegetation structure—specifically, spatially- and temporally-extensive areas of low vegetation stature—that provides habitat for only a narrow suite of rangeland wildlife (Fuhlendorf & Engle 2001). The structurally-homogeneous landscape created by such grazing management contrasts with the spatially-heterogeneous pattern understood to emerge from landscapes in which grazing is coupled with fire.

Grazers seek out recently-burned areas and concentrate their herbivory and physical impacts in those patches, responding to the "magnet effect" created by the high nutritive quality and overall high palatability that characterizes post-fire plant regrowth (Allred *et al.* 2011c; Archibald *et al.* 2005). Meanwhile, grazers generally avoid unburned areas, allowing these patches to reach later successional stages and accumulate aboveground plant biomass useful for wildlife that prefers dense vegetation until those patches, with their higher fuel loads, carry subsequent fire (Fig. 4). The result is a spatially and temporally variable "shifting mosaic" across the landscape driven by fire and grazing that increases niche diversity for rangeland wildlife (Fuhlendorf & Engle 2004; Fuhlendorf *et al.* 2006; Hovick *et al.* 2014).

When managers of working rangeland landscapes shift objectives from maximizing livestock production to enhancing the delivery of multiple ecosystem services, a frequent strategy is restoring pre-settlement pattern and processes. Specifically, rangelands benefit from the restoration of the shifting mosaic of vegetation structure via re-coupling the fire-grazing interaction (Fuhlendorf *et al.* 2012). Not only does landscape-level heterogeneity create a broader range of habitat for grassland-obligate species in space (Fig. 5), but spatial heterogeneity stabilizes ecological structure and function by reducing temporal variability (Fuhlendorf *et al.* 2017). Especially in the context of management, the implementation of pyric-herbivory is known as *patch-burn grazing* (Fuhlendorf & Engle 2004; McGranahan *et al.* 2012b).

Large conservation-focused units in the Great Plains have also sought to restore fire-grazing interactions; it is not limited to working landscapes and commercial ranches. For example, in the Flint Hills of Kansas (known as the Osage in Oklahoma), both the Nature Conservancy's Tallgrass Prairie Preserve and the NPS Midwest Region's Tallgrass Prairie National Preserve have implemented prescribed fire management programs in their grazed landscapes designed to promote the interaction of fire and herbivory (Hamilton 2007; Leis *et al.* 2013).

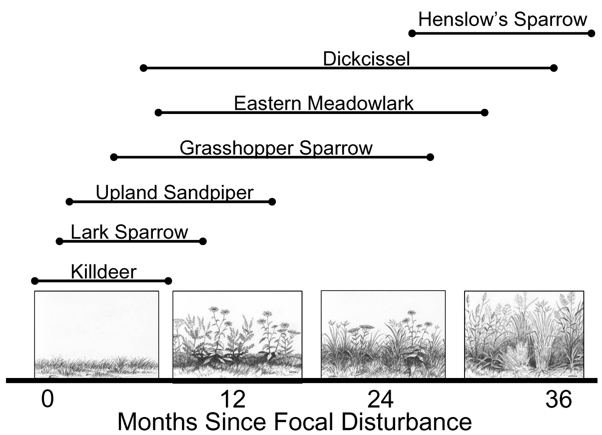


Figure 5: Vegetation structure varies with time-since-fire and creates a gradient of distinct habitat types that are each required by different species of grassland-dependent wildlife. Recently-burned patches are characterized by short stature as grazers focus on high-quality post-fire regrowth. Grazers ignore patches with longer time-since-fire, which allows those areas to develop rank material used by other species and increase the probability of carrying fire after subsequent ignitions. Widely used in the pyric-herbivory literature, this version of the figure came from Fuhlendorf *et al.* (2009).

Implementation & management It is significant for our recommendations that Tallgrass Prairie National Preserve (TAPR) has successfully managed an interactive fire and grazing management regime with patch-burn grazing (p. 47). It demonstrates that not only can ecological disturbance regimes be coupled on NPS land, but management perspectives and personnel can be synchronized, as well. However, the TAPR is an ecological outlier in the Midwest Region, given that all other units are located both farther west and farther north in cool-temperate climate zones dominated by northern mixed-grass prairie. Furthermore, the historical context of ranching that is brought so heavily to bear in the TAPR's cultural preservation (e.g., barns on-site) and inclusion of livestock grazing also includes a regionally-unique appreciation for the role of fire in rangeland ecosystems. Finally, TAPR has a unique partnership with The Nature Conservancy that promotes better consideration of landscape-level management.

Despite a similar evolutionary history of fire in the northern mixed-grass prairie, prescribed fire has a much lower cultural status among residents of the region outside of Kansas. From politicians to landowners, fire is viewed much more skeptically and is considered a very limited tool, rather than a necessary ecological process. This is a fundamental barrier to prescribed fire use on NPS units in the northern mixed-grass prairie and demands further research from the social science side of natural resource management.

Despite the positive model for pyric-herbivory on NPS land offered by TAPR, we posit coupled fire-grazing regimes on other NPS units in the Midwest Region are better modeled on the TNC's Tallgrass Prairie Preserve (TPP) in northeastern Oklahoma. In the main bison unit of the TPP, the desired aesthetic reflects more the shifting mosaic of disturbance-driven patches across a broad landscape, rather than the discrete patch contrast created by burning subsets of pastures as in patch-burn grazing as implemented by TAPR. Facilitated by a much larger spatial area, the TPP makes use of natural fire breaks to delineate non-angular burn patches and burns throughout the year and under a certain degree of randomness in spatial burn unit selection to effect a "messy" landscape in which the human agency behind the disturbance regime is less obvious. We suspect this aesthetic is more consistent with the visitor experience sought by NPS units in the Midwest Region outside of the TAPR.

General considerations

Fire return interval An important step in formulating managed fire regimes is the desired *fire return interval*—the duration of time between prescribed fires. Fire return interval is synonymous with fire frequency, reported as the number of burns within a specific period of time. The main ecological consequence of fire frequency relates to succession. Longer fire return intervals allow greater time for successional dynamics to play out in the plant community. Generally speaking, in grasslands, the potential bounds of fire frequency are determined by fuels. Fires cannot occur more frequently than fuel accumulation allows an ignition to spread. Thus, more arid areas typically have longer fire return intervals than wetter areas. For areas with sufficient rainfall and without other disturbance, lengthy fire return intervals allow woody plants to establish. Should woody plants reach such a density that herbaceous species decline, fire regime shifts with the plant community, likely away from frequent surface fires to infrequent surface fires and/or high-severity canopy fires.

Appropriate fire return intervals can be determined via two main approaches. The typical approach, especially for conservation areas, is to determine the "natural" fire frequency for the area under the desired conditions to be conserved or restored to. In general, the North American Great Plains are believed to have burned, on average, once every 3-10 years, with longer fire return intervals in drier, less productive, and cool-temperate (northern) sub-regions.

Another approach to determining appropriate fire frequency is to emphasize the management needs of the area in question. This is especially relevant for the initial phases of rangeland restoration or the continued management of *novel ecosystems*—ecosystems in which the plant composition or other ecological dynamics lack a known ecological analog. A regional example of novel ecosystems might be rangelands heavily invaded by Kentucky bluegrass (*Poa pratensis*) or other cool-season invasive grasses, which introduce novel fuel components (excessive thatch or high-moisture live biomass; McGranahan *et al.* (2012a) and Toledo *et al.* (2014)).

Obviously, the two approaches can be combined. For example, estimations of "natural" fire frequency often span wide ranges (e.g., 3-5 yrs), and specific fire return intervals within those bounds can be informed by management objectives (e.g., 3 yrs for fewer burn units and/or lower-intensity fires, 5 yrs for greater fuel accumulation).

Successfully coupling fire and grazing disturbance regimes requires target fire return intervals to be established as a means to determine how much of an area should be burned each year. A basic tenet, of course, is that fire must occur each year to provide high-quality forage for grazers and subsequent low-stature vegetation for wildlife. In a simplified patch-burn grazing system, a manager simply burns one-third of a pasture to achieve a three-year fire return interval, or one-quarter of the pasture to achieve a four-year fire return interval.

The situation is less clear on large, open conservation areas supporting herds of native grazers in a natural setting, which is why we suggest TNC's Tallgrass Prairie Preserve is likely a better model for the NPS Midwest Region than even the Region's own Tallgrass Prairie National Preserve. The TPP manages a much more "messy" system in which fire return intervals are actual averages over time and space, with some burn units burning slightly more or less frequently than prescribed.

Stocking rate and forage utilization Once the size of annual burn *area* is determined from the target fire *frequency* within the *extent* of the grazing unit, one must determine the desired number of grazers. Any sustainable stocking decision-making ensures that the grazing demand does not exceed the forage available. In general, successfully coupling fire and grazing regimes involves additional considerations, and doing so within the context of grazing ecosystem conservation and native herbivore management on NPS properties, specifically, raises further challenges. Many of these are discussed below. But independent of management objectives and resources, decision-making for sustainable stocking is impossible without robust data on forage availability. Thus, we discuss below existing data gaps and how they can be addressed within the framework of coupled fire and grazing regimes. The process begins with basing burn unit delineations on expected plant community responses.

Burn units based on ecological sites

Effective management of grazing ecosystems based on a strategy of coupled fire and grazing regimes requires information about vegetation that our research indicates is absent from NPS decision-making in the Midwest Region. Furthermore, based on our data audits of NPS units in the region, it does not appear that relevant data are available even if they were to be included in decision-making processes.

Here, we describe data necessary to inform robust delineation of prescribed fire units that support forage resources and a sustainable and resilient grazing ecosystem. We also outline protocols to both establish baseline information on forage production and monitor responses to the restoration of coupled fire and grazing.

Establishing site productivity

Rangelands in the western United States are delineated by *ecological sites*, which the USDA NRCS defines as

> ... a distinctive kind of land with specific soil and physical characteristics that differ from other kinds of land in its ability to produce a distinctive kind and *amount of vegetation* and its ability to respond similarly to management actions and natural disturbances.

We've added the emphasis on *amount of vegetation* to highlight the central role that ecological site descriptions—ESDs, or the ecological information assembled for each ecological site—play in sustainable rangeland management. ESDs include information about annual aboveground primary production by plant species and functional group, at monthly intervals through the growing season. When weighted by the area within a unit each ecological site represents, these productivity data give valuable insight into total forage production and thus the number of grazing animals the unit can support.

We recommend NPS units in the Midwest Region incorporate ecological site descriptions into decision-making processes to support a strategy of sustainable grazing ecosystem management. Our research indicates that ecological sites are not currently in use at all within the study region. The system is either unknown to managers, or considered too fine-scale to inform management of areas as large and environmentally variable as national parks. This is a legitimate concern that has been already been addressed in rangeland science. Stringham *et al.* (2016) increased the utility of fine-scale ecological site descriptions by identifying *disturbance response groups* that combine similar ecological sites into broader landscape delineations. A similar approach could be applied to each Midwest Region NPS unit.

The primary means by which ecological site information should be applied is in the delineation of burn units. Coupling fire and grazing regimes requires that grazers find sufficient forage in burned areas to support their energetic requirements. Other considerations for stocking are discussed below. When relying on burned patches for sufficient forage quality and availability, it is essential that the plant communities be sufficiently diverse to provide stable productivity from season to season and from year to year. This is best achieved by taking advantage of the selection effect, delineating burn units that are equally represented by highly-productive ecological sites.

A poor example of burn patch delineation would be a burned area in one year that encompasses most of the spatial distribution of highly-productive, bottomland sites, and in another year a burned area that is almost entirely thin upland sites. Such differences in productivity are especially sensitive to climate variability. For example, if the year in which the lowland sites are burned is particularly high in precipitation, forage production is at risk of exceeding the ability of grazers to maintain short stature in the burned patch, resulting in a loss of the fire-grazing interaction (condition A, fig. 6). Likewise, if the year in which the burned patch comprises mostly upland sites has particularly low precipitation, forage production will fall substantially below grazer requirements and sites will be overgrazed (condition C, fig. 6). Thus, interannual variability is mitigated by ensuring burn units include a diversity of ecological sites.

Necessary vegetation data

Making these decisions requires site-specific knowledge of plant community composition and productivity. Given the unique conservation objectives and management of NPS units compared to working rangeland (e.g., privately-owned rangeland, US Forest Service or other federal grazing allotments), we suggest it should not be assumed that vegetation dynamics on NPS units are optimally reflected in existing ecological site descriptions. Thus we recommend Midwest Region NPS units initiate a concerted ground-truthing effort to verify plant community phases and productivity at the level of individual ecological sites. These data could then easily support a subsequent effort to identify disturbance response groupings (as per Stringham *et al.* 2016) that would ultimately be used as the basic unit of landscape management. Once vegetation status is established, less-intensive sampling within disturbance response groupings can be conducted over time to monitor potential community phase transitions in response to management.

Two models exist for initial data collection within ecological sites and subsequent monitoring of disturbance response groupings. Firstly, Dr. Kevin Sedivec in North Dakota State University's Range Science Program developed a protocol for the Little Missouri National Grasslands to verify soil series, vegetation composition, and annual primary productivity within grazing allotments. This is an intensive protocol in which (1) a soil pit is dug to verify the soil series on which the ecological site identification is based, and (2) aboveground vegetation is clipped by species to determine species-level productivity. Such an intensive protocol would only be required to establish the current state of plant communities on ecological sites in Midwest Region NPS units, and could be scaled back substantially.

Secondly, Symstad *et al.* (2012) developed a protocol for plant community composition and structure monitoring with the aim to

> provide park managers with early warning of undesirable change, measure digression from or progress towards a desired state, and evaluate effectiveness of management programs.

The protocol was recently used in the Midwest Region, at Badlands National Park (Ashton & Swanson 2019). Although the protocol does not specifically sample for aboveground plant biomass production, clipping data from representative plant communities could easily calibrate the species composition data obtained via point-intercept methods (Yurkonis *et al.* 2012). We strongly encourage managers in the NPS Midwest Region to consider how this protocol could be adapted to initially ground-truth ecological sites and subsequently monitor disturbance response groups to support fire and grazing management.

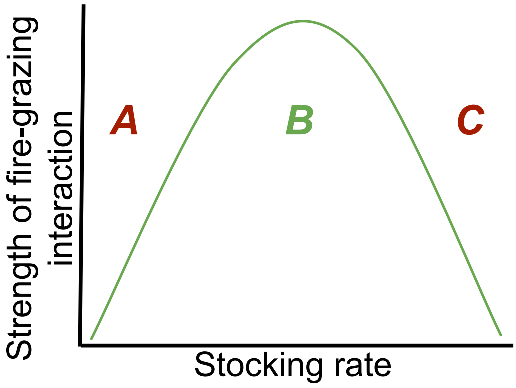
Stocking for sustainability

Sustainable grazing management—critical to the health of grazing ecosystems in NPS units—essentially relies on matching grazer demand to forage availability. Above, we discuss how information on plant productivity can inform the delineation of burn units to stabilize the forage availability side of the stocking equation. Here we discuss two aspects of grazing management that will likely arise in the pursuit of coupled fire and grazing regimes and potentially contrast with established modes of thinking about conservation grazing: the importance of domestic livestock, and apparent grazing severity.

Domestic livestock

The Midwest Region NPS must not overlook the conservation value of domestic livestock in sustainable grazing ecosystem management. Unfortunately there is persistent conventional wisdom

Figure 6: Successfully coupling fire and grazing regimes requires a moderate stocking rate (B) that matches grazer offtake to vegetation production. Under excessive stocking (C), the fire-grazing interaction is weakened as grazers are forced to forage beyond the perimeter of the burned patch. The consequences of overstocking are intuitive: poor grazer performance and excessive severity to the plant community. Less intuitive—especially in the context of conservation grazing—are the consequences of understocking (A). If plant production exceeds the capacity of grazers to consume the available forage, vegetation will reach maturity and subsequent declines in forage quality risks weakening the magnet effect that concentrates grazers to burned patches.



regarding livestock grazing on public lands that primarily associates domestic grazers with degradation (Fleischner 1994). But it is important to remember that *grazing management* has greater influence on environmental impacts than *grazer identity*, and that well-managed cattle grazing has been shown to advance rangeland biodiversity management goals in the Great Plains (Ahlering & Merkord 2016; Allred *et al.* 2011b).

As such, cattle grazing facilitated by coöperation with local ranchers should be viewed as a potent and flexible resource for the sustainable management of grazing ecosystems in Midwest Region NPS units. In its most obvious application, coöperative grazing agreements can ensure grazing disturbance on NPS units that do not currently have bison filling the large herbivore niche. Less obviously, coöperative grazing agreements potentially serve as a flexible resource for managers to adjust grazing intensity from year to year or even within grazing seasons, depending on precipitation and grassland resource response to "baseline" grazing pressure from resident bison.

While there are several approaches to managing stocking rates, given the importance of maintaining a minimum level of grazing intensity in burned areas, we recommend Midwest Region NPS units adopt an opportunistic stocking strategy. We specifically recommend the "tracking" strategies described by Campbell *et al.* (2006) in which stocking rates are varied in response to precipitation to protect against overgrazing in dry years and under-utilization in wet years. Campbell *et al.* (2006) outline two tracking strategies:

- *Low-tracking*—is conservative; stocking rates are kept below the ecological carrying capacity and vary based on rainfall.
- *High-tracking*—in which managers attempt to maintain stocking rates at the ecological carrying capacity and vary based on rainfall.

The high-tracking strategy might be preferable given grassland resources across Midwest Region NPS units are generally under-utilized, and management would benefit from a stronger influence of grazing disturbance. Whether NPS units have the capacity to make the necessary adjustments to match stocking rate to forage availability likely depends on their willingness to include domestic livestock in grazing ecosystem management. NPS units are unique among grazing land managers in that the objective is to maintain populations of native herbivores in natural settings. This reduces flexibility and responsiveness in stocking rate management, as it is logistically challenging to increase or decrease herd sizes, especially within grazing seasons.

We suggest a hybrid approach to bison grazing management that includes regional satellite herds and domestic livestock. *In NPS units with core bison herds,* bison should be considered the primary grazers and annual stocking rates set just below ecological carrying capacity. If reductions are necessary, animals can be transferred to satellite herds. Additional grazing up to the ecological carrying capacity can be facilitated by spatially- and temporally-targeted livestock grazing. Meanwhile, *NPS units without core bison herds* would consider livestock their primary grazers and adjust livestock numbers to accommodate whatever bison they take on as a satellite herd, if any. While such an approach likely constitutes a radical departure from current management perspectives, resource allocations, considerations for visitor experience, and perhaps even policy, we suggest it as a means to stimulate novel approaches to active grazing management.

Grazing severity

Another counter-intuitive component of sustainable grazing ecosystem management is that successful restoration of the fire-grazing interaction will likely bear signs of grazing that many in the conservation community have been conditioned to interpret as indicators of degradation rather than optimal ecological function. In this sense, the key take-home of the relationship between stocking rate and the successful coupling fire and grazing (Fig. 6) is not the optimality of moderate stocking, but the requirement that a minimum level of grazing intensity be maintained. Thus, it is entirely possible to stock too lightly such that grazers lose body condition and vegetation degrades.

Ensuring that grazing activity matches plant production begins with setting stocking rates with respect to the expected productivity of the *entire grazing unit*, even though it is anticipated that grazers focus the majority of their activity within *burned patches*. A misconception among managers of conservation areas regarding patch-burn grazing is that stocking rates be set based on the burned patch alone, but the result will likely be understocking and a weak fire-grazing interaction as in condition A in Figure 6. Furthermore, grazers will fail to maintain the low vegetation structure sought for grassland biodiversity (Fig. 5).

Proper stocking in a coupled fire-grazing system creates high-impact grazing in the burned patch, which is necessary to maintain desired vegetation structure. The key is that native prairie plant communities have evolved to tolerate high-intensity grazing for a season or two. As long as the shifting mosaic creates another burned area to draw grazers away in subsequent seasons, such high-intensity grazing will not have lasting effects on plant community composition or productivity.

Managers and visitors alike might balk at what appears to be severe over-utilization in discrete areas. Substantial buy-in and understanding among NPS staff and targeted interpretative educational materials will likely be required to ensure the appearance of success in restoring a functional grazing ecosystem is not misinterpreted.

Future research objectives

We offer the following topics for future CESU research projects, in the order we believe best advances our recommendations:

Site-specific productivity models Workers should generate ecological site GIS layers for all NPS Units with current or expected large ungulate grazing and model expected annual primary productivity on an area-weighted basis under various vegetation and precipitation scenarios as reported in NRCS ecological site descriptions. All productivity data should be verified and corrected as necessary with ground-truthed data from clipped plots and vegetation monitoring.

Monitor fire-grazing interaction Although coupling fire and grazing disturbance regimes is the overarching recommendation in this report, we are aware that many uncertainties require a cautious and adaptive approach to implementation—the dynamics of manipulating forage for large bison herds with prescribed fire in topographically-diverse Northern Mixed-Grass prairie with legislative mandates for preservation, conservation, and visitor experience are understandably complex. Thus, a robust monitoring program should be designed alongside novel management practices that integrates vegetation as fuel, fire behavior, forage and grazer response, and finally back to vegetation composition.

Assess climate change resilience Accomplishing general NPS objectives for natural and cultural preservation as well as specific objectives such as sustainable bison and prairie management requires that NPS units be maximally resilient to climate change. We strongly believe that the ecosystem perspective encouraged in this report is necessary to achieve the operational goal of enhanced resilience of NPS Units to climate change. Additional work should assess susceptibility of NPS units to climate change, and how ecosystem-based management—specifically, coupling fire and grazing disturbances—impacts resilience of grassland resources.

References cited

1. Ahlering, M. A. & Merkord, C. L. Cattle Grazing and Grassland Birds in the Northern Tallgrass Prairie. *The Journal of Wildlife Management* **80,** 643–654 (2016).
2. Allred, B. W. *et al.* The Role of Herbivores in Great Plains Conservation: Comparative Ecology of Bison and Cattle. *Ecosphere* **2,** art26 (2011).
3. Allred, B. W. *et al.* The Role of Herbivores in Great Plains Conservation: Comparative Ecology of Bison and Cattle. *Ecosphere* **2,** art26 (2011).
4. Allred, B. W. *et al.* Ungulate Preference for Burned Patches Reveals Strength of Fire-Grazing Interaction. *Ecology and Evolution* **1,** 132–144 (2011).
5. Archibald, S. *et al.* Shaping the Landscape: Fire-Grazer Interactions on an African Savanna. *Ecological Applications* **15,** 96–109 (2005).
6. Ashton, I. & Davis, C. *Plant Community Composition and Structure Monitoring for Wind Cave National Park: 2011-2015 Summary Report* Natural Resource Report NPS/NRSS/BRD/NRR 2016/1236 (National Park Service, Fort Collins, CO, 2016).
7. Ashton, I. & Swanson, D. *Plant Community Composition and Structure Monitoring at Badlands National Park: 2018 Data Report* Natural Resource Data Series NPS/NGPN/NRDS—2019/1207 (National Park Service, Fort Collins, CO, 2019).
8. Axelrod, D. I. Rise of the Grassland Biome, Central North America. *The Botanical Review* **51,** 163–201 (1985).
9. Bachelet, D. *et al.* Interactions between Fire, Grazing and Climate Change at Wind Cave National Park, SD. *Ecological Modelling* **134,** 229–244 (2000).
10. Bestelmeyer, B. T. & Briske, D. D. Grand Challenges for Resilience-Based Management of Rangelands. *Rangeland Ecology & Management* **65,** 654–663 (2012).
11. Bilotta, G. *et al.* The Impacts of Grazing Animals on the Quality of Soils, Vegetation, and Surface Waters in Intensively Managed Grasslands. *Advances in Agronomy* **94,** 237–280 (2007).
12. Blair, J. *et al.* In *Ecology and the Environment* (ed Monson, R.) 389–423 (2014).
13. Bond, W. & Keeley, J. Fire as a Global 'Herbivore': The Ecology and Evolution of Flammable Ecosystems. *Trends in Ecology and Evolution* **20,** 387–394 (2005).
14. Campbell, B. M. *et al.* In Search of Optimal Stocking Regimes in Semi-Arid Grazing Lands: One Size Does Not Fit All. *Ecological Economics* **60,** 75–85 (2006).
15. Chamaillé-Jammes, S. & Bond, W. J. Will Global Change Improve Grazing Quality of Grasslands? A Call for a Deeper Understanding of the Effects of Shifts from C4 to C3 Grasses for Large Herbivores. *Oikos* **119,** 1857–1861 (2010).
16. Clements, F. E. *Plant Succession: An Analysis of the Development of Vegetation* (Carnegie Institution of Washington, Washington, D.C., 1916).
17. Cole, D. N. & Yung, L. *Beyond naturalness: rethinking park and wilderness stewardship in an era of rapid change* (Island Press, 2012).
18. Collins, S. L. *et al.* Modulation of Diversity by Grazing and Mowing in Native Tallgrass Prairie. *Science* **280,** 745 (1998).
19. Courtwright, J. " When We First Come Here It All Looked Like Prairie Land Almost": Prairie Fire and Plains Settlement. *Western Historical Quarterly* **38,** 157–179 (2007).
20. Courtwright, J. *Prairie Fire: A Great Plains History* (University Press of Kansas Press, Lawrence, KS, 2011).

21. Craine, J. M. *et al.* Climate Change and Cattle Nutritional Stress. *Global Change Biology* **16,** 2901–2911 (2010).
22. Craine, J. M. *et al.* Precipitation Timing and Grazer Performance in a Tallgrass Prairie. *Oikos* **122,** 191–198 (2013).
23. Creswell, J. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* [Online; accessed 2016-04-10] (Sage Publications, Thousand Oaks, California, 2003).
24. Driscoll, D. A. *et al.* Fire management for biodiversity conservation: Key research questions and our capacity to answer them. *Biological Conservation* **143,** 1928–1939 (2010).
25. Erichsen-Arychuk, C. *et al.* Northern Dry Mixed Prairie Responses to Summer Wildlife [Sic] and Drought. *Journal of Range Management,* 164–170 (2002).
26. Fleischner, T. L. Ecological Costs of Livestock Grazing in Western North America. *Conservation Biology* **8,** 629–644 (1994).
27. Frank, D. A. *et al.* The Ecology of the Earth's Grazing Ecosystems. *BioScience* **48,** 513–521 (1998).
28. Franzluebbers, A. J. *et al.* Well-Managed Grazing Systems: A Forgotten Hero of Conservation. *Journal of Soil and Water Conservation* **67,** 100A–104A (2012).
29. Fuhlendorf, S. D. & Engle, D. M. Application of the fire–grazing interaction to restore a shifting mosaic on tallgrass prairie. *Journal of Applied Ecology* **41,** 604–614 (2004).
30. Fuhlendorf, S. D. *et al.* Should Heterogeneity Be the Basis for Conservation? Grassland Bird Response to Fire and Grazing. *Ecological Applications* **16,** 1706–1716 (2006).
31. Fuhlendorf, S. D. & Engle, D. M. Restoring heterogeneity on rangelands: Ecosystem management based on evolutionary grazing patterns. *BioScience* **51,** 625–632 (2001).
32. Fuhlendorf, S. D. *et al.* Pyric herbivory: rewilding landscapes through the recoupling of fire and grazing. *Conservation Biology* **23,** 588–598 (2009).
33. Fuhlendorf, S. D. *et al.* Conservation of Pattern and Process: Developing an Alternative Paradigm of Rangeland Management. *Rangeland Ecology & Management* **65,** 579–589 (2012).
34. Fuhlendorf, S. D. *et al.* In *Rangeland Systems* 169–196 (Springer, Cham, 2017).
35. Gitzen, R. *et al.* *Northern Great Plains Network Vital Signs Monitoring Plan* tech. rep. (2010).
36. Hamilton, R. G. *Restoring Heterogeneity on the Tallgrass Prairie Preserve: Applying the Fire-Grazing Interaction Model* in *Proceedings of the 23rd Tall Timbers Fire Ecology Conference: Fire in Grassland and Shrubland Ecosystems* (Tall Timbers Research Station, Tallahassee, Florida, USA, 2007), 163–169.
37. Hardy, A. & Plumb, G. *Call to Action Item #26 - Back Home on the Range* Natural Resource Report NPS/NRSS/BRD/NRR 2016/1367 (National Park Service, Fort Collins, CO, 2016).
38. Hovick, T. J. *et al.* Structural heterogeneity increases diversity of non-breeding grassland birds. *Ecosphere* **5,** 1–13 (2014).
39. Huang, R. *RQDA: R- based Qualitative Data Analysis* (2018).
40. Lebel, L. *et al.* Governance and the Capacity to Manage Resilience in Regional Social-Ecological Systems. *Ecology and Society* **11** (2006).
41. Leis, S. A. *et al.* Spatiotemporal Variation in Vegetation Structure Resulting from Pyric-Herbivory. *Prairie Naturalist* **45,** 13–20 (2013).
42. Leis, S. & Morrison, L. *Long-term Trends in Vegetation and Management Intensity: Tallgrass Prairie National Preserve 1995-2014* tech. rep. (2018), 27.

43. Limb, R. F. *et al.* Assessment of Research on Rangeland Fire as a Management Practice. *Rangeland Ecology & Management* **69,** 415–422 (2016).

44. Lubell, M. N. *et al.* Conservation Program Participation and Adaptive Rangeland Decision-Making. *Rangeland Ecology & Management* **66,** 609–620 (2013).

45. McGranahan, D. A. & Yurkonis, K. A. Variability in Grass Forage Quality and Quantity in Response to Elevated CO_2 and Water Limitation. *Grass and Forage Science* **73,** 517–521 (2018).

46. McGranahan, D. A. *et al.* An Invasive Cool-Season Grass Complicates Prescribed Fire Management in a Native Warm-Season Grassland. *Natural Areas Journal* **32,** 208–214 (2012).

47. McGranahan, D. A. *et al.* An invasive cool-season grass complicates prescribed fire management in a native warm-season grassland. *Natural Areas Journal* **32,** 208–214 (2012).

48. McGranahan, D. & Kirkman, K. Multifunctional Rangeland in Southern Africa: Managing for Production, Conservation, and Resilience with Fire and Grazing. *Land* **2,** 176–193 (2013).

49. Montello, D. & Sutton, P. *An introduction to scientific research methods in geography and environmental studies* (Sage, 2012).

50. Newbold, T. *et al.* Has Land Use Pushed Terrestrial Biodiversity beyond the Planetary Boundary? A Global Assessment. *Science* **353,** 288–291 (2016).

51. Organic Act. *An Act to Establish a National Park Service, and for Other Purposes* 1916.

52. Patton, B. D. *et al.* Effects of Grazing Intensity, Precipitation, and Temperature on Forage Production. *Rangeland Ecology & Management* **60,** 656–665 (2007).

53. R Core Team. *R: A Language and Environment for Statistical Computing* version 3.3.3. Vienna, Austria: R Foundation for Statistical Computing, 2017.

54. Samson, F. B. *et al.* Great Plains Ecosystems: Past, Present, and Future. *Wildlife Society Bulletin* **32,** 6–15 (2004).

55. Samson, F. & Knopf, F. Prairie Conservation in North America. *BioScience* **44,** 418–421 (1994).

56. Stringham, T. K. *et al.* Disturbance Response Grouping of Ecological Sites Increases Utility of Ecological Sites and State-and-Transition Models for Landscape Scale Planning in the Great Basin. *Rangelands* **38,** 371–378 (2016).

57. Symstad, A. *et al.* Plant Community Composition and Structure Monitoring Protocol for the Northern Great Plains I&M Network- Standard Operating Procedures (2012).

58. Taub, D. R. *et al.* Effects of Elevated CO_2 on the Protein Concentration of Food Crops: A Meta-Analysis. *Global Change Biology* **14,** 565–575 (2008).

59. Temme, A. A. *et al.* Meta-Analysis Reveals Profound Responses of Plant Traits to Glacial CO_2 Levels. *Ecology and Evolution* **3,** 4525–4535 (2013).

60. Thomas, J. W. Forest Service perspective on ecosystem management. *Ecological Applications* **6,** 703–705 (1996).

61. Toledo, D. *et al.* Extent of Kentucky Bluegrass and Its Effect on Native Plant Species Diversity and Ecosystem Services in the Northern Great Plains of the United States. *Invasive Plant Science and Management* **7,** 543–552 (2014).

62. Toombs, T. P. *et al.* Managing for Biodiversity and Livestock: A scale-dependent approach for promoting vegetation heterogeneity in western Great Plains grasslands. *Rangelands* **32,** 10–15 (2010).

63. Transeau, E. N. The Prairie Peninsula. *Ecology* **16,** 423–437 (1935).

64. Twidwell, D. *et al.* The rising Great Plains fire campaign: citizens' response to woody plant encroachment. *Frontiers in Ecology and the Environment* **11** (2013).

65. Umbanhowar Jr, C. E. Recent fire history of the northern Great Plains. *American Midland Naturalist,* 115–121 (1996).

66. Walker, B. *et al.* Resilience, Adaptability and Transformability in Social–Ecological Systems. *Ecology and Society* **9,** art5 (2004).

67. Wand, S. J. E. *et al.* Responses of Wild C_4 and C_3 Grass (Poaceae) Species to Elevated Atmospheric CO_2 Concentration: A Meta-Analytic Test of Current Theories and Perceptions. *Global Change Biology* **5,** 723–741 (1999).

68. Watkinson, A. R. & Ormerod, S. J. Grasslands, Grazing and Biodiversity: Editors' Introduction. *Journal of Applied Ecology* **38,** 233–237 (2001).

69. Weir, J. R. & Scasta, J. D. Vegetation Responses to Season of Fire in Tallgrass Prairie: A 13-Year Case Study. *Fire Ecology* **13,** 137 (2017).

70. Westoby, M. *et al.* Opportunistic Management for Rangelands Not at Equilibrium. *Journal of Range Management* **42,** 266–274 (1989).

71. Whisenant, S. G. & Uresk, D. W. Burning Upland, Mixed Prairie in Badlands National Park. *Prairie Naturalist* **21,** 221–227 (1989).

72. Wright, C. K. & Wimberly, M. C. Recent Land Use Change in the Western Corn Belt Threatens Grasslands and Wetlands. *Proceedings of the National Academy of Sciences* **110,** 4134–4139 (2013).

73. Wright, H. A. & Bailey, A. W. *Fire Ecology: United States and Southern Canada* (John Wiley & Sons, 1982).

74. Yurkonis, K. A. *et al.* Initial Species Pattern Affects Invasion Resistance in Experimental Grassland Plots. *Journal of Vegetation Science* **23,** 4–12 (2012).

Unit-specific appendices

The following appendices detail the results of site visits, interviews, and data audits for each NPS unit in the Midwest region. Specifically, each Appendix summarizes the following for each unit:

- Current grassland management goals and programs
- Existing management plans (2008–2018)
- Data available from studies that included the unit (2008–2018)
- A description of managed disturbance regimes
- Identified data gaps
- Suggestions for future research
- Management recommendations from the perspective of ecosystem-based management of grassland resources

Appendix A. Agate Fossil Beds National Monument

Current Grassland Management Goals and Programs

Grassland Management Goals

The majority of management goals within Agate Fossil Beds National Monument (AGFO) pertain to cultural resources management. The Foundational Document and Resource Management Plan, focus on cultural resource management and interpretation. Natural resources are not a fundamental resource of value for AGFO, nor are they mentioned to any specifics in the enabling legislation of the unit. Interviews conducted at AGFO stated the focus on cultural resources and managing the prairie because it is included within the NPS property they protect. Two stated goals included (1) maintain the prairie such that the landscape mimics what the area looked like when Red Cloud and James Cook were present, and (2) strive for invasive species eradication.

Grassland Management Programs

There are no continuous natural resource management efforts conducted by unit staff as there are no natural resource staff stationed at the monument.

Management Plans and Data Available

Management Plans

The Foundational Document, written in 2012, describes the prairie as an “other important resource”. The Foundational Document states that the “shortgrass prairie and the Niobrara riparian ecotone are regionally important parts of the high plains ecosystem.” It gives no further ecological details. Management plans published in the last ten years are listed in Table A.1. The most recent, the Natural Resource Condition Assessment, was a useful resource in the completion of this report. The Foundation Statement was also beneficial as it laid out the goals and the main reasons for establishment of the monument. There are more management plans written, but they are over ten years old. Effective adaptive management will likely require these older plans to be revisited and perhaps revised, particularly the 2001 fire management plan.

Table A.1: Management documents for AGFO published from 2008-2018

Title	Year
Interpretive Plan	2011
Foundation Document	2012
Bison Reintroduction Feasibility	2014
Natural Resource Condition Assessment	2018

Data Available

Interviews expressed not much data is used or thought to exist at AGFO. Monument staff interact with Northern Great Plains I&M network professionals. It was stated several times that they rely on I&M staff or other regional professional staff to alert AGFO to natural resource issues that arise. AGFO moved from the Heartland Monitoring Network to the Northern Great Plains Monitoring Network. This is the reason for two sets of monitoring data.

Table A.2: Selected data collected in AGFO, 2008-2018.

Data title	Data type	Spatial extent	Frequency	Duration	Collecting agency	Format located
Climate Change Exposure	Climate	weather at the park unit	research study	1901-2012	Monahan & Fisichelli	IRMA
Geologic Resources Inventory Report	Geology	park wide	inventory of all available data on geology	summary of all park history up to 2009	NPS- Geologic Resources Division	IRMA
Plant Community Composition	Vegetation	Unit wide	annually samples 6 plots	2011- current	NPS- NGP I&M	IRMA
Plant Community Monitoring	Vegetation	11 monitoring sites established	each site sampled seven times	1999-2009	NPS- Heartland Network I&M	IRMA
Riparian Invasive Plant	Vegetation	48 2x2m plots in high yellow flag iris wetland areas	3 separate data collections	2014-2015	Thesis- Colorado State University	IRMA
Groundwater Monitoring	Water	three wells within the unit	pressure and temperature recorded by data loggers at half-hour intervals	2006-2010	NPS-WRD	IRMA
Nebraska Stream Biological Monitoring Program	Water	Niobrara River	Began in 1997 and sampling was conducted on a five year cycle.	2004-2008	Nebraska Department of Environmental Quality	web search
Fish Inventory	Wildlife	2,000m of Niobrara river electro fished	over three days of June 2008	2008	University of Nebraska-Lincoln	IRMA

Table B.2, *continued.*

Data title	Data type	Spatial extent	Frequency	Duration	Collecting agency	Format located
Aquatic Invertebrate Community	Wildlife	3 locations separated by 3km along Niobrara river, samplers deployed monthly over the summer	annually	1996-2009	NPS- Heartland Network I&M	IRMA, (data sheets for the study available on site)
Aquatic Invertebrates	Wildlife	Three sampling points in the Niobrara River across the unit	seven sampling frames per summer	2010-2014	NGP- I&M	IRMA
Landbird Monitoring	Wildlife	96 points surveyed across the unit (geospatially displayed in report)	once per year	2013-2016	NGP- I&M	IRMA
Acoustic Bat Surveys	Wildlife	43 stations across the unit	4-7 nights each year	2014-2016	NGP- I&M	IRMA
Fish of the Niobrara River	Wildlife	8 locations within monument boundaries	June 26-28, 2011	2011	University of Nebraska-Omaha	IRMA
Status of Native Stream Fishes in Protected Areas of the Niobrara River	Wildlife	Niobrara river within AGFO	Four times	1979, 1989, 2008, 2011	various	IRMA
2010 Field Season Report Bird Monitoring at AGFO	Wildlife	40 points across the monument	one time study	May 18- June 23, 2010	Rocky Mountain Bird Observatory	IRMA

Disturbance Regimes

Grazing

Heavy levels of livestock grazing were present on monument lands from the late 1880's until monument authorization in 1965. Removal of grazing allows fuel loads to build up causing AGFO to be of high danger for extreme fire behavior. The Department of Interior initiative, "Back Home on the Range", communicated the importance of establishing native herbivores, and particularly bison herds, within NPS units in the Great Plains (Hardy & Plumb 2016). AGFO was selected as a possible unit for reintroduction. Due to surrounding land management, Monument staff seem to be more open to a livestock grazing program than bison grazing.

Fire

The 2001 Fire Management NEPA EA states, "Park lands have not been grazed, burned (except for a few acres in a research project), or mowed (other than maintenance and thistle control) since the park's authorization." Since 2001, there has been some fire to create a burned mosaic on the landscape (Fig. A.2). There are five burn units across the monument (Fig. A.1). Since 1992, there have been eight prescribed fires and two wildfires covering 1,907 acres.

Data gaps and suggested research

Data Gaps

Written documentation of landscape ecosystem goals would highly benefit the managers at AGFO. With little staff and scant funds to apply to natural resource management, having the most information available would allow them to best assign the resources they are allotted for the highest impact. Overall, there are data available from I&M on vegetation and wildlife as well as extensive information on water quality and other aquatic resources. Using the data to implement some kind of management is the missing piece for AGFO. Although, as the landscape has not been disturbed significantly in recent years, the vegetative response to disturbance is a key data gap. Productivity data as well as erosion data is missing in terms of understanding the effect of a large grazer. Livestock impact on the Niobrara River would be beneficial ahead of establishing a grazing disturbance.

Suggested Research

Of particular note was that during the interviews, Monument staff believe that a large grazer such as cattle may help to diminish their largest invasive species problem: the yellow flag iris. Repeated trampling by a large grazer seems to lessen populations of the invasive iris on surrounding lands (2016 graduate research by Jordan Spark). There should be further research of grazing impacts on the AGFO prairie.

Management Recommendations

Establish a grazer on the landscape

Given the lack of natural resources staff and a natural resources management program (and the goal of filling cultural positions ahead of natural resource positions stated in our on-site interviews), it is likely easier to implement a livestock grazing program with local coöperators than a bison grazing program. Although bison are the NPS preferred alternative, cattle can accomplish a similar goal with significantly less budgetary and staff input. To accomplish this, AGFO take suggestions from Tallgrass

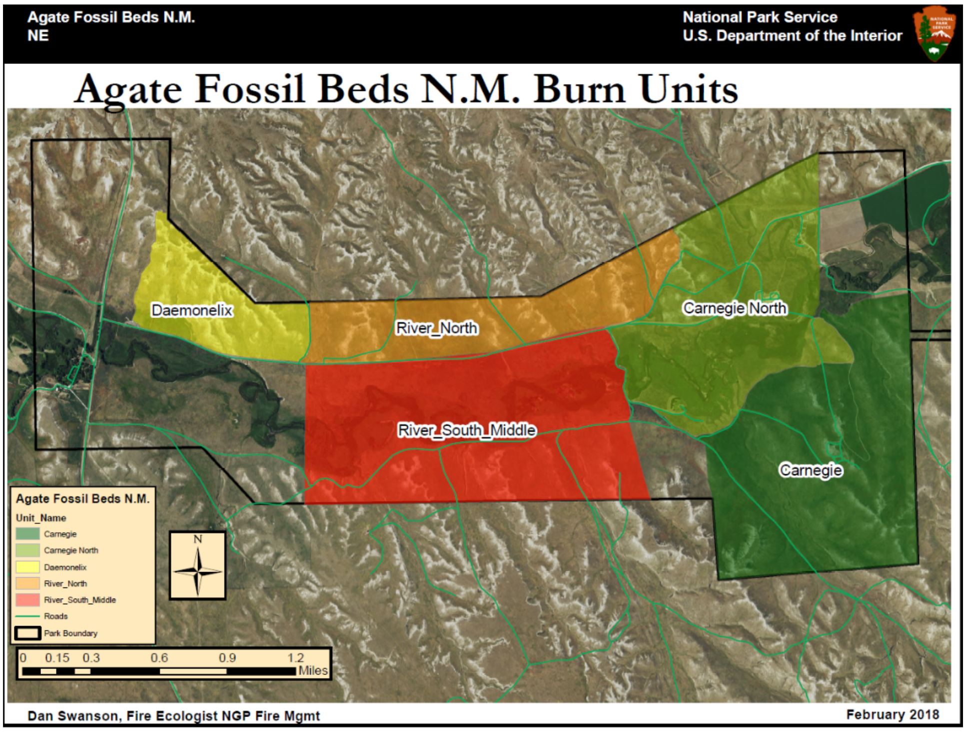


Figure A.1: Burn units of AGFO

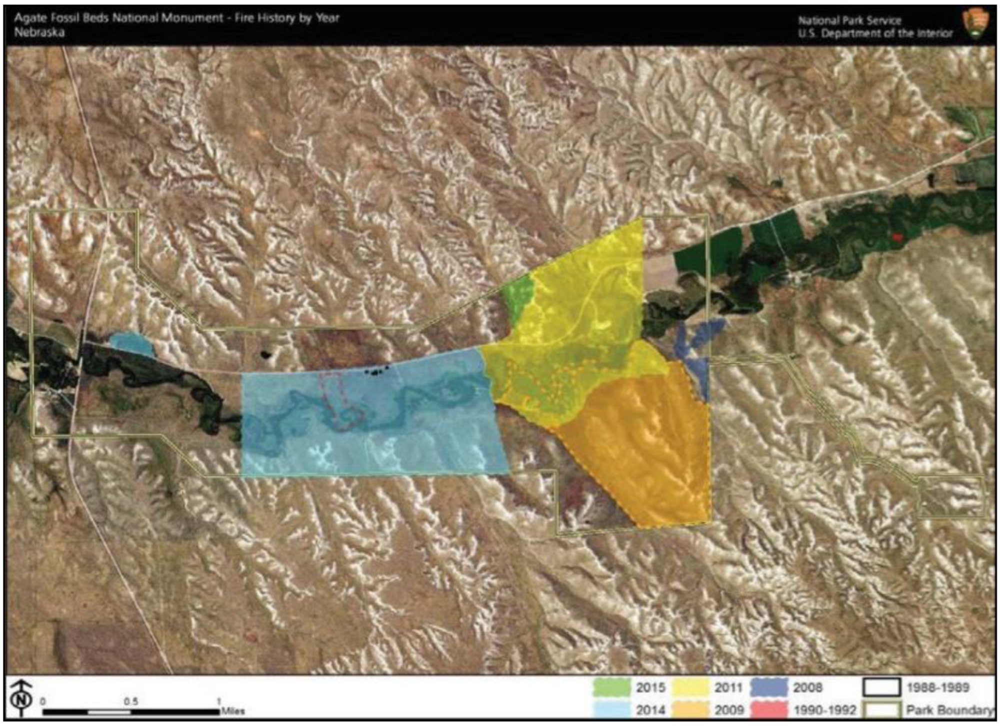


Figure 4.8.11. Map of recent fire history at Agate Fossil Beds National Monument (NPS) (Ashton and Davis 2016).

Figure A.2: Mosaic created through periodic burning at AGFO.

Prairie National Preserve who lease a pasture of their land to local cattle owners to manage the prairie to the most conservative stocking rate and seasonality of cattle grazing. Cattle would also accomplish the cultural focus of the Monument in wanting to restore the prairie to what it looked like when James Cook and Red Cloud were living in the area. Revenue from cattle grazing fees could be used to support cultural resource management. A focus would be put on restoring a grazer to the ecosystem while also increasing budgetary support to the true meaning of the Monument: cultural preservation.

Once the large grazer were established, fire should be more present on the landscape. It will aid in the movement of cattle across the unit. It is our recommendation that a coupled disturbance regime be established to increase heterogeneity of the grassland. Very little disturbance is currently present on the landscape. Introducing a coupled disturbance regime would benefit the wildlife that depend on this patch of habitat for their vitality.

Appendix B. Badlands National Park

Current Grassland Management Goals and Programs

Grassland Management Goals

Native Mixed Grass Prairie. The park purpose includes protections of cultural and ecological resources. A bulleted list of management priorities begins with the unique landforms and scenery of the Badlands and the preservation of paleontological and geological resources. The third point discusses preserving natural processes of the mixed-grass prairie ecosystem. Badlands National Park (BADL) protects the largest mixed-grass prairie within the national park system (Foundation Statement, 2017). Stated goals during interviews were broad in their scope. They include “maintain a fully functioning ecosystem” and “protect the native mixed-grass prairie”. With the lack of a vegetation management plan, specific goals are not communicated in writing. Invasive species are an issue, but achievable goals have not been set. The weed management plan, written in 2003, emphasizes specific treatments, but is out of date and should be rewritten.

Grassland Wildlife. A definitive focus at BADL is wildlife. Species reintroductions occurred periodically over the last few decades. This placed staff and budgets focus on species management. Interview responses on site focused heavily on species specific wildlife goals naming specific species when asked about overall natural resources management goals. Bison, black-footed ferrets and bighorn sheep are a few of the charismatic species that require consistent management to maintain healthy populations. Bison and bighorn sheep in particular are popular with visitors. Due to this, other divisions have also focused on these more visible species to the avail of the other resources in the park. Goals for wildlife management are numerous, but laser focused in their scope of species vigor.

Grassland Management Programs

Exotic Plant Management Team. Region-wide, the exotic plant management team (EPMT) targets invasive species using mechanical or chemical treatments. The team is stationed and managed from BADL. This means there is significant use of mechanical and chemical means of exotic removal at BADL. The species of most concern at this unit is exotic yellow sweet clover. Annual brome grasses (*Bromus* spp.) continue to be an issue with an Annual Brome Adaptive Management (ABAM) study ongoing in MWR units. Budgets have reduced the impact that the EPMT can have on landscapes within BADL.

Fire Program. The fire management plan at BADL was written in 2004. This plan split BADL into two management units, the “Boundary FMU” and the “Natural FMU”. The “Boundary FMU” uses only suppression and prescribed fire whereas the “Natural FMU” allows some naturally ignited fires to burn under supervision. Goals of the 2004 fire management plan include enhancing productivity of the native grasses, decrease the spread of some exotic species and controlling woody species. The program discusses restoring fire to 80% of the vegetated landscape within 15 years of 2004, and restoring a mosaic of grassland seral stages to the landscape.

Wildlife Management Program. As stated previously, a substantial amount of Park resources are directed towards wildlife management. The amount of projects related to wildlife management warrants its status as a program within the Natural Resources division at BADL. This program conducts yearly data collection of species within the unit and population roundups to assess species composition. Visitor experience at BADL is also centered on the wildlife management program with “unparalleled views of native wildlife" present in the park (Foundation Statement, 2017). This has allotted more funding towards the wildlife program from higher up sources in the unit and the region. The Natural Resources Condition Assessment (NRCA) states that overall wildlife is populations are doing well, with the exception of plague contractions in the black footed ferret populations.

Management Plans and Data Available

Management Plans

Several management plans are older and were collected or published before BADL lost a significant amount of staff. Evidence of this is shown in that three key management plans are not displayed in our table as they are outdated by our year parameters: Fire management plan (2004), general management plan (2006), and Black tailed prairie dog plan (2007). Across the NPS, general management plans are being phased out and replaced by foundation documents (2017), but an updated fire management plan should be of priority as climactic drivers are altering the effects that fire has on landscapes. The 2018 NRCA is also extremely relevant. A complete list of published management plans for BADL can be seen in Table B.1.

Table B.1: Management documents for Badlands National Park published from 2008-2018.

Title	Year
Prairie Dog Management Plan	2008
Memorandum of Understanding for Wildland Fire Management	2008
Genetic Based Management Plan for Bison	2008
Climate Change Vulnerability Assessment	2012
Bison Management Plan and EA	2016
Foundation Document	2017
Grasshopper and Mormon Cricket EA	2017
Natural Resource Condition Assessment	2018
Wilderness Stewardship Plan	2018
South Dakota Bighorn Sheep Management Plan	2018-2022

Data Available

Our data audit includes studies from 2008-2018 (Table B.2), but a complete list of data beyond our year parameters can be accessed from the NRCA. Evident, is the focus of budget, time and staff at BADL. Ten of the 18 studies in this table are focused on wildlife and the viability of the protected species within the park. Vegetation management data is collected by I&M as the park currently has no botanist. I&M data is a resource the unit must use to make decisions pertaining to the prairie. Community composition data and fire effects data are present in I&M monitoring documents. Data available is scant as told in interviews, the focus with less staff is to just continue managing what they have and not lose anything they have now rather than take on new projects and new data collection.

Table B.2: Selected data collected in BADL, 2008-2018.

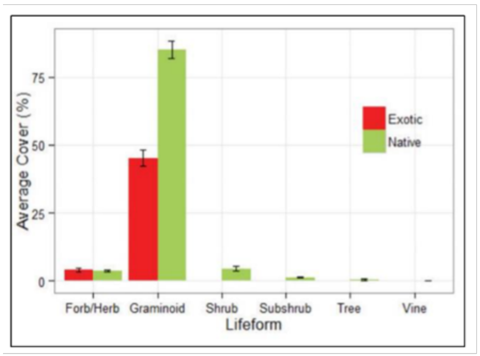
Data title	Data type	Spatial extent	Frequency	Duration	Collecting agency	Format located
Mapping of Nutrient- Nitrogen Critical Loads for Selected National Parks in the Intermountain West and Great Lakes Region	Air	park wide	Assessed once via vegetation maps of park units	2016	E&S Environmental Chemistry, Inc./ NPS Air Resources Division	IRMA
Resource Management Annual Report 2016	All	park wide	Collections each year	2016	NPS	on site at BADL
Climate Change Vulnerability Assessment	Climate	Park wide	Historical Assessment	Historical-2012	NPS	IRMA
Erosion Rates	Geology	park wide	fall 2010 and 2011	2010-2011	South Dakota School of Mines and Technology	IRMA
Geologic Maps of BADL	Geology	Park wide	Once	Published 2008	NPS Geologic Resources Division	IRMA
Exotic Plant Management Team Achievements	Vegetation	varying acres treated per summer	summer season	have reports from 2003-2011	NPS EPMT	on site at BADL
Plant Community Composition	Vegetation	127 plots across the park	each plot visited for two consecutive years and then rested for eight years on a ten year rotating basis	2011-current	NGPFire and NGP I&M	IRMA
Northern Great Plains Fire Ecology Annual Report	Vegetation	Park wide	annually	1996-current	NPS Fire Effects Team	IRMA
Bison weights from National Parks in the Northern Great Plains.	Wildlife	bison herds at three parks	once each fall in each year of collection	1983-2014	NPS	online

Table B.2, *continued.*

Data title	Data type	Spatial extent	Frequency	Duration	Collecting agency	Format located
Monitoring the birds of Badlands National Park: 2011 report	Wildlife	25 cells in the north unit of BADL	One season	22 May –8 July 2011	Rocky Mountain Bird Observatory	IRMA
Land bird Monitoring	Wildlife	161 points across the park	annually	2012-current	NGP I&M	IRMA
Conservation assessment and conservation strategy for swift fox in the United States—2011 update	Wildlife	United States	Historical assessment	1992 –2011	South Dakota Game Fish and Parks	Online search
Swift Foxes in Southwestern South Dakota: Assessing the Current Status of a Reintroduced Population	Wildlife	Seven-county area of SD	1000 scent stations established once per year for two years	2014–2016	South Dakota State University	Online search
2016 Bighorn Sheep Population Status	Wildlife	opportunistic counts combined with trail camera	50 hours	1996-2016	NPS	on site
2016 Breeding Bird Survey	Wildlife	three routes	3 minutes per stop (50 stops) once each year on each route	2016	NPS	on site
Acoustic Surveys of Bats	Wildlife	park wide	4-7 consecutive nights at each point	2014-2016	NPS NGP I&M	IRMA
Observations of Bobcats, *Lynx refus*, Hunting Black-tailed prairie dogs, *Cynomys ludovicianus*, in Western South Dakota	Wildlife	Park wide	Winters of 2009-2010	2008-2010	NPS	IRMA

Table B.2, *continued.*

Data title	Data type	Spatial extent	Frequency	Duration	Collecting agency	Format located
Grazing Resources for Integrated Conservation of Bison and Native Prairie at Badlands National Park, South Dakota	Wildlife and Vegetation	Park wide	Different aspects of study occurring over three years	Ongoing	USGS	On site



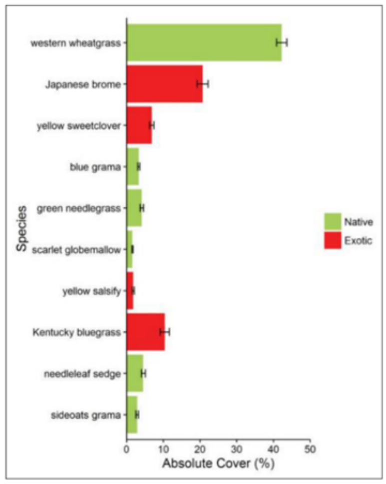


Figure B.1: Vegetation status of BADL prairie 2015 (Ashton and Davis, 2016)

Disturbance Regime

Grazing

Livestock grazing was prevalent in the area before BADL establishment. Livestock grazing also occurred following Park establishment (1942–1962). Bison reintroduction began in 1963, with more animals added in 1983. The park currently manages for around 1,000 bison. BADL strives for 40% stocking rate. Bighorn sheep, pronghorn and mule deer also contribute to grazing disturbance, but bison are the main conservation herd. Bison are currently maintained in one pasture (Fig. B.2). This constrains their natural movements across the landscape, although a bison expansion project is planned for the coming years (from interviews, this seems to be mostly motivated by enhancing visitor experience pertaining to bison viewing). Park reports state that a grazing disturbance has had a positive impact on the landscape. Native species richness is higher in pastures containing bison (Ashton & Davis 2016).

The eastern edge of the park where grazing and fire are underutilized due to the threat to visitors, the litter layer is in excess inhibiting the vitality of the prairie. (B. York, on-site interviews, 2018)

Fire

Fire operations for the region are stationed at BADL. Similar to the EPMT, this means resources are easily available for dispatching to prescribed fires. The area has evolved with the use of fire as a disturbance and historical disturbance regimes included fire return intervals of five years on "level to gently rolling topography" and 15-30 years on "more broken topography" within the park. In the 20th century, suppression was the norm for all fires. As mentioned earlier, the fire management program changed slightly with the use of a management area where naturally ignited fires are allowed to burn under supervision. Prescribed fires have created a mosaic of burned patches across the unit from the 1980's until 2012 (Fig. B.3), but recently, funding constraints inhibited the use of prescribed fire in BADL (Foundation Statement, 2017). Annual brome has increased in patches not recently burned. To achieve BADL's grassland management goal of a native mixed-grass prairie with few invasive species, disturbances, such as fire, must be used.

BADL knows the importance of a coupled disturbance regime, but implementation has not occurred. One report notes that "fire and grazing alone consistently do not perform adequately to accomplish management objectives," and goes on to say that the coupling of the two to create the native distur-

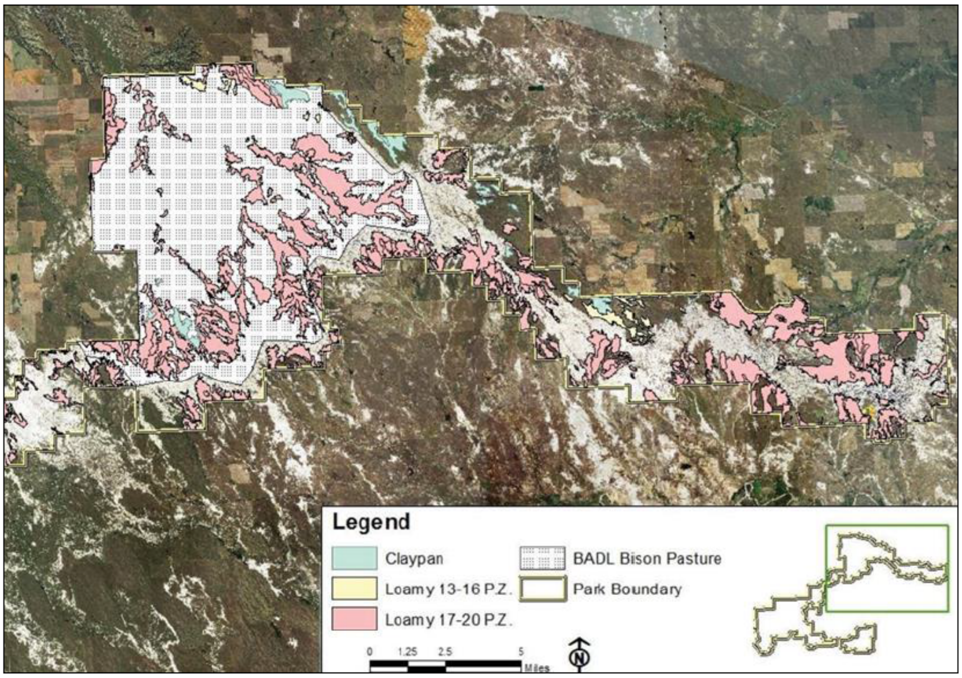


Figure B.2: Bison pasture at BADL and corresponding ecological sites (Ashton & Davis 2016)

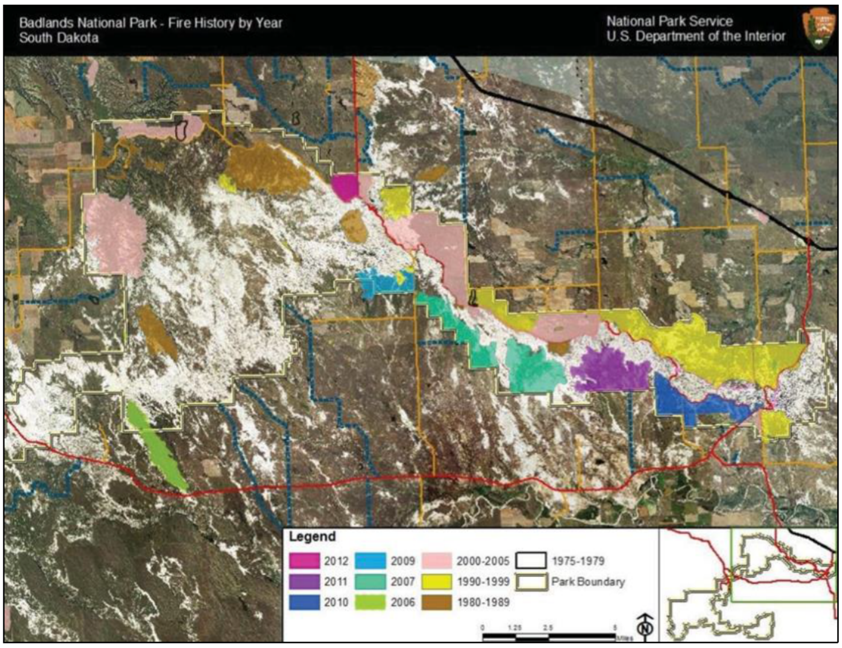


Figure 4.8.13. Map of recent fire history at Badlands National Park (Ashton and Davis 2016).

Figure B.3: Fire mosaic created by patch burning in BADL (Ashton & Davis 2016).

bance regime is necessary to the maintenance of the prairie, "grazing regulates fire, fire regulates transitions (to altered plant community composition states)". Spatial and temporal heterogeneity are cited as being important to maintain native processes on the landscape.

Data gaps and suggested research

Data Gaps

Data from BADL are focused on wildlife. There is a lot of information on wildlife presence or absence as well as vigor with frequent captures and monitoring of wildlife populations. Vegetation data for the unit is completely reliant on the I&M network. Although this is extremely beneficial data, the monitoring done by the network has no strength in proving cause and effect (B. York, on-site interviews, 2018). Studies done in the park either by outside researchers or staff personnel would be beneficial to best understand what varied intensities of disturbance would do to the extremely diverse landscape of BADL.

The recently published NRCA and Foundation Document have cited several data and plan gaps that we would like to echo. Most importantly, to establish a disturbance regime, knowledge of the effects of disturbance on your landscape are critical. This includes vegetation effects (both native and non-native), erosion rates due to grazing, understanding of the landscape at the soil level with ecological site descriptions, and tracking of grazers across a landscape to understand their grazing preferences. The inherent heterogeneity of BADL makes this information important so that the imposed heterogeneity through a disturbance regime works positively to enhance ecosystem resilience.

Suggested Research

Future research should be focused on how disturbance interacts with the landscape at BADL. Fortunately, BADL has two studies underway looking at these interactions. The first is studying the effect of grazing on vegetative resources. This study will help establish stocking rates, written about in the 2017 Foundation Statement as a gap in data. The second is tracking bison across the landscape. BADL, WICA and THRO are using GPS collars for bison (as well as other large ungulates) to track their movement in the unit. This is used for understanding plant community use by grazers. While the effect of grazing is being investigated, it should be studied within the context of other disturbances. Beneficial studies would be:

- The effect of fire on exotic yellow sweet clover
- The fire return interval for burn units in light of changing climactic factors
- The use of fire and the movement of large grazers in response
- Beneficial coupling of the inherent BADL heterogeneity and imposed heterogeneity via fire
- Coupling the known erosion rates and ungulate movement to determine grazer impact

Management Recommendations

Prioritize fire in staff and funding

Current staff and budget priorities at BADL are wildlife related. Species reintroductions have required staff to allot lots of time to these projects. As such, other resources have been managed on minimal budgets and personnel. This has also prompted the need of partnerships with outside agencies or funding organizations to accomplish tasks within the park which is not always guaranteed money. The fire management program has severely suffered from lack of prioritization. Over the last five years, there has been one prescribed burn in BADL. To create a heterogeneous landscape via a disturbance regime, a piece of the landscape needs to be burned each year. Bison can also be moved through a landscape by attracting them to recently burned patches. This aids in the management of grazers constrained within a fenced pasture so that certain areas are not grazed too heavily. This can limit the amount of staff timing to move bison via horseback or helicopter.

To burn each year under a strapped budget, there needs to be forethought of when in the season a burn should occur. Vegetation monitoring may suggest that to achieve certain invasive species management goals there needs to be fall prescribed burns. This may be unrealistic with staff and budget constraints. Spring burning may be required to create a mosaic of different grass stands to best benefit wildlife and other ecosystem processes. Spring burning is beneficial for targeting annual bromes when they emerge before native species. It also allows the unit to maintain a full crew of firefighters before they have exceeded their hours fighting fires across the United States.

Appendix C. Tallgrass Prairie National Preserve

Current Grassland Management Goals and Programs

Grassland Management Goals

Maintain tallgrass prairie remnant Tallgrass Prairie National Preserve (TAPR) is unique in that they were explicitly created to protect the prairie and the cultural impact of the tallgrass prairie in the Kansas Flint Hills. This allows all management focus to center on maintaining a native prairie and all of the processes and resources that depend on that goal. Relics of legacy land use have created some areas of non-native prairie. Restoration is ongoing to restore bottomlands to native species.

Wildlife habitat TAPR is not focused on single resource pertaining to wildlife. Other units in this study focus on the vigor of individual wildlife species. The wording of management documents at TAPR is vastly different. Rather than managing for wildlife species, their management documents focus on the prairie and the habitat that it can provide for a multitude of species. Similarly, although the Topeka Shiner is a key threatened species in the unit, TAPR is focused on improving aquatic habitat via altered cattle grazing. This is a systems focus that will benefit the resilience of the grassland.

Upland stream maintenance The Topeka Shiner is an endangered species present in prairie streams flowing through TAPR. Partnerships with state agencies and academic researchers have focused on the status of this fish and the habitat it depends on. Due to its importance as an endangered species, the unit is looking into how to best manage for the stream habitat in upland areas of the unit.

Grassland Management Programs

Mechanical removal of woody species TAPR is extremely susceptible to woody encroachment. As such, they have an extensive management program to remove these invasive species. Constant efforts make headway, but unit staff expressed the need for more focused management on herbaceous invasive species rather than a constant battle against woody encroachment.

Bison management Bison were reintroduced to TAPR in 2009. They are managed as a satellite herd of the Wind Cave NP population. More animals may be introduced in the future to maintain the genetics of this population as they currently do not maintain enough animals to continue as a viable herd. Bison are stocked year round and grazing is coupled with fire to impose disturbance on the landscape at TAPR.

Cattle management The Flint Hills have a ranching history that is part of the cultural narrative of TAPR. Establishment of the unit required that cattle continue to graze on some lands within the unit. A lessee is allotted a certain amount of AUMs each season and the park manages cattle under different management systems such as early intensive grazing. There is also fire coupled with livestock grazing. Recently, stocking rates have been lower and monitoring shows vegetation has slightly declined in quality (Leis & Morrison 2018).

Management Plans and Data Available

Table C.1: Management documents for TAPR published from 2008-2018

Title	Year
Bison Management Plan	2009
Fire Management Plan	2016
TAPR General Agreement	2016
Foundation Document	2017

Management Plans

TAPR is a newer NPS unit established, in its current form, in 2005. There are fewer published plans because of this. At this unit, more so than others, interviews revealed that management decisions are made adaptively either seasonally or annually. This is communicated as both positive and negative. Positive, as they are able to make changes quickly to address management issues. Negative, because there aren't clear goals they are working towards other than the broad goal of a healthy native ecosystem. The partnership between NPS and TNC makes it especially important to have clear goals that both parties agree on for management. Published management plans are listed in Table C.1.

Data Available

Water, wildlife and vegetation are of equal study at TAPR. The unit is less dependent on I&M data as outside agencies and outside researchers contribute a significant amount of research to the unit. The status of resources is highly documented which means expansion of the disturbance regime would be plausible. The continuation of management decision making may be more challenging as there are not consistent programs in the currently available data (Table C.2).

Table C.2: Selected data collected in TAPR, 2008-2018.

Data title	Data type	Spatial extent	Frequency	Duration	Collecting agency	Format located
Night Skies and Photic Environment Resource Summary	Air	unit wide	compiled once	2013	NPS	on network
Soil Survey	Geology	unit wide	once	2010	NPS/ USDA/ NRCS	on network
Lithology and Paleontology of the Stratigraphic Units Cropping out TAPR	Geology	unit wide	written 2008	park historical report	Kansas Geological Survey	on network
Fixed Point Repeat Photography	Vegetation	preserve wide and outside preserve for comparison	once per year	1997- 2015	NPS/ TNC	on network
Vegetation Classification and Mapping of TAPR	Vegetation	Preserve wide	Data collected once	July 2008	Kansas Natural Heritage Survey	Online search
Grazing Stocking Database	Vegetation	pastures with stocked grazers	updated annually	1995-current	NPS/ TNC	on network
Restoration Transect Data	Vegetation	different fields with restoration ongoing	summer	2013	NPS	on network
TAPR Post Burn Summaries	Vegetation	fire patch varies each year	post fire	once after each annual burn	NPS/Heartland Network	IRMA
Evaluating Long- term trends in vegetation and management intensity	Vegetation	unit wide	vegetation data collected once every four years by Heartland network	1995-2014	NPS/ Heartland Network	IRMA

Table C.2, *continued.*

Data title	Data type	Spatial extent	Frequency	Duration	Collecting agency	Format located
Assessing Fluvial Geomorphology Conditions of Upland Prairie Stream Reaches on the Tallgrass Prairie National Preserve	Water	unit wide	once per year	2006-2016	Kansas State University/ The Watershed Institute	on network
Palmer Creek Water Assessment	Water	Palmer Creek	one trip	2015	KDWP	on network
Palmer Creek Fluvial Geomorphology	Water	Palmer Creek	once in the season	2009	The Watershed Institute	on network
Fox Creek Hydrology	Water	Fox Creek	sensors collecting frequently throughout the years	2009-2013	NPS	on network
Fish Assemblage Survey	Wildlife	all ponds on the preserve through seining	once per pond	April- June 2014	Emporia State University	on network
Bat Surveys	Wildlife	unit wide	one season	17 nights from May-June 2017	NPS/ TNC	on network
Butterfly Count Site Totals	Wildlife	unit wide	each season	2009-2016	NPS/ other investigators	on network
Wildlife Fire Effects	Wildlife	unit wide	yearly effects collected	2010	Missouri State University	IRMA
Fishes in Lower Fox Creek	Wildlife	unit wide	May- August 2014	2014	Emporia State University	on network
Lek Data	Wildlife	unit wide	once per year	2008-2011	NRCS	on network

Table C.2, *continued.*

Data title	Data type	Spatial extent	Frequency	Duration	Collecting agency	Format located
Butterfly Inventory and Effects of Fire and Grazing	Wildlife	6 transects per management unit	once	7-10 day period each month from May -Sept	Emporia State University	on network
Impacts of Alternative Grassland Management Regimes on the Population Ecology of Grassland Birds	Wildlife	land across the Flint Hills region	463 surveys 156 different 300m line transects	Feb 2011- Feb 2014	KSU, MSU, Benedictine College	on network
Fishes of TAPR	Wildlife	lower Fox Creek	once in 2014	30 May to 12 August 2014 but compiling with other previously collected data 2018	NPS/ Emporia State University	on network
Semiaquatic turtles of TAPR	Wildlife	Fox Creek	21 dates	14 June - 18 September 2014	Emporia State University	on network
Kansas Winter Bird Count	Wildlife	unit wide	once each winter	have data from 2016-2018	NPS	on network
Monitoring Summary for TAPR of Bird Communities	Wildlife	58 points unit wide	yearly effects collected	May 14- June 12	NPS	on network
USFWS FH Bird Survey	Wildlife	51 sampling routes	yearly effects collected	March- May 2013	TNC/ USFWS/ volunteers	on network

Disturbance Regime

Grazing

Cattle and bison are managed at TAPR in conjunction with ecological objectives. Bison were reintroduced to TAPR in 2009 with animals from Wind Cave NP and are managed in separate pastures—cattle only graze for 90 days in an early intensive stocking system. Cattle stocking rates are assigned each year by TNC staff at TAPR based off of the previous year's conditions. Bison are also rounded up annually to determine herd size and health. A coupled disturbance regime is used at TAPR, which entails moving grazers through the landscape using burning as an attractant. This is beneficial to protect sensitive streams from grazer impact. Grazing is also somewhat unnaturally managed so that tall grass is present for visitor experience. Fire can also be used to move grazers away from certain visitor heavy areas.

Fire

TAPR monitoring follows national fire effects guidelines as per the fire effects guidebook. The plant community monitoring protocol states that, "resource limitations have resulted in sampling designs oriented toward short-term, burn unit-specific information to determine whether the objectives of a specific prescribed fire or mechanical treatment project have been met." There is heterogeneity present in a patch burn grazing system at TAPR (Fig. C.1). Prescribed fires have been conducted in varying seasons in recent years. This is beneficial to the ecosystem increasing pyro-diversity. Variety in fire behavior and fire season mimics the natural disturbance regime.

Data gaps and suggested research

Data Gaps

To implement further heterogeneity through a coupled disturbance regime, there are several areas where TAPR could collect further data. Formal overall status of resources is lacking. The four other parks in this study have a complete Natural Resource Condition Assessment (NRCA) detailing the resources protected. TAPR does not have this document. An overall assessment of resources at the unit would aid in the establishment of a standard disturbance regime. Available data is consistently a one-time study or collected over several years and then halted due to staff or budget constraints. Unit staff stressed the need for consistent annual data to make decisions off of. TAPR is unique in that the Heartland I&M network only surveys the unit once every four years rather than annually which is typical for other NPS units in this study.

More consistent data is also needed on invasive species management and seasonal wildlife populations. Staff mentioned adaptive management, but not having "hard" data to inform these annual decisions. TAPR has a coupled disturbance regime occurring on several areas of the unit. Annual data on grazer forage demand and productivity are needed to optimize the fire-grazing interaction as a disturbance regime. Unit staff also expressed desires to better manage for prairie streams and the threatened Topeka Shiner. As such, there is data missing on grazer impact on water resources as well as erosion rates in high use areas.

Suggested Research

The disturbance regime at TAPR has a high level of established heterogeneity. Patch-burn grazing has created diversity on the landscape that benefits wildlife species. Annual management is required in an ongoing disturbance regime. Disturbances cannot be applied once in a while as a tool but must

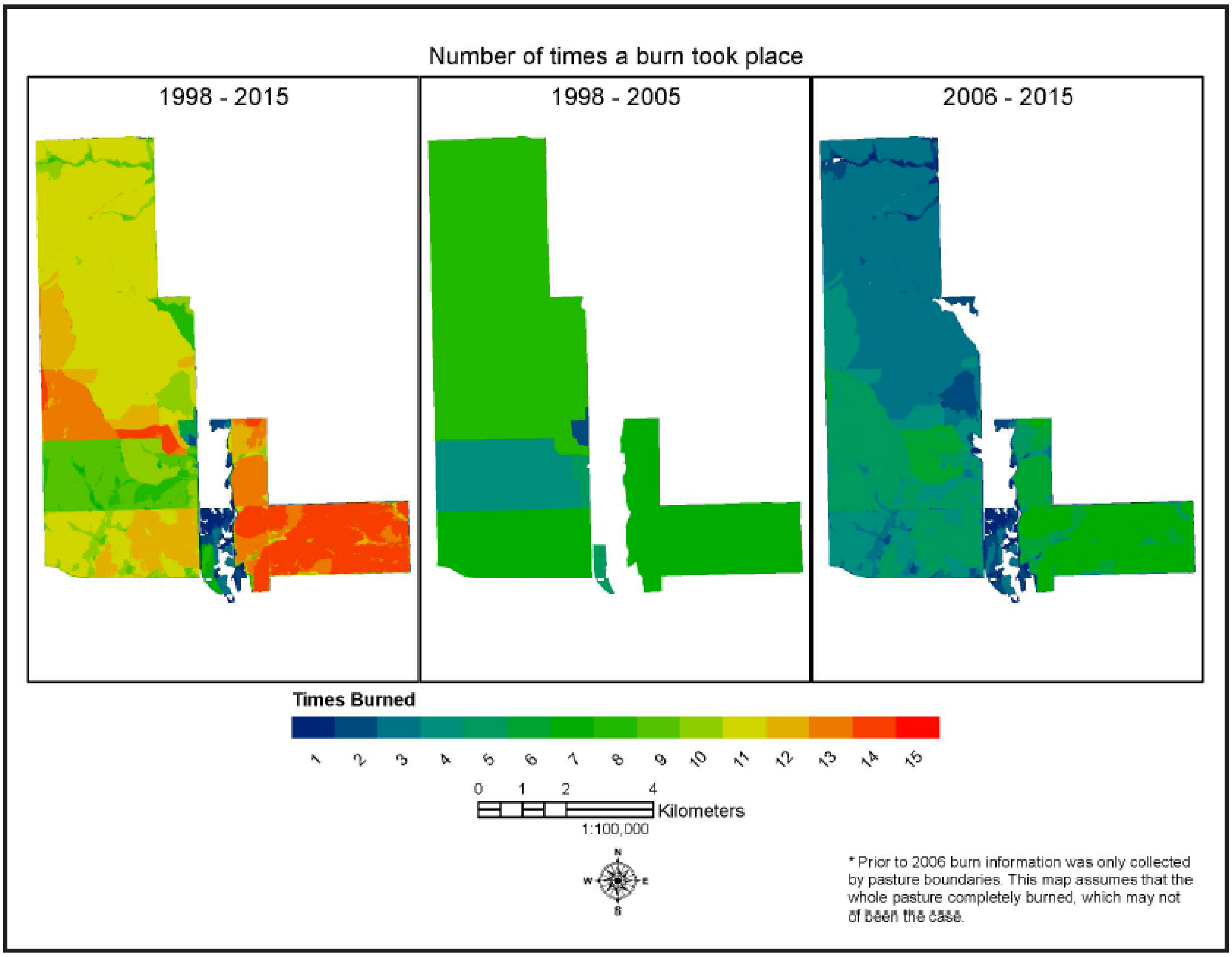


Figure C.1: Mosaic created through patch burn grazing at TAPR (Leis & Morrison 2018).

be a continuous process. Invasive species management is a major issue at TAPR. This includes both herbaceous and woody species. Goals need to be established for management of these species. Fire and grazing might have impacts, but goals need to be established to prescribe an effective disturbance regime.

- The effects of grazing on erosion and water resources/aquatic species
- Range utilization collected each year

Management Recommendations

Expand coupled disturbance regime

Expanding the coupled disturbance regime at TAPR will increase the resilience of the tallgrass prairie. Expanding the disturbance process can also help manage more of the landscape affected by invasive species. *Sericea lespedeza* is a critical concern at TAPR. Late spring burning or fall burning are known to affect this species, but further research in the context of the landscape at TAPR would be beneficial to understand the best course of action.

Target woody encroachment

Mechanical treatment of woody invasives is time-intensive. Strapped budgets and staff at TAPR could be used in many other ways if woody species were targeted via a natural disturbance regime. Preliminary data suggest fall burns and more intense burns can reduce woody species in tallgrass prairie (Weir & Scasta 2017). TAPR has begun to burn in other seasons, but researching the impacts and communicating these to the public could make the use of fall prescribed fires more acceptable to surrounding landowners.

Appendix D. Theodore Roosevelt National Park

Current Grassland Management Goals and Programs

Grassland Management Goals

Lightly utilized prairie Grasslands at THRO are lightly stocked. This allows the protected lands within the park to contrast the heavily grazed lands surrounding the three units of the park. The bison herds at THRO are culled to maintain this light utilization and horse bands are being assessed for contraceptive control to inhibit the growing population. The landscape at THRO is inherently heterogeneous. A patchy disturbance regime needs to interact positively with this diverse landscape to maintain forage banks for herbivores in the unit. Intense but spatially-discrete disturbance is needed rather than broadly lightly-utilized prairie.

Conservation and cultural wildlife management Population genetics of wildlife are studied at THRO. Genetic testing of bison informs which animals to cull in annual roundups to maintain an even spread across age and sex. This aligns with the "conservation herd" parameters the MWR sets for bison. Genetics are also used in feral horse management. The small genetic pool of the band has led to non-viable offspring. Feral horses and longhorn cattle are managed as cultural exhibits, although these non-native species still require substantual effort on the part of natural resources staff.

Grassland Management Programs

Wildlife Management Feral horses, bison, longhorn cattle, and several other herbivores graze in the park. Feral horses and longhorn cattle are managed as an interpretive exhibit while bison are managed as a conservation herd. Bison are the focus as they are a native grazer, reintroduced in 1956. The park maintains 200-400 animals in the south unit of the park and 100-300 animals in the north unit. Feral horses are maintained for the cultural aspect and visitor experience. Both bison and feral horse genetics are studied extensively to optimize population vitality. Finally, longhorn cattle are maintained as an interpretive exhibit in the Elkhorn Ranch Unit to recreate Theodore Roosevelt's ranch. Elk were also reintroduced to the south unit in 1985 with a major cull occurring 2010-2013.

Invasive Species In 2018, the park began treating invasive species after a period (2012-2017) without treatment of any kind. This gap allowed leafy spurge, Kentucky bluegrass, and Canada thistle to increase (Folluo, 2017). Riparian areas are especially invaded with smooth brome and Kentucky bluegrass. Priority is placed on the management of these species so that the prairie is not taken over by non-native species.

Management Plans and Data Available

Management Plans

Plans at THRO cover a diverse range of resources. The Fire Management Plan, written in 2008, although present in our time parameters, could be updated. Management goals in the unit have changed. Invasive species are increasing, and climactic conditions are changing at an accelerated rate. A complete list of published management plans for THRO is shown in Table D.1. The vegetation management strategy from 2012 gives a complete background on vegetation management done in the park and previous research completed pertaining to vegetation.

Table D.1: Management documents for THRO published from 2008-2018

Title	Year
Fire Management Plan	2008
Elk Management Plan	2010
Long Range Interpretive Plan	2011
Vegetation Management Strategy	2012
Natural Resource Condition Assessment	2014
Foundation Document	2014

Data Available

In 2012, THRO lost their park botanist and efforts related to vegetation ceased for some time. I&M still collected data, but park staff communicated that I&M data are not the most useful due to the variability present on the THRO landscape. Selected data can be seen in Table D.2. Vegetation data collected prior to 2008 can be found in the vegetation management strategy. Table D.2 shows the vegetation data gap from 2012-2017. Wildlife data is up to date and has recently been the focus of collection and management efforts. This lack of time on vegetation is the impetus for vegetation data collection starting again in 2018.

Table D.2: Selected data collected in THRO, 2008-2018.

Data title	Data type	Spatial extent	Frequency	Duration	Collecting agency	Format located
Oil and gas impacts on air quality in federal lands in the Bakken region: an overview of the Bakken Air Quality Study and first results	Air	Bakken surrounding region	48 hr integrated samples, 6 days per week-15 February- 6 April	began in 2013	NPS - Air Resources Division	unit network
Pre- Burn Pedestrian Survey of the Halliday Wells Burn Unit at THRO	Fire	one burn unit	once to assess archeological resources in a planned burn area	April 20, 2015-May 21, 2015	Midwest Archeological Center	unit network
Acoustic Monitoring Report	Sound	parkwide	30 day monitoring periods- 831 sound level meters	2012-2015	NPS	unit network
THRO Vegetation Monitoring – 2017 Summary Report	Vegetation	all three units of the park. Leafy Spurge (20 plots S, 3 N, 5 ER), Canada Thistle (13 N, 1 ER)	plots each summer	2008-2012 then lapsed and began again in 2017	NPS (Jenna Folluo, RM Volunteer)	unit network
Dendroclimatic Potential of Plains Cottonwood from the Northern Great Plains, USA	Vegetation	north unit of THRO	cored random tree once	July-October, 2010	USGS, University of Arizona, University of Arkansas	unit network
Plant Community Composition and Structure Monitoring for THRO	Vegetation	parkwide	once per summer	2011-current	NGP I&M	IRMA

Table D.2, *continued.*

Data title	Data type	Spatial extent	Frequency	Duration	Collecting agency	Format located
Exotic Plant Management Team 2008 Annual Report	Vegetation	parkwide	annual report written each year for work accomplished during the summer season	EPMT established in 2000	NGP EPMT	unit network
Summary of observations on dieback of ash trees THRO (south unit)	Vegetation	three sites in the south unit of THRO	once	Aug-10	NDSU	unit network
Herbicide Application Report	Vegetation	parkwide			NPS	paper copy at unit
Canada Thistle and Leafy Spurge plot data	Vegetation	parkwide	once per season	2008-2012	NPS	unit network
North Dakota Plant Species of Concern	Vegetation	state wide		published 2010	ND Natural Heritage Inventory	unit network
Leafy Spurge Density Charts	Vegetation	parkwide	once per season	1983-2011	NPS	unit network
Leafy Spurge Status Report	Vegetation	parkwide	different areas treated each year	data as far back as 1970, report published in 2009	NPS	unit network
Plant Community Descriptions of THRO	Vegetation	parkwide		describing characteristic landscapes in THRO	NPS	unit network
Canada Thistle Status Report	Vegetation	parkwide	annual report written each year for work accomplished during the summer season	1997-2009	NPS	unit network

Table D.2, *continued.*

Data title	Data type	Spatial extent	Frequency	Duration	Collecting agency	Format located
Brine Contamination to Aquatic Resources from Oil and Gas Development in the Willison Basin, US	Water	three sites across the basin	one time in 2008	2008	USGS	unit network
Aquatic Resources along the Little Missouri River near THRO	Water	four sites along the Little Missouri River	once	Aug 30 2011-Sept 1 2011	University of Wyoming	unit network
Annual Wildlife Report	Wildlife	parkwide	each year surveys of different wildlife populations	2008-2011	NPS	unit network
Elk Surveys	Wildlife	parkwide	one survey each year	1985-2000, 2010-2012	NPS	unit network
Gypsy Moth Trap Record	Wildlife			2017		
Pronghorn Migration and Resource Selection	Wildlife	southwest ND	tracking fall migrations	2004-2008	University of Missouri-Columbia	unit network
Detections of *Yersina pestis* East of the Known Distribution of Active Plague in the United States	Wildlife	five NPS units: THRO, WICA, DETO, SCBL, BADL	once per year in different months	2009-2011	University of South Dakota	unit network
The prairie dog: a century of confusion and conflict in park management	Wildlife	NPS units with prairie dogs	assessing data for one time report	written in 2009 assessing data from history-2009	NPS	unit network
Use of water developments by female elk at THRO	Wildlife	parkwide	26,081 samples at 7-h intervals	June- September, 2003-2006	USGS, NPS	unit network

Table D.2, *continued.*

Data title	Data type	Spatial extent	Frequency	Duration	Collecting agency	Format located
Bison Handling Database	Wildlife	parkwide	yearly added to database	1985-current	NPS	unit network
Elk Handling Database	Wildlife	parkwide	yearly added to database	1985-current	NPS	unit network
2016 NU Bison Roundup Data	Wildlife	north unit of THRO	each roundup	this report is from 2016	NPS	unit network
Elk Count Data	Wildlife	parkwide	each year surveys of different wildlife populations	fall 2015	NPS	unit network
2010 Bighorn Sheep Capture	Wildlife	north unit of THRO	once	15-Feb-10	NPS	unit network
Description of Bobcat Harvest	Wildlife	state wide	yearly added to database	2004-2008	ND Game and Fish Department	unit network

Disturbance Regime

Grazing

Bison are free to roam in the north unit and south unit of the park. Elk and feral horses roam the south unit. The goal of herbivory in the park is a lightly utilized landscape in comparison to the surrounding heavily grazed lands. Bison are stocked at a conservative rate and forage quality seems to be good (Licht, 2016). Some areas of the park are heavily grazed. A study is ongoing to determine locations of bison in the park using GPS collars. This will help in developing forage use management. Grazers can be drawn away from an area through a coupled disturbance regime. They can also be drawn to an area that has been recently burned to feed on nutritive new growth.

Fire

Fire is another natural disturbance on the landscape at THRO. The unit is inherently heterogeneous. This complicates goal setting for ecosystem processes. Imposed heterogeneity must align with the inherent heterogeneity to create beneficial patches on the landscape. Fire has been absent on the landscape at THRO recently. Nine fires have occurred in the last ten years with four of those occurring in 2009. An 8,000-acre fire occurred in May of 2018 but was the first since 2011. Due to generally lower annual primary productivity, the fire return interval at THRO might be longer than other units in the Midwest Region, but some fire should occur in some form each year to ensure nutritive new growth for herbivores the following year. Regular prescribed burning would also contribute to management of woody encroachment and other invasive species issues.

Data gaps and suggested research

Data Gaps

The main data gap in the last decade is vegetation related. Staff time and money has been focused on wildlife research. Vegetation surveys and invasive species treatment was highly documented, but then ceased in 2012. The park is beginning to reassess vegetative resources, but the status of the prairie after this management gap is needed. This includes assessment of I&M documented community composition data as well as determining the status of various ecological sites within the park that the I&M data may not capture. Once resource status is quantified, specific data collection can begin to assess beneficial disturbance to the landscape. The North Dakota Badlands are highly-erodible landforms. Understanding the erosion rates in highly grazed areas will help identify sites that cannot handle as much grazing disturbance.

Suggested Research

To develop a disturbance regime in the prescribed manner, there are several areas the park could investigate. The first is understanding the status of vegetative resources in the unit. Second, collecting productivity data for varying ecosystem types in the park. Ecological site descriptions (ESD) are available for the unit. Interview responses state the ecosystem is so highly variable that ESDs are not the best tool to use in management prescriptions. Site- specific data is necessary especially on an extremely diverse landscape to create disturbance patches. Lack of fire in recent years has also allowed woody encroachment to expand in the park. Intense fire behavior is necessary to combat woody encroachment once individuals have established. Altering season of fire can create more intense fires. Understanding how the landscape at THRO responds to altered fire season would benefit resource managers in establishing a disturbance regime to achieve invasive management objectives.

- Establish cages to determine productivity of the range in various areas of the park
- Impact of grazers on erosion rates of riparian areas
- Highly grazed areas and effects on that landscape pertaining to high grazing pressure
- Invasive species response to season of burn

Management Recommendations

Maintain prairie through coupled disturbance regime

The most significant issue at THRO is invasive species management coupled with the necessary focus of time and money on wildlife species. Better managing the processes that the prairie depends on will benefit both wildlife and native species competitive ability. An important natural process in the THRO landscape is a disturbance regime. Coupling disturbances to create a regime will impose heterogeneity on the already diverse landscape at THRO. These imposed disturbances can be used to target specific areas for invasive species management. There can also be a benefit of burning in different seasons of the year or at different intensities to reduce exotic cover. Recently, a prescribed burn was conducted with the goal of lessening woody encroachment. To do this, fire intensity needs to be high. The fire was 8,000 acres and was much more focused on extent than on intensity of the patch disturbance. A smaller patch of disturbance can then concentrate a secondary disturbance such as grazing. With uniform light grazing, the park is not creating enough heterogeneity for certain wildlife species. Concentrating grazers in a small area post fire creates intensive disturbance for a season. This benefits the landscape by creating patches of disturbance while still maintaining other areas of the unit in mid to late seral stages in case of detrimental weather conditions.

Appendix E. Wind Cave National Park

Current Grassland Management Goals and Programs

Grassland Management Goals

Diverse ecosystems Wind Cave National Park (WICA) is set within the eastern slope of the Black Hills region of South Dakota. Because of this, it has an array of ecosystems ranging from montane woodlands to open grasslands. It is also unique in that it has a teeming ecosystem underground within the cave that the unit is known for. This variety in ecosystems and processes requires a diverse set of management goals. The Foundation Statement voices the desire to maintain wildlife populations with the acknowledgment of maintaining natural plant communities.

Water Another management goal is groundwater. Pressures from outside the park are impacting both quality and quantity of groundwater reaching the park. Interviews revealed that park staff expect development and other pressures to increase in the future. Overall, WICA staff desire management to focus on how best to maintain the natural state of the ecosystem.

Grassland Management Programs

Wildlife Management Program Wildlife management includes the most pure herd of bison in the NPS system. Many satellite herds of the WICA herd exist across the MWR. This has spawned the creation of the Bison Leadership Team which is assessing the status of bison and the grazing resources it depends on. Reintroductions at WICA include black footed ferret, bison, elk and pronghorn. Management plans for these species include an aspect of ecosystem effects.

Invasive Species Management Over the last two years, rather than the EPMT visiting Wind Cave, they have managed invasive species with their own budgets and staff. The unit was not approved for use of chemicals until 2011. Without fire and herbicide, invasive species have expanded across the park. The most concerning ive species are Canada thistle, leafy spurge, and horehound. The park has ramped up herbicidal control efforts in recent years for these species.

Management Plans and Data Available

Management Plans

Along with the Zoning Management Plan, there have been several other strategies written from 2008-2018. Although, a vegetation management plan, fire management plan and many wildlife management plans fall outside of the last ten years. Although these directives are in all likelihood still followed, operating on information that is over 10 years out of date is keeping the unit from most skillfully managing the landscape. See Table E.1 for a full list of management documents published from 2008–2018.

According to the foundation document for the park, with a draft document written in 2011, the desired conditions for vegetation are to maintain healthy plant communities and to further research endemic flora. At the time this document was written, 20-25% of the landscape was ponderosa pine ecosystem type and 75-80% was prairie. This showcases the uniqueness of this area as a “mixing zone” of ecosystem components.

Interview responses expressed that these plans are written by species and then integrated to manage ecosystem wide. Ecosystem management goals have not been laid out within the last ten

Table E.1: Management documents for WICA published from 2008-2018

Title	Year
Integrated Pest Management Plan	2010*
Foundation Statement	2011*
Invasive Species Action Plans	2010-2018
Elk Management Plan	2009
Natural Resource Condition Assessment	2011
Long Range Interpretive Plan	2012
Zoning Management Plan	2015

years. A comprehensive management plan with current management plans would benefit WICA. This would make the integration of single resource management plans seamless.

Data Available

WICA has a significant amount of ecosystem data. It is fairly spread among resources as well. Staff at WICA, compared to other parks is fairly specialized giving focus to data collection for different resources at the park. WICA is the only unit with a designated, permanent vegetation specialist on staff.

Table E.2: Selected data collected in WICA, 2008-2018.

Data title	Data type	Spatial extent	Frequency	Duration	Collecting agency	Format located
Develop Forage Production and Allocation Model for WICA	Vegetation	cages across the park and using the park GIS to get the rest of the data other than production	once	2008	University of Missouri-Columbia/ NPS	site network
AUM Range Stocking Rate	Wildlife/ Vegetation	site wide	range assessments each year	2001-2009	NPS/ NRCS	site network
Park rare plant survey/monitoring	vegetation	site wide		2004-2008	NPS	site network
Scotch Thistle locations	Vegetation	sitewide		2000-2008	NPS	site network
Forage Management WICA	Vegetation	sitewide	range assessments each year	2001-2008	NPS	site network
Pronghorn Survey	Wildlife	sitewide	this count was in 2010	2010	NPS	site network
Fuel Sampling History	Vegetation	sitewide	this was an assessment of previous data ahead of the begin of the Fire Effects monitoring through I&M	2011	NGP I&M	site network
Reduce highly invasive white horehound impacting prairie dog/ black-footed ferret habitat	Vegetation/ Wildlife	prairie dog towns across the unit	applications of herbicide in 2009-2011	2009-2012	NPS	site network PMIS
Water Resources of WICA	Water	parkwide	an overview of water resources in the unit	2016	NPS	site network

Table E.2, *continued.*

Title of Data	Type of Data	Spatial Extent	Frequency of Collection	Duration of Collection	Agency Collecting Data	Format Located
Example of Herbicide application data sheets	Vegetation	specific sites within the park	each application	2016	NPS	on site
Bison, Pronghorn and Butterfly Survey	Wildlife	parkwide	once	2015-2017	NPS	on site
Habitat restoration guidelines for highly disturbed natural areas (prairie dog towns) following invasive weed eradication	Vegetation	prairie dog towns across the unit		2009	NPS	on site
Determine strategies for efficient early detection of invasive plants after prescribed fire	Vegetation	215 plots site wide	once each year (pre-burn and post-burn)	2010-2012	USGS, NGPFire	on site
Monitoring of Sharp-tailed Grouse Leks in WICA	Wildlife	parkwide	once in spring	1999-2011	NPS	on site
Monitoring Bird Populations in WICA using point counts and autonomous recording units	Wildlife	parkwide	once	May-July 2008	Rocky Mountain Bird Observatory	on site
WICA Nightjar Survey	Wildlife	parkwide	2 survey routes per year	2009-2017	NPS	on site
WICA precipitation	Weather	parkwide	average each month	1983-2017	NPS	site network
Bison Population Numbers	Wildlife	parkwide	yearly numbers	1996-current	NPS	site network
Vegetation Projections for WICA with Three Future Climate Scenarios	Vegetation	parkwide	modeled using already collected data	2013	Oregon State University/ USGS	site network

Table E.2, *continued.*

Title of Data	Type of Data	Spatial Extent	Frequency of Collection	Duration of Collection	Agency Collecting Data	Format Located
Vegetative Reproduction and Bud Bank Dynamicsof the Perennial Grass Andropogon gerardii in Mixedgrass and Tallgrass Prairie	Vegetation	parkwide	once	2010 compared to previously collected data in 2008	Kansas State University	site network
What role does prescribed fire play in managing annual bromes in northern Great Plains grasslands?	Vegetation	inside edges of Headquarters east burn unit/ inside edges of Bison Flats burn unit			USGS/NPS	on site
An Adaptive Management Framework to Control Cheatgrass in Norhtern Great Plains Parks	Vegetation	parks throughout the MWR			NPS	PMIS
Vegetation Baseline for Casey Addition in WICA	Vegetation	new addition to WICA			NPS	PMIS

Disturbance Regime

Grazing

Livestock grazing was common in the area before establishment of WICA in 1903. In 1913, management began of a bison herd. The bison management plan, written in 2006, discusses the cultural and genetic importance of the herd while also acknowledging effective use of the range. The focus of bison management lies on maintaining a viable genetic population. The park maintains a herd of near 400 animals using over 28,000 acres of mixed grass prairie and Ponderosa pine forest. Bison at WICA are free to move about the entire park. The herd at WICA had consistently lower body weights compared to other parks. This could be attributed to poor forage quality within the unit or herd changes due to lack of predators or climate change (Licht, 2016). Elk, mule deer and pronghorn also contribute to the grazing disturbance at the park.

Fire

Wind Cave National Park was the first MWR unit to reinstate prescribed fire in 1973 following decades of complete suppression (Wienk et al., 2011). The largest threats to WICA are fuel loads throughout the park (Interviews, 2018). Fire has not occurred as frequently as it could and is highly susceptible to a stand replacing fire. In the last ten years there have been ten prescribed fires with some years seeing no fire. Minimal use of fire has created a mosaic on the landscape (Fig. E.1a). The zone management plan treats different areas of the unit in different ways, either letting them burn or extinguish immediately.

Data gaps and suggested research

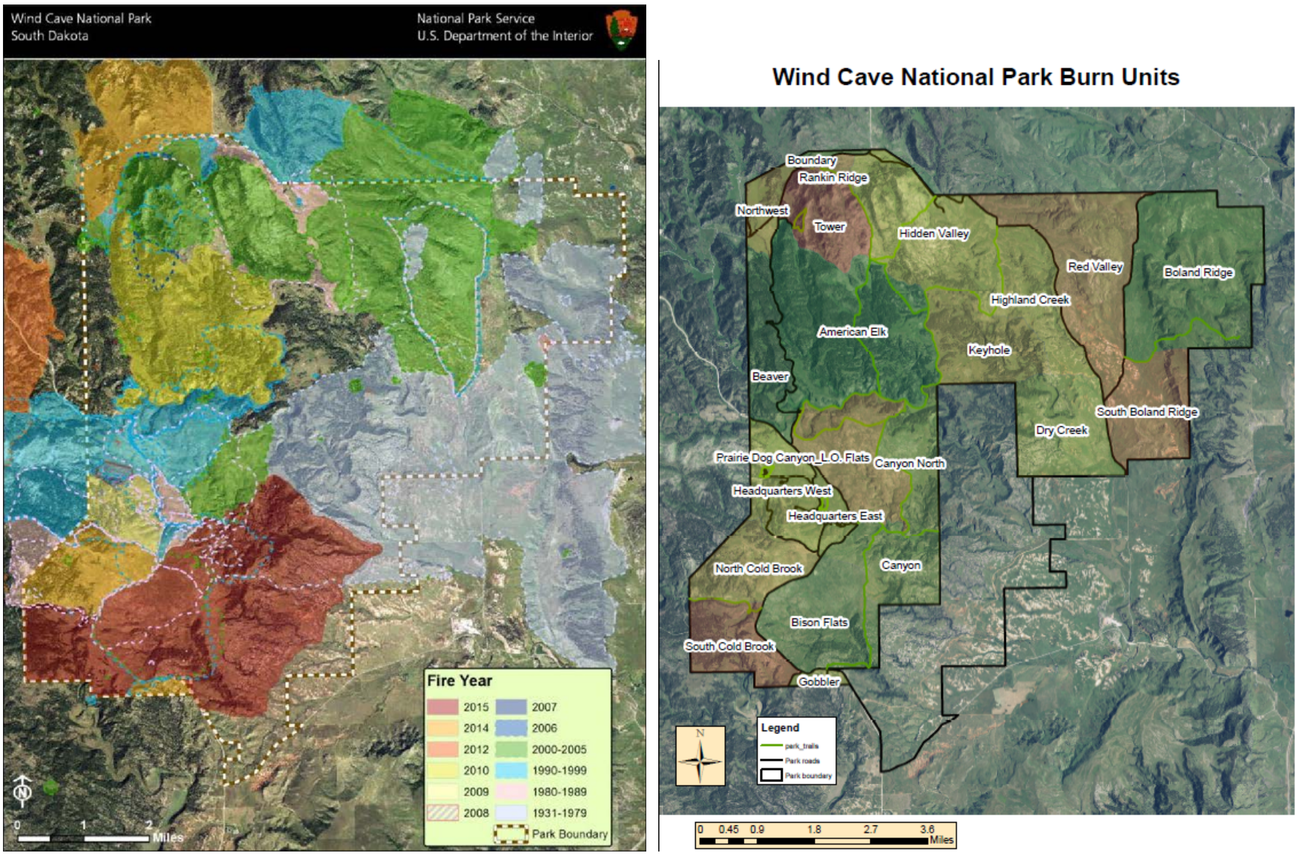
Data Gaps

WICA data is substantial in comparison to other units in this study. It covers many resources and will aid in the development of a coupled disturbance regime. Understanding the status of resources in the park is the first step in planning. The effect of disturbance on resources is the next. Diversity of fuels is an issue at the park. Beneficial data would be understanding how different ecosystems within the park respond to varied fire season and varied intensity. The inherent heterogeneity of the WICA landscape is critical to its character. Imposed disturbance will be critical in maintaining inherent heterogeneity. For example, in the last year, a stand replacing fire occurred in the ponderosa pine ecotone. Diverse fire behavior can have desired effects on the landscape to remove dangerous fuel loading.

Bison movement in response to fire is also missing. On a fenceless landscape, bison are free to graze in whatever area they choose. Bison GPS collars are currently used in BADL, THRO, and WICA. Combining this with fire data could determine if fire is a beneficial attractant to bison to move them or disperse them to desired areas of the landscape naturally. Finally, a vegetation management plan with specific vegetation goals would aid in the development of a disturbance regime.

Suggested Research

There is historical data of exclosure locations in WICA. This makes the possibility of collecting exclosure clippings to determine vegetation productivity replicable. Aligning exclosure locations with burn unit locations is beneficial. A park that protects such vastly different ecosystems requires a heightened sense of site-specific data. Productivity data will aid in developing a coupled disturbance regime. This is needed to determine the amount of disturbance the landscape would benefit from. The diversity of ecosystems in WICA would benefit from the following studies:



(a) Mosaic created by prescribed fires.

(b) Burn units.

Figure E.1: Prescribed fire maps for WICA (Aston & Davis, 2016).

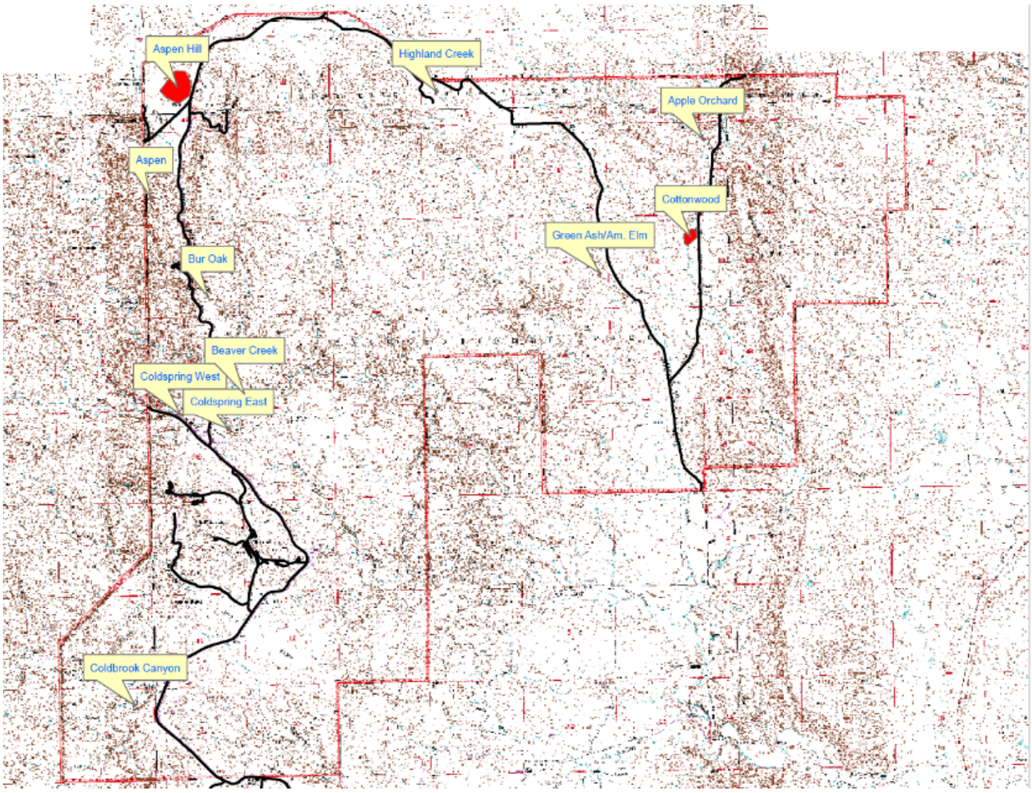


Figure E.2: Past exclosure locations within WICA

- Season of fire effect on vegetation resources
- Effect of frequent fire on forage quality
- Response of horehound to patchy fires
- Bison movement in response to fire
- Erosion rates in relation to bison occupation

Management Recommendations

Reduce high fuel loads, create disturbance mosaic

WICA manages the landscape to benefit the ecosystem. Management plans are written to specific species, but interviews revealed that the integration of the plans is forefront. Interviews also revealed that the biggest threat to the unit is wildfire. This may be attributed to recent events in the park, but is a definite concern nonetheless. The landscape at WICA requires a varied disturbance regime. One way to achieve this is through pyro diversity. Fire in the mixed-grass prairie should be managed differently than fire in the Ponderosa pine forests. WICA contains a fire prone ecosystem with large fuel loading particularly in the forested regions of the unit. Prescribed fires may not remove all wildfire threat from the landscape but will significantly reduce the likelihood of a stand replacing fire.

Appendix F. Interview prompts

To begin, we would just like to get a little background on you and your management history.

Question	*Probes*
• What is your role with the NPS?	
• How long have you been with the NPS?	• *How long have you been at this unit?*
• How long have you been working in land stewardship?	• *How long in this region?* • *What is your background? (Edu, work)* • *Have you worked with any other land management agencies or organizations?*

The first things that we want to cover are the ecological aspects of this unit. We are wondering your thoughts on the current state and current management of ecological resources in your NPS unit.

Question	*Probes*
• Describe the ecosystem your unit protects…	• *Look to touch on several ecosystem aspects*
• I noticed from various management plans in your park that __________ is an important resource to your unit. How often is this resource considered in decision-making?	• *Is it considered in management outside of NR management?*
• What does disturbance mean to you in the context of ecosystem functioning at your unit?	• *What role do you see it playing in this ecosystem?* • *Do you manage disturbance? How?*
• Do you notice any effects of climate change in your unit?	• *If yes, how?* • *Are you taking any steps to mitigate this?*
• Is there evidence of legacy land use here?	• *If yes, what?* • *If no, do you know the legacy land use?*

We suspect that the social system that the park operates within can hold a lot of power in what is managed for. Due to this, we want to understand the social system that the park operates within.

Question	*Probes*
• Has your unit made major operational changes in the past few years?	• *If yes, what?* • *What was the most recent?* • *What was the impetus for this alteration?* • *What in particular has been done in natural resources?*
• Do you feel able to make mgmt. decisions that you would prefer?	• *If no, what barriers do you encounter? (financial, tools, trainings, etc.)* • *How do you inform these preferences?* • *If yes, where do you receive support?* • *If no, who is dictating mgmt. if not you?*
• Describe your relationship with surrounding landowners…	• *Do you feel that your neighbors generally agree on the importance of management actions within the park unit?* • *How do they show their support/lack of support?* • *Do you think that surrounding land managers look to the NPS for management ideas? Why?*

• What sources do you utilize for seeking out new management information/techniques?	
• How much collaboration/ communication/ coordination is there within unit? Regional parks? Park outside the region? Other agencies? I&M?	• *What do each of these mean to you?* • *Would you like to see this changed in the future?* • *Describe your autonomy vs. dependence.*
• How much flexibility does your park have in making management decisions that your management team has decided on?	• *Do you think this level is common among the Midwest units? Among NPS units in general?*

Finally, we are interested in how the park units are managing for grassland ecosystems as a whole. To help us understand this, we want to know a bit more about the space in which your unit makes decisions. The next few questions will cover this:

Question	*Probes*
• What goals do you feel you are currently achieving? Not achieving?	• *What are the factors that make it more difficult for you to achieve the goals laid out in your plans? (insufficient data, clarity of action, training in/comfort level in applying recommended action)* • *How do you reconcile management priorities under limited allocation of funds?*
• Suppose your unit had an unlimited budget. What would be at the top of the list for management?	• *What would be managed for that is not currently?*
• What are some significant challenges you face in ecosystem management within your unit?	• *How are you actively addressing these challenges?* • *What do you see as the biggest barriers to achieving holistic ecosystem management?*
• How does your unit define success or failure of management efforts?	• *How were these criteria selected?* • *Who is in charge of monitoring?* • *What sorts of data do you rely on to assess environmental conditions within your unit?*
• How much adaptation occurs if ecological objectives are not being achieved?	
Overall, what are the largest threats to this NPS unit?	

Thank you so much for your help in answering these questions. We are finished with the interview, but I wonder…

- Have your views on land management changed since beginning your current position?
- Do you feel like there is anything else that is important to management and decision-making within your unit that we have not touched upon?
- Do you have any other questions for me?

Appendix G. Online survey

1. **What Park Service unit are you stationed in?**
Mark only one oval.
   - ◯ Agate Fossil Beds National Monument
   - ◯ Badlands National Park
   - ◯ Tallgrass Prairie National Preserve
   - ◯ Theodore Roosevelt National Park
   - ◯ Wind Cave National Park
   - ◯ Other: ____________

2. **What is your role with the Park Service?**
Mark only one oval.
   - ◯ Superintendent
   - ◯ Division Chief
   - ◯ Natural Resources Staff
   - ◯ Interpretation Staff
   - ◯ Maintenance Staff
   - ◯ Other: ____________

3. **Please state how long you have worked for the National Park Service:**

   ____

4. **Please state how long you have worked at your current Park Service unit:**

   ____

Ecosystem Management

Please identify the extent to which you agree or disagree with the following statements about natural resources in your Park Service unit.

5. **Long-term goals for wildlife management are clearly defined at my Park Service unit.**
Mark only one oval.
   - ◯ Strongly Disagree
   - ◯ Disagree
   - ◯ Neutral
   - ◯ Agree
   - ◯ Strongly Agree
   - ◯ I do not have enough information to say.

6. **Short-term goals for wildlife management are clearly defined at my Park Service unit.**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree
- I do not have enough information to say.

7. **Long-term goals for vegetation management are clearly defined at my Park Service unit.**
Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree
- I do not have enough information to say.

8. **Short-term goals for vegetation management are clearly defined at my Park Service unit.**
Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree
- I do not have enough information to say.

9. **The following impacts affect natural resource planning at my Park Service unit**
Mark only one oval per row.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Expansion of invasive species					
Establishment of new invasive species populations					
Seasonal weather variability (precipitation, freeze-thaw dates, minimum and maximum temperatures)					
Long-term regional shifts of weather patterns					
Fragmentation/ Development					
Pollution					
Loss of top predators					
Surrounding land management practices					
Previous land use					

10. **I believe we understand what drives our ecosystem at short-term scales**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree
- I do not have enough information to say

11. **I believe we understand what drives our ecosystem at long-term scales**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree
- I do not have enough information to say

12. **I believe our management is responsive to changes that occur at (check all that apply):**
Check all that apply.

- Short- term time scales
- Long- term time scales
- Neither

13. **Identify whether you believe it is appropriate for any of the following management practices to be used in your Park Service unit.**
Mark only one oval per row.

	Appropriate	Not Appropriate
Grazing with domestic livestock		
Grazing with native herbivores		
Prescribed fire		
Herbicidal control of undesired vegetation		
Mechanical control of undesired vegetation		
Native vegetation restoration		
Native wildlife population reductions		

14. **If you feel inclined, you may type more here:**

For the following table please check all that apply.

Please check all that apply. When considering your answer reflect on the terms "sufficient" and "adequate" within the context of monitoring and adaptive management not necessarily a perfect understanding of the issue.

15. *Check all that apply.*

	There is sufficient data to make management decisions	Clear objectives have been adequately defined	We have sufficient knowledge of how targeted resources will respond	We have sufficient knowledge of broader ecosystem responses	Adequate resources (funding, staff) to apply
Grazing with domestic livestock					
Grazing with native herbivores					
Prescribed fire					
Herbicidal control of undesired vegetation					
Mechanical control of undesired vegetation					
Native vegetation restoration					
Native wildlife population reductions					

16. **If you feel inclined, you may type more here:**

17. **The focus of natural resources management at my Park Service unit reflects the needs of the entire ecosystem.**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

18. **My Park Service unit is equipped to manage dynamic ecosystem processes.**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

19. **Ecological Site Descriptions are a useful tool for management of natural resources at my Park Service unit.**
Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree
- I am not familiar with Ecological Site Descriptions

20. **I have the data to make management decisions based on the outcomes of last year's management actions.**
Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree
- I do not have enough information to say

21. **There is sufficient data at my Park Service unit to make sound management decisions in terms of (check all that apply):**
Check all that apply.

- [ ] Wildlife
- [ ] Vegetation
- [ ] Air Quality
- [ ] Water Resources
- [ ] Geology
- [ ] Cultural Resources
- [ ] Fire Effects
- [ ] Invasive Species Management

22. **My Park Service unit manages for conservation in terms of (if you feel neither is an appropriate answer, select "other" and please explain.)**
Mark only one oval.

- Species Perspective (Emphasis on populations of plant and animal species)
- Systems Perspective (Emphasis on ecosystem function and resilience)
- Other: ____________________

Ecosystem Resilience

For the following questions, please provide your best estimate of the resilience of the following categories of resources at your park (i.e., an ecosystem's ability to maintain key processes and functions in the face of natural or anthropogenic disturbance)

23. **Please rate the resilience of the following resources from 1 (Very Low) to 5 (Very High)**
Mark only one oval per row.

	1	2	3	4	5
Vegetative Resources					
Wildlife Resources					
Water Resources					
Geologic Resources					
Air Quality					
Cultural Resources					

Open Ended Responses on Resource Management

Please give a short description in response to the following prompts. These questions are not required.

24. **In what way do invasive plant species most impact your park?**

25. **What is the current focus or "flavor of the day" of the National Park Service?**

Management within the Social System

Please identify the extent to which you agree or disagree with the following statements about social dimensions that may affect management within your Park Service unit.

26. **Surrounding landowners are considered when making ecosystem management decisions at my Park Service unit.**
Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

27. **My park service unit maintains partnerships with:**
Check all that apply.

- [ ] Other federal agencies (BLM, USFS, USFWS, etc.)
- [ ] State agencies
- [ ] Non- Profit Organizations
- [ ] Interest Groups
- [ ] Surrounding Landowners

28. **These partnerships make positive contributions towards the stated goals of my Park Service unit.**
Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

29. **Our partnerships with outside agencies determine how resources (staff, budget, etc.) are allocated in natural resource management.**
Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree
- We do not have partnerships.

30. **Leadership at my unit collaborates when writing management plans**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

31. **Divisions at my Park Service unit share feedback (data, opinions, observations, etc.) on outcomes of other divisions' operational actions.**
Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

32. **My Park Service unit is equipped to deal with increased visitor use.**
Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

33. **In what way does visitor experience affect natural resource management?**

34. **For the following grid, please respond to the availability and utility of management plans for your Park Service unit.**
Check all that apply.

	My park has this document	My park uses this document in management planning	This document reflects current management priorities
General Management Plan	☐	☐	☐
Foundation Document	☐	☐	☐
Fire Management Plan	☐	☐	☐
Wildlife Management Plans	☐	☐	☐
Vegetation Management Plan	☐	☐	☐
Resource Management Plan	☐	☐	☐
Resource Stewardship Strategy	☐	☐	☐
Exotic Plant Management Plan	☐	☐	☐

35. **If you feel inclined, you may type more here:**

36. **Midwest Region goals align well with on-the-ground management needs.**
Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

37. **Which best describes your Park Service unit's definition of "natural"?**
Mark only one oval.

- Pristine and uninfluenced by humans
- Freedom from intentional human control/management
- True to the pre-European settlement condition of the ecosystem
- Other: