CESU Grassland Management

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Review of Project Objectives

Primary project goals:

1. Identify multi- species management goals and ecological objectives for each 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 which may be barriers to managing for resilient grassland ecosystems and prioritize research needs to address high priority data gaps

Each unit of the National Park Service is responsible to, “conserve the scenery and the natural and historic objects and the wild life 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. The five NPS units in this study, 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), differ 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.

Introduction and Background

The goal of this report is to communicate strategies for increasing grassland resilience. Two ways to achieve this are to (1) focus on ecosystem processes, and (2) maintain native disturbance regimes. The rationale for these management needs is given in this report. We will communicate the importance of these two foci and give evidence of the NPS units’ lack of information or plans to work towards these management goals.

The idea that dynamic ecosystems are imperative to grassland resilience is one of the most important scientific acknowledgments in recent history (Thomas 1996). Current management practices on grasslands in Midwest Region NPS units follow a very species specific approach. Unit expert statements and management plans typically focus on single species and how they are affected by the ecosystem. A systems perspective focuses on interactions and ecosystem function rather than emphasizing vigor of individual species.

Vegetation and wildlife management are species focused. In particular, invasive species management depends on the specific invasive species units must manage (Bestelmeyer & Briske 2012). Four units in the Midwest region have bison with plans for a future Wind Cave satellite herd at AGFO. All units contain some kind of native grazer, either a managed herd, such as bison or cattle, or migratory herds, such as pronghorn.

Resilient ecosystems require a departure from species perspectives management, a very common practice in 20th century park planning (Lebel *et al.* 2006). Enhancing ecosystem resilience requires focusing on system level processes, and less of a focus on requiring certain species to be present. Diversity of pressures on protected lands is increasing. Ecosystems must be able to receive threats and bounce back continuing to produce their characteristic ecosystem services (i.e., carbon sequestration, wildlife habitat, erosion control, viewscapes, etc.) Recommendations included at the conclusion of this report will communicate how specific management practices will maintain ecosystem services via Great Plains grassland resilience.

Review of the Literature on Grassland Management

Current Issues. In grasslands across the Midwest there are many issues that warrant attention. Chief among these is fire suppression. The major issue is the removal of a key disturbance and the alteration of the native disturbance regime in the area. One result of this is a buildup of fuels, allowing plant species to reach late successional stages. Woody encroachment will alter grassland ecosystems and the wildlife that depends on grassland ecosystems (Fuhlendorf *et al.* 2012). Native plants are adapted to the native fire regime and perform well under cycles of burning. Suppression has also removed burned areas as a means to move animals across a landscape. Grazers must be fenced in to keep them in the desired grazing space. These fences have partitioned off areas of the landscape, inhibiting wildlife movement and adding fence maintenance costs to already strapped NPS unit budgets.

Historic Regimes. Most issues and resulting recommendations addressed in this report will center on the idea of historic disturbance regimes. This means that the issue we are addressing is the removal or suppression of historic disturbance regimes and will communicate management actions striving to restore or mimic, as best as possible, historic regimes. Grasslands are ecologically adapted to thrive under disturbance Samson *et al.* 2004. The species and processes that make up grasslands need disturbance to flourish. For example, several species of plants require the clearing effect of fire in order to continue their life cycle. Also, some prairie obligate species have adapted to different stages of their life cycles in varied seral stage of plants (Ricketts & Sandercock 2016). Looking to the past and how the grassland has functioned for centuries is an indicator for what the protected ecosystem needs going forward.

Importance of Disturbance in Grasslands

Grazing as a Disturbance Grazing.

Stomping. The presence of grazers on the landscape is also beneficial for the large impact that their weighty bodies make on the landscape. Grazers physically and chemically disturb the landscape through wallowing, walking, and defecating (Allred *et al.* 2011). Without this physical impact, micro heterogeneity is absent which is another key piece of grassland ecosystem vitality for diminutive wildlife species (Fuhlendorf *et al.* 2017). Stomping can also disproportionately affect non-native vegetation species. As grazing is a native disturbance to grasslands, native species have adapted to this pressure/ disturbance. Less hardy species may be minimized by intense grazing pressure (i.e. Yellow Flag Iris (Spaak 2016). On top of the removal of grassland species through grazing, the impact that large grazers physically have on the landscape can give a competitive advantage to native species of wildlife and vegetation.

Fire as a Disturbance Fuels Reduction. In the 20th century, fire suppression was the norm across 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. Instilling fire as a consistent process on NPS landscapes will remove dangerous fuel loading. Consistently burning patches year to year will allow fuels to build up so that prescribed fires can continue to be carried, but decades will not pass allowing fuels to build to dangerous and difficult to remove late seral stages of grassland.

Native Species Competition. Native prairie species have evolved along with disturbance. They have many adaptations (emergence, root structure, seed banks, etc.) which allow them to respond to these disturbances in a positive way (Hobbs & Huenneke 1992; Lawes *et al.* 2013; Midgley *et al.* 2016; Russell *et al.* 2015). Exotic species may not fare as well or in as predictable a manner as the prairie natives. Altered seasons of burning can be used to target when invasive species are at a critical juncture in their life cycle in order to burn the individuals making it less likely they will successfully complete their life cycle (McGranahan *et al.* 2012, 2013).

Woody encroachment also competes with native species for landscape resources. When grasslands are subject to woody encroachment, water and sunlight are claimed by larger woody species (Twidwell *et al.* 2013). This does not allow critical grasses the means to flourish meaning less forage for grazers. This also creates a domino effect in that as grasses are less vigorous, it allows openings for woody species to germinate and establish. Also, grazers are naturally drawn to grasses and if there is less grass productivity due to the beginning of woody encroachment, the grasses that are present will be subject to higher grazing pressure making them less vigorous to compete (Briggs *et al.* 2005). Fire is necessary in order to stave off the invasion of woody species into a functioning grassland or else a conversion of the ecosystem could occur.

Importance of Heterogeneity in Grasslands

We must see fire and grazing as critical to ecosystem processes rather than just management tools used whenever time and money allow (Fuhlendorf *et al.* 2012). The past century has commonly used the ecosystem management idea of "command-and-control". This stressed the need for managers to alter the landscape to the point where it was predictable to humans (Holling & Meffe 1996). In more recent history, scientists have recognized that variability is essential to ecosystem processes (Larkin *et al.* 2016; Turner 1989; Wiens 1997) This variety which includes physical characteristics of the landscape can be referred to as heterogeneity of an ecosystem. It is also important to instill a "shifting mosaic" so that ecosystem processes change over time and are not consistently in one space (Fuhlendorf & Engle 2004). Creating coupled disturbance regimes of fire and grazing begets diversity which begets resilience of a grassland ecosystem.

Diversity of Habitat. Wildlife in the Great Plains has adapted to variability in the landscape. Some of the more imperiled species in this region have come to this status due to alterations in their habitat. An example of this is the greater prairie chicken (GPC). The GPC, like many prairie obligate species, requires multiple successional states to successfully reproduce (Svedarsky *et al.* 2003). Early succession stage patches for mating and late succession stage patches for nesting. Homogeneous landscapes do not satisfy one of these preferred stages thus making it more likely the prairie chicken will not successfully reproduce. This is just one example, but there are a diversity of grassland birds that have proven to benefit from habitat heterogeneity (Churchwell *et al.* 2008; Coppedge *et al.* 2008; Hovick *et al.* 2014; Stroppel 2009). Benefits include an increase in species richness and density.

Forage Quantity and Quantity. Heterogeneity begets variation in grassland successional stage. When dealing with a highly variable climate, as is typical across the Great Plains region, having a variety of grass stands may be the difference in the future health of your grassland (McGranahan *et al.* 2014). By introducing a heterogeneous landscape, patches are created of vegetation that are in different stages of their development. Not only is this beneficial for habitat, but it also benefits herbivores' diet. Patches increase the resilience of the landscape to a variety of stressors which may impact forage production (Fuhlendorf *et al.* 2017). This could be anything from drought, to development, to unplanned fires. All of these have the ability to create a stand replacing disturbance, leaving grazers in your protected area no options for sustenance. These situations can be insured against with a patchy landscape.

On top of the availability of forage generally, it has also been proven that the combination of fire and grazing has the ability to increase the level of nitrogen availability (Anderson *et al.* 2006). This study proved that the coupled disturbance regime is even more beneficial in terms of nitrogen availability than simply using fire alone to create disturbance of a grassland.

Resilience. The inherent nature of heterogeneity means that a landscape demonstrating this would be more able to adapt to variable conditions either on a seasonal basis or over several years. For example, if a year of drought hits, the current year new growth may not fare well enough to support a grazing herd of bison. A patch of grass that has not been burned may be designated as a forage bank for this particular reason (McGranahan *et al.* 2013). Another aspect of resilience comes in the form of wildlife presence due to patchiness of habitat available. When there are many different habitat types available for species, it encourages the presence of a diverse population (Moranz *et al.* 2012; Ricketts & Sandercock 2016). The more diverse a population of wildlife or vegetation is, the more resilient an ecosystem can be in continuing to provide a variety of ecosystem services (Peterson *et al.* 1998; Walker & Salt 2012). This is especially important in the face of a barrage of pressures in the future.

Unit Specific Priorities and Constraints

"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 values" (Cole & Yung 2012). For this reason, although we can look to the scientific literature for ways to better increase the functioning of grassland ecosystems, all the suggestions may not take. This is why we also answered the call of this project by talking with managers at the units to best understand what priorities they have in management. The enabling legislation of units guides the focus of management, budget and staffing needs for park units throughout the country. There are also external and internal pressures which guide what tasks are preferred. Supporting our recommendations with social characteristics of the units will better enable the best scientific suggestions to be implemented within a diverse cross section of park service units.

In this study we used qualitative and quantitative methods to achieve the outlined goals. By using both of these methodologies, we could better build and understanding of management in the units and both what data is physically not present and what the managers feel needs to be more of a focus in management. Results are communicated by way of data audits, interviews, and surveys. This gives strength to our results presented and makes our recommendations extremely relevant to the NPS units for whom this study was undertaken.

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. 1):

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 certain topics in each interview while allowing managers to discuss what they are passionate about (Creswell 2003; Montello & Sutton 2012). Items in the interview guide can be seen in Appendix F. Interview questions were developed by using an established framework (Fig. 2) created under previous social-ecological

Figure 1: Geographic location of NPS units included in this study.

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, 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

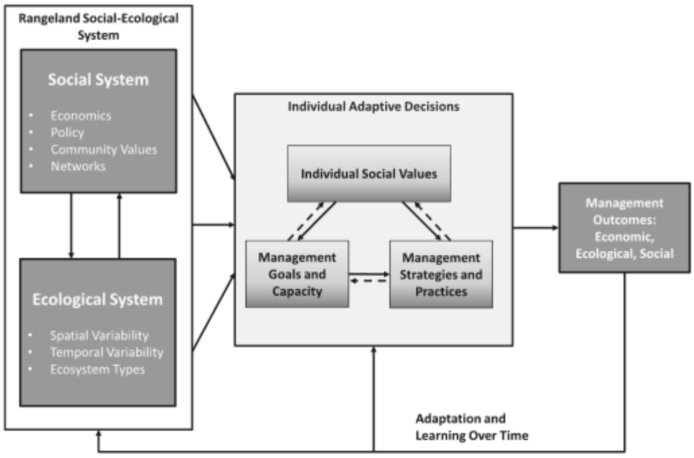

Figure 2: Adaptive management decision-making framework from Lubell *et al.* (2013).

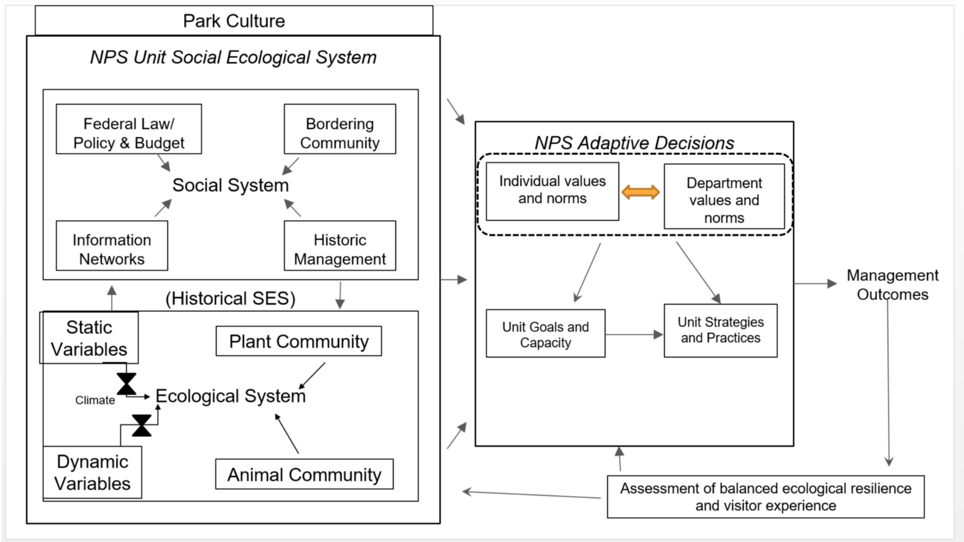

Figure 3: An NPS-specific framework for adaptive management modified from the adaptive rangeland management decision-making framework by Lubell *et al.* (2013, see fig. 2).

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 in Google Forms and questions can be seen in Appendix G. The NDSU research team analyzed responses collectively to give support to 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. Researchers looked through publicly available data and management plans housed within IRMA. They also 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. A search of file cabinets yielded paper copies of management plans, data files, and research studies conducted in the park. A researcher 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. Organization of files occurred once back at NDSU.

Finally, the data audit was completed with a literature review where we looked 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 site specific appendices following this report.

Results

If you're going to make adaptive management decision in terms of our perspective (interactive disturbance regime ecosystem) these are data that will support these adaptive management decisions.

Identification of Current Multi-Species Management Goals and Ecological Objectives

Bison management

Invasive species management

Native ecosystems

Bison Management

Of particular importance at these NPS units is bison management. Four out of the five units currently have bison on site (BADL, TAPR, THRO, and WICA) and three out of four currently have a management plan written for bison (BADL, TAPR, and WICA). When looking at these management plans, the overall goal is the genetic viability of the herd. Ecologically, in the BADL bison management plan, vegetation is considered, but effects on other wildlife are not.

Invasive Species Management

In terms of vegetation, invasive species management is the top concern. For example, in a vegetation management strategy written for THRO, invasive species management is thoroughly discussed rather than enhancing the vigor of native populations.

Native Ecosystems

Our interview guide asked managers what their goals were for the ecosystem they protect. Typically, this goal included some aspect of maintaining a natural ecosystem. The particulars of how this could be achieved were not explicit. The feeling that we have is that there needs to be a higher level of consistency in getting fire on the landscape. Figure 5 displays the fires history of the five units in this study. One thing to note is although Tallgrass has many more fires per year, which is a construct of the type of ecosystem that TAPR protects. The fire return interval in this area of the country is much shorter and makes fire a much more frequent disturbance than at the other units in this study. Accordingly, TAPR has more consistent fires compare to other units.

Figure 4: Prescribed fires in Midwest region NPS units 2008–2017.

In further detail, THRO had no prescribed fire occurrence from 2012–2017. The fire history in THRO was rich until 2012, but 2018 saw a large fire in pursuit of impacting juniper encroachment. BADL has also had an inconsistent fire occurrence with no fires occurring from 2013–2015. Interviews revealed that this had to do somewhat with budget and staffing concerns. WICA and AGFO have also had periods of no fire which did not create any areas of patch contrast.

Recommended Management Changes

Establish coupled disturbance regimes

Manage for ecosystem processes

Establish Coupled Disturbance Regime

In order to achieve heterogeneity we suggest coupling ecosystem disturbances. In particular it has been proven to be beneficial in that past to couple fire and grazing into a disturbance regime.

A technique that has had success in this region is a process called patch burn grazing. Through patch burn grazing, pastures are created with contrasting ecosystem characteristics. Each year, one pasture is burned and this contrast benefits wildlife, grazers, vegetation, etc. The following year, the areas that were burned grow back with nutritive new growth benefiting herbivores.

An example of a successful program coupling disturbances is occurring at TAPR. In 2006, they established a technique called patch burn grazing in one pasture at their unit. Patch burn grazing techniques require annual burns on different patches of the designated area (Fuhlendorf *et al.* 2009; Scasta *et al.* 2016; Toombs *et al.* 2010). As seen in Fig. 5, the pasture has been split into three patches which are burned on an annual schedule. By burning on this schedule, there are heterogeneous patches benefiting native grazers and other wildlife as well as the vegetation structure of the preserve. As this is already occurring on an NPS unit, it makes it more plausible to instill a coupled disturbance regime on other units across the Midwest region. This disturbance regime has benefitted TAPR in many ways and I&M monitoring data has showed... (Leis & Morrison 2018).

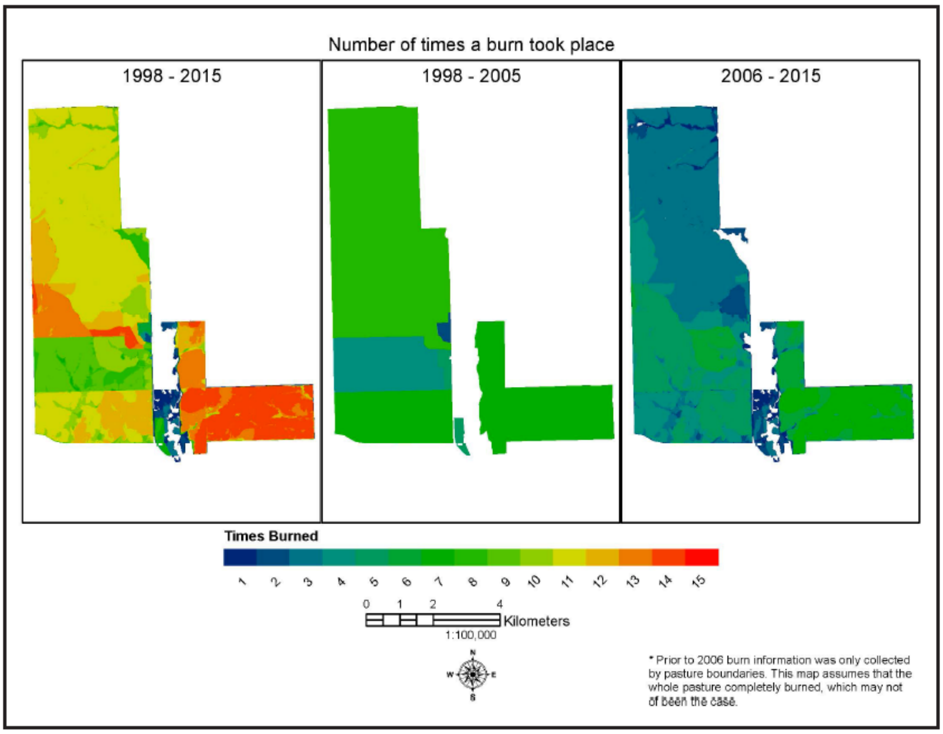

Figure 5: Depiction of burn schedule in the Big Pasture Patch Burn Grazing system at TAPR.

Patch-burn grazing research has typically occurred in southern grasslands and wetter climates. Lots of data has come out of the Konza Prairie Research Center in Kansas ((Powell & Stouffer 2006) and the Tallgrass Prairie Preserve in Oklahoma (Fuhlendorf *et al.* 2009). Positive effects on grassland ecosystems have been the norm in these studies. There have also been less numerous, but just as impactful, studies conducted in northern Great Plains displaying the positive aspects of patch burn grazing and specifically studying how the practice does not impact the drier landscapes via erosion, soil water content and soil temperature (Vermeire *et al.* 2005).

Research has also focused on the use of livestock in a patch burn grazing system (Fuhlendorf & Engle 2001; Scasta *et al.* 2016; Toombs *et al.* 2010; Vermeire *et al.* 2004). The effects of fire and the interaction with livestock grazing has been studied and shown to increase productivity in forage and thus the vigor of cattle grazing within this system. Another studied aspect is seasonality with little effect difference on the cattle using the landscape (Vermeire *et al.* 2004). This means that season of fire can be adjusted in terms of other management goals with no negative effects on herbivores.

Manage for System Processes

Overall, units need to focus on the enhancement of ecological resilience. The ideal way to naturally enhance ecological resilience is to increase the level of heterogeneity within on the landscape. Heterogeneity creates diversity which is important to encourage diversity of resources. Diverse allows the ecosystem to respond to a variety of negative pressures.

Key Uncertainties and Data Gaps

Vegetation management plans

Forage productivity data

Vegetation Management Plans

A common issue communicated by management staff was they feel they do not have written plans to manage for vegetation within their units. A definite focus of the NPS is wildlife as this is the charismatic entity that most visitors can connect with. At many units within this study, there are several plans in place for the mammalian species within their management boundaries (bison, bighorn sheep, prairie dogs, black footed ferrets, etc.) There is data on vegetative communities collected both by the units themselves and I&M surveyors, but, without management plans, there are no short-term or long-term specific goals to use these data to achieve. For example, species specific plans give numbers of animals or seral states to achieve through stocking rate, but vegetation is a more difficult resource to establish thresholds based on its dynamic nature especially in consideration of natural disturbances in a grassland ecosystem. The future of management could be defined by the creation of an ecosystem plan rather than a continuance of resource specific plans. This could be the beginning of a new way of managing an ecosystem for all its parts rather than defining goals by one resource at a time. Vegetation sampling appears to currently be the charge of the Northern Great Plains Network Inventory and Monitoring Program. An established monitoring protocol exists and is used at plots which were created across the units (Symstad et al. 2012). A depiction of the sampling plots is shown in Fig. 6.

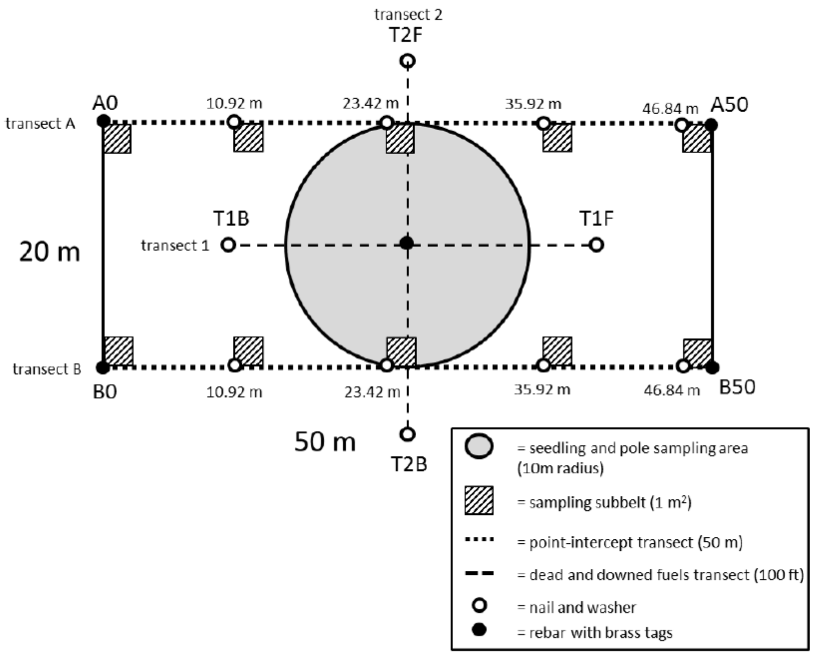

Figure 6: NGPN Plant Community Composition Monitoring Protocol

Forage Productivity Data

In order to create a coupled disturbance regime, the piece of data we believe is most needed is plant productivity data of the vegetative community. Knowing how productive the protected landscape is each year allows you to better understand what type of disturbance regime will most positively impact your ecosystem. Factors of disturbance that would be influenced by plant productivity data could include: stocking rate of managed herbivore populations, fire return intervals, spatial extent of both fire and grazing, season of fire, etc.

Vegetation data collected by park units is lacking significantly behind wildlife data on a year-to-year basis. Vegetation data seems to be the focus of inventory and monitoring (I&M) networks across the country. This form of data collection is beneficial, but is also a standardized methodology not suited to alteration for varying unit-specific goals. It is also, as it was designed, monitoring focused. This means that it has no use as evidence of the effect of different management actions. I&M collects species composition, forage cover etc., but not plant productivity data.

Studies that have used plant productivity as a means to determine disturbance rates have typically used NRCS Web Soil Survey data related to ecological site descriptions. Ecological site descriptions can be a very helpful metric, but climate and landscape topography are extremely variable in units within this region. This variety encourages the need for landscape specific data meaning data collected on site in specific locations of the unit. With this site specific data, the most positive disturbance regime is designed.

A unit that has prioritized the need for plant productivity data is BADL. Researchers are collecting data to better understand grazing resources and vegetative health (Symstad & Sargeant 2016). The key piece of this project is they are focusing on the integration of vegetation health and thinking of the vegetation as a grazing resource. This is the beginning of systems thinking and as per our objectives, aligns with our hopes for recommended management changes. We recommend collecting plant productivity data and as this study is already established in the region, similar data collection methods could be transferred to other units in this study.

Data collection methods include aspects of a range assessment. Caged exclosures and the analysis of clipped vegetative material beget information on how productive the landscape is without grazing pressure. This illuminates the amount of forage the landscape can produce and thus helps to determine how much the landscape can provide for grazers. This can also show how much of the landscape can be burned in order to maintain enough forage for the amount of grazers chosen. This is why coupling the two disturbances is important, it is necessary to consider both in order to best benefit the landscape and the broad range of resources that make up and depend on it.

Clipping vegetative material and then weighing this materials for mass productivity is a standard weigh to understand productive capability of a landscape (McNaughton *et al.* 1996). The input of staff to accomplish these data collection methods may be cumbersome to achieve in some instances, so we propose altering the methodology from this study slightly if implementation were to take place across the Midwest region. In the BADL study, they clip and sort the vegetation by species in order to get species composition across the landscape. Although this is beneficial information for forage selection by herbivores, when just looking at plant productivity, the time taken for sorting is unnecessary. Focusing on a species perspective versus a systems perspective, the individual species of vegetation does not matter as much as the overall production capability of the landscape.

Discussion

Conceptual Justification

The research team's recommendations focus on the re-establishment of natural disturbance regimes. This entails an active management program in which disturbances, such as fire and grazing, are used to create diverse patches on the landscape.

There must be diversity in areas of disturbance, but there must also be diversity in those areas from year to year. By creating a mosaic on the landscape of different patches, the ecosystem as a whole will be better adapted to evolve, change, and grow with varying threats to the Great Plains. As described above, patch burn grazing is one way to create heterogeneity. Burning different areas each year creates burned and unburned areas which offer diverse benefits to the ecosystem. Newly burned areas are beneficial for forage quality and wildlife habitat. Unburned areas maintain grass availability in case of drought.

Management techniques to achieve heterogeneity are briefly discussed in both fire management plans and native grazer management plans in some units.

Key Uncertainties and Data Gaps

According to Driscoll et al, there are three areas of required knowledge when looking at ecologically sustainable management and in particular in terms of fire management which is a key management practice of grassland ecosystem management (Driscoll *et al.* 2010). The three areas that must be looked into are:

1. Species response to fire regimes
2. Knowledge of how spatial and temporal characteristics of a fire affect biota
3. How fire regimes interact with other ecological processes

According to a manager survey, most parks in the Great Plains are managed from a species perspective. For this reason, there is lots of data collected both at most unit levels as well as at a region level within the units. The first point made by Driscoll is to better understand the system by considering all species and their response to a disturbance. This is incorporating each species into a larger framework of management.

Species response to fire regimes. Things that should be looked at are species dependence on specific habitat resources, spatial distribution of fire and how this influences the availability of limiting resources, development of functional groups (also plays into resilience of a SYSTEM vs resilience of a SPECIES), thresholds of fire behavior, and testing of the predictions. Particularly in the face of maintaining ecosystem resilience with changing climactic factors in the region, it will be important to understand how different species respond to fire regimes across their range. It is also very important to understand how fire regimes affect the establishment and spatial arrangement of different species. One example of this is understanding how invasive species emerge and establish post fire and if spatial variability of fire can influence this cycle to minimize the establishment of new populations of invasive species.

Knowledge of spatial and temporal effects of fire. There are three key pieces to define when establishing a patch burn grazing system on a landscape. These include: the stocking rate, the fire return interval and the season of burning. This is where further research on the beneficial nature of a variety of different combinations would be beneficial. Shorter fire return intervals are beneficial for wetter areas while longer fire return intervals benefit drier climates. The importance of site specific data cannot be overstated. There have been few studies conducted in the northern Great Plains but those that have been conducted have been beneficial in showing that fire does not negatively impact this ecosystem (Vermeire *et al.* 2011). The fact that this study displayed the importance of fire, this supports the recommendation of providing resources to reinvigorate this disturbance regime.

Interaction of fire regimes and other processes. Fire is overall, the most intense form of disturbance on grasslands and also the piece that needs the most direct and constant management while it is affecting the landscape. Once the season of fire, the spatial extent of fire and the intensity of fire is determined for the most positive effects on the landscape in question, then you can begin to add to this disturbance to exacerbate benefits to the ecosystem. We advise looking at how grazing processes interact with fire. This takes an understanding of how large your patch sizes created by fire will be and then how many animals those patches can stand. Based on how many animals your landscape contains may also cause you to revise the fire regime you have established. The interaction will take constant adjustment to create a regime to achieve unit specific goals. Unit specific data and research studies to determine the capacity of your landscape for disturbance will be intensive at the outset, but once initial data has been collected to establish a regime, the natural processes should carry out ecosystem functioning and eventually require less constant human control.

Looking at both sides of interactions, the disturbance regime affects the landscape, but factors of the landscape or factors created on the landscape also impact the regime. For example, grazing management and invasive species can alter fuel load and constrain burn season. Understanding the effects that management practices create for the disturbance regime is always something to be cognizant of.

Implications for Management

Our recommendations include focusing prescribed fire and grazing on pre-determined patches within NPS units. We also recommend focusing on a system perspective and creating management plans that incorporate several aspects of the ecosystem rather than writing one plan per species. Thinking in this systems perspective will slowly change the goals of NPS management from species vitality to ecosystem processes vitality. If we want to maintain ecosystems as they are and "unimpaired for future generations", the processes that make grasslands what they are should demand the most attention. Functional groups of species can perform similar functions in an ecosystem. As long as a required function is performed, less pressure needs to be placed on what specific species is performing that function. By taking this mind frame, less pressure will be placed on budgets and personnel to maintain unrealistic expectations for grassland ecosystems into the future.

Following along with the three pieces of information previously mentioned, we specifically recommend, region-wide, to "continue to research the response of specific target species response to fire and specifically prescribed fire in different seasons" (Driscoll *et al.* 2010).

Specific studies to focus on and data to collect would be

Spatial and Temporal Characteristics of Fire and How that Affects Biota

How Fire Affects Ecosystem Processes

Disturbance regimes are essential processes for native grasslands of the Midwest region. By acknowledging this fact and focusing management on the establishment of this disturbance regime could ultimately lead to less management inputs in the year. Instilling a disturbance regime creates native heterogeneity across the protected landscape. Heterogeneity implies diversity of the landscape and all things that depend on or makeup that landscape. When diversity is present, an ecosystem is best prepared to absorb shocks and pressures (Walker & Salt 2012). Shocks and pressures are inherent parts of managing a protected area in a surrounding landscape of utilitarian focus. A resilient landscape will influence the amount of management time and budget required to maintain essential processes. When the landscape is thought of as a system, and that system is poised to rebound, it can be more so left to its own devices with the trust that instilling nature regimes will beget natural processes going forward.

In conclusion, we suggest coupling disturbances into a disturbance regime. Two native disturbances on grasslands that align and benefit one another are fire and grazing. This has been implemented on one grassland unit in the region with native herbivores in a technique called patch-burn grazing. This technique is a way to encourage pyric herbivory on the landscape. As this has been seen to benefit the landscape at TAPR, we suggest translating this technique to other units. In order to translate and set up this process in new locations, plant productivity is required to prescribe the preferred stocking rate and spatial extent of the patches created by patch- burn grazing. New data will need to be collected through grassland exclosures and weighing of vegetative material.

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