THUNDER BASIN WYOMING

Ecological Assessment of Terrestrial Ecosystems

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Contents

1.0 INTRODUCTION

The Thunder Basin region, located in eastern Wyoming (Figure 1), is recognized as one of the most ecologically significant grasslands in the United States (Forrest et al. 2004, The Nature Conservancy 2008). It is an area of open prairies, occasional badlands, and steep but low hills with colorful soils and vegetation. It includes mixed and short-grass prairies which support rich plant and animal communities, including numerous grassland obligate species identified as species of concern. The area also supports sagebrush ecosystems and a number of sagebrush obligate and sagebrush associated species of concern. Ranching and energy production play a key economic role. Thunder Basin supports some of the largest coal mines in the world as well as substantial oil and gas production. Land ownership is mixed, with a majority of the land in private ownership, but with substantial public lands including lands of the Thunder Basin National Grasslands, Bureau of Land Management, and State of Wyoming. Subsurface ownership is mixed as well, with the Federal government being by far the largest mineral owner.

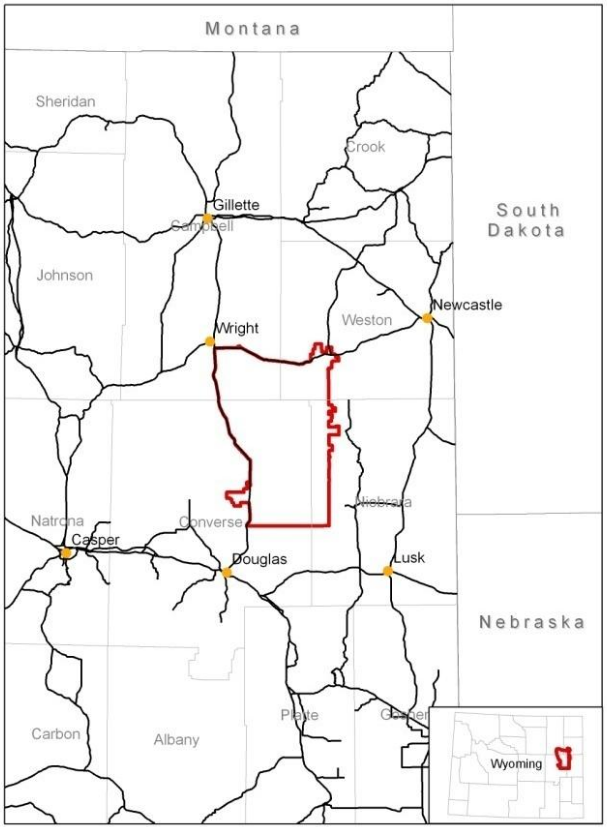

Figure 1. Location of the Thunder Basin planning area within Wyoming.

The Thunder Basin Grasslands Prairie Ecosystem Association (Association) is a membership-based, non-profit organization that was formed in 1999 to provide private landowner leadership (both ranching and energy industry) in developing a responsible, common-sense, science-based approach to long-term management of their lands. The Association was established with the objective of maintaining responsible economic use of the landscape while demonstrating how effective stewardship of natural resources can be provided through voluntary, privately-led, collaborative efforts. A management objective is to provide for the habitat needs of all native species occurring in this mixed-ownership landscape, accomplished through the application of an ecosystem-based approach.

PURPOSE

This ecological assessment summarizes data from three years (2003-2005) of intensive vegetation sampling conducted throughout the Thunder Basin project area. It also develops a baseline description of native ecosystem diversity, estimates pre-European settlement conditions, and evaluates cumulative changes that have occurred to native ecosystem diversity.

SCOPE

The planning area delineated by the Association for the purpose of this assessment is a 945,450 acre area comprised of both private and public ownerships within four eastern Wyoming counties; Converse, Campbell, Weston, and Niobrara (Figure 2). Private landowners own 58.6% of the surface area, with Association members owning 25.4% of the area and include ranchers and energy production companies. Public lands in the planning area include the USDA Forest Service, Thunder Basin National Grasslands, Wyoming Office of State Lands and Investments and USDI Bureau of Land Management lands, representing 31.4% 6.0%, and 4.0% of the surface ownership respectively.

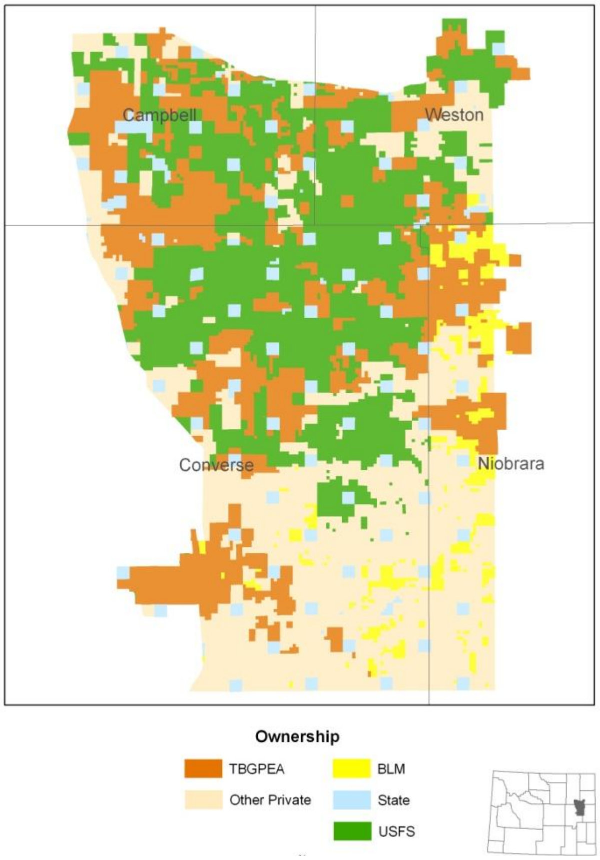

Figure 2. Mixed ownership landscape within the Thunder Basin planning area in eastern Wyoming.

BACKGROUND

The Association was formed with the objective of maintaining responsible economic use of the landscape while demonstrating how effective stewardship of natural resources can be provided through voluntary, privately-led, collaborative efforts.

The Association recognized that addressing the needs of species of concern, one species at a time, was not an effective way to plan for either stewardship or economic objectives. They also recognized that each landowner, working independently, would not be as effective as an association of private landowners working together collaboratively. With these considerations, the Association focused its efforts on developing an ecosystem-based approach to land management.

One of the most critical components in the application of the ecosystem approach is clearly articulating how the ecological objectives are to be met. The Association has agreed upon an ecosystem management process that provides a strong foundation for determining ecological objectives, but that will in turn provide a reasonable mechanism for integrating social and economic objectives in the planning area. The ecosystem management process is identified in

Figure 3. An ecological assessment was conducted as Phase 1 of this process and provides the baseline information that can be used in Phase 2 - the development of an ecosystem management plan. With an ecosystem management plan, the Association will be able to work collaboratively with landowners, agencies, and non-government organizations to implement the plan, which represents Phase 3 of this process. Plant species discussed in this document are referred to by common name, with the complete listing of species and their scientific names included in Appendix A.

PHASE 1 – THE THUNDER BASIN ECOLOGICAL ASSESSMENT

This document represents the results of Phase 1, which began with identification of the key issues and objectives to be addressed by the ecological assessment, as outlined below.

Key Issues

1. Several species of concern could be listed under the Endangered Species Act and impact economic uses of the project area.
2. Land uses and processes which may affect ecosystem services at both site and landscape levels need to be understood and managed.
3. Effects of drought on ecosystem services with specific emphasis on maintaining grassland productivity and functions for both biological diversity and ranching operations need to be understood and managed.
4. The spread of noxious weeds and other invasives, particularly annual brome species, needs to be understood and managed.

Objectives

1. This document will provide the information needed for development and implementation of an ecosystem management plan that could be the basis for a Candidate Conservation Agreement with Assurances between the Association and the U.S. Fish and Wildlife Service.
2. This document can provide the basis for a corresponding and coordinated Candidate Conservation Agreement in cooperation with the U.S. Forest Service and Bureau of Land Management on public grazing attotments.

Primary Components of this Document

There are nine primary components to Phase 1 that correspond to the Sections of this report.

1. Description of the project and provision of background information.
2. Description of the setting, landscape features, and land use history of the region.
3. Description of the conservation strategy used as the basis of the ecological assessment.
4. Description and quantification of the historical or native ecosystem diversity.
5. Description and quantification of the conditions present on the landscape today.
6. Description and quantification of the cumulative changes to native ecosystem diversity.
7. Identification of species of concern and a description of their habitat requirements as well as threats to their persistence.
8. Presentation of the key findings and implications of the ecological assessment for ecosystem management planning.
9. Discussion of additional or future research and assessment needs.

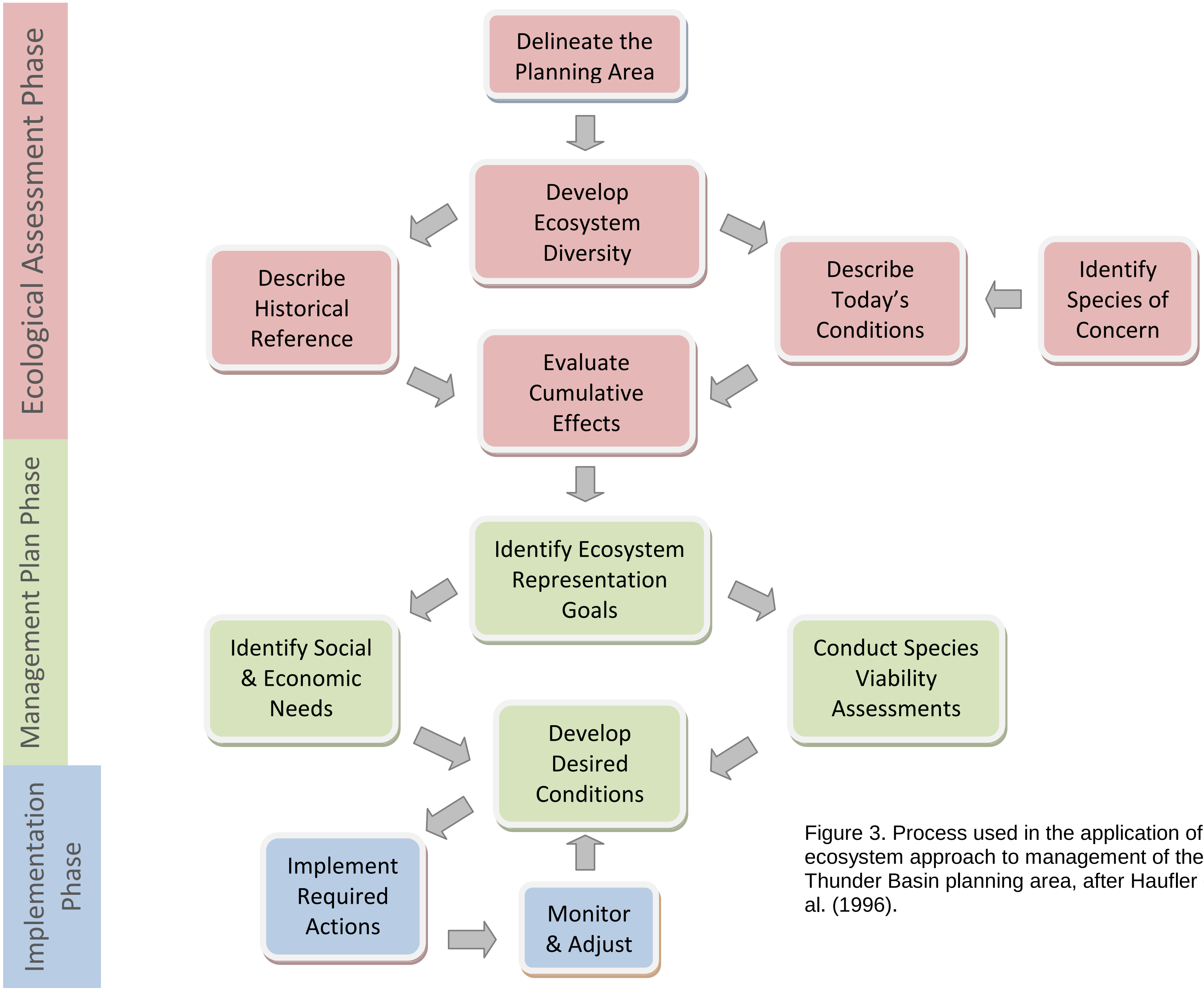

Figure 3. Process used in the application of an ecosystem approach to management of the Thunder Basin planning area, after Haufler et al. (1996).

2.0 LANDSCAPE FEATURES AND LAND USE HISTORY

Figure 4. Location of the Thunder Basin planning region (red feature) within the greater Great Plains landscape (tan feature) of the United States.

The Great Plains were formed during the half million years that shallow seas were present across the interior of the North American continent (Trimble 1980). Layered sediments mostly between 5,000 and 10,000 feet thick were deposited onto the floor of this interior ocean. At about 70 million years ago this interior ocean was displaced by the slow uplift of the continent. The landscape that appeared after the oceans retreated was the extensive, nearly flat floor of the former sea (Trimble 1980). The Thunder Basin planning area occurs along the western, central edge of the overall Great Plains province (Figure 4), thereby falling within a broad zone of transition between the Great Plains province and the Wyoming Basin and Rocky Mountain provinces, lying to the west of the planning region (Fenneman and Johnson 1946).

The following landscape features and physiographic descriptions of the Thunder Basin planning area are limited to primarily those features which influence terrestrial ecosystem diversity and vegetative communities across the planning region. These features include: 1) landforms, 2) geology, 3) climate, 4) soils, and 5) surface hydrology and drainage patterns.

LANDFORMS

The project area is characterized by open high hills in the northern region and tablelands with moderate relief in the central and southern regions, with all three regions having intermittent escarpments (Hammond 1964). The northern region is also described as having gentle slopes on approximately 20 to 50% of the land surface with most of these occurring in the lowlands. The central and southern regions are described as having gentle slopes occurring on 50 to 80% of the land surface with over half of these occurring in the lowlands of the central region and over half occurring in the uplands of the southern region. Elevation ranges from 4,000 to 5,300 feet within the planning area. Local relief ranges between 500 and 1,000 feet in the north and 300 to 500 feet in the central and southern regions (Hammond 1964).

GEOLOGY

Thunder Basin geology is comprised of deposits from the Cretaceous, Tertiary, and Quaternary Periods (Munn 2001). Most of Wyoming was under water during the Cretaceous and subsequently a large proportion of the geologic formations deposited during this time are shales of marine origin. The Tertiary Period marks a time where much of the geology seen throughout the Thunder Basin planning area was deposited. About 60 million years ago, uplift of the Rocky Mountains was associated with massive amounts of debris that were deposited throughout Wyoming basins and beyond in the form of alluvial fans. It is estimated that twenty thousand feet of sedimentary rocks were eroded off the young Rocky Mountains and deposited into basins (Munn 2001), which are recognized as the Fort Union and Wasatch formations, the dominant bedrock geology in the Thunder Basin planning area (Figure 5) (USGS 1994). Scoria, a reddish slag formed by the fusion and baking of strata overlaying coalbeds when they burn, occurs along the contact between the Fort Union and Wasatch formations, forming a caprock for the escarpment. Tullock is the oldest member of the Fort Union Formation and is comprised of calcareous sandstone and shale, as well as, interbedded sandstone. The Lebo member is comprised of shale and interbedded sandstone. Along the riparian systems alluvium and colluvium comprise the dominant bedrock geology (Munn 2001).

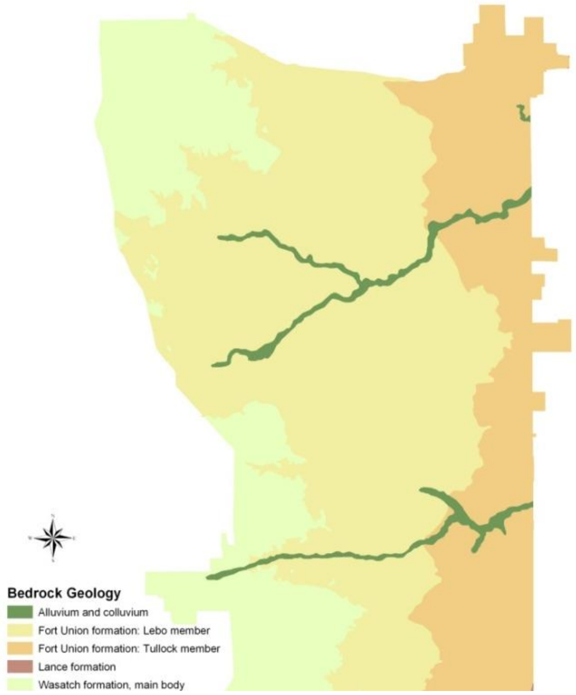

Figure 5. Bedrock geology of the Thunder Basin planning area (USGS 1994).

The surface geology of the Thunder Basin planning area is dominated by residuum (i.e., weathered bedrock) mixed with alluvium, eolian, slopewash, grus, and bedrock (Figure 6) (Case et al. 1998). Surfaces characterized as Eolian have materials transported by wind and can be mixed with scattered deposits of residuum, alluvium, and slopewash. Clinker surface geology is associated with coal seam locations and is mixed with deposits of residuum, slopewash, alluvium, and bedrock. One playa deposit, resulting from ephemeral water accumulation, is found within the planning area and is mixed with alluvium and eolian scattered deposits. Alluvium deposits are found along the streams and rivers and occur with scattered deposits of terrace, slopewash, eolian, residuum, grus, and glacial materials. Bedrock surface geology found in this area is mixed with shallow deposits of eolian, grus, slopewash, colluvium, and residuum (USGS 1994). Slopewash and colluvium surface geology include rock and soil

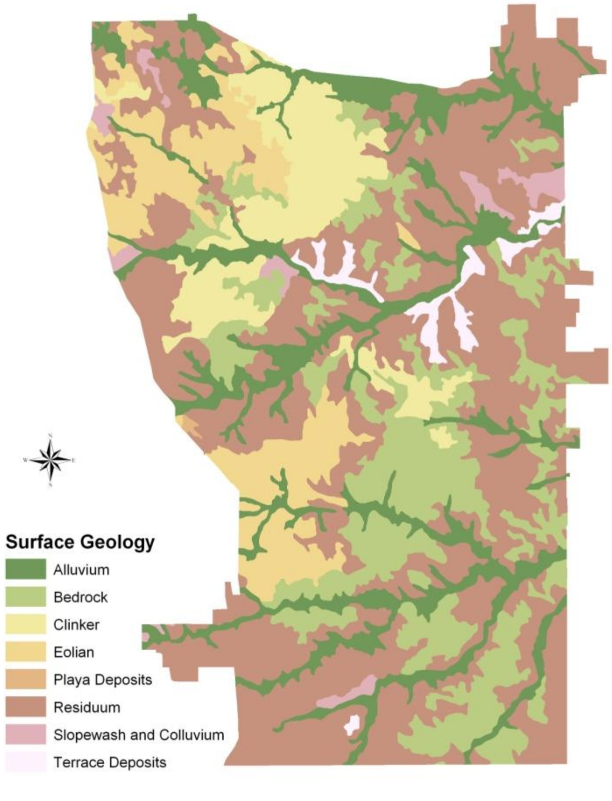

Figure 6. Surface geology of the Thunder Basin planning area (Case et al. 1998).

transported downslope by either water or gravity and are found mixed with residuum, grus, glacial, periglacial, alluvium, eolian, and bedrock.

CLIMATE

The climate of the Thunder Basin region is broadly characterized as interior continental with hot summers and cold winters. Winds are common to the region and frequently strong. Westerly winds are the prevalent wind direction. Wind velocity ranges from an average of 10 miles per hour during July and August to 16 miles per hour during November through April (Lowry and Wilson 1986). Average annual precipitation is 12.5 inches, with a range of 5.6 to 19.5 inches on average. Average annual snowfall is 44.1 inches. The mean monthly temperature is highest for July (72.9 ^{o} F) and lowest for January (23.5^{o} F) (Western Regional Climate Center 2008). Approximately 80% of the precipitation each year falls between April and October and occurs primarily as rain. Most precipitation between November and April occurs as snow (Lowry and Wilson 1986). The majority of plant growth occurs between April and September. The amount of precipitation that occurs each year can be highly variable (Figure 7).

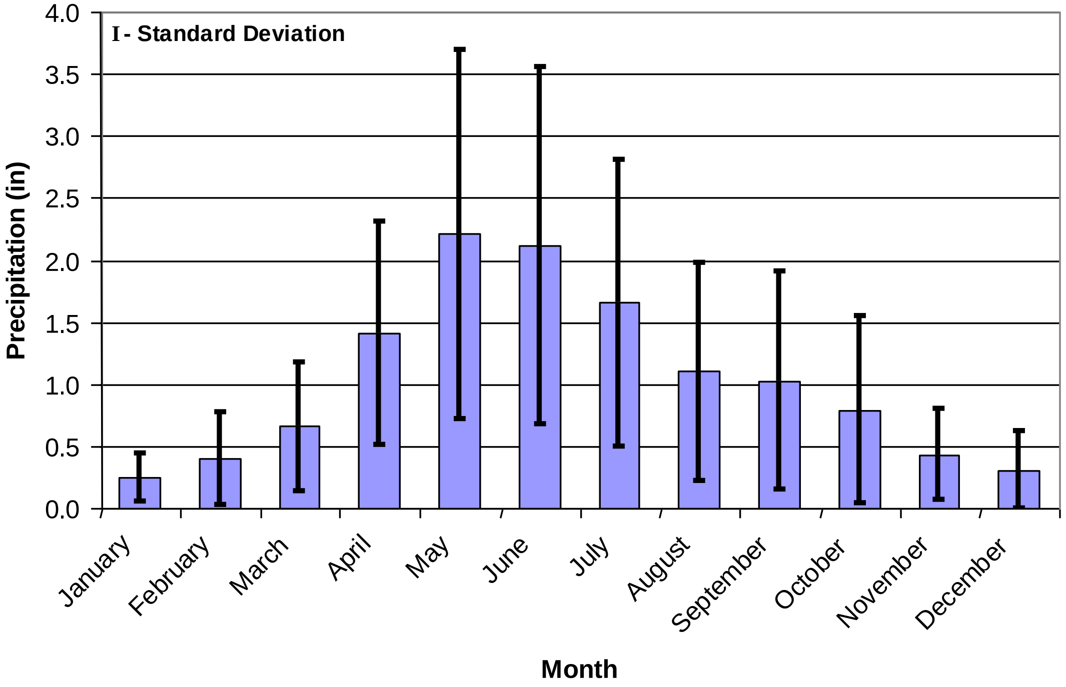

Figure 7. Average annual precipitation for the Thunder Basin planning region (Western Regional Climate Center 2008).

SOILS

Aridisols (i.e., desert soils) and Entisols (i.e., new soils) soil orders dominate the Thunder Basin planning area, however Mollisols (i.e., prairie soils) are also found to a lesser extent. Aridisols and Mollisols are typically found on flat to gently sloping topography, and Entisols are typically found on sloping topography in the planning area. There are 8 suborders that occur in this area (Munn and Arneson 1998) (Figure 8). Haplargids, Haplocalcids, Haplocambids, and

Haplogypsids are Aridisols suborders, Torrifluvents and Torriorthents are Entisols suborders, and Haplustolls and Hapludolls are Mollisols suborders found within the planning area. Haplargids are characterized by illuvial accumulations of clay, Haplocalcids are soils with a basic pH from carbonate and lime accumulations, Haplogypsides are soils associated with clayey playas with gypsum accumulations, and Haplocambids are soils that have cambic horizons or soil horizons that have been altered by chemical reactions or physical transport of soil (Munn and Arenson 1998). Torrifluvent soils occur along small streams and are subject to flooding but are typically not flooded for an extended period of time (Munn and Arneson 1998). Torriorthents are coarse stony soils that occur where coal seams have formed clinker (Munn and Arneson 1998). Haplustolls are soils with enhanced soil water because of snow accumulation and Hapludolls are fertile soils on gentle sloping topography (Munn and Arneson 1998).

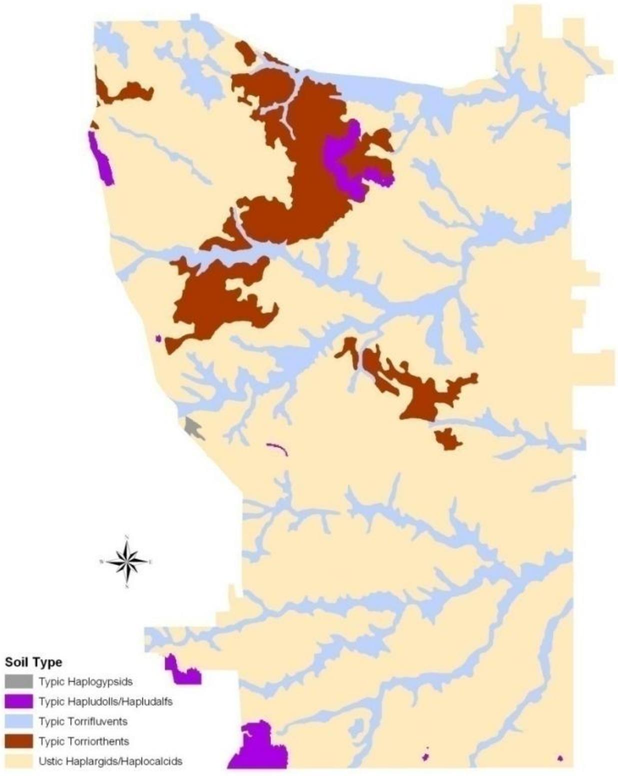

Figure 8. Soil suborders found within the Thunder Basin planning area (Munn and Arneson 1998).

SURFACE HYDROLOGY AND DRAINAGE PATTERNS

The project area is located in the headwaters of the Cheyenne River Basin and includes the Dry Fork of the Cheyenne, Upper Cheyenne, Lance, Lightning, and Antelope Creek sub-basins (Figure 9). The Cheyenne River Basin flows eastward and is part of the larger Missouri River Basin (Haie 1980). Surface water is collected by primarily ephemeral (i.e., flow occurs for a short time after extreme storms) tributaries (Lowry and Wilson 1986). However, in average or above average precipitation cycles, some stream reaches in the Rochelle Hills are perennial (flow occurs 90% of time, or more) or intermittent (flow occurs 50% of the time, or less) due to springs or higher ground water tables (Apley 1976) (Figure 10). Most of the streams and tributaries within this region are deeply eroded with wide floodplains and sand channels bordered by three terraces: the Lightning terrace at approximately 6 feet, the Moorcroft terrace at approximately 14

feet, and the Kaycee terrace at about 33 feet above the channel (Leopold and Miller 1954).

From May to July, 70 to 80% of the annual precipitation occurs as rain or intense, widely scattered thunderstorms of relatively small areal extent (Haie 1980). The remaining precipitation is usually from snowmelt in early spring. Due to the sporadic nature of the precipitation, ephemeral streamflow is often limited to 8 to 10 days per year (Smith 1974).

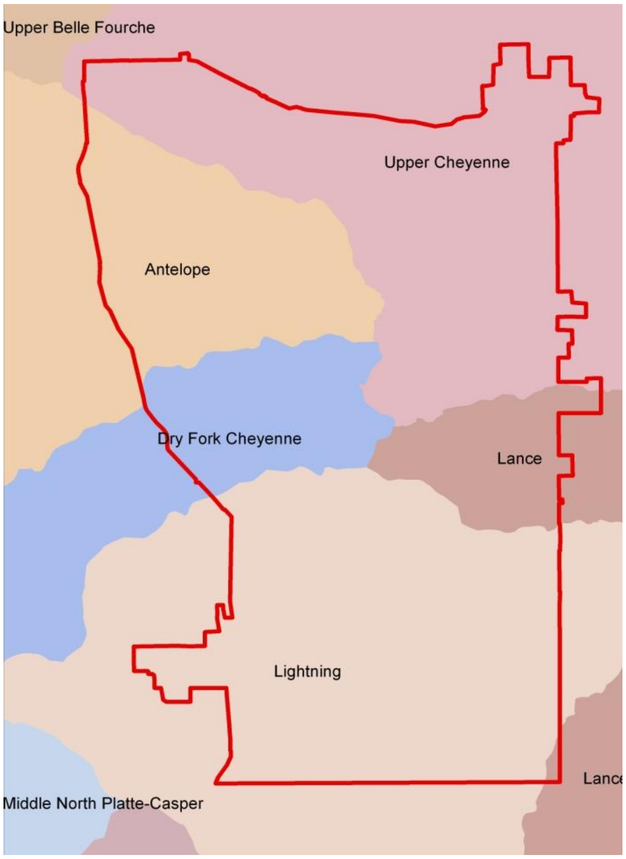

Figure 9. Hydrological sub-basins of the Thunder Basin planning region (USGS 1990).

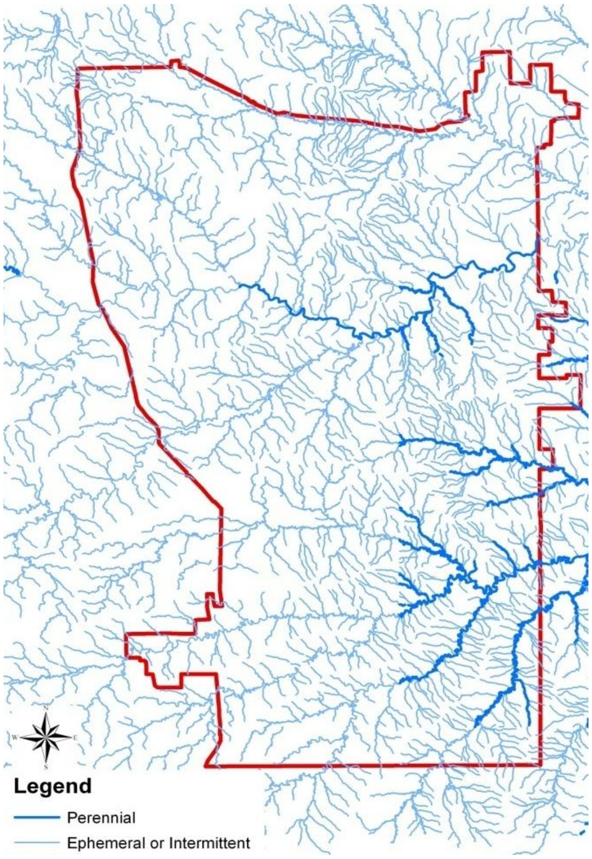

Figure 10. Ephemeral/intermittent and perennial stream types in the Thunder Basin planning area (USGS 2006).

Historical Land Use of the Region

Native Americans

The Thunder Basin region was an important Native American hunting ground and was formally designated “Indian Territory” with the signing of the Fort Laramie treaty of 1868 (Campbell County 2008). By the early 1870s, the bison population was in steep decline due in part to increased Euro- American settlement into western regions. Under pressure from miners and settlers, the U.S. Government asked all Native Americans to leave northeastern Wyoming or be subject to military action. Armies were deployed to the region in 1876 (Campbell County 2008). By the late 1870’s, free ranging bison were gone from the landscape and the Native American way of life was over. Indian reservations were established at that time but none of these reservations were located in eastern Wyoming and the region was opened for permanent Euro-American settlement (Campbell County 2008).

Settlement

The Wyoming Territory was formed in 1868 (e-Reference Desk 2008). In its early days, Wyoming Territory was primarily influenced by a free-range livestock ranching economy. Cattle were driven north to the Wyoming Territory from Texas by the thousands. Wealthy ranchers ruled vast segments of the territory and controlled the affairs of the territorial government until 1887. The severe winter of 1887 caused thousands of cattle tp perished resulting in many of the ranchers going bankrupt and consequently many lost their political power in the territory (MSN Encarta 2008). Converse County was organized in 1888 and Weston County was organized in 1890 (Wikipedia 2008). Niobrara County and Campbell County were both established in 1911 (Wikipedia 2008).

Homesteading

Early western expansion activities that included exploration, fur trapping, military activities, and open range grazing by sheep and cattle did not bring many early settlers to the Thunder Basin region. It was not until the railroad was constructed in 1868 and the town of Gillette, a shipping point, was established in northeastern Wyoming in the late 1880s, that homesteads started to develop in the region (Campbell County 2008). By the turn of the century, Wyoming's population was rapidly growing. Settlers were provided with free land by the Homestead acts of 1909, 1912 and 1916. Livestock ranching and dryland farming were encouraged on these early homesteads. During the Great Depression of the 1930’s, an extensive drought contributed to failed crops and poor crop prices. Those whose homesteads survived the drought turned to ranching as their primary source of sustenance and income. Today, farming is not practiced within the planning landscape.

History of the Thunder Basin National Grasslands

In the late 1920’s, the federal government recognized the problem of submarginal lands that were sold to homesteaders for agricultural purposes and authorized the Federal Farm Board to investigate the problem. After several years of review, it was recommended that the federal government acquire some 75 million acres of submarginal land. Several years of emergency Executive Orders allowed this acquisition to begin in 1934 but it wasn’t until 1937 that the Bankhead-Jones Farm Tenant Act provided a permanent status for the land acquisition program (Olsen 1997). Specifically, this Act provided federal money to buy out impoverished homesteaders and place the acquired lands into federal holdings. Many of the National Grasslands, including Thunder Basin National Grasslands were a product of this Act. The Act required the Secretary of Agriculture to develop a program of land conservation and utilization to correct for maladjustments in land use, and assist in controlling soil erosion, reforestation, preserving natural resources, protecting fish and wildlife, developing and protecting recreational facilities, mitigating floods, preventing impairment of dams and reservoirs, developing energy resources, conserving surface and subsurface moisture, protecting the watersheds of navigable streams, and protecting the public lands, health, safety and welfare.

With the establishment of the Thunder Basin Grasslands, came the development of the Thunder Basin Grazing Association. Eathorne (2001) discussed how the Grazing Association functions as a permittee of the U.S. Forest Service. The Grazing Association, in turn, issues grazing permits to their members, local ranchers. Membership qualifications and rules of governance are developed by the Grazing Association. Board members are elected by the membership. The Forest Service sets the seasons of grazing use and stocking rates. Grazing permits are allocated to the membership based on guidelines developed by the Grazing Association. The Forest Service provides guidance for grazing through an Allotment Management Plan that details how and when each unit of the allotment will be grazed and by what kind of livestock. The Forest Service considers the land capabilities and the public need in the development of the Allotment Management Plan.

Ranching

Since Euro-American settlement, ranching has been the most consistent land use within the Thunder Basin planning area. Initially cattle were the most dominant livestock produced but gradually sheep production increased as well (Campbell County 2008). Some ranches raised both sheep and cattle and this still occurs today. Horses have been used and raised for many years to assist with ranching maintenance and production activities. They are still used today although less extensively as new equipment (e.g., ATV’s) has become more convenient.

Energy Production

The Thunder Basin region is characterized by an unusual wealth of coal, oil, gas, and other mineral resources. The U.S. government is the largest owner of mineral rights in the landscape, with the ownership pattern primarily influenced by the various Homestead Acts discussed above (Figure 11). For many lands, surface ownership and mineral ownership are not owned by the same entity, a condition termed "split estate". Understanding both surface and mineral ownerships is important to planning within the landscape.

Oil production has occurred in the Thunder Basin region from the early 1900's and was for a time, the primary energy produced in the state and region. In the 1920's, the Lance Creek field located in Niobrara County on the southeast border of the planning area, was the Nation's top producing field for several years. Production continued strongly until its peak in the 1970's.

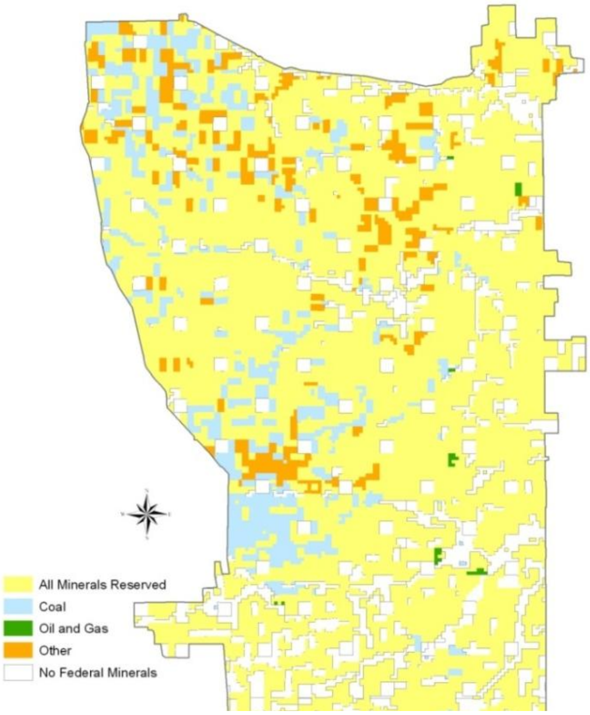

Figure 11. Federal ownership of coal, oil, gas, and other minerals (i.e., uranium, bentonite, etc.) in the Thunder Basin planning area (Anderson et al. 1990).

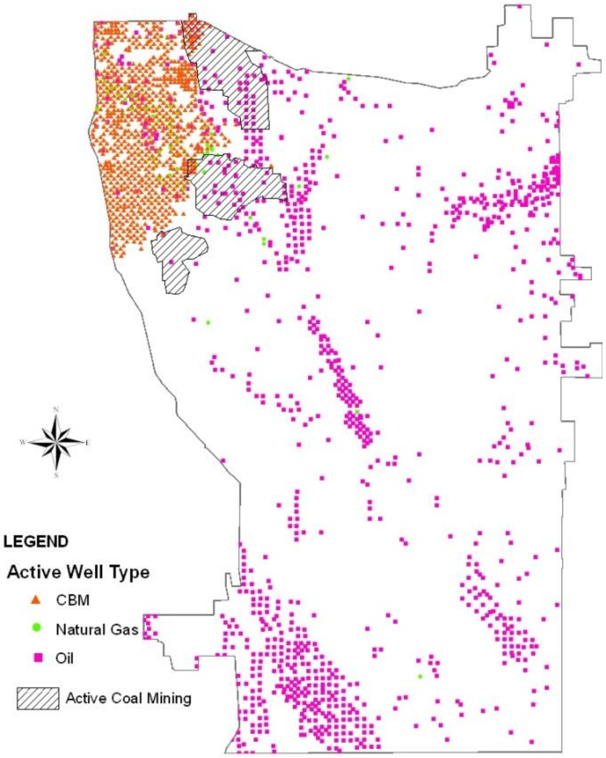

Figure 12. Distribution of existing wells by type in the Thunder Basin planning area (www.skytruth.org) and existing coal mines delineated from aerial imagery.

The Thunder Basin planning area supports several types of natural gas production. Within the last 10 years, the region has experienced significant development of natural gas associated with coal seams (ENSR Corporation 2005). Most of this coal bed natural gas production in the planning area is occurring in Campbell County. In addition to coal bed natural gas, natural gas production has also occurred in other locations within the planning area. Distribution of gas and oil wells is displayed in Figure 12. Several large coal mines are actively being mined in the northwest quarter of the planning area (Figure 12). These have contributed substantially to the economic base in the surrounding area.

3.0 THE CONSERVATION STRATEGY

Conservation strategies refer to the framework and the underlying basis and assumptions used in planning to maintain or restore ecosystem and biological diversity to an identified area. A wide range of strategies exist, each with advantages and disadvantages (Haufler 1999a;1999b). Some are narrowly focused, only striving to address a subset of biological diversity, while others are broadly focused, striving to address biological diversity within a defined area at all four of its levels (landscape, ecosystem, species, and genetic). Selection of a strategy is dependent on the unique objectives of an individual planning effort. To achieve the objectives identified by the Association for the Thunder Basin planning area, a strategy that focused primarily on maintaining and restoring ecosystem diversity was selected.

OVERVIEW OF CONSERVATION STRATEGIES

Coarse filter and fine filters are terms that have been widely used to describe conservation strategies. Coarse filter strategies focus on providing an appropriate mix of ecosystems or ecological communities across a planning landscape, while fine filter strategies focus on providing for the needs of individual or multiple species within a landscape (The Nature Conservancy 1982, Marcot et al. 1994, Schwartz 1999, Haufler 1999a). While many conservation planning efforts blend the two strategies, there is a fundamental difference in whether the primary basis of a strategy is focused on ecosystems or species. Each type of strategy is based on various assumptions as to how it can provide for biodiversity conservation (Haufler 1999a).

Coarse Filter Strategies

Coarse filter strategies have the goal of maintaining enough diversity of ecosystems or ecological communities to maintain the ecological integrity of these ecosystems and to provide for the habitat needs of all species and their genetic diversity inherent to a landscape. A key to the success of a coarse filter strategy is to use an appropriate classification of ecosystem diversity that is applied at an appropriate scale (Schwartz 1999, Mayer and Cameron 2003) to address the specific conservation objectives identified for an area. Few efforts have considered the appropriateness of the classification system used and more frequently use whatever classification happens to be available for an area. Numerous authors have discussed the importance of ensuring that appropriate types and amounts of ecosystems are identified and represented within a planning region (Pressey 1998, Schwartz 1999, Shaffer and Stein 2000, Lambeck and Hobbs 2002, Groves 2003). Both biological and physical factors should be determined when identifying ecosystem diversity and various authors (Haufler et al. 1996, Haufler et al. 1999, Poiani et al. 2000b, de Blois et al. 2002, Groves 2003, Saxon 2003) have identified the importance of understanding both the role of physical factors that create different types of ecological sites within a planning landscape, and the biological response, or how ecosystems change over time following disturbance across these different ecological sites.

Another important consideration of coarse filter strategies is that the composition and structure of communities identified to represent ecosystems must be appropriate for that specific ecosystem. This addresses the concern for resiliency identified in numerous publications (Haufler et al. 1996, Shafer 1999, Shaffer and Stein 2000, Groves 2003). For example, if a particular area posseses a large amount of exotic species that may exceed an appropriate threshold level, then this area should not be considered representative of the targeted ecosystem conditions. However, few coarse filter strategies have addressed more than landscape level measures of different ecosystems. Various tests of coarse filter strategies have shown that they can be effective for biological diversity conservation (Nichols et al. 1998, Wessels et al. 1999, Ben Wu and Smeins 2000, Kintsch and Urban 2002, Oliver et al. 2004).

Haufler (1999a, 1999b, 2000) discussed strategies for biological diversity conservation and identified several types of coarse filter strategies. One type of strategy, termed the historical reference approach or historical range of variability-based approach (Haufler 1999a), has been proposed or utilized in various planning efforts. This approach is based on the premise that the ecosystem diversity that occurred in an area over the past hundreds to several thousand years defined biodiversity at the ecosystem and landscape levels, and also provided the habitat that supported the species and genetic diversity of a landscape (Poiani et al. 2000a, Haufler et al. 2002). This approach has as a primary objective the maintenance of all historically occurring ecosystems at some level of representation. The historical reference approach strives to understand, characterize, and quantify the historical ecosystem diversity that occurred within a planning area, and then attempts to maintain suitable representation of these ecosystems within that area factoring in the historical reference at both landscape and ecosystem levels (Haufler et al. 2002). The goal is not to return a landscape to historical conditions, but to use this understanding as a baseline or reference for providing representation of ecosystems at both the landscape and ecosystem levels. Use of this approach requires the development of information on historical ecosystem diversity (Morgan et al. 1994, Landres et al. 1999). This approach generally focuses on understanding how natural disturbances and processes combined with different ecological sites within a planning area produced the dynamics of historical or native ecosystem diversity. The approach then uses this information to determine how the extent and distribution of historical ecosystems have been changed by recent human activities (i.e., post Euro-American settlement).

Fine Filter Strategies

Fine filter strategies have a primary focus on planning for single or multiple species. Related topics in many publications describe such measures as species richness or species diversity, and the use of hotspots for identifying conservation areas. A majority of the recent publications on fine filter strategies have been focused on reserve planning, and use species as a basis for identifying the most appropriate places to locate reserves.

Fine filter strategies have the advantage of having a legal basis for their use in conservation planning in the United States and other countries through provisions of endangered species legislation (Schwartz 1999). Proponents who favor fine filter strategies over coarse filter strategies argue that species are the fundamental parts of ecosystems, and that using coarse filter analyses to represent species needs is inaccurate and inadequate (Noon et al. 2003, Cushman et al. 2008). A primary concern is that the number of species occurring in any area is so large that they cannot all be accounted for in fine filter approaches. Attempts to simplify this complexity through the use of surrogates have many problems associated with them (Groves 2003). Further, most fine filter strategies fail to consider the landscape and ecosystem levels of biodiversity, so their ability to represent all levels of biodiversity is limited.

Combination Strategies

Today, many conservation planning initiatives use a combination of approaches to address their objectives. Many coarse filter approaches combine in some way with fine filter approaches. The Nature Conservancy approach (Groves 2003) combined a rarity focus in identifying both fine and coarse filter elements for representation in reserves. Haufler (1999a; 2000) and Haufler et al. (1996a) used a coarse filter approach based on an historical reference, but then suggested that this be checked using indicator species selected to test the effectiveness of the coarse filter.

Combination approaches have the capability of addressing many of the concerns identified with individual strategies. The goal of any specific initiative should be to develop a comprehensive and cohesive conservation planning approach, and to carefully review the approach to identify any holes in coverage where elements of biodiversity might not be sufficiently addressed. As noted by many including Haufler et al. (2002) and Groves (Groves 2003), much is unknown about conservation planning, so monitoring and adaptive management designs are important considerations.

SELECTED CONSERVATION STRATEGY

For conservation planning within the Thunder Basin, a combined coarse filter and fine filter conservation strategy was selected. The coarse filter is the primary strategy and is based on the historical reference for the region. The fine filter is conducted secondarily to the coarse filter and is used to check the selected levels of representation used in the application of the coarse filter. This conservation strategy provides a strong scientific foundation for conservation of biological diversity as well as the flexibility to consider other land uses in the overall landscape. The coarse filter - historical reference strategy combined with the fine filter - species assessment evaluates ecosystem integrity and biological diversity relative to what has occurred historically across the planning area compared with what is currently present.

The success of a coarse-filter strategy will largely depend on properly identifying the historical or native ecosystem diversity and the conditions that influenced the historical reference. This will require identifying and understanding natural disturbance patterns (i.e., sizes and frequencies of wildfire, intensities of bison grazing, etc.) and native ecosystem distributions (i.e., locations where physical conditions are present to support them). Application of the coarse filter will focus on providing representation of native ecosystems in appropriate amounts, sizes, and distributions based on reference to these ecosystems under natural disturbance regimes.

Representation goals for the coarse filter will need to be checked for the likelihood of continued persistence of selected species. In Thunder Basin, use of a habitat-based species viability approach (Roloff and Haufler 1997, Roloff and Haufler 2002) has ben proposed. These species assessments will provide a check on the assumptions and proper functioning of the coarse filter. If a species that had a high probability of persistence under historical conditions was found to not have an acceptable probability of persistence under the planned conditions, then the coarse filter would need to be reevaluated and modified. However, if conditions for the species selected are shown to provide an acceptable likelihood of persistence, then the coarse filter is supported in its function to address the maintenance of biological diversity and ecosystem integrity.

4.0 NATIVE ECOSYSTEM DIVERSITY

Native ecosystems are the product of the combination of communities of living organisms with the physical environment in which they live. The range of ecosystem conditions, or ecosystem diversity, occurring across a landscape and available as habitat for native plants and animals is usually the result of natural disturbance processes (e.g., grazing, fire, etc.) that typically occur within that landscape. Native ecosystem diversity is often described by the range of vegetation types occurring on similar sites as these are often the most obvious characteristic, particularly for terrestrial ecosystems. While ecosystems can be clearly distinct from each other, more frequently they have less clearly defined edges that transition from one ecosystem type to another. However, in order to describe and quantify the amounts of these ecosystems for assessment and management purposes, it is necessary to map a line between ecosystems while recognizing that these delineations may not always be obvious to the naked eye or easy to define without field surveys and on-site sampling.

■ NATURAL DISTURBANCE AND THE HISTORICAL REFERENCE

Prior to Euro-American settlement, natural disturbance processes such as fire and grazing by large herbivores were a primary influence on the ecosystem diversity that occurred in eastern Wyoming (Knight 1994). Native Americans have also interacted and influenced ecosystem diversity for thousands of years, but typically in ways that used naturally occurring disturbance processes to benefit their subsistence strategies, such as using fire to create better wildlife habitat for hunted species or maintaining travel corridors in more open conditions (Williams 2005). The influences of natural disturbance processes and Native Americans on historical ecosystem diversity are incorporated in what is known as the historical reference.

Historical references are utilized in ecosystem assessments to help identify, describe and quantify the native ecosystem diversity that occurred in a region. For the purpose of this ecological assessment, an historical reference is defined as the ecosystem diversity that resulted from natural disturbance (i.e., fire, grazing, etc.) and human-influenced disturbance (i.e., native American) that created the dynamic conditions that plant and animal species were familiar with and dependent upon. Natural disturbance regimes are the patterns of frequency and intensity that can be quantified using ecological evidence. For example, both fire and grazing regimes are frequently described relative to frequency of occurrence and relative intensity.

Another term often used in relation to historical reference is the historical range of variability. Historical range of variability is an important concept because it emphasizes that many ecosystems varied in amounts, compositions, and structures due to variations in climate and stochastic events that influenced natural disturbance regimes (Aplet and Keeton 1999). Historical references are usually confined to a period less than 1000 years prior to Euro-American settlement, as these reflect the habitat conditions most relevant to the species that are present today (Morgan et al. 1994). Quantifying historical references may be a difficult task in some areas due to a lack of ecological information to help describe the effects of natural disturbance, for example fire regimes in grassland ecosystems. Furthermore, native ecosystems were not static during any defined reference period. Species distributions were changing, disturbance regimes were changing, and species themselves were adjusting to these changes through behavioral and genetic alterations. However, developing an understanding of the ecosystem diversity that occurred during an identified timeframe prior to Euro-American settlement provides critical reference information for defining and quantifying a baseline of what should be considered "natural" or "native" for an area. In the following paragraphs, the primary disturbances that influenced ecosystem diversity within the Thunder Basin planning area are described.

Fire

Fire was a relatively common disturbance event in eastern Wyoming prior to Euro-American settlement (Fisher et al. 1987, Knight 1994, Perryman and Laycock 2000). Historically, fires were started by lightning and the activities of Native Americans (Higgins 1984). Native Americans often used fire throughout the year to improve wildlife habitat, hunting, travel conditions, and for ceremonial purposes (Higgins 1984). In contrast, fires started by lightning occurred mostly in hot and dry summer conditions, late growing season, or during the dormant season (Higgins 1984, Perryman and Laycock 2000). Komarek (1964) examined causes of fire north of Douglas, Wyoming in 1960, and reported that for over 120 fires started that year, lightning caused over 3 times the number than human causes, with the vast majority occurring in July and August.

Specific information on the spatial extent of historical fires is not available for most of the Thunder Basin landscape but fires occurring during the growing season are expected to have been limited in spread, whereas fires occurring after the growing season (July-September) likely had the greatest spatial extent. Furthermore, even within fire-maintained landscapes, microhabitats that prevent or slow fire spread existed in some riparian zones, badlands, ravines, and other fire-protected locations (Anderson 1990) such as adjacent to prairie dog colonies. Fire return intervals may have varied widely due to climate, site conditions, or previous grazing disturbance.

For thousands of years, fire events have been an integral part of the grassland ecosystem on the Great Plains (Daubenmire 1968). Grassland species exhibit a number of characteristics making them more suited to a fire-prone landscape, where low humidity, drying winds, and low soil moisture are common (Knight 1994). Fire effects on grassland ecosystems are a function of fire frequency, intensity, and timing, as well as the interaction of these factors with grazing (Engle and Bidwell 2001). Fire can influence grassland vegetation in a number of ways including changes to productivity, composition, and structure (Knight 1994, Engle and Bidwell 2001). Fire also releases important nutrients into the soil for root uptake and releases nutrients bound in litter.

Recent studies have found a link between fire frequency and drought cycles in the northern Great Plains. Drought cycles were found to occur on a consistent basis throughout the last 4,500 years, reoccurring at roughly 160 year intervals (Brown et al. 2005). As conditions become drier, grass cover is reduced until it is almost gone. The reduction in fuel results in a corresponding reduction in fire occurrence. Surface erosion increases with the reduction in grass cover. When moist conditions return, the grasses recover, helping to stem soil erosion and provide fuel for fires (Brown et al. 2005). The fire cycle begins again and contributes to landscape diversity and grass productivity.

In the Thunder Basin region, natural fire events still occur but their frequency and extent have been reduced from what occurred historically (Perryman 1996, Perryman and Laycock 2000). Historical fire return intervals for this area have been reported in a number of studies (Figure 13). Perryman (1996) and Perryman and Laycock (2000) determined a mean fire return interval in the Rochelle Hills of the Thunder Basin through dendrochronology, and found it to average 7.9 years prior to Euro-American settlement. Brown and Hull-Sieg (1999) estimated mean fire return intervals of 10 to 12 years for southwestern South Dakota. Wendtland and Dodd (1990) estimated fire return intervals for mixed grass prairies of 5 years on smooth to rolling terrain of western Nebraska, and longer (15-30 years) on more diverse terrain. Fisher et al. (1987) estimated mean fire return intervals of 14 years for the Devil's Tower National Monument of northeasten Wyoming. Hahn (2003) estimated the mean fire return interval for the northern Great Plains Grassland region, which includes eastern Wyoming, to be 11 years using the results of existing studies. LANDFIRE (www.landfire.gov) modeled fire return intervals based on maps of potential natural vegetation, and displayed mean fire return intervals for the Thunder Basin ranging from 6 years to 25 years for 70% of the planning area and 30% at greater than 25 years (Table 1). This is consistent with the above observation that mean fire return intervals within a landscape may have varied due to climate, site conditions, and grazing disturbance.

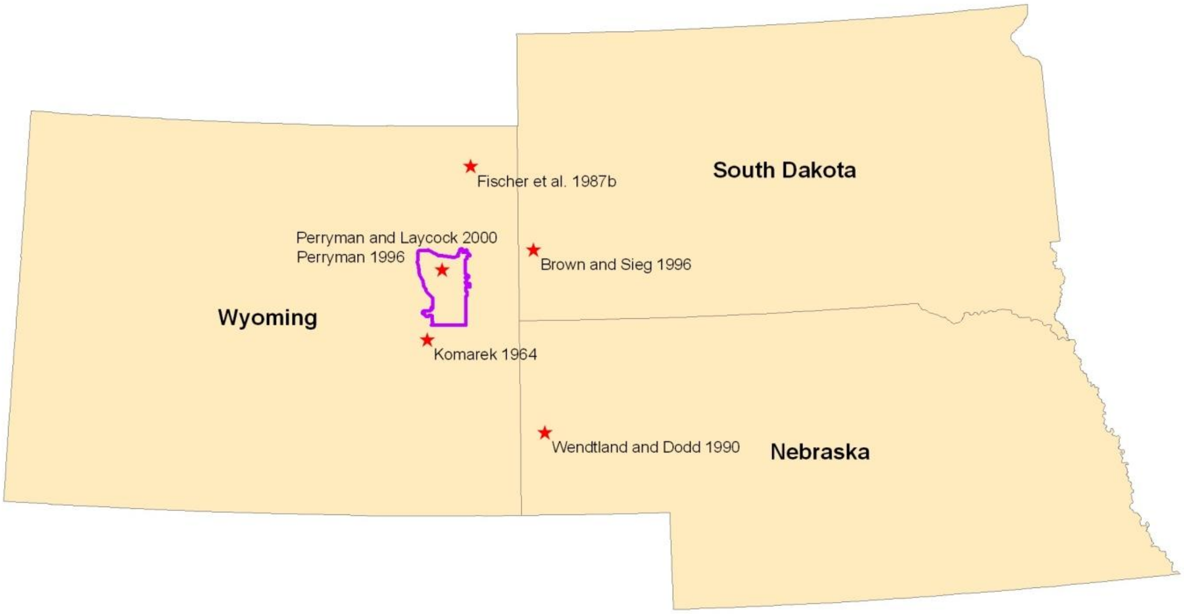

Figure 13. The locations of studies that have described historical fire return intervals in relation to the project area (purple line).

LANDFIRE supporting documentation did note that it is based on coarse scale data and is designed to be used at regional or national scales, and that finer analyses are needed for use at landscape or project level scales.

Table 1. The number of acres for each identified range of mean fire return intervals (MFRI) identified by the LANDFIRE modeling effort (www.landfire.gov) for the Thunder Basin planning region. The "% of the total" indicates the total number of acres representing MFRI less than or greater than 25 years.

MFRI-years	Acres	% of Total
0-5	0	70%
6-10	7	
11-15	111479	
16-20	372997	
21-25	181664	
26-30	84880	30%
31-35	44740	
36-40	25476	
41-45	15517	
46-50	10209	
51-60	12543	
61-70	5996	
71-80	3135	
81-90	2204	
91-100	1233	
101-125	1946	
126-150	806	
151-175	603	
176-200	224	
201-300	269	
301-500	204	
501-1000+	69041	

In the Thunder Basin project area, Perryman (1996) examined sagebrush communities in the planning area, and found that they generally initiated in the mid to late 1900's. He documented a number of years when sagebrush was able to establish a new cohort, but found no sagebrush that originated prior to the 1930's. He reported that the decreased frequency of fires in the Thunder Basin throughout the 1900's has allowed for an increase in the amounts of sagebrush.

The implications of the changes in this natural disturbance process on ecosystem diversity within Thunder Basin is poorly understood and not well documented. However, it is clear that the role of fire in this region has been reduced from what it was historically.

Grazing

Although eastern Wyoming grasslands were grazed by many herbivores, no single species was more influential than bison in shaping grassland ecosystem diversity. Bison were the largest herbivore both in size and numbers prior to Euro-American settlement. Historical population numbers of bison in North America have been estimated at 30 million individuals. However, by 1890, bison were functionally and physically extirpated from eastern Wyoming (Shaw et al. 1995, Shaw 1995, Knapp et al. 1999). Loss of bison from North American grasslands occurred before any meaningful research could be conducted on their foraging habits and movement patterns. Therefore, much of the information available today is extrapolated from ungulate studies of similar grazing systems around the world or from research conducted on the remaining small bison herds that are confined within relatively small portions of a landscape.

South Dakota Dept. Fish and Game

The historical movement pattern of free-ranging bison has been a contentious topic for researchers (Hart and Hart 1997). However, the dominant view is that bison occurred in herds that had two distinct, but not mutually exclusive habits, non-migrant resident herds and migrant herds. Migrant herds of bison are estimated to have outnumbered resident herds by more than four to one (Shaw 1995). Many grazing ecosystems around the world have been and continue to be dominated by migratory herbivores. Migratory grazers track high-quality forage across a large geographic region. Since the nutritional content of plants is highest during the early stages of growth, grazers tend to seek areas where plants are actively growing (McNaughton 1985, Frank et al. 1998). At the landscape level, location and seasonal extent of the nutritional forage is primarily controlled by annual climate variability. Grazing is often intense in the path of a herd but usually does not last long because the animals are continually moving. The time a bison herd would remain in an area was dependent on the availability of high-quality forage and the proximity of water. This long evolutionary history between grasslands and migratory grazers has resulted in an interdependent web of energy and nutrient flows (Albertson et al. 1957).

The intensity of grazing by bison was further influenced by juxtaposition to water sources and recent fire events. Bison, like most herbivores, require a regular supply of water. Sites surrounding rivers, lakes, and ponds typically receive a disproportionate amount of heavy grazing due to the congregating herd of animals. In contrast, sites farthest from water sources typically receive the lower levels of grazing (Soper 1941). Many researchers have also found that a recently burned site will attract bison (Bamforth 1987, Coppedge and Shaw 1998, Frank 1998, Frank et al. 1998, Biondini et al. 1999). The release of nutrients to the soil and the corresponding rapid new growth results in high-quality forage for several seasons following a fire event. At the landscape level, historical fire and grazing disturbance regimes interacted to provide a mosaic of structural and successional conditions across grassland ecosystems. Fire and bison grazing interacted because recently burned sites attracted bison grazing, and subsequently the amount of forage removed from a site and its distribution in the landscape determined the probability and intensity of the next fire event (Fuhlendorf and Engle 2001). Thus, the combination of fire and grazing yielded the dynamic habitat mosaic and landscape heterogeneity to which prairie wildlife species were well adapted.

Knight (1994) also noted the effects of grasshoppers on grasslands in Wyoming. Historical reports document periodic outbreaks of grasshoppers, particularly during drought years. During these outbreaks, grasshoppers could consume or clip very high percentages of the vegetation.

Black-tailed Prairie Dogs

Prior to Euro-American settlement, black-tailed prairie dogs occurred throughout eastern Wyoming (Wuerthner 1997, Fuhlendorf and Engle 2001;2004). Although there is some disagreement regarding their historical range and distribution (Knowles et al. 2002, Virchow and Hygnstrom 2002, Vermeire et al. 2004) and their current population status (Luce 2003), it is accepted that the black-tailed prairie dog has experienced a dramatic decline over the past 100 years (Mulhern and Knowles 1995). Black-tailed prairie dogs are considered a natural disturbance component in Wyoming due to the effect of their colonies on grassland ecosystems. Prairie dogs alter prairie ecosystems by creating above and below ground disturbances that produce large and unique habitat patches and thereby alter the structural and functional properties of grassland ecosystems (Whicker and Detling 1988). They may also alter natural disturbance processes such as wildfire dynamics. Because prairie dog disturbance is unique and disproportionately large relative to their abundance, prairie dogs are generally considered to be a “keystone species” (Miller et al. 1994, Kotliar et al. 1999, Kotliar 2000).

Much of the current research on prairie dogs is limited to the study of artifact colonies which are generally fragmented, significantly smaller, and highly influenced by human activity compared to historical populations (Miller et al. 1994). For these reasons, it is doubtful that the historical role of prairie dogs in grassland ecosystems will ever be fully understood. However, regardless of the ecological role of prairie dogs prior to Euro-American settlement, it remains clear that prairie dogs have and continue to exert profound influences on grassland ecosystems (Kotliar et al. 1999) including influences on vegetation, soils, and wildlife.

Prairie dogs construct ground burrows for their shelter and protection from predators. As many as 30 to 60 occupied and unoccupied burrows could occur in one acre of prairie dog colony (Clippinger 1989, May 2001). Prairie dogs are primarily herbivores and feed on grasses and forbs surrounding their burrows (Clippinger 1989). The clipping and foraging activities of prairie dogs keeps plants on colony sites in a homogenized state with vegetation appearing small statured and dwarfed (Krueger 1986). As a result, prairie dog colonies appear distinct from surrounding grassland and they tend to be composed of species that are more resistant to repeated heavy grazing (Bonham and Lerwick 1976, Whicker and Detling 1993). Prairie dog herbivory changes the overall species composition, nutrient content, biomass, and canopy height of an area (Coppock et al. 1983). Prairie dogs also influence nutrient cycling and trophic dynamics in grassland ecosystems (Coppock et al. 1983, Whicker and Detling 1988).

Prairie dogs exert influence on the amount of above-ground and below-ground biomass and the nutrient cycling patterns below the soil surface (Ingham and Detling 1984). Plant communities subjected to intensive grazing (such as that of prairie dogs) demonstrate reduced overall standing biomass and develop shorter and less extensive root systems (Schuster 1964, Ingham and Detling 1984). Prairie dogs influence below ground nutrient dynamics (Archer and Detling 1986, Carlson and White 1987), soil structure and composition (Koford 1958, Whicker and Detling 1993), and the rates of weathering (Costello 1970). However, the extent to which these influences are observed on any specific colony will depend on site specific variables such as the type of grassland, local environmental factors, the age of the colony, and population density. Prairie dog colonies have also been found to be preferentially grazed by other herbivores including bison (Whicker and Detling 1988). An increase in forage nutritional quality and digestibility has been observed on colony sites when compared to uncolonized sites (O'Meilia et al. 1982, Coppock et al. 1983, Krueger 1986), although the role of fire in influencing forage nutritional quality was not factored into these comparisons.

Prairie dog ecosystems are frequently characterized as active or inactive. While fewer wildlife species may be associated with inactive prairie dog colonies, an inactive colony has important structural and compositional differences from active prairie dog colonies for many years after abandonment. The slowly collapsing burrows continue to provide habitat for various wildlife species. In addition, plant species composition and the percentage of forbs species increases on abandoned colonies relative to active colonies and are often different than the surrounding grassland ecosystem as well (Koford 1958). The length of time a prairie dog colony can influence the vegetation and habitat structure of a grassland ecosystem after abandonment can be variable by ecological site and length of colony establishment.

Historical Evidence

Various sources of information, including early explorers, fur trappers, and settlers accounts, historical photographs and paintings, natural resource expeditions, and presettlement land survey records have been used to describe the native vegetation of the United States before settlement impacts occurred (Egan and Howell 2001). All of these sources of early information were also reviewed and evaluated for use in this assessment. The following sections summarize the results of this review.

Natural Resource Expeditions

There are very few detailed descriptions of the vegetation of central, eastern Wyoming prior to Euro-American settlement. Most of the early accounts provide very general descriptions that have been documented by explorers, expeditions, and settlers traveling west near or through the planning region. The North Platte River flows generally east to west and lies roughly 15 miles south and southwest of the project area. The account of Freemont (1845) refers repeatedly to “the great expanse of short grasses” as he travelled up the North Platte.

Sagebrush was first mentioned when the party turned at the Laramie River and traveled west to southwest along the base of the Laramie foothills (Fremont 1845).

Two important scientific expeditions passed through the planning area in the 1850's. The first occurred in 1856 under the command of Topographical Corps Lieutenant Governor Kemble Warren. The second occurred in 1859 under William F. Raynolds. Raynolds (Raynolds 1868) recorded notes for each day of his expedition. The following are the notes that described the approximate location and references to vegetation that he observed in the planning area:

October 26, 1859 (Traveled and camped along northern boundary of the planning area and heading east along Little Thunder Creek)

> *I camped just above the opening in the ridge, where the timber commenced, in a barren little valley covered with sage and with poor grass…..The ridges around are sprinkled with pine. In many places the hills are denuded of vegetation, and the black, "bad land" soil presents a very barren appearance.*
>
> *As we proceeded the timber increased in size and quantity; the valley was covered with sage, greasewood, and cactus, crossed by narrow deep gullies that run out from the piney ridge. After passing through the narrow opening left by these ridges, the country was more rolling and the hills were covered with grass. Several drains empty into the creek, some of which are thickly timbered…I camped in a bend in a thick grove of cottonwood trees. The bed of the creek (northern branch of the south fork of the Cheyenne) here is 20 yards wide; grass not very good.*

October 27, 1859 (Starting from approximately 1.5 miles east of the planning area boundary along Black Thunder Creek and traveling east)

> *The country passed over was more open and rolling….The creek bottom is heavily timbered with large cottonwood, and a great deal of dead timber lies scattered aobut. The bottom is sandy, covered with good grass all around.*

October 28, 1859 (Starting from approximately 2 miles east of the planning area boundary on the Cheyenne River and heading southwest)

> *Leaving the valley, in a short distance I passed over a low point of hills coming in two and a half miles to the main south fork (of the Cheyenne)….the banks are fringed with willow and young cottonwood. I travelled down through a well-wooded bottom, the trees growing over sand ridges….Our camp was surrounded by a dense thicket of young cottonwood…..good grass covers the bottom and neighboring hills.*

October 29, 1859 (Starting from the east-central portion of the planning area and heading south)

> *The ridge….is covered to some extent with pine. Descending from the divide over a sandy slope, thence across a sage plain, I camped on the tributary. This creek is fringed with large cottonwood, and has good water in holes, with a deep narrow bed; greasewood and sage covers the bottom; grass good and abundant.*

October 30, 1859 (travelling in a south to southeasterly direction through the southeastern portion of the planning area and beyond the planning areas southern boundary)

> *I crossed a dry bed of a small creek which rises in the ridge on the left, thence over a low sandy spur, where a few pines grew, and many stumps and dead trees showed that a good deal of timber had been destroyed either by the fires or atmospheric agencies…From this place I could see a very broken country ahead…..Leaving the ridge, over some very rough and bad lands, we crossed two well-wooded branches near their junction with each other; both were dry, with high steep banks; the valleys barren and filled with greasewood, and enclosed by broken "bad land" spurs. Crossing a ridge I camped on another of these branches; here we found good water in the shallow; timber sufficient for camping purposes, and grass good, but not abundant.*

An early 1900's vegetation mapping effort for the entire Great Plains (Shantz 1923) identified the Thunder Basin planning area as belonging to the "Grama-grass Association" (Figure 14). The description of this Association, as presented by Shantz, is provided as follows (today's common names are included in parenthesis for reference):

> ***Grama-grass association** – the dominant plant in this association is (blue) grama grass (Bouteloua gracilis). With this there are also found in many places Carex filifolia (threadleaf sedge), C. stenophylla (needleleaf sedge), Koeleria cristata (june grass), and a wide range of herbaceous plants, such as Artemisia frigida (fringed sagebrush) and phlox hoodii (spiny phlox). In general appearance it is typical short-grass land.*

The map also identifies several sagebrush associations that occur west (i.e., Sagebrush and western-wheatgrass associes) and southwest (i.e., Grama-grass and mountain-sage associes) of the planning area. Shantz describes these as follows:

> ***Grama-grass and mountain-sage associes** – Along the mountain front (blue) grama grass is often mixed with a great variety of plants which are more typical of the mountain grasslands. Among these may be mentioned Artemisia frigida (fringed sagebrush), Carex filifolia (threadleaf sedge), Achillea millefolium (common yarrow), Eriogonums of various species, penstemons, wild roses, and lupines. These characterize an area in which the rainfall is greater than that of the adjacent grama-grass land.*
>
> ***Sagebrush and western-wheatgrass associes** – Where the short grasses drop out and the wheat–grass remains or is mixed with sagebrush, the soil is a heavy impermeable clay. There is alkali present in places but such areas are usually free from sagebrush which is replaced by saltbush. No continuous grass cover is formed on the breaks and clay flats.*

Shantz also goes on to say:

> *The true sagebrush desert is not represented in the area here considered (Great Plains, in general). There are, however, intrusions of the desert type on some of the poorer land of the northwest (plains). These areas are largely the result of poor or alkali soils and more extreme climatic conditions. The most extensive areas occur on the heavy clay soils of Montana and Wyoming. Where the short grasses drop out and the wheat-grass remains or is mixed with sagebrush, the soil is a heavy impermeable clay. There is alkali present in places but such areas are usually free from sagebrush which is replaced by saltbush. No continuous grass cover is formed on the breaks and clay flats.*

The implication of Shantz's mapping effort is that the "Grama-grass associes" was the predominant vegetation association occurring in the Thunder Basin planning area at the time the map was produced. According to Shantz's descriptions and mapping, sagebrush dominated or co-dominated communities appear to have been less common and primarily associated with sites or conditions that would not carry a fire in the understory vegetation. Vegetation reported by Shantz would have been influenced by the use of these areas by livestock over the previous 45 years, as discussed previously in the land use history section of this document. Knight (1994) discussed that herds of livestock were widespread in the western states by 1890. He reported from a New York Times article that 125,000 head of cattle had been on the range between the North Platte and Powder Rivers, west of Fort Laramie, causing much of the land to be devoid of grass.

Historical Photographs

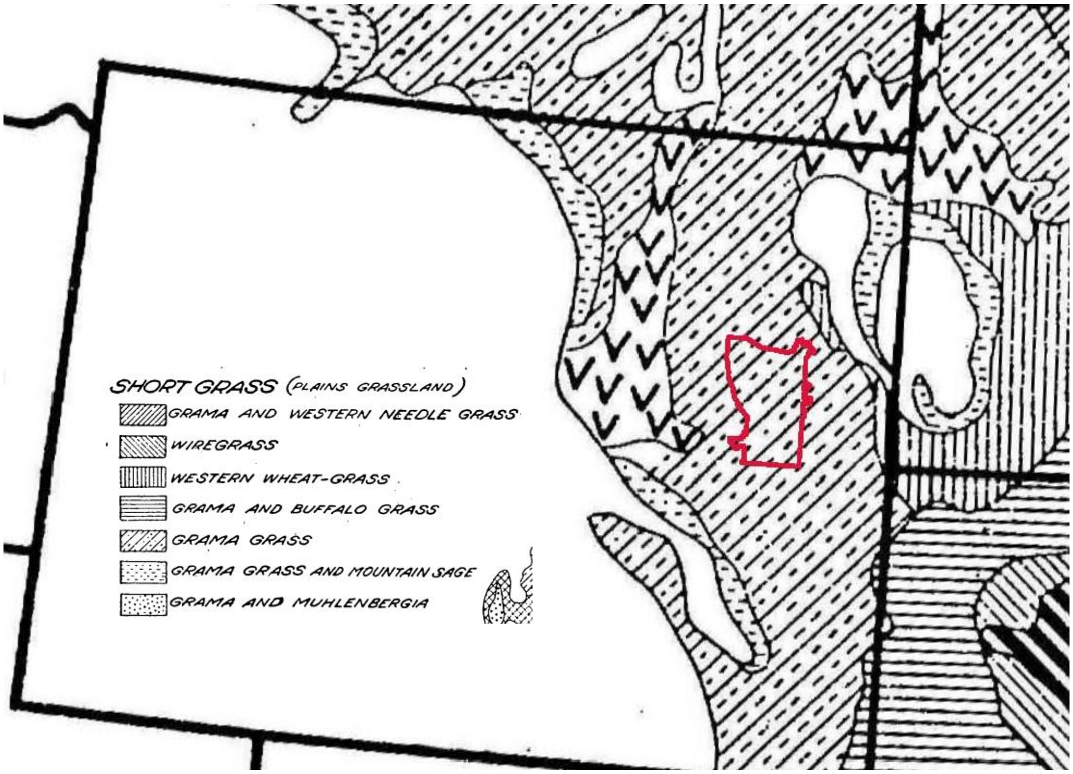

Figure 14. An historical snapshot of the natural vegetation of Wyoming, from Shantz (1923). The Thunder Basin planning area is highlighted in red.

Johnson (1987) reconstructed the views contained within old photographs of the 1870 Hayden Expedition, portions of which were located just southwest of the project area along the North Platte River, and compared them to vegetation conditions occurring on the same locations today. The site of a repeat photograph closest to the project area is located approximately 11 miles southwest of the planning area. Johnson's comparison of the two photos indicated that the more recent photo demonstrates "an apprarent increase of big sagebrush", "blue grama and threadleaf sedge in very low production", "a striking absence of forbs", and "an increase of woody vegetation along the North Platte River".

Presettlement Land Survey Records

Presettlement Land Survey Records (PLSRs) were collected in the Thunder Basin region during the early to mid-1880s. PLSR data were collected and conducted by the General Land Office to inventory land quality and to establish landmarks for land sale and settlement purposes (Wang 2005). Surveys were conducted in Wyoming using the Public Land Survey methodology (i.e., Township, Range, and Section) that is still in use today. These early surveyors erected posts or landmarks, or marked trees where available, at the intersection of section lines (section corners), the midpoint between section corners (quarter corners), and where section lines crossed navigable rivers or lakes.

One of the inventory conditions noted during these surveys were general vegetation descriptions of the area surrounding an erected post or landmark. For this reason, studies across the country have attempted to use PLSR data to describe presettlement vegetation conditions and compare them to existing vegetation conditions. However, because the data were not collected for ecological purposes, they must be used with caution and careful review of limitations (Wang 2005). PLSR data collected in the Thunder Basin region have identified very broad categories of vegetation descriptions (Table 2).

Two primary concerns occur with the PLSR data collected in the Thunder Basin region for comparison with existing conditions. These include:

1) Overly generalized vegetation descriptions, and
2) Possible surveyor bias for vegetation descriptions

Of particular concern, the amount of sagebrush described was clearly correlated to individual surveyors. Of the six surveyors, several surveyors almost always noted sagebrush and other surveyors almost never noted sagebrush; even when overlapping in survey areas, suggesting the lack of a consistent system for identifying the dominant or co-dominant vegetation. This surveyor bias makes the applicability of the PLSR results somewhat limited for direct comparison to existing conditions, particularly for comparing the historical amounts of sagebrush to the amount of sagebrush present today. In addition, sagebrush may be over emphasized in general vegetation descriptions because it is easy to identify and tends to stand out when found in association with grasses and forbs.

Several general conditions were identifiable from the PLSR data. First, bunchgrasses and buffalo grass were common in the planning landscape. Sagebrush did occur within the Thunder Basin landscape in the 1880's but the extent of sagebrush dominance or co-dominance to bunchgrasses and buffalograss is not possible to discern from the descriptions provided. The vegetation descriptions and the number of times they were noted at a marker are provided in Table 2.

Table 2. Vegetation descriptions and the number of times they are listed at a marker are summarized for the Public Land Survey Record data occurring in the planning area.

Vegetation Description	# of corner sections
Buffalo grass	57
Buffalo grass and sagegrush	18
Bunchgrasses	560
Bunchgrasses and buffalograss	1
Bunchgrasses and cactus	11
Bunchgrasses and sagebrush	225
Bunchgrasses, cactus, and sagebrush	21
Sagebrush	98
Sagebrush and buffalograss	29
Sagebrush and bunchgrasses	475

NATIVE TERRESTRIAL ECOSYSTEM DIVERSITY

Terrestrial ecosystems of the Thunder Basin region, as stated previously, are the combination of communities of living organisms with the physical environment in which they live. To characterize native ecosystem diversity for this assessment, we used a combination of two primary drivers of ecosystem diversity: ecological sites and disturbance states. Ecological sites represent the physical environment component of an ecosystem and disturbance states represent the vegetation communities that can occur on an ecological site in response to natural disturbance regimes. The following sections describe the native terrestrial ecosystem diversity that occurred within the Thunder Basin region relative to these two primary drivers, disturbance states and ecological sites.

Disturbance States

Although ecological sites provide valuable information on the physical environment of terrestrial ecosystems, they do not identify the full range of successional conditions, or disturbance states, possible on a site as a result of natural disturbance events and processes. Thus, prairie dogs, fire, large herbivore grazing (i.e., bison), and their interactions, were included as the primary disturbance mechanisms that historically influenced terrestrial ecosystems of eastern Wyoming (Figure 15). Climate cycles such as drought are an important stochastic process that should also be evaluated and considered in discussions of disturbance states and overall planning. The natural fire regime was characterized for this area by using information developed for the fire regime condition class Interagency Handbook Reference Conditions (Hahn 2003) as well as supplemental literature (Wright and Bailey 1980;1982, Fisher et al. 1987, Wendtland and Dodd 1990, Brown and Hull Sieg 1996, Perryman 1996, Brown 1999, Perryman and Laycock 2000). Bison grazing disturbance was divided into three levels of influence; light, moderate, and heavy grazing. Fire and grazing disturbance transitions for each ecological site were developed using the best available information on ecosystem and plant species response to these disturbance events. Prairie dog colony disturbance is characterized using two categories: active colony and inactive colony. Active colonies are identified by the presence of prairie dogs and inactive colonies are identified by the presence of burrows that are still functional as habitat for other species (i.e., they have not collapsed). Additional information on disturbance states are provided in the following discussion of native ecosystem diversity and each terrestrial ecological site identified for the Thunder Basin planning area.

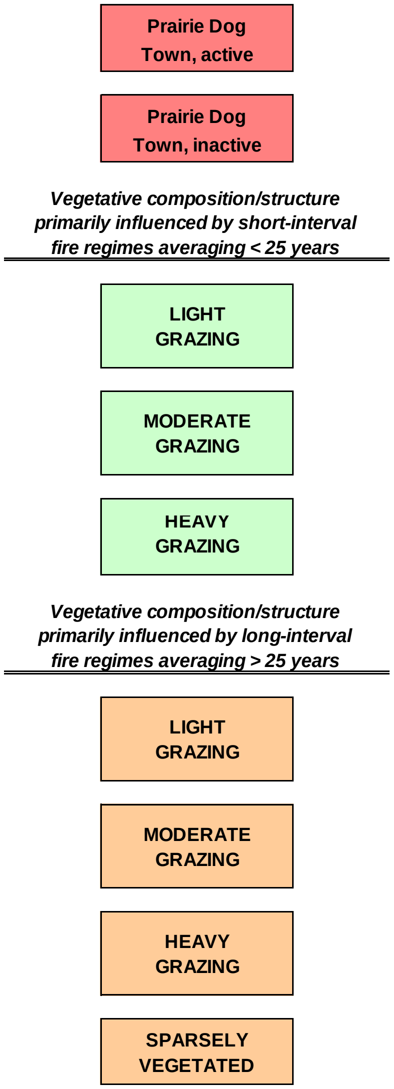

Figure 15. Disturbance states identified for terrestrial ecosystems of the Thunder Basin planning area, as influenced by natural disturbance regimes of fire, bison grazing and prairie dog colonies.

Ecological Sites

Ecological sites are a type of landscape classification system that identifies the different abiotic conditions (e.g., climate, soils, aspect, elevation, moisture, etc.) that influence disturbance patterns and plant communities that can occur on a site. There are two primary ecological site classifications in use within the Western United States today, by land management agencies. These include:

1) Ecological Sites – developed by the Natural Resource Conservation Service (Natural Resource Conservation Service 2003), and
2) Habitat Types – originally developed by Daubenmire (1968) but later adopted and expanded by the U.S. Forest Service.

Both of these site classification systems offer advantages for their use in different planning areas and have applicability to the ecosystem diversity framework under certain conditions. The Habitat Type classification has been found to be very useful for western forested ecosystems where elevation, slope, aspect, and moisture gradients greatly influence site potential. Most of these forested regions have wide ranges in temperatures, rainfall, snow, and other factors, and have not generally been mapped for soils. The NRCS ecological site classification is correlated to existing soil maps. Soils alone are not sufficient to capture different ecological sites under topographically diverse conditions. However, in grassland dominated landscapes where elevation, slope, and aspect are less influential, the NRCS ecological site classification works well to delineate differences in ecological sites and descriptions developed for ecological sites has included useful information relative to disturbance states as influenced by historical disturbance processes. The Thunder Basin planning area is a grassland and shrub-dominated landscape with relatively low topographic diversity. For this reason, NRCS's ecological site classification was selected for the ecological site component of the ecosystem diversity framework.

While the NRCS ecological site classification is suitable for the objectives of the ecosystem diversity framework in the Thunder Basin planning area, some limitations should be noted. A primary limitation is the fact that current soil mapping methodologies are often based on groupings of similar soils and may include inclusions of other soil types that may in fact represent another ecological site, within a larger soil type. As with most classification systems, the issue of mapping resolution is a common theme. While soil mapping is often finer resolution data than most existing vegetation classification systems, it still may represent less diverse conditions than actually occur on the landscape. Ecological sites as mapped for the planning area, and their associated acres, are presented in Figure 16.

The following sections provide more detailed information on the 10 terrestrial ecological sites occurring in the Thunder Basin planning area and their associated disturbance states, as influenced by natural disturbance regimes. While much of this information has been gathered from NRCS ecological site descriptions, additional information was developed and acquired to augment this information for the purpose of describing native ecosystem diversity. Ecological site descriptions provide valuable information on abiotic conditions and they provide information on some of the potential states that could occur on each site. This information was further developed to describe the primary historical states relative to natural disturbance regimes. As discussed previously, fire, large herbivore grazing (i.e., bison), and prairie dog colonies were the primary disturbance mechanisms that historically operated in grass and shrub ecosystems of eastern Wyoming. Fire, grazing, and prairie dog colony disturbance transitions for each

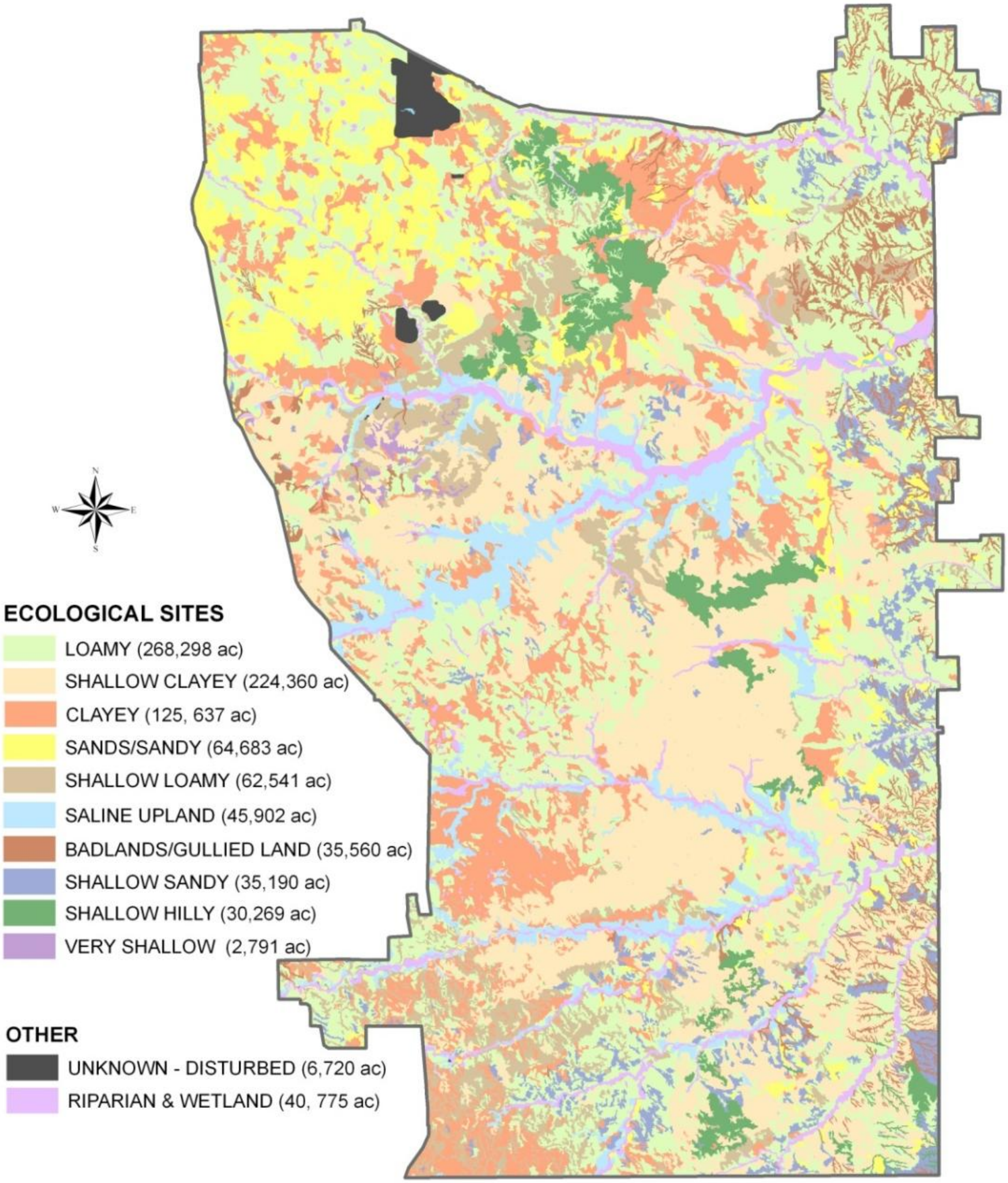

Figure 16. Ecological sites and their associated acres occurring within the Thunder Basin planning area (as modified/grouped from existing NRCS ecological sites).

ecological site were developed using the best available information on ecosystem and plant species response. For example, canopy cover of plant species that typically increase or decrease with different levels of grazing pressure were used as indicators of historical states driven by different grazing regimes. Plant species likely to occur on a particular ecological site and how those species typically respond to grazing were developed from existing NRCS ecological site descriptions, or developed from a team of range ecologists knowledgeable of the plant dynamics of the area. Plant dynamics and rates of change for each plant species included as indicators of either fire return interval or grazing level were based on input from the team of rangeland ecologists or developed from species information available in existing scientific literature.

Clayey Ecological Sites

Clayey ecological sites occupy approximately 14% of the terrestrial ecological sites in the Thunder Basin planning area. Soils on these sites were derived from shale and are characterized as well drained with moderate to slow permeability. They are also moderately deep at greater than 20” to bedrock. These sites are frequently associated with alluvial fans, stream terraces, and hill sides where slopes are less than 30%. Clayey ecological sites are moderately to highly productive in the planning area with an average annual productivity range of 600 to 1400 lbs. per acre, depending on the current disturbance state and the amount of precipitation received during the year.

Native ecosystem diversity on clayey ecological sites was influenced by natural disturbance regimes of fire, grazing, and prairie dogs. Grazing played an important role in influencing the species composition of ecosystems on this ecological site. Plant species that respond as decreasers with increasing grazing pressure on clayey sites include green needlegrass and bluebunch wheatgrass. Species like western wheatgrass, thickspike wheatgrass, and winterfat may initially respond as increasers, however, they decrease as grazing pressure becomes more intense. Species that commonly increase as grazing becomes heavy include blue grama, hairy grama, prairie junegrass, birdfoot sage, Sandberg bluegrass, plains pricklypear, and greasewood. The frequent fire return interval historically occurring across this ecological site also played an important role in shaping the structure and species composition of the native ecosystems. In general, grass species were the dominant component and shrubs were a more

Examples of clayey ecological sites and two different disturbance states.

minor component on these sites due to the influence of fire. Areas that were protected from fire likely experienced an increase in Wyoming big sagebrush and silver sagebrush. Clayey ecological sites are considered suitable habitat for prairie dog colonies, with preference given to those sites exhibiting relatively level conditions and with water sources nearby.

Figure 17 demonstrates the clayey ecological site state and transition model for different disturbance states within the Thunder Basin planning area, as influenced by natural disturbance regimes of fire, bison grazing, and prairie dog colonies. The combined total of all of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on clayey ecological sites. The plant species identified in each box or disturbance state, indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x clayey ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species and their associated animal species. The following descriptions provide additional information on each disturbance state identified in Figure 17 and are referenced to the letter code in the upper left corner of each box in Figure 17.

- ### A. Short Fire Return Interval x Light Grazing Regime

Fire Return Interval: less than 25 years, averaging 5-15 years; this disturbance state exhibits heavier grass cover that will support larger, more intense fires
Grazing: intermittent with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: green needlegrass, western wheatgrass, thickspike wheatgrass, Cusick’s bluegrass, prairie coneflower, prairie clover, and American vetch
Other Characteristic Species: Sandberg bluegrass, hawksbeard
Historical Grass and Forb Productivity Estimate: 1,000 lbs/acre
Structure: mixed grasses, 5-8” vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: sagebrush<10%
Light grazing indicators: green needlegrass>20% and blue grama<30%

- ### B. Short Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: less than 25 years, averaging 5-15 years; this disturbance state exhibits moderate grass cover that will support moderately intense fires
Grazing: variable, but occurring most years at moderate levels
Dominant Species: western wheatgrass, thickspike wheatgrass, Sandberg bluegrass, blue grama, and prairie junegrass
Other Characteristic Species: green needlegrass, plains pricklypear, prairie clover, prairie coneflower, western yarrow, needleleaf sedge, plains reedgrass, and prairie sagewort
Historical Grass and Forb Productivity Estimate: 850 lbs/acre
Structure: mixed grasses, 4-6“ vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short fire return interval = sagebrush<10%
Moderate grazing = green needlegrass<20% and blue grama<30%

C. Short Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: less than 25 years, average 10 to 20 years; this disturbance state exhibits lower fuel levels due to heavier grazing, resulting in less intense fires and more of a mosaic of burned and unburned areas, than in other short-interval fire regimes
Grazing: occurring most years as season long grazing; used more frequently possibly due to location factor such as close proximity to water sources for grazers
Dominant Species: blue grama, plains pricklypear, prairie junegrass, western wheatgrass, thickspike wheatgrass, western yarrow, pussytoes, needleleaf sedge, prairie sagewort
Other Characteristic Species: plains reedgrass, goldenweed, textile onion, scarlet gaura, white sagebrush scurfpea
Historical Grass and Forb Productivity Estimate: 500 lbs/acre
Structure: mixed grasses, 3-5” in height
Primary indicators of natural disturbance regimes (% cover):
Short fire return interval = sagebrush<10%
Heavy grazing = green needlegrass<20% and blue grama>30%

D. Long Fire Return Interval x Light Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: generally light and variable, with considerable rest between significant use; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: big sagebrush green needlegrass, western wheatgrass, thickspike wheatgrass, Cusick’s bluegrass, prairie coneflower, prairie clover, and American vetch
Other Characteristic Species: Sandberg bluegrass, hawksbeard
Historical Grass and Forb Productivity Estimate: 900 lbs/acre
Structure: mixed grass with shrubs, herbaceous vegetation 5-8” in height, shrubs up to 3’ in height
Primary indicators of natural disturbance regimes (% cover):
Long fire return interval = sagebrush>10%
Light grazing = green needlegrass>20% and blue grama<30%

E. Long Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: variable, but occurring most years at moderate levels
Dominant Species: big sagebrush, western wheatgrass, thickspike wheatgrass, Sandberg bluegrass, blue grama, and prairie junegrass
Other Characteristic Species: green needlegrass, plains pricklypear, prairie clover, prairie coneflower, western yarrow, needleleaf sedge, plains reedgrass, and prairie sagewort
Historical Grass and Forb Productivity Estimate: 750 lbs/acre
Structure: mixed grass with shrubs; herbaceous vegetation 4-6” in height; shrubs up to 3’ in height
Primary indicators of natural disturbance regimes (% cover):
Long fire return interval = sagebrush>10%
Moderate grazing = green needlegrass<20% and blue grama<30%

Clayey Ecological Site Native Ecosystem Diversity State and Transition Model

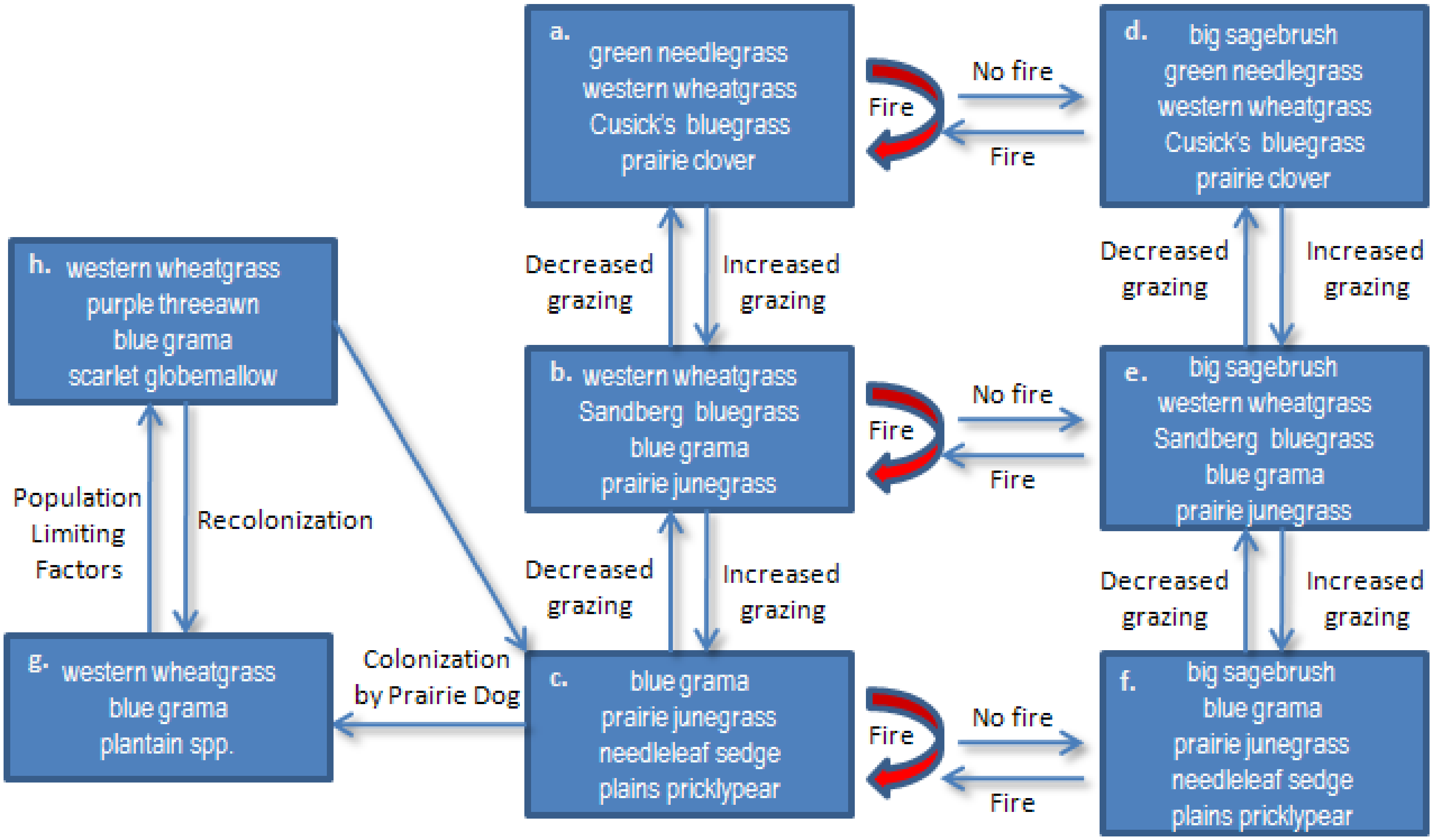

Figure 17. State and transition model for clayey ecological sites of the Thunder Basin planning area, identifying the disturbance states or range of native ecosystem diversity resulting from natural disturbance regimes.

F. Long Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: occurring most years as season long grazing; used more frequently possibly due to location factor such as close proximity to water sources for grazers
Dominant Species: big sagebrush, blue grama, plains pricklypear, prairie junegrass, western wheatgrass, thickspike wheatgrass, western yarrow, pussytoes, needleleaf sedge, prairie sagewort
Other Characteristic Species: plains reedgrass, goldenweed, textile onion, scarlet gaura, white sagebrush, and scurfpea
Historical Grass and Forb Productivity Estimate: 450 lbs/acre
Structure: mixed grass with shrubs; herbaceous vegetation 3-5" in height; shrubs 2.5' in height.
Primary indicators of natural disturbance regimes (% cover):
Long fire return interval = sagebrush>10%
Heavy grazing = green needlegrass<20% and blue grama>30%

G. Prairie Dog Colony, Active Regime

Fire was infrequent on prairie dog colonies because of discontinuous fine fuel resulting from soil disturbance and prairie dog herbivory. Selective grazing by bison and pronghorn antelope also occurred, however the plant community dynamics were driven primarily by the prairie dog activities. Vegetation on active prairie dog colonies and to lesser extent in-active colonies exhibited a dwarfed or stunted growth pattern, due to repeated clipping. Characteristic species that occur on prairie dog colonies include western wheatgrass, blue grama, purple threeawn, scarlet globemallow, plantain spp., common yarrow, needleleaf sedge, and plains pricklypear. Plant community composition on active prairie dog colonies was driven by factors that included colony density and age.

H. Prairie Dog Colony, In-active Regime

Prairie dog colonies are considered inactive as long as they are not currently used by prairie dogs, and they still provide the burrow structure characteristic of prairie dog communities, that other wildlife species are dependent upon. Field observations in the Thunder Basin planning area indicate that after approximately 7 years of non-use, most prairie dog burrows have collapsed and no longer serve the role as an inactive prairie dog colony. Plant community composition on inactive prairie dog colonies was driven by previous levels of disturbance by prairie dogs and length of time since abandonment. Colonies that previously had higher levels of disturbance were in early successional stages and took considerable time to recover to pre-disturbance conditions.

Shallow Clayey Ecological Sites

Shallow clayey ecological sites occupy approximately 25% of the terrestrial ecological sites in the Thunder Basin planning area. Soils on these sites were derived from shale and are characterized as well drained soils with moderate to slow permeability. These sites are frequently associated with ridge tops and hillsides where slopes are less than 60%. Shallow clayey ecological sites are moderately productive in the planning area with an average annual productivity range of 450 to 1000 lbs. per acre, depending on the current disturbance state and the amount of precipitation received during the year.

The primary landscape feature that differentiates shallow clayey ecological sites from clayey ecological sites is the depth to bedrock, which has an influence on plant productivity and structure. Shallow clayey sites have less than 20 inches of soil before reaching bedrock, whereas clayey ecological sites have greater than 20 inches, therefore productivity and plant vigor is generally higher on clayey sites. The bedrock on these sites is virtually impenetrable to plant roots. These site differences are generally visible when comparing the general density, height and stature of plant species like big sagebrush, which reaches greater densities, heights and statures on clayey sites relative to shallow clayey sites.

Native ecosystem diversity on shallow clayey ecological sites was influenced by natural disturbance regimes of fire and grazing. Prairie dogs do not prefer these sites for burrowing due to the shallow soil depths. Grazing played an important role in influencing the species composition of ecosystems on this ecological site. Plant species that respond as decreasers with increasing grazing pressure on shallow clayey sites include green needlegrass and bluebunch wheatgrass. Species like western wheatgrass, thickspike wheatgrass, and winterfat may initially respond as increasers, however, they decrease as grazing pressure becomes more intense. Species that commonly increase as grazing becomes heavy include blue grama, hairy grama, prairie junegrass, birdfoot sage, Sandberg bluegrass, plains pricklypear, and greasewood. The frequent fire return interval played an important role in shaping the structure and species composition of native ecosystems on shallow clayey ecological sites. In general, grass species were the dominant component and shrubs were a relatively minor component on these sites due to frequent fires. Areas that were protected from fire likely experienced an increase in Wyoming big sagebrush and silver sagebrush.

Examples of shallow clayey ecological sites and two different disturbance states.

Figure 18 demonstrates the shallow clayey ecological site state and transition model for different disturbance states within the Thunder Basin planning area, as influenced by natural disturbance regimes of fire and grazing. The combined total of all of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on shallow clayey ecological sites. The plant species identified in each box or disturbance state, indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x shallow clayey ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species and their associated animal species. The following descriptions provide additional information on each disturbance state identified in Figure 18 and are referenced to the letter code in the upper left corner of each box in Figure 18

- A. Short Fire Return Interval x Light Grazing Regime

Fire Return Interval: less than 25 years, averaging 5-15 years; this disturbance state exhibits heavier grass cover that will support larger, more intense fires
Grazing: intermittent with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: bluebunch wheatgrass, green needlegrass, western wheatgrass, thickspike wheatgrass, Cusick's bluegrass, prairie coneflower, prairie clover, and American vetch
Other Characteristic Species: Sandberg bluegrass, blue grama, hawksbeard
Historical Grass and Forb Productivity Estimate: 725 lbs/acre
Structure: mixed grasses, 5-7" in height
Primary indicators of natural disturbance regimes (% cover):
Short fire return interval = sagebrush<10%
Light grazing = green needlegrass>20% and blue grama<30%

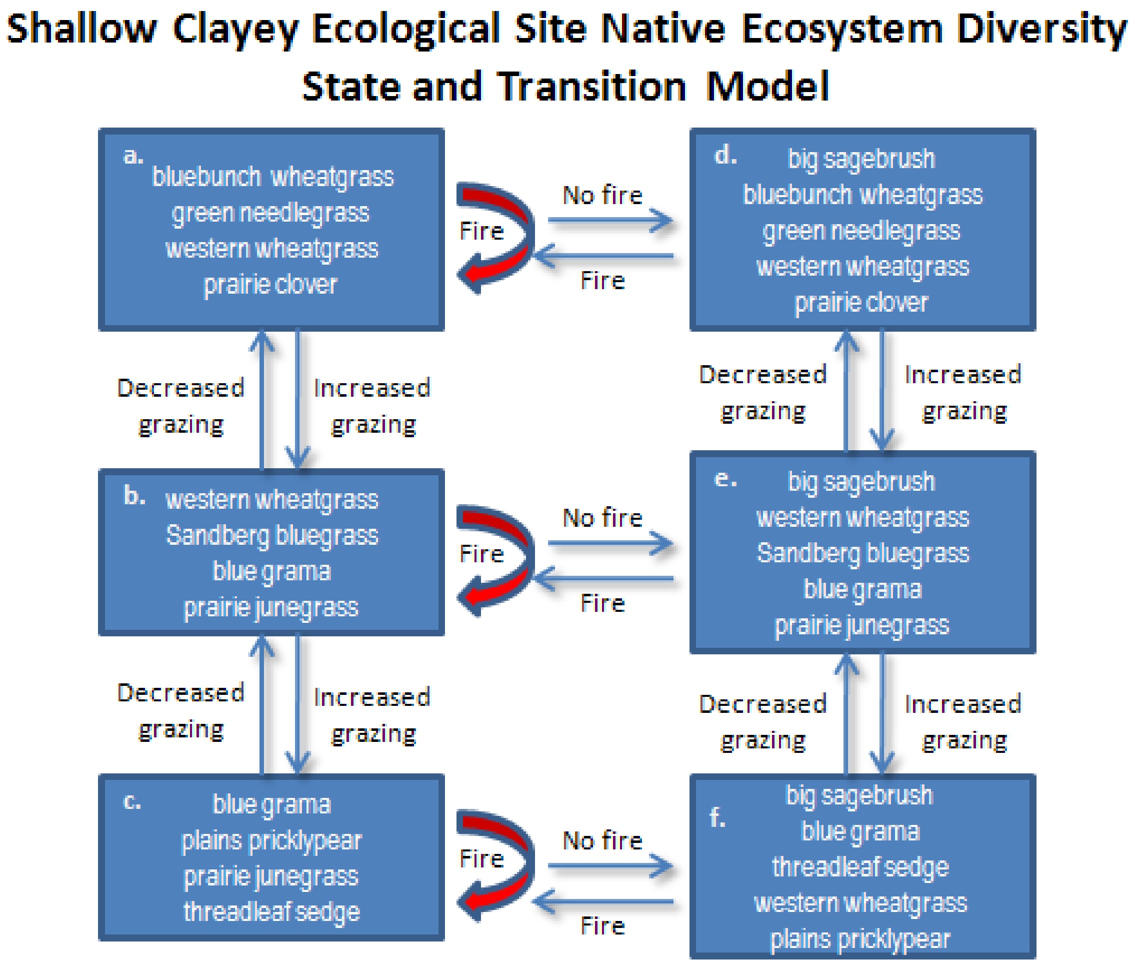

Figure 18. State and transition model for shallow clayey ecological sites of the Thunder Basin planning area, identifying the range of historical disturbance states or native ecosystem diversity, resulting from natural disturbance regimes.

- ### B. Short Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: less than 25 years, averaging 5-15 years; this disturbance state exhibits moderate grass cover that will support moderately intense fires
Grazing: variable, but occurring most years at moderate levels
Dominant Species: western wheatgrass, thickspike wheatgrass, Sandberg bluegrass, blue grama, and prairie junegrass
Other Characteristic Species: bluebunch wheatgrass, green needlegrass, plains pricklypear, prairie clover, prairie coneflower, western yarrow, threadleaf sedge, plains reedgrass, and plains muhly
Historical Grass and Forb Productivity Estimate: 625 lbs/acre
Structure: mixed grasses, 3-5” in height
Primary indicators of natural disturbance regimes (% cover):
Short fire return interval = sagebrush<10%
Moderate grazing = green needlegrass<20% and blue grama<30%

- ### C. Short Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: less than 25 years, average 10 to 20 years; this disturbance state exhibits lower fuel levels due to heavier grazing, resulting in less intense fires and more of a mosaic of burned and unburned areas, than in other short-interval fire regimes
Grazing: occurring most years as season long grazing; used more frequently possibly due to location factor such as close proximity to water sources for grazers
Dominant Species: blue grama, plains pricklypear, prairie junegrass, western wheatgrass, thickspike wheatgrass, western yarrow, pussytoes, threadleaf sedge,
Other Characteristic Species: plains reedgrass, goldenweed, textile onion, scarlet gaura, white sagebrush, scurfpea, bottlebrush squirreltail, plains muhly, hairy goldenaster, two grooved milkvetch, and goldenweed
Historical Grass and Forb Productivity Estimate: 450 lbs/acre
Structure: mixed grasses, 2-5” in height
Primary indicators of natural disturbance regimes (% cover):
Short fire return interval = sagebrush<10%
Heavy grazing = green needlegrass<20% and blue grama>30%

- ### D. Long Fire Return Interval x Light Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: generally light and variable, with considerable rest between significant use; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: big sagebrush, bluebunch wheatgrass, green needlegrass, western wheatgrass, thickspike wheatgrass, Cusick’s bluegrass, prairie coneflower, prairie clover, and American vetch
Other Characteristic Species: Sandberg bluegrass, blue grama, hawksbeard
Historical Grass and Forb Productivity Estimate: 575 lbs/acre
Structure: mixed grass with shrubs, herbaceous vegetation 5-7” in height, shrubs up to 2’ in height
Primary indicators of natural disturbance regimes (% cover):
Long fire return interval = sagebrush>10%
Light grazing = green needlegrass>20% and blue grama<30%

- ### E. Long Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: variable, but occurring most years at moderate levels

Dominant Species: big sagebrush, western wheatgrass, thickspike wheatgrass, Sandberg bluegrass, blue grama, and prairie junegrass
Other Characteristic Species: bluebunch wheatgrass, green needlegrass, plains pricklypear, prairie clover, prairie coneflower, western yarrow, threadleaf sedge, plains reedgrass, plains muhly, and birdfoot sage
Historical Grass and Forb Productivity Estimate: 475 lbs/acre
Structure: mixed grass with shrubs, herbaceous vegetation 3-5” in height, shrubs up to 2’ in height
Primary indicators of natural disturbance regimes (% cover):
Long fire return interval = sagebrush>10%
Moderate grazing = green needlegrass<20% and blue grama<30%

- F. Long Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: occurring most years as season long grazing; used more frequently possibly due to location factor such as close proximity to water sources for grazers
Dominant Species: big sagebrush, blue grama, plains pricklypear, prairie junegrass, western wheatgrass, thickspike wheatgrass, western yarrow, pussytoes, threadleaf sedge,
Other Characteristic Species: plains reedgrass, goldenweed, textile onion, scarlet gaura, white sagebrush, scurfpea, bottlebrush squirreltail, plains muhly, birdfoot sage, hairy goldenaster, two groved milkvetch, and goldenweed
Historical Grass and Forb Productivity Estimate: 350 lbs/acre
Structure: mixed grass with shrubs, herbaceous vegetation 2-5” in height, shrubs up to 1.5’ in height.
Primary indicators of natural disturbance regimes (% cover):
Long fire return interval = sagebrush>10%
Heavy grazing = green needlegrass<20% and blue grama>30%

Loamy Ecological Sites

Loamy ecological sites occupy approximately 30% of the terrestrial ecological sites in the Thunder Basin planning area. Soils on these sites are derived from sandstone and shale parent material and are characterized as well drained soils with moderate permeability. These sites are frequently associated with alluvial fans, ridges, stream terraces and hillsides where slopes are less than 30%. Loamy ecological sites are moderately to highly productive in the planning area with an average annual productivity range of 700 to 1500 lbs. per acre, depending on the current disturbance state and the amount of precipitation received during the year.

Native ecosystem diversity on loamy ecological sites was influenced by natural disturbance regimes of fire, grazing, and prairie dogs. Grazing played an important role in influencing the species composition of ecosystems on this ecological site. Plant species that respond as decreasers with increasing grazing pressure on loamy sites include green needlegrass and Indian ricegrass. Species like western wheatgrass, thickspike wheatgrass, needleandthread, and little bluestem initially respond as increasers, however, they decrease as grazing pressure becomes more intense. Species that commonly increase as grazing becomes heavy include blue grama, hairy grama, threadleaf sedge, prairie junegrass, and Sandberg bluegrass. The frequent fire return interval played an important role in shaping the structure and species composition of native ecosystems on loamy ecological sites. In general, grass species were the dominant component and shrubs were a relatively minor component on these sites due to frequent fire. Areas that were protected from fire likely experienced an increase in Wyoming big sagebrush and silver sagebrush. Loamy ecological sites were considered highly suitable habitat for prairie dog colonies, with preference given to those sites exhibiting relatively level conditions and with water sources nearby.


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Examples of loamy ecological sites in two different disturbance states.

Figure 19 demonstrates the loamy ecological site state and transition model for different disturbance states within the Thunder Basin planning area, as influenced by natural disturbance regimes of fire, bison grazing, and prairie dog colonies. The combined total of all of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on loamy ecological sites. The plant species identified in each box or disturbance state, indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x loamy ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species and their associated animal species. The following descriptions provide additional information on each disturbance state identified in Figure 19 and are referenced to the letter code in the upper left corner of each box in Figure 19.

• A. Short Fire Return Interval x Light Grazing Regime

Fire Return Interval: less than 25 years, averaging 5-15 years; this disturbance state exhibits heavier grass cover that will support larger, more intense fires

Grazing: intermittent with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers

Dominant Species: needle and thread, green needlegrass, western wheatgrass, thickspike wheatgrass, bluebunch wheatgrass, prairie clover, and prairie coneflower

Other Characteristic Species: Indian ricegrass, Cusick's bluegrass, needleleaf sedge, American vetch, hawksbeard, biscuitroot, dotted blazing star, and evening primrose

Historical Grass and Forb Productivity Estimate: 1,100 lbs/acre

Structure: mixed grasses typically occurring in 5-8" height

Primary indicators of natural disturbance regimes (% cover):

Short fire return interval = sagebrush<10%

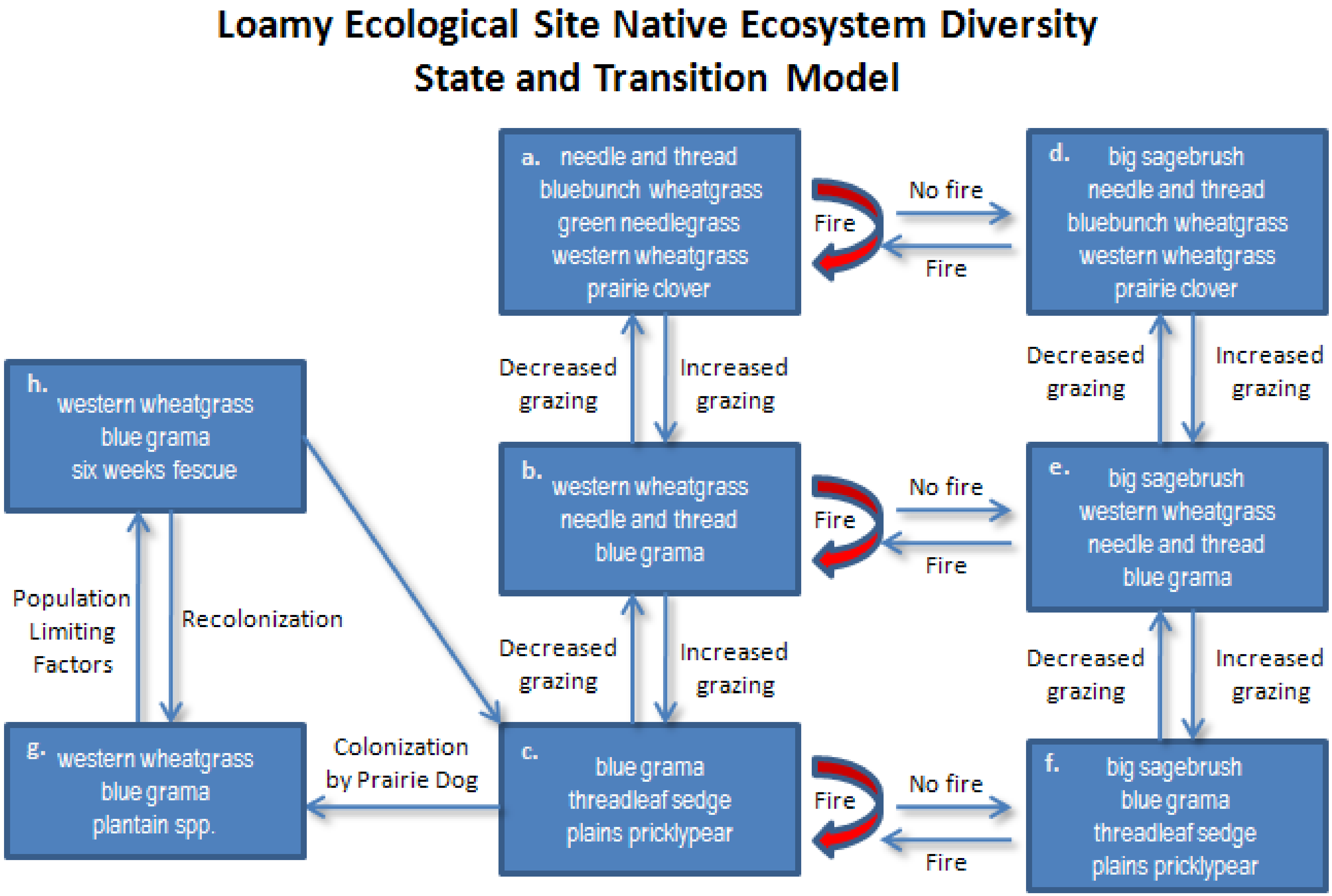

Loamy Ecological Site Native Ecosystem Diversity
State and Transition Model

Figure 19. State and transition model for loamy ecological sites of the Thunder Basin planning area, identifying the historical disturbance states or range of native ecosystem diversity, resulting from natural disturbance regimes.

Light grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass>15% and blue grama<30%

B. Short Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: less than 25 years, averaging 5-15 years; this disturbance state exhibits moderate grass cover that will support moderately intense fires
Grazing: variable, but occurring most years at moderate levels
Dominant Species: western wheatgrass, needle and thread, Sandberg bluegrass, thickspike wheatgrass, blue grama, threadleaf sedge, and western yarrow
Other Characteristic Species: Indian ricegrass, bluebunch wheatgrass, Cusick's bluegrass, needleleaf sedge, prairie junegrass, prairie coneflower, prairie clover, biscuitroot, scurfpea, rosy pussytoes, milkvetch, stemless goldenweed, hawksbeard, textile onion, bluebells, scarlet globemallow, scarlet gaura, penstemon, and common pepperweed
Historical Grass and Forb Productivity Estimate: 900 lbs/acre
Structure: Mixed grass species with variable heights, averaging 4-6" height
Primary indicators of natural disturbance regimes (% cover):
Short fire return interval = sagebrush<10%
Moderate grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass<15% and blue grama<30%

C. Short Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: less than 25 years, average 10 to 20 years; this disturbance state exhibits lower fuel levels due to heavier grazing, resulting in less intense fires and more of a mosaic of burned and unburned areas, than in other short-interval fire regimes
Grazing: occurring most years as season long grazing; used more frequently possibly due to location factor such as close proximity to water sources for grazers
Dominant Species: blue grama, threadleaf sedge, plains pricklypear, prairie junegrass, western yarrow, rosy pussytoes, and common pepperweed
Other Characteristic Species: Western wheatgrass, thickspike wheatgrass, Sandberg bluegrass, scurfpea, milkvetch, penstemon, scarlet globemallow, scarlet gaura, stemless goldenweed, textile onion, bluebells, and Hood's phlox
Historical Grass and Forb Productivity Estimate: 550 lbs/acre
Structure: Mixed grass species with variable heights
Primary indicators of natural disturbance regimes (% cover):
Short fire return interval = sagebrush<10%
Heavy grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass<15% and blue grama>30%

D. Long Fire Return Interval x Light Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: generally light and variable, with considerable rest between significant use; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: big sagebrush, needle and thread, green needlegrass, western wheatgrass, thickspike wheatgrass, bluebunch wheatgrass, prairie clover, prairie coneflower, dotted blazing star, and winterfat
Other Characteristic Species: Indian ricegrass, Cusick's bluegrass, needleleaf sedge, American vetch, hawksbeard, biscuitroot, and evening primrose
Historical Grass and Forb Productivity Estimate: 925 lbs/acre
Structure: Herbaceous vegetation typically 5-8" height, sagebrush up to 3' in height
Primary indicators of natural disturbance regimes (% cover):
Long fire return interval = sagebrush>10%

Light grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass>15% and blue grama<30%

E. Long Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: variable, but occurring most years at moderate levels
Dominant Species: big sagebrush, western wheatgrass, needle and thread, Sandberg bluegrass, thickspike wheatgrass, blue grama, threadleaf sedge, western yarrow, and winterfat
Other Characteristic Species: Indian ricegrass, bluebunch wheatgrass, Cusick's bluegrass, needleleaf sedge, prairie junegrass, prairie coneflower, prairie clover, biscuitroot, scurfpea, rosy pussytoes, milkvetch, stemless goldenweed, hawksbeard, textile onion, bluebells, scarlet globemallow, scarlet gaura, penstemon, and common pepperweed
Historical Grass and Forb Productivity Estimate: 750 lbs/acre
Structure: Herbaceous vegetation typically 4-6" height, sagebrush up to 3' in height
Primary indicators of natural disturbance regimes (% cover):
Long fire return interval = sagebrush>10%
Moderate grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass<15% and blue grama<30%

F. Long Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: occurring most years as season long grazing; used more frequently possibly due to location factor such as close proximity to water sources for grazers
Dominant Species: big sagebrush, blue grama, threadleaf sedge, plains pricklypear, and prairie junegrass, western yarrow, rosy pussytoes, and common pepperweed
Other Species: Western wheatgrass, thickspike wheatgrass, Sandberg bluegrass, scurfpea, milkvetch, penstemon, scarlet globemallow, scarlet gaura, stemless goldenweed, textile onion, bluebells, and Hood's phlox
Historical Grass and Forb Productivity Estimate: 475 lbs/acre
Structure: Herbaceous vegetation typically occurring in 3-5" height, sagebrush about 2.5' height
Primary indicators of natural disturbance regimes (% cover):
Long fire return interval = sagebrush>10%
Heavy grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass<15% and blue grama>30%

G. Prairie Dog Colony, Active Regime

Fire was infrequent on prairie dog colonies because of discontinuous fine fuel resulting from soil disturbance and prairie dog herbivory. Selective grazing by bison and pronghorn antelope also occurred, however the plant community dynamics were driven primarily by the prairie dog activities. Vegetation on active prairie dog colonies and to lesser extent in-active colonies exhibited a dwarfed or stunted growth pattern, due to repeated clipping. Characteristic species that occur on prairie dog colonies include western wheatgrass, blue grama, purple threeawn, six weeks fescue, threadleaf sedge, plantain spp., common yarrow, and aster species. Plant community composition on active prairie dog colonies was driven by factors that included colony density and age.

H. Prairie Dog Colony, In-active Regime

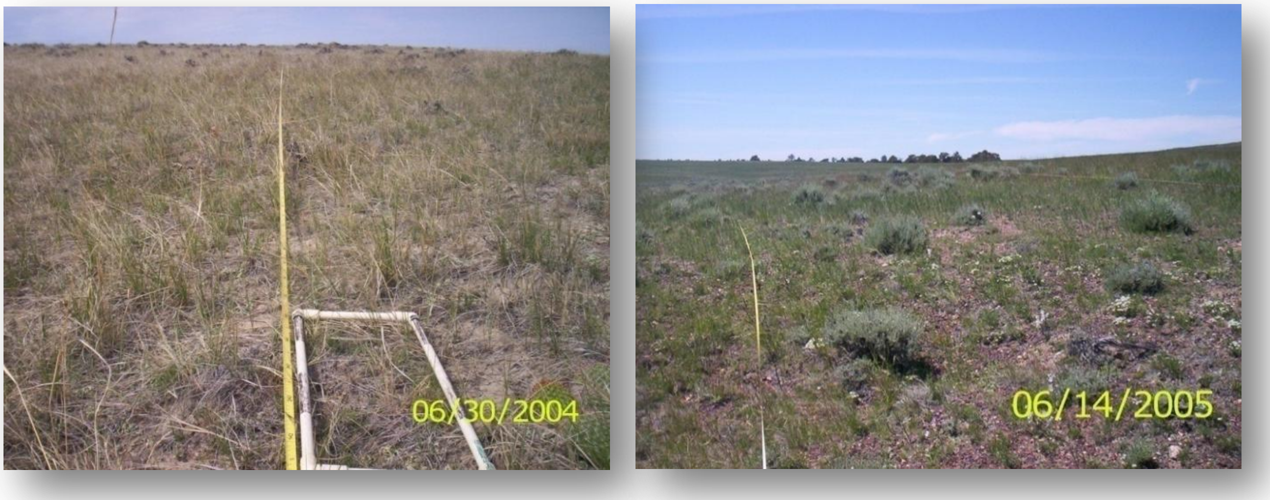
Prairie dog colonies are considered inactive as long as they are not currently used by prairie dogs, and they still provide the burrow structure characteristic of prairie dog communities, that other wildlife species are dependent upon. Field observations in the Thunder Basin planning area indicate that after approximately 7 years of non-use, most prairie dog burrows have collapsed and no longer serve the role as an inactive prairie dog colony. Plant community composition on inactive prairie dog colonies was driven by previous levels of disturbance by prairie dogs and length of time since abandonment. Colonies that previously had higher levels of disturbance were in early successional stages and took considerable time to recover to pre-disturbance conditions.

Shallow Loamy Ecological Sites

Shallow loamy ecological sites occupy approximately 7% of the terrestrial ecological sites in the Thunder Basin planning area. Soils on these sites are derived from sandstone and shale parent material and are characterized as well drained soils with moderate permeability. These sites are frequently associated with ridge tops and hillsides where slopes are less than 60%. Shallow loamy ecological sites are moderately productive in the planning area with an average annual productivity range of 450 to 1200 lbs. per acre, depending on the current disturbance state and the amount of precipitation received during the year.

The primary landscape feature that differentiates shallow loamy ecological sites from loamy ecological sites is the depth to bedrock, which has an influence on plant productivity and community structure. Shallow loamy sites have less than 20 inches of soil before reaching bedrock, whereas loamy ecological sites have greater than 20 inches, therefore productivity and plant vigor is generally higher on loamy sites. The bedrock on these sites is virtually impenetrable to plant roots. These site differences are generally visible when comparing the general density, height and stature of plant species like big sagebrush, which reach greater densities, heights and statures on loamy sites relative to shallow loamy sites.

Native ecosystem diversity on shallow loamy ecological sites was influenced by natural disturbance regimes of fire and grazing. Prairie dogs did not prefer these sites for burrowing due to the shallow soil depths. Grazing played an important role in influencing the species composition of ecosystems on this ecological site. Plant species that respond as decreasers with increasing grazing pressure on shallow loamy sites include green needlegrass and Indian ricegrass. Species like western wheatgrass, thickspike wheatgrass, needleandthread, and little bluestem initially respond as increasers, however, they decrease as grazing pressure becomes more intense. Species that commonly increase as grazing becomes heavy include blue grama, hairy grama, threadleaf sedge, prairie junegrass, and Sandberg bluegrass. The frequent fire return interval historically occurring in this landscape also played an important role in shaping the structure and species composition of native ecosystems on shallow loamy ecological sites. In general, grass species were the dominant component and shrubs were a relatively minor component on these sites due to frequent fires. Areas that were protected from fire likely experienced an increase in Wyoming big sagebrush and silver sagebrush.



Examples of shallow loamy ecological sites in two different disturbance states.

Figure 20 demonstrates the shallow loamy ecological site state and transition model for different disturbance states within the Thunder Basin planning area, as influenced by natural disturbance regimes of fire and bison grazing. The combined total of all of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on shallow loamy ecological sites. The plant species identified in each box or disturbance state, indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x shallow loamy ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species and their associated animal species. The following descriptions provide additional information on each disturbance state identified in Figure 20 and are referenced to the letter code in the upper left corner of each box in Figure 20.

A. Short Fire Return Interval x Light Grazing Regime

Fire Return Interval: less than 25 years, averaging 5-15 years; this disturbance state exhibits heavier grass cover that will support larger, more intense fires

Grazing: intermittent with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers

Dominant Species: bluebunch wheatgrass, green needlegrass, western wheatgrass, thickspike wheatgrass, prairie clover, and prairie coneflower

Other Characteristic Species: Indian ricegrass, Cusick's bluegrass, needle and thread, littlebluestem, needleleaf sedge, American vetch, hawksbeard, biscuitroot, dotted blazing star, and evening primrose

Historical Grass and Forb Productivity Estimate: 850 lbs/acre

Structure: mixed grasses, 5-7" in height

Primary indicators of natural disturbance regimes (% cover):

Short fire return interval = sagebrush<10%

Light grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass>15% and blue grama<30%

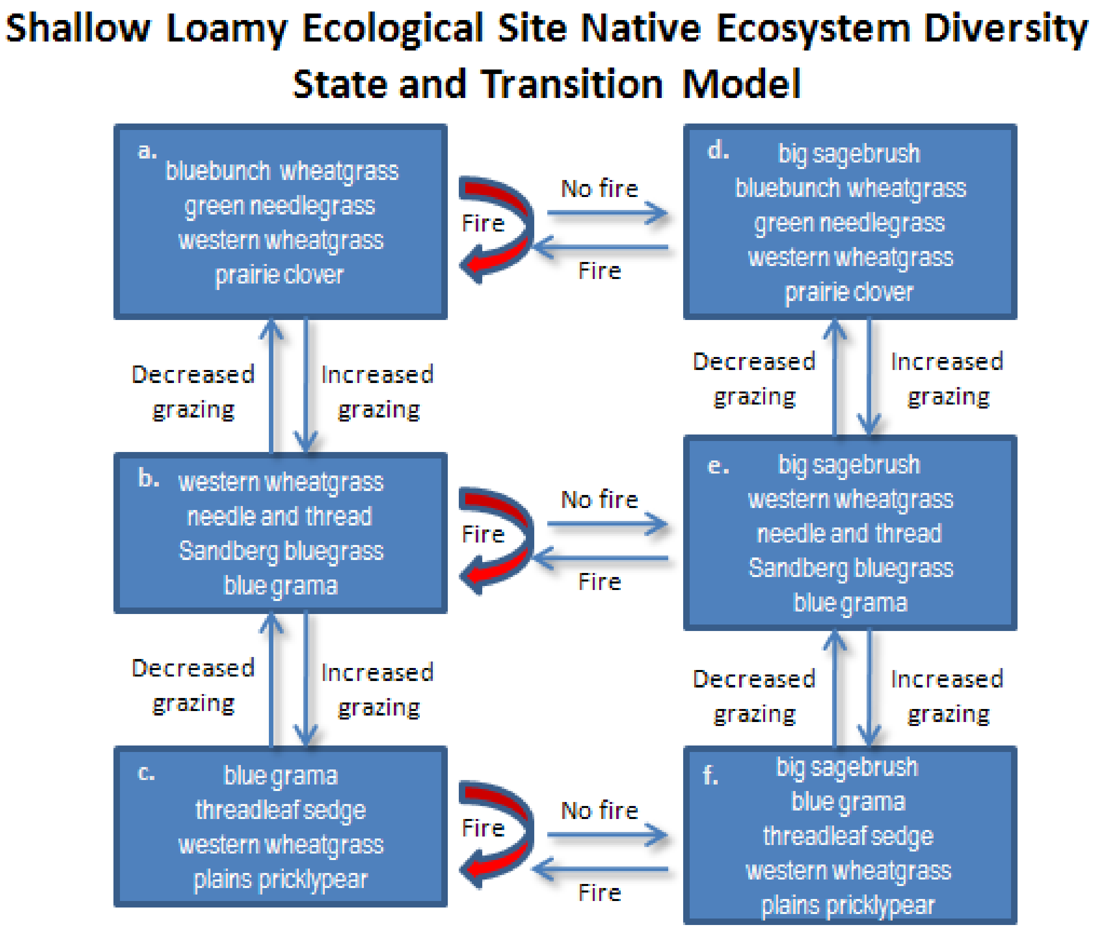


Figure 20. State and transition model for shallow loamy ecological sites of the Thunder Basin planning area, identifying the historical disturbance states or range of native ecosystem diversity, resulting from natural disturbance regimes.

B. Short Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: less than 25 years, averaging 5-15 years; this disturbance state exhibits moderate grass cover that will support moderately intense fires

Grazing: variable, but occurring most years at moderate levels

Dominant Species: western wheatgrass, needle and thread, Sandberg bluegrass, thickspike wheatgrass, blue grama, threadleaf sedge, and western yarrow

Other Characteristic Species: Indian ricegrass, bluebunch wheatgrass, Cusick's bluegrass, green needlegrass, needleleaf sedge, prairie junegrass, prairie coneflower, prairie clover, biscuitroot, scurfpea, rosy pussytoes, milkvetch, stemless goldenweed, hawksbeard, textile onion, bluebells, scarlet globemallow, scarlet gaura, penstemon, and common pepperweed

Historical Grass and Forb Productivity Estimate: 700 lbs/acre

Structure: mixed grasses, 4-6" in height

Primary indicators of natural disturbance regimes (% cover):

Short fire return interval = sagebrush<10%

Moderate grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass<15% and blue grama<30%

C. Short Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: less than 25 years, average 10 to 20 years; this disturbance state exhibits lower fuel levels due to heavier grazing, resulting in less intense fires and more of a mosaic of burned and unburned areas, than in other short-interval fire regimes
Grazing: occurring most years as season long grazing; used more frequently possibly due to location factor such as close proximity to water sources for grazers
Dominant Species: blue grama, threadleaf sedge, plains pricklypear, prairie junegrass, western yarrow, rosy pussytoes, and common pepperweed
Other Characteristic Species: Western wheatgrass, thickspike wheatgrass, Sandberg bluegrass, plains muhly, scurfpea, milkvetch, penstemon, scarlet globemallow, scarlet gaura, goldenweed, textile onion, bluebells, and Hood's phlox
Historical Grass and Forb Productivity Estimate: 500 lbs/acre
Structure: mixed grasses, 3-5 " in height
Primary indicators of natural disturbance regimes (% cover):
Short fire return interval = sagebrush<10%
Heavy grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass<15% and blue grama>30%

D. Long Fire Return Interval x Light Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: generally light and variable, with considerable rest between significant use; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: big sagebrush, bluebunch wheatgrass, green needlegrass, western wheatgrass, thickspike wheatgrass, prairie clover, prairie coneflower, and dotted blazing star
Other Characteristic Species: Indian ricegrass, Cusick's bluegrass, needleleaf sedge, American vetch, hawksbeard, biscuitroot, skunkbush sumac, and evening primrose
Historical Grass and Forb Productivity Estimate: 700 lbs/acre
Structure: mixed grasses and shrubs, herbaceous vegetation 4-6" in height, shrubs up to 2' in height
Primary indicators of natural disturbance regimes (% cover):
Long fire return interval = sagebrush>10%
Light grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass>15% and blue grama<30%

E. Long Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: variable, but occurring most years at moderate levels
Dominant Species: big sagebrush, western wheatgrass, needle and thread, Sandberg bluegrass, thickspike wheatgrass, blue grama, threadleaf sedge, and western yarrow
Other Characteristic Species: Indian ricegrass, bluebunch wheatgrass, Cusick's bluegrass, green needlegrass, bluebunch wheatgrass, needleleaf sedge, prairie junegrass, prairie coneflower, prairie clover, biscuitroot, scurfpea, rosy pussytoes, milkvetch, stemless goldenweed, hawksbeard, textile onion, bluebells, scarlet globemallow, scarlet gaura, penstemon, and common pepperweed
Historical Grass and Forb Productivity Estimate: 550 lbs/acre
Structure: mixed grasses and shrubs, herbaceous vegetation 3-5" in height, shrubs up to 2' in height.
Primary indicators of natural disturbance regimes (% cover):
Long fire return interval = sagebrush>10%
Moderate grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass<15% and blue grama<30%

F. Long Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks

Grazing: occurring most years as season long grazing; used more frequently possibly due to location factor such as close proximity to water sources for grazers

Dominant Species: big sagebrush, blue grama, threadleaf sedge, plains pricklypear, and prairie junegrass, western yarrow, rosy pussytoes, and common pepperweed

Other Characteristic Species: Western wheatgrass, thickspike wheatgrass, Sandberg bluegrass, plains muhly, scurfpea, milkvetch, penstemon, scarlet globemallow, scarlet gaura, goldenweed, textile onion, bluebells, and Hood's phlox

Historical Grass and Forb Productivity Estimate: 400 lbs/acre

Structure: mixed grasses and shrubs, herbaceous vegetation 2-5" in height, shrubs up to 1.5' in height.

Primary indicators of natural disturbance regimes (% cover):

Long fire return interval = sagebrush>10%

Heavy grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass<15% and blue grama>30%

Sands/Sandy Ecological Sites

Sands/sandy ecological sites make up approximately 7% of the terrestrial ecological sites in the Thunder Basin planning area. Soils on these sites were derived from sandstone parent material and are characterized as well drained soils with moderate to rapid permeability. These sites are frequently associated with alluvial fans, plateaus, ridges, stream terraces and hillsides where slopes are less than 30%. Sands/sandy ecological sites are highly productive in the planning area with an average annual productivity range of 750 to 1700 lbs. per acre, depending on the current disturbance state and the amount of precipitation received during the year.

Native ecosystem diversity on sands/sandy ecological sites was influenced by natural disturbance regimes of fire and grazing. Prairie dogs rarely use sands/sandy ecological sites due to the difficulty of building burrows in sandy soils. Grazing played an important role in influencing the species composition of ecosystems on this ecological site. Plant species that respond as decreasers with increasing grazing pressure on sands/sandy sites include Indian

Examples of sands/sandy ecological sites in two different disturbance states.

ricegrass, sand bluestem, prairie sandreed, and bluebunch wheatgrass. Species like western wheatgrass, thickspike wheatgrass, needleandthread, and little bluestem initially respond as increasers, however, they decrease as grazing pressure becomes more intense. Species that commonly increase as grazing becomes heavy include blue threadleaf sedge, blue grama, hairy grama, sand dropseed, prairie, Sandberg bluegrass, yucca, prairie junegrass, fringed sagewort, and plains prickley pear. The frequent fire return interval played an important role in shaping the structure and species composition of native ecosystems on sands/sandy ecological sites. In general, grass species were the dominant component and shrubs were a relatively minor component on these sites due to frequent fire. Areas that were protected from fire likely experienced an increase in Wyoming big sagebrush and western snowberry.

Figure 21 demonstrates the sands/sandy ecological site state and transition model for different disturbance states within the Thunder Basin planning area, as influenced by natural disturbance regimes of fire and bison grazing. The combined total of all of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on sands/sandy ecological sites. The plant species identified in each box or disturbance state, indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x sands/sandy ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species and their associated animal species. The following descriptions provide additional information on each disturbance state identified in Figure 21 and are referenced to the letter code in the upper left corner of each box in Figure 21.

- ### A. Short Fire Return Interval x Light Grazing Regime

Fire Return Interval: less than 25 years, averaging 5-15 years; this disturbance state exhibits heavier grass cover that will support larger, more intense fires
Grazing: intermittent with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: prairie sandreed, Indian ricegrass, needle and thread, western wheatgrass, thickspike wheatgrass, prairie coneflower, American vetch, and prairie clover
Other Characteristic Species: little bluestem, threadleaf sedge, Sandberg bluegrass, and hawskbeard
Historical Grass and Forb Productivity Estimate: 1,100 lbs/acre
Structure: mixed grasses, 5-8” in height.
Primary indicators of natural disturbance regimes (% cover):
Short fire return interval = sagebrush<5%
Light grazing = prairie sandreed>10% and blue grama/threadleaf sedge<30%

- ### B. Short Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: less than 25 years, averaging 5-15 years; this disturbance state exhibits moderate grass cover that will support moderately intense fires
Grazing: variable, but occurring most years at moderate levels
Dominant Species: needle and thread, western wheatgrass, threadleaf sedge, Sandberg bluegrass, and blue grama
Other Characteristic Species: little bluestem, prairie sandreed, Indian ricegrass, prairie junegrass, plains pricklypear, prairie coneflower, American vetch, yucca
Historical Grass and Forb Productivity Estimate: 900 lbs/acre
Structure: mixed grasses, 4-7” in height.

Sands/Sandy Ecological Site Native Ecosystem Diversity State and Transition Model

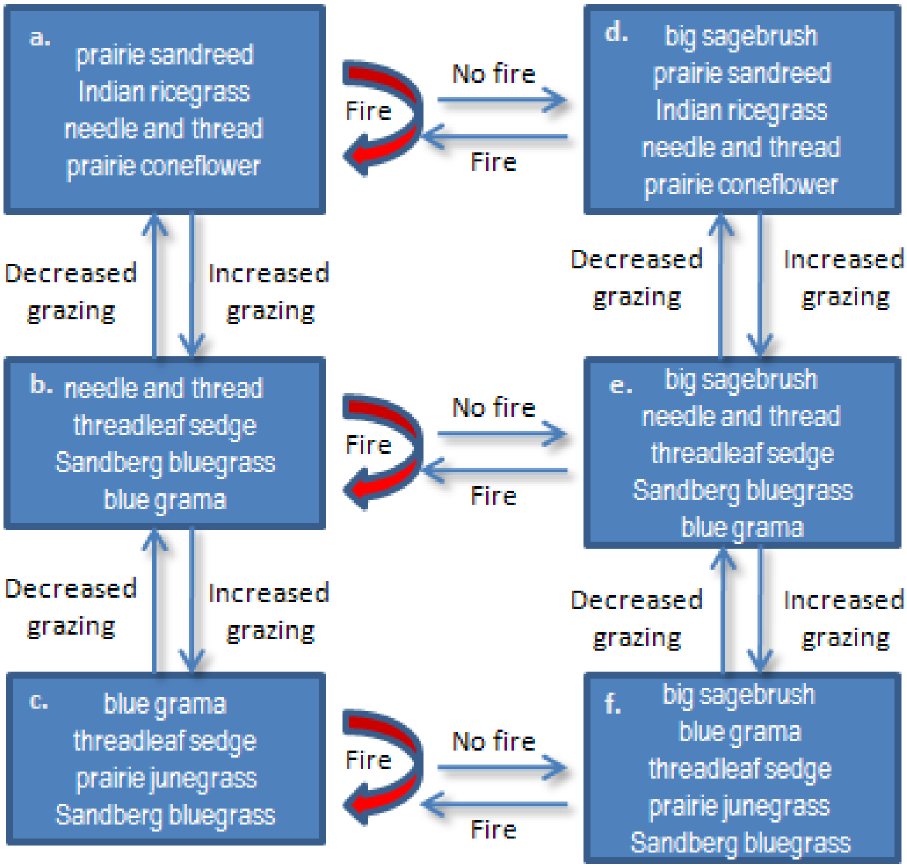


Figure 21. State and transition model for sands/sandy ecological sites of the Thunder Basin planning area, identifying the historical disturbance states or range of native ecosystem diversity, resulting from natural disturbance regimes.

Primary indicators of natural disturbance regimes (% cover):

Short fire return interval = sagebrush<5%
Moderate grazing = prairie sandreed<10% and blue grama/threaleaf sedge<30%

C. Short Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: less than 25 years, average 10 to 20 years; this disturbance state exhibits lower fuel levels due to heavier grazing, resulting in less intense fires and more of a mosaic of burned and unburned areas, than in other short-interval fire regimes

Grazing: occurring most years as season long grazing; used more frequently possibly due to location factor such as close proximity to water sources for grazers

Dominant Species: needle and thread, threadleaf sedge, plain pricklypear, prairie junegrass, Sandberg bluegrass, blue grama, western yarrow

Other Characteristic Species: western wheatgrass, pussytoes, textile onion, fringed sagewort, scurfpea, and yucca

Historical Grass and Forb Productivity Estimate: 550 lbs/acre

Structure: mixed grasses, 3-5 inches in height.

Primary indicators of natural disturbance regimes (% cover):
Short fire return interval = sagebrush<5%
Heavy grazing = prairie sandreed<10% and blue grama/threadleaf sedge>30%

D. Long Fire Return Interval x Light Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: generally light and variable, with considerable rest between significant use; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: big sagebrush, prairie sandreed, Indian ricegrass, needle and thread, western wheatgrass, thickspike wheatgrass, prairie coneflower, American vetch, and prairie clover
Other Characteristic Species: little bluestem, threadleaf sedge, Sandberg bluegrass, hawskbeard, and winterfat
Historical Grass and Forb Productivity Estimate: 925 lbs/acre
Structure: mixed grasses and shrubs, herbaceous vegetation 5-8" in height, shrubs up to 3' in height.
Primary indicators of natural disturbance regimes (% cover):
Long fire return interval = sagebrush>5%
Light grazing = prairie sandreed>10% and blue grama/threadleaf sedge<30%

E. Long Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: variable, but occurring most years at moderate levels
Dominant Species: big sagebrush, needle and thread, western wheatgrass, threadleaf sedge, Sandberg bluegrass, and blue grama
Other Characteristic Species: little bluestem, prairie sandreed, Indian ricegrass, prairie junegrass, plains pricklypear, prairie coneflower, American vetch, yucca
Historical Grass and Forb Productivity Estimate: 750 lbs/acre
Structure: mixed grasses and shrubs, herbaceous vegetation 4-6 " in height, shrubs up to 3' in height.
Primary indicators of natural disturbance regimes (% cover):
Long fire return interval = sagebrush>5%
Moderate grazing = prairie sandreed<10% and blue grama/threadleaf sedge<30%

F. Long Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: occurring most years as season long grazing; used more frequently possibly due to location factor such as close proximity to water sources for grazers
Dominant Species: big sagebrush, needle and thread, threadleaf sedge, plain pricklypear, prairie junegrass, Sandberg bluegrass, western yarrow
Other Characteristic Species: western wheatgrass, pussytoes, textile onion, fringed sagewort, scurfpea, and yucca
Historical Grass and Forb Productivity Estimate: 475 lbs/acre
Structure: mixed grasses and shrubs, herbaceous vegetation 3-5" in height, shrubs up to 2.5' in height.
Primary indicators of natural disturbance regimes (% cover):
Long fire return interval = sagebrush>5%
Heavy grazing = prairie sandreed<10% and blue grama/threadleaf sedge>30%

Shallow Sandy Ecological Sites

Shallow sandy ecological sites make up about 4% of the terrestrial ecological sites in the Thunder Basin planning area. Soils on these sites were derived from sandstone parent material and are characterized as well drained soils with moderate to rapid permeability. These sites are frequently associated with ridge tops, escarpments and hillsides where slopes are less than 50%. Shallow sandy ecological sites are moderately productive in the planning area with an average annual productivity range of 600 to 1300 lbs. per acre, depending on the current disturbance state and the amount of precipitation received during the year.

The primary landscape feature that differentiates shallow sandy ecological sites from sands/sandy ecological sites is the depth to bedrock, which has an influence on plant productivity and community structure. Shallow sandy sites have less than 20 inches of soil before reaching bedrock, whereas sands/sandy ecological sites have greater than 20 inches, therefore productivity and plant vigor is generally higher on loamy sites. The bedrock on these sites is virtually impenetrable to plant roots. These site differences are generally visible when comparing the general density, height and stature of plant species like big sagebrush, which reach greater densities, heights and statures on sands/sandy sites relative to shallow sandy sites.

Native ecosystem diversity on shallow sandy ecological sites was influenced by natural disturbance regimes of fire and grazing. Prairie dogs do not use shallow sandy ecological sites due to the shallow soil depths and sandy soil textures. Grazing played an important role in influencing the species composition of ecosystems on this ecological site. Plant species that respond as decreasers with increasing grazing pressure on shallow sandy sites include Indian ricegrass, sand bluestem, prairie sandreed, and bluebunch wheatgrass. Species like western wheatgrass, thickspike wheatgrass, needleandthread, and little bluestem initially respond as increasers, however, they decrease as grazing pressure becomes more intense. Species that commonly increase as grazing becomes heavy include blue threadleaf sedge, blue grama, hairy grama, sand dropseed, prairie, Sandberg bluegrass, yucca, prairie junegrass, fringed sagewort, and plains prickley pear. The frequent fire return interval historically occurring in this landscape also played a role in shaping the structure and species composition of native ecosystems on shallow sandy ecological sites, although less so than on sands/sandy ecological sites. In

Examples of shallow sandy ecological sites in two different disturbance states.

general, grass species were the dominant component and shrubs were a less dominant component on these sites due to fire. Areas that were protected from fire likely experienced an increase in Wyoming big sagebrush and western snowberry.

Figure 22 demonstrates the shallow sandy ecological site state and transition model for different disturbance states within the Thunder Basin planning area, as influenced by natural disturbance regimes of fire and bison grazing. The combined total of all of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on shallow sandy ecological sites. The plant species identified in each box or disturbance state, indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x shallow sandy ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species and their associated animal species. The following descriptions provide additional information on each disturbance state identified in Figure 22 and are referenced to the letter code in the upper left corner of each box in Figure 22.

A. Short Fire Return Interval x Light Grazing Regime

Fire Return Interval: less than 25 years, averaging 5-15 years; this disturbance state exhibits heavier grass cover that will support larger, more intense fires
Grazing: intermittent with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: prairie sandreed, Indian ricegrass, needle and thread, bluebunch wheatgrass, western wheatgrass, thickspike wheatgrass, prairie coneflower, American vetch, and prairie clover
Other Characteristic Species: little bluestem, threadleaf sedge, Sandberg bluegrass, and hawskbeard
Historical Grass and Forb Productivity Estimate: 850 lbs/acre
Structure: mixed grasses, herbaceous vegetation 5-7” in height.
Primary indicators of natural disturbance regimes (% cover):
Short fire return interval = sagebrush<5%
Light grazing = prairie sandreed>10% and blue grama/threadleaf sedge<30%

B. Short Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: less than 25 years, averaging 5-15 years; this disturbance state exhibits moderate grass cover that will support moderately intense fires
Grazing: variable, but occurring most years at moderate levels
Dominant Species: needle and thread, western wheatgrass, threadleaf sedge, Sandberg bluegrass, and blue grama
Other Characteristic Species: little bluestem, prairie sandreed, Indian ricegrass, bluebunch wheatgrass, sideoats grama, plains muhly, prairie junegrass, plains pricklypear, prairie coneflower, American vetch, and yucca
Historical Grass and Forb Productivity Estimate: 700 lbs/acre
Structure: mixed grasses, herbaceous vegetation 3-5” in height.
Primary indicators of natural disturbance regimes (% cover):
Short fire return interval = sagebrush<5%
Moderate grazing = prairie sandreed≤10% and blue grama/threaleaf sedge<30%

Shallow Sandy Ecological Site Native Ecosystem Diversity State and Transition Model

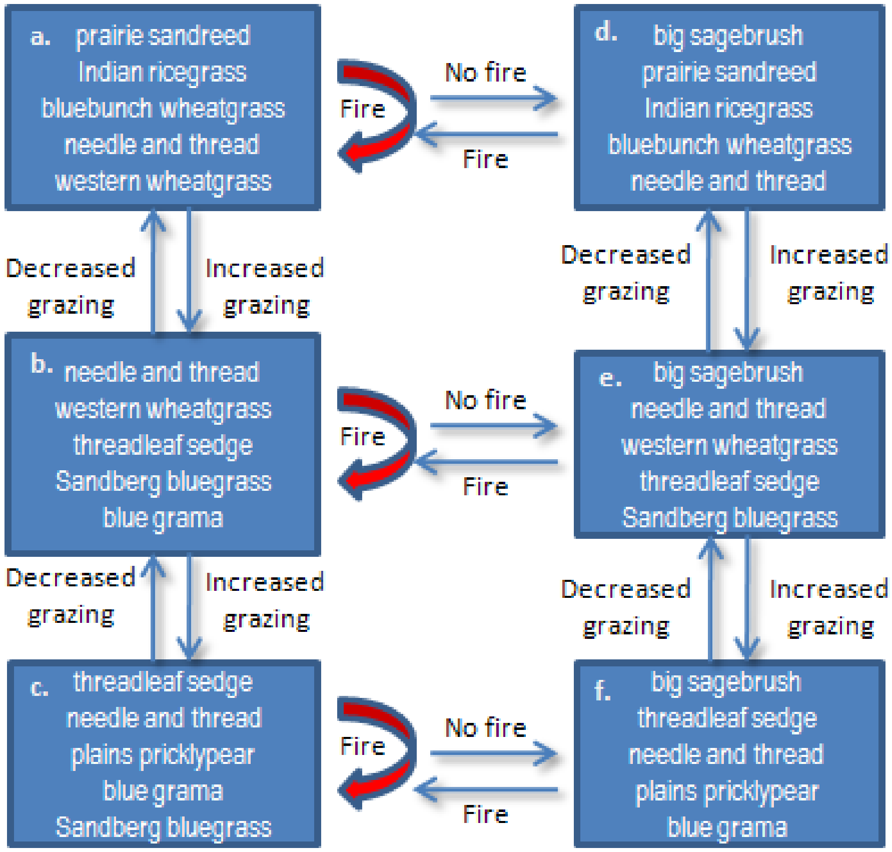


Figure 22. State and transition model for shallow sandy ecological sites of the Thunder Basin planning area, identifying the historical disturbance states or range of native ecosystem diversity, resulting from natural disturbance regimes

- ### C. Short Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: less than 25 years, average 10 to 20 years; this disturbance state exhibits lower fuel levels due to heavier grazing, resulting in less intense fires and more of a mosaic of burned and unburned areas, than in other short-interval fire regimes

Grazing: occurring most years as season long grazing; used more frequently possibly due to location factor such as close proximity to water sources for grazers

Dominant Species: needle and thread, threadleaf sedge, plain pricklypear, prairie junegrass, Sandberg bluegrass, and western yarrow

Other Characteristic Species: western wheatgrass, side oats grama, plains muhly, pussytoes, textile onion, fringed sagewort, scurfpea, and yucca

Historical Grass and Forb Productivity Estimate: 500 lbs/acre

Structure: mixed grasses, herbaceous vegetation 2-5” in height.

Primary indicators of natural disturbance regimes (% cover):

Short fire return interval = sagebrush<5%
Heavy grazing = prairie sandreed≤10% and blue grama/threadleaf sedge≥30%

D. Long Fire Return Interval x Light Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks

Grazing: generally light and variable, with considerable rest between significant use; used less frequently possibly due to location factor such as long distance to a water source for grazers

Dominant Species: big sagebrush, prairie sandreed, Indian ricegrass, needle and thread, bluebunch wheatgrass, western wheatgrass, thickspike wheatgrass, prairie coneflower, American vetch, and prairie clover

Other Characteristic Species: little bluestem, threadleaf sedge, Sandberg bluegrass, hawskbeard, and winterfat

Historical Grass and Forb Productivity Estimate: 700 lbs/acre

Structure: mixed grasses and shrubs, herbaceous vegetation 3-5" in height, shrubs up to 2.5' in height.

Primary indicators of natural disturbance regimes (% cover):

Long fire return interval = sagebrush≥5%
Light grazing = prairie sandreed>10% and blue grama/threadleaf sedge<30%

E. Long Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks

Grazing: variable, but occurring most years at moderate levels

Dominant Species: big sagebrush, needle and thread, western wheatgrass, threadleaf sedge, Sandberg bluegrass, and blue grama

Other Characteristic Species: little bluestem, prairie sandreed, Indian ricegrass, bluebunch wheatgrass, sideoats grama, plains muhly, prairie junegrass, plains pricklypear, prairie coneflower, American vetch, and yucca

Historical Grass and Forb Productivity Estimate: 550 lbs/acre

Structure: mixed grasses and shrubs, herbaceous vegetation 3-5" in height, shrubs up to 2.5' in height.

Primary indicators of natural disturbance regimes (% cover):

Long fire return interval = sagebrush≥5%
Moderate grazing = prairie sandreed≤10% and blue grama/threadleaf sedge<30%

F. Long Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks

Grazing: occurring most years as season long grazing; used more frequently possibly due to location factor such as close proximity to water sources for grazers

Dominant Species: big sagebrush, needle and thread, threadleaf sedge, plain pricklypear, prairie junegrass, Sandberg bluegrass, and western yarrow

Other Characteristic Species: western wheatgrass, side oats grama, plains muhly, pussytoes, textile onion, fringed sagewort, scurfpea, and yucca

Historical Grass and Forb Productivity Estimate: 400 lbs/acre

Structure: mixed grasses and shrubs, herbaceous vegetation 3-5" in height, shrubs up to 2.5' in height.

Primary indicators of natural disturbance regimes (% cover):

Long fire return interval = sagebrush≥5%
Heavy grazing = prairie sandreed≤10% and blue grama/threadleaf sedge≥30%

Shallow Hilly Ecological Sites

Shallow hilly is the only ecological site occurring in the Thunder Basin planning area that exhibits forest conditions. This ecological site occurs within the isolated hills of the Thunder Basin grasslands and occupies approximately 3.5% of the terrestrial ecological sites within the Thunder Basin planning area. It is typically associated with soils that are shallow loamy but on slopes greater than 6%.

The dominant tree occurring on this site is ponderosa pine. In this area, ponderosa pine was primarily found in a fire-maintained savannah state characterized by low density, open canopy stands of multi-aged ponderosa pine. The understory of ponderosa pine savannah was dominated by grasses which in combination with low tree densities provided conditions for patchy, low intensity fires that historically occurred with relatively high frequency, that is, approximately every 8 to 14 years (Fisher et al. 1987, Brown and Hull Sieg 1999, Perryman and Laycock 2000). Rocky mountain juniper and Wyoming big sagebrush also historically occurred on this ecological site, however, the frequent, low intensity surface fires that characterize ponderosa pine savannahs typically reduced the occurrence of fire susceptible rocky mountain juniper and Wyoming big sagebrush from these sites (Wright and Bailey 1982).

Ponderosa pine also occurred in dense forest stands in the Thunder Basin grasslands, albeit rarely. In contrast to ponderosa pine savannah, this forest type is a closed canopy ponderosa pine forest with a relatively dense understory of shrubs and smaller trees. This forest type is a product of infrequent fire, which explains its rare occurrence historically in Thunder Basin. Conditions that would have facilitated the development of this stand type include natural fire breaks and/or heavy grazing by bison which would reduce the fine fuel necessary to carry a fire and thus reduce the probability of a fire. When fire did occur in stands like this they were typically stand replacing because of the density of fuel in the understory and overstory.

Example of shallow hilly ecological site.

Native ecosystem diversity on shallow hilly ecological sites was influenced by natural disturbance regimes of fire and bison grazing. Prairie dogs were not associated with this ecological site due to the shallow nature of the soils and the excessive slopes. Grazing played an important role in influencing the species composition of ecosystems on this ecological site. Plant species that respond as decreasers with increased grazing pressure on shallow hilly ecological sites include bluebunch wheatgrass, American vetch, and purple prairie clover. Species like western wheatgrass and little bluestem initially respond as increasers, however, they decrease as grazing pressure becomes more intense. Species that commonly increase as grazing becomes heavy include prairie junegrass, blue grama, and threadleaf sedge.

Figure 23 demonstrates the shallow hilly ecological site state and transition model for different disturbance states within the Thunder Basin planning area, as influenced by natural disturbance regimes of fire and bison grazing. The combined total of all of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on very shallow ecological sites. The plant species identified in each box or disturbance state, indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x shallow hilly ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species and their associated animal species. A more complete description of each state was not developed aas part of this assessment.

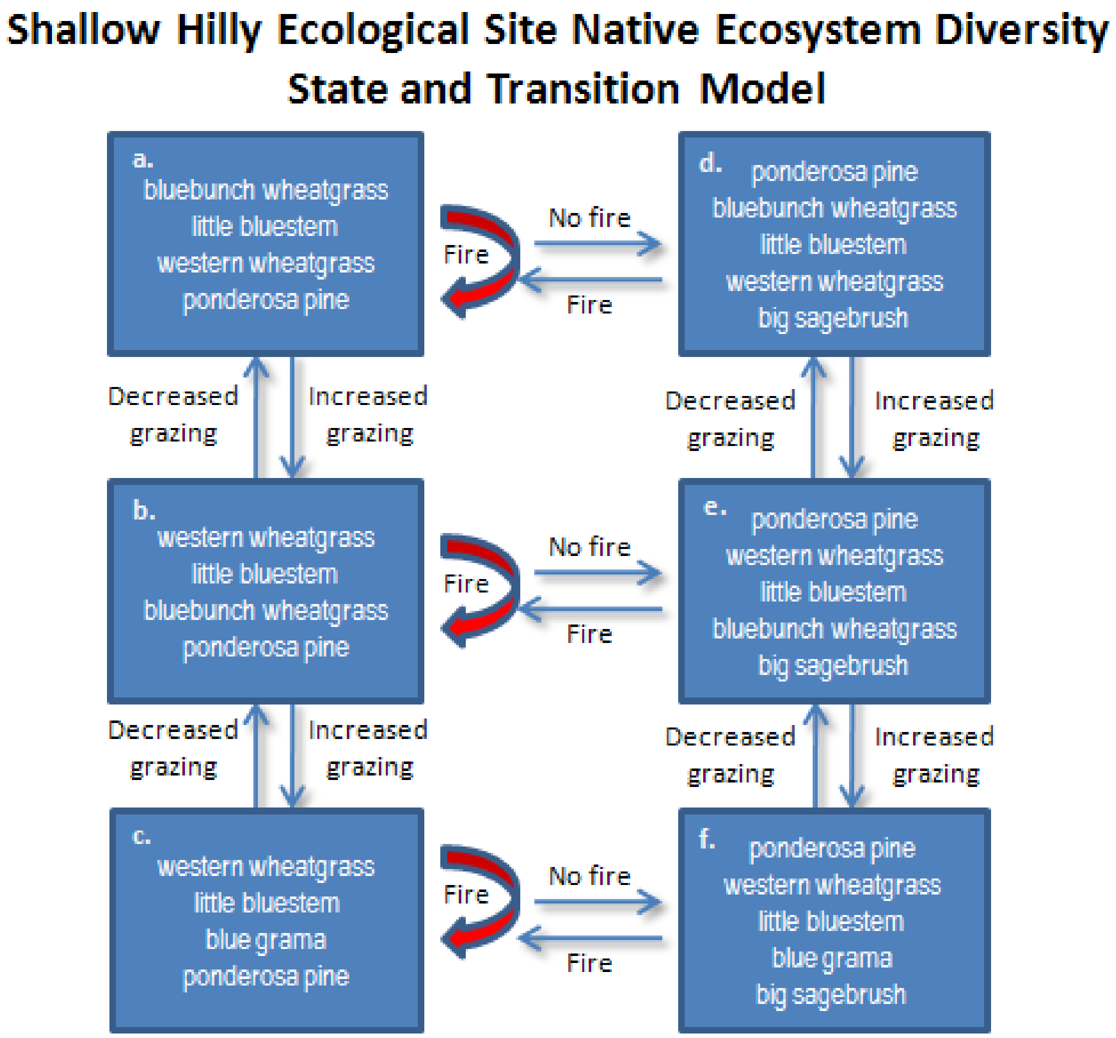

Shallow Hilly Ecological Site Native Ecosystem Diversity State and Transition Model

Figure 23. State and transition model for shallow hilly ecological sites of the Thunder Basin planning area, identifying the historical disturbance states or range of native ecosystem diversity, resulting from natural disturbance regimes.

Very Shallow Ecological Sites

Very shallow ecological sites are rare in the Thunder Basin planning area and occupy approximately 0.3% of the landscape. Soils on these sites are derived from sandstone and shale and are characterized as well drained soils with a wide range of permeability resulting from the wide range of surface soil textures that occur on very shallow sites. These ecological sites occur on steep side slopes associated with predominantly south and western facing aspects and within draws of hill complexes (Perryman and Laycock 2000). Very shallow ecological sites exhibit low levels of productivity in the planning area with an average annual range of 250 to 500 lbs. per acre, depending on the current disturbance state and the amount of precipitation received during the year.

Very shallow ecological sites are associated with shallow (generally less than 10 inches to bedrock) and poorly developed soils. Native ecosystem diversity on very shallow ecological sites was primarily influenced by grazing regimes. Prairie dogs do not use very shallow ecological sites due to the excessively shallow soil depths. The topographic position of very shallow ecological sites in Thunder Basin and sparse forage result in lower levels of grazing than the previously described ecological sites. Species that typically decrease with grazing include bluebunch wheatgrass and prairie sandreed. Species that respond as decreasers with persistent grazing included little bluestem and western wheatgrass. Species that respond as increasers include blue grama, Sandberg bluegrass, prairie junegrass, and plains muhly. Very shallow ecological sites are characterized by sparse, fine fuel and thus infrequent fire, which allows Rocky Mountain juniper to persist on these sites. Understory vegetation is generally sparse and low in diversity (Perryman and Laycock 2000).

Example of very shallow ecological site.

Figure 24 demonstrates the very shallow ecological site state and transition model for different disturbance states within the Thunder Basin planning area, as influenced by natural disturbance regimes of bison grazing. The combined total of all of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on very shallow ecological sites. The plant species identified in each box or disturbance state, indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of fire frequency x grazing intensity x very shallow ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species and their associated animal species. The following descriptions provide additional information on each disturbance state identified in Figure 24 and are referenced to the letter code in the upper left corner of each box in Figure 24.

Very Shallow Ecological Site Native Ecosystem Diversity State and Transition Model

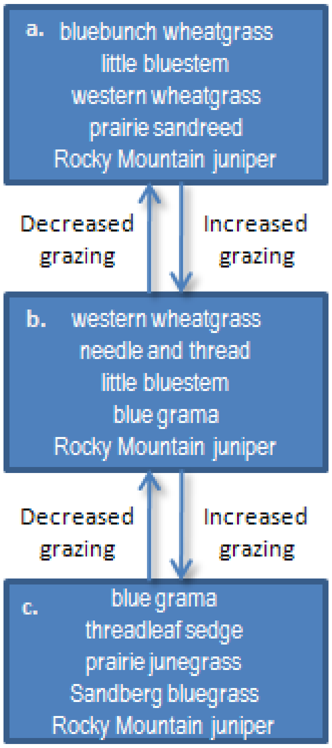


Figure 24. State and transition model for very shallow ecological sites of the Thunder Basin planning area, identifying the historical disturbance states or range of native ecosystem diversity, resulting from natural disturbance regimes.

A. Long Fire Return Interval x Light Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks

Grazing: generally light and variable, with considerable rest between significant use; used less frequently possibly due to location factor such as long distance to a water source for grazers

Dominant Species: bluebunch wheatgrass, little bluestem, western wheatgrass, thickspike wheatgrass, Rocky Mountain Juniper, prairie sandreed, and American vetch

Other Characteristic Species: skunkbush sumac, prairie coneflower, prairie clover, needle and thread, Sandberg bluegrass, big sagebrush, ponderosa pine

Historical Grass and Forb Productivity Estimate: 400 lbs/acre

Structure: mixed grasses, shrubs, and trees, herbaceous vegetation 4 to 6” in heights.

Primary indicators of natural disturbance regimes (% cover):

Light grazing = prairie sandreed/bluebunch wheatgrass>10% and blue grama<30%

B. Long Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks

Grazing: variable, but occurring most years at moderate levels

Dominant Species: western wheatgrass, needle and thread, little bluestem, Sandberg bluegrass, Rocky Mountain juniper,

Other Characteristic Species: bluebunch wheatgrass, prairie sandreed, prairie junegrass, plains muhlyAmerican vetch, prairie coneflower, prairie clover, western yarrow, scarlet globemallow, pussytoes, blue grama, threadleaf sedge, big sagebrush, ponderosa, pine, and skunkbush sumac

Historical Grass and Forb Productivity Estimate: 350 lbs/acre

Structure: mixed grasses, shrubs, and trees, herbaceous 3 to 5" in heights.

Primary indicators of natural disturbance regimes (% cover):

Moderate grazing = prairie sandreed/bluebunch wheatgrass≤10% and blue grama<30%

C. Long Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks

Grazing: occurring most years as season long grazing; used more frequently possibly due to location factor such as close proximity to water sources for grazers

Dominant Species: blue grama, threadleaf sedge, prairie junegrass, Sandberg bluegrass, plains muhly, western yarrow, scarlet globemallow, pussytoes, white sagebrush, hairy goldenaster, and Rocky Mountain juniper

Other Characteristic Species: prairie thermopsis, textile onion, plains wallflower, big sagebrush, and ponderosa pine.

Historical Grass and Forb Productivity Estimate: 300 lbs/acre

Structure: mixed grasses, shrubs, and trees, herbaceous vegetation 2-4" in height.

Primary indicators of natural disturbance regimes (% cover):

Heavy grazing = prairie sandreed/bluebunch wheatgrass≤10% and blue grama≥30%

Saline Upland Ecological Sites

Saline Upland ecological sites occupy approximately 5% of the Thunder Basin planning area. Soils on these sites are derived from sandstone and shale and have moderate to slow permeability. These sites are frequently associated alluvial fans, stream terraces and hillsides where slopes are less than 15%. Saline upland ecological sites exhibit low levels of productivity in the planning area with an average annual range of 250 to 650 lbs. per acre, depending on the current disturbance state and the amount of precipitation received during the year.

The distinguishing characteristic for saline upland ecological sites is the saline properties it has, which is identified by measuring the level of electrical conductivity of the soil (i.e., soils with electrical conductivity greater than 4 dS/m are considered saline). Soil salinity results from the accumulation of neutral soluble salts, which are chlorides and sulfates of calcium, magnesium, potassium, and sodium (Brady and Weil 2002). Saline soils are sometimes associated with sodic soils have high levels of exchangeable sodium and subsequently high pH levels (Brady and Weil 2002). The exchangeable sodium ions cause soil aggregates to break up and clog soil pores, which results in a reduction in water infiltration. Soil salinity can influence plant growth and thus productivity.

Native ecosystem diversity on saline upland ecological sites was influenced by natural disturbance regimes of grazing and prairie dogs. Grazing played an important role in influencing the species composition of ecosystems on this ecological site. Plant species that respond as decreasers with increased grazing pressure on saline upland ecological sites include alkali sacaton, Indian ricegrass, and Gardner's saltbush. Species like western wheatgrass and thickspike wheatgrass initially respond as increasers, however, they decrease as grazing pressure becomes more intense. Species that commonly increase as grazing becomes heavy include inland saltgrass, Sandberg bluegrass, greasewood, woody aster, threadleaf sedge, and plains pricklypear. Similar to very shallow ecological sites, saline upland sites historically did not have enough continuous fine fuel to support short fire return intervals. Saline upland ecological sites are considered highly suitable habitat for prairie dog colonies, with preference given to those sites exhibiting relatively level conditions and with water sources nearby.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Example of saline upland ecological sites in two different disturbance states.

Figure 25 demonstrates the saline upland ecological site state and transition model for different disturbance states within the Thunder Basin planning area, as influenced by natural disturbance regimes of bison grazing and prairie dogs. The combined total of all of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on very shallow ecological sites. The plant species identified in each box or disturbance state indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of fire frequency x grazing intensity x saline upland ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species and their associated animal species. The following descriptions provide additional information on each disturbance state identified in Figure 25 and are referenced to the letter code in the upper left corner of each box in Figure 25.

A. Long Fire Return Interval x Light Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to low fuel levels as well as surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks

Grazing: generally light and variable, with considerable rest between significant use; used less frequently possibly due to location factor such as long distance to a water source for grazers

Dominant Species: alkali scaton, Indian ricegrass, western wheatgrass, thickspike wheatgrass, Gardner's saltbush, winterfat, prairie coneflower, and prairie clover

Other Characteristic Species: American vetch, Sandberg bluegrass, hawskbeard, squirreltail

Historical Grass and Forb Productivity Estimate: 500 lbs/acre

Saline Upland Ecological Site Native Ecosystem Diversity State and Transition Model

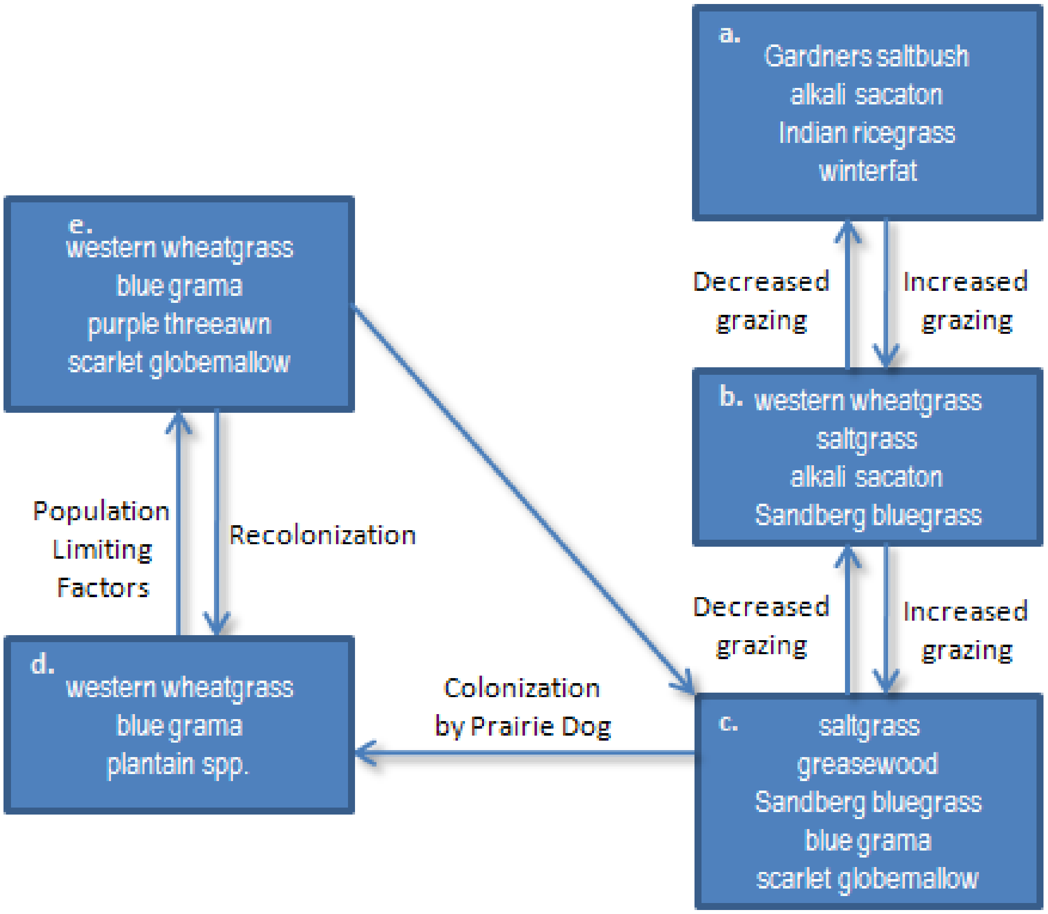


Figure 25. State and transition model for saline upland ecological sites of the Thunder Basin planning area, identifying the historical disturbance states or range of native ecosystem diversity, resulting from natural disturbance regimes.

Structure: mixed grasses and shrubs, herbaceous vegetation 4-6” in height, shrubs up to 3’ in height.
Primary indicators of natural disturbance regimes (% cover):
Light grazing = Gardner’s saltbush≥30%

B. Long Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: variable, but occurring most years at moderate levels
Dominant Species: western wheatgrass, saltgrass, Sandberg bluegrass, thickspike wheatgrass, squirreltail, and blue grama
Other Characteristic Species: Indian ricegrass, alkali sacaton, Gardner’s saltbush, winterfat, and greasewood
Historical Grass and Forb Productivity Estimate: 400 lbs/acre

Structure: mixed grasses and shrubs, herbaceous vegetation 3-5” in height, shrubs up to 3’ in height.
Primary indicators of natural disturbance regimes (% cover):
Moderate grazing = Gardner’s saltbush>10% and <30%

C. Long Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: greater than 25 years; this disturbance state exhibits conditions that indicate the site is normally protected from fire due to surrounding badlands or shallow soils, riparian areas, or prairie dog colonies that could act as fire breaks
Grazing: occurring most years as season long grazing; used more frequently possibly due to location factor such as close proximity to water sources for grazers
Dominant Species: saltgrass, squirreltail, blue grama, Sandberg bluegrass, greasewood, scarlet globemallow, woody aster
Other Characteristic Species: prairie thermopsis, textile onion, American licorice, hairy goldenaster, plains pricklypear, scarlet gaura
Historical Grass and Forb Productivity Estimate: 300 lbs/acre
Structure: mixed grasses and shrubs, herbaceous vegetation 2-4” in height, shrubs up to 3’ in height.
Primary indicators of natural disturbance regimes (% cover):
Heavy grazing = Gardner’s saltbush<10%

D. Prairie Dog Colony, Active Regime

Fire was infrequent on prairie dog colonies because of discontinuous fine fuel resulting from soil disturbance and prairie dog herbivory. Selective grazing by bison and pronghorn antelope also occurred, however the plant community dynamics were driven primarily by the prairie dog activities. Vegetation on active prairie dog colonies and to lesser extent in-active colonies exhibited a dwarfed or stunted growth pattern, due to repeated clipping. Characteristic species that occur on prairie dog colonies include western wheatgrass, blue grama, inland saltgrass, purple threeawn, six weeks fescue, plantain spp., scarlet gaura, common yarrow, aster spp., and plains pricklypear. Plant community composition on active prairie dog colonies was driven by factors that included colony density and age.

E. Prairie Dog Colony, In-active Regime

Prairie dog colonies are considered inactive as long as they are not currently used by prairie dogs, and they still provide the burrow structure characteristic of prairie dog communities, that other wildlife species are dependent upon. Field observations in the Thunder Basin planning area indicate that after approximately 7 years of non-use, most prairie dog burrows have collapsed and no longer serve the role as an inactive prairie dog colony. Plant community composition on inactive prairie dog colonies was driven by previous levels of disturbance by prairie dogs and length of time since abandonment. Colonies that previously had higher levels of disturbance were in early successional stages and took considerable time to recover to pre-disturbance conditions.

Badlands/Gullied land Ecological Sites

The Badland/Gullied land ecological sites occupy approximately 4% of the Thunder Basin planning area. Soils on these sites are derived from sandstone and shale and are characterized by a wide variety of surface soil textures. Topography varies extensively and consists of shale and sandstone outcrops that are interspersed with seams of lignite coal that vary in thickness (Brown 1971). In general, the soils on these sites are alkaline with high sodium content, which have dispersive characteristics similar to that seen in saline upland ecological sites. Topography coupled with the sodic soil conditions make these sites susceptible to water erosion. Vegetation composition varies extensively in these ecological sites which is largely a function of topographic position, soil depth, and surface soil texture which have a strong influence on soil moisture availability. Herbaceous cover is generally low and bare ground is high, which historically resulted in low levels of grazing and very infrequent fire on these ecological sites. Due to the sparsely vegetated nature of these sites, species composition is not likely to be significantly influenced by grazing. Species that occurred on these sites include bluebunch wheatgrass, Indian ricegrass, western wheatgrass, needle and thread, little bluestem, blue grama, threadleaf sedge, plains muhly, American vetch, pussytoes, fringed sagewort, scarlet globemallow, buckwheat species, yucca, greasewood, saltbush, skunkbush sumac, big sagebrush, and Rocky Mountain Juniper.

Example of Badlands/Gullied Land ecological site.

Ecosystem Diversity Matrix

While the diversity of ecosystems occurring across each ecological site can be described individually, a tool for displaying all of the native ecosystem diversity in a landscape has been developed and is termed an ecosystem diversity matrix (EDM) (Haufler et al. 1996, 2000, 2002). For the purposes of the conservation strategy, the EDM represents the coarse filter. The EDM is a conservation planning tool used to describe the native ecosystem diversity of a planning area. Figure 26 provides an example of the EDM framework. For terrestrial ecosystems, the columns of the EDM identify the terrestrial ecological sites occurring in the planning region that exhibit physical differences in soils, moisture, etc., and that in turn influence the potential for a plant community to occur on that site. The rows of the EDM represent the disturbance states as they relate to vegetation communities that can occur on an ecological site due to the influences of historical (both natural and Native American) disturbance regimes. Ecological sites and disturbance states of the Thunder Basin planning area were discussed in Section 4. The intersection of ecological sites (i.e., column) with the disturbance state (i.e., rows) can be described by the resulting vegetation community (i.e., cell) that characterizes that particular condition. Figure 27 represents the EDM for native ecosystem diversity of the Thunder Basin planning region. Each of the vegetation communities within a column correspond to the disturbance states discussed in Section 4. All of the vegetation communities within the entire EDM represent the range of conditions or native ecosystem diversity that can occur in the planning area for terrestrial ecosystems. The amount of each vegetation community can vary over time and this variation is often referred to as the historical range of variability, as discussed in a previous section. The EDM framework is a particularly useful tool for quantifying, assessing, and displaying the cumulative impacts or changes in a landscape relative to historical or native ecosystem diversity.

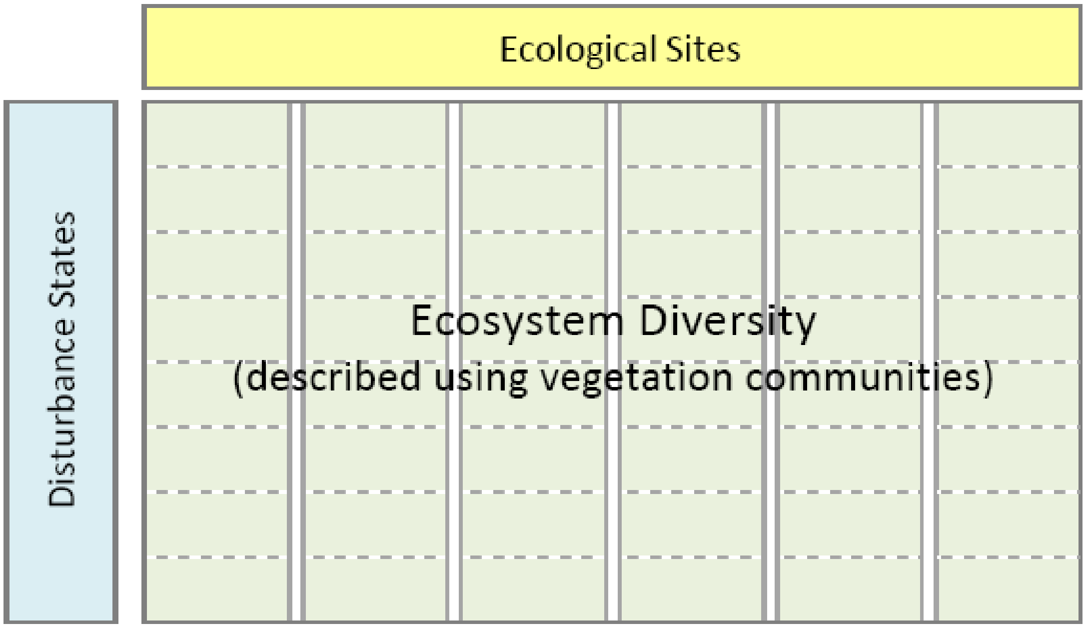


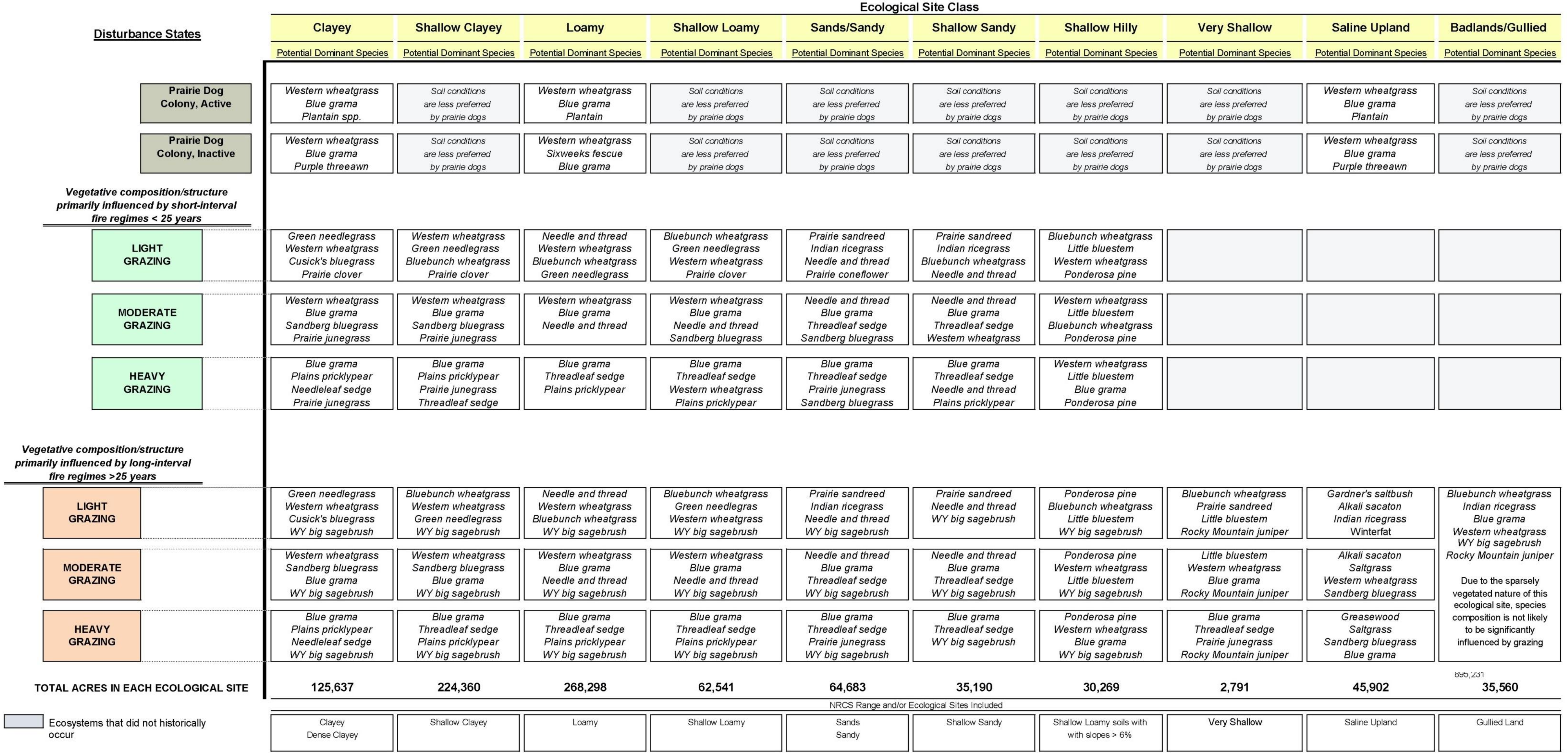
Figure 26. Example of the Ecosystem Diversity Matrix framework.

MODELING THE HISTORICAL REFERENCE

Historical range of variability was modeled for terrestrial ecosystems in Thunder Basin using the spatially explicit landscape model SIMPPLLE (SIMulating Patterns and Processes at Landscape scales)(Chew et al. 2004). SIMPPLLE was used to simulate plant community dynamics as a result of natural disturbance events (e.g., fire, bison grazing, and prairie dog activity), climate, and landscape elements (e.g., ecological site, proximity to water, and elevation). SIMPPLLE uses stochastic probabilities and disturbance response parameters that are specified to annually assign climate disturbance patterns discussed below. Although SIMPPLLE has a variety of potential applications, SIMPPLLE was specifically used to derive the historical range of variability (HRV) for each terrestrial ecosystem. HRV was characterized using the average, minimum, and maximum number of acres that each terrestrial ecosystem occupied in simulations. Below is a description of the model parameters and model assumptions used in the SIMPPLLE simulations of the Thunder Basin planning area.

ECOSYSTEM DIVERSITY MATRIX - WYOMING THUNDER BASIN LANDSCAPE

TERRESTRIAL ECOSYSTEMS



Disturbance States	Ecological Site Class									
	Clayey	Shallow Clayey	Loamy	Shallow Loamy	Sands/Sandy	Shallow Sandy	Shallow Hilly	Very Shallow	Saline Upland	Badlands/Gullied
	Potential Dominant Species	Potential Dominant Species	Potential Dominant Species	Potential Dominant Species	Potential Dominant Species	Potential Dominant Species	Potential Dominant Species	Potential Dominant Species	Potential Dominant Species	Potential Dominant Species
Prairie Dog Colony, Active	Western wheatgrass Blue grama Plantain spp.	Soil conditions are less preferred by prairie dogs	Western wheatgrass Blue grama Plantain	Soil conditions are less preferred by prairie dogs	Soil conditions are less preferred by prairie dogs	Soil conditions are less preferred by prairie dogs	Soil conditions are less preferred by prairie dogs	Soil conditions are less preferred by prairie dogs	Western wheatgrass Blue grama Plantain	Soil conditions are less preferred by prairie dogs
Prairie Dog Colony, Inactive	Western wheatgrass Blue grama Purple threeawn	Soil conditions are less preferred by prairie dogs	Western wheatgrass Sixweeks fescue Blue grama	Soil conditions are less preferred by prairie dogs	Soil conditions are less preferred by prairie dogs	Soil conditions are less preferred by prairie dogs	Soil conditions are less preferred by prairie dogs	Soil conditions are less preferred by prairie dogs	Western wheatgrass Blue grama Purple threeawn	Soil conditions are less preferred by prairie dogs
Vegetative composition/structure primarily influenced by short-interval fire regimes < 25 years										
LIGHT GRAZING	Green needlegrass Western wheatgrass Cusick's bluegrass Prairie clover	Western wheatgrass Green needlegrass Bluebunch wheatgrass Prairie clover	Needle and thread Western wheatgrass Bluebunch wheatgrass Green needlegrass	Bluebunch wheatgrass Green needlegrass Western wheatgrass Prairie clover	Prairie sandreed Indian ricegrass Needle and thread Prairie coneflower	Prairie sandreed Indian ricegrass Bluebunch wheatgrass Needle and thread	Bluebunch wheatgrass Little bluestem Western wheatgrass Ponderosa pine	▨	▨	▨
MODERATE GRAZING	Western wheatgrass Blue grama Sandberg bluegrass Prairie junegrass	Western wheatgrass Blue grama Sandberg bluegrass Prairie junegrass	Western wheatgrass Blue grama Needle and thread	Western wheatgrass Blue grama Needle and thread Sandberg bluegrass	Needle and thread Blue grama Threadleaf sedge Sandberg bluegrass	Needle and thread Blue grama Threadleaf sedge Western wheatgrass	Western wheatgrass Little bluestem Bluebunch wheatgrass Ponderosa pine	▨	▨	▨
HEAVY GRAZING	Blue grama Plains pricklypear Needleleaf sedge Prairie junegrass	Blue grama Plains pricklypear Prairie junegrass Threadleaf sedge	Blue grama Threadleaf sedge Plains pricklypear	Blue grama Threadleaf sedge Western wheatgrass Plains pricklypear	Blue grama Threadleaf sedge Prairie junegrass Sandberg bluegrass	Blue grama Threadleaf sedge Needle and thread Plains pricklypear	Western wheatgrass Little bluestem Blue grama Ponderosa pine	▨	▨	▨
Vegetative composition/structure primarily influenced by long-interval fire regimes >25 years										
LIGHT GRAZING	Green needlegrass Western wheatgrass Cusick's bluegrass WY big sagebrush	Bluebunch wheatgrass Western wheatgrass Green needlegrass WY big sagebrush	Needle and thread Western wheatgrass Bluebunch wheatgrass WY big sagebrush	Bluebunch wheatgrass Green needlegrass Western wheatgrass WY big sagebrush	Prairie sandreed Indian ricegrass Needle and thread WY big sagebrush	Prairie sandreed Needle and thread WY big sagebrush	Ponderosa pine Bluebunch wheatgrass Little bluestem WY big sagebrush	Bluebunch wheatgrass Prairie sandreed Little bluestem Rocky Mountain juniper	Gardner's saltbush Alkali sacaton Indian ricegrass Winterfat	Bluebunch wheatgrass Indian ricegrass Blue grama Western wheatgrass WY big sagebrush Rocky Mountain juniper Due to the sparsely vegetated nature of this ecological site, species composition is not likely to be significantly influenced by grazing
MODERATE GRAZING	Western wheatgrass Sandberg bluegrass Blue grama WY big sagebrush	Western wheatgrass Sandberg bluegrass Blue grama WY big sagebrush	Western wheatgrass Blue grama Needle and thread WY big sagebrush	Western wheatgrass Blue grama Needle and thread WY big sagebrush	Needle and thread Blue grama Threadleaf sedge WY big sagebrush	Needle and thread Blue grama Threadleaf sedge WY big sagebrush	Ponderosa pine Western wheatgrass Little bluestem WY big sagebrush	Little bluestem Western wheatgrass Blue grama Rocky Mountain juniper	Alkali sacaton Saltgrass Western wheatgrass Sandberg bluegrass	
HEAVY GRAZING	Blue grama Plains pricklypear Needleleaf sedge WY big sagebrush	Blue grama Threadleaf sedge Plains pricklypear WY big sagebrush	Blue grama Threadleaf sedge Plains pricklypear WY big sagebrush	Blue grama Threadleaf sedge Plains pricklypear WY big sagebrush	Blue grama Threadleaf sedge Prairie junegrass WY big sagebrush	Blue grama Threadleaf sedge WY big sagebrush	Ponderosa pine Western wheatgrass Blue grama WY big sagebrush	Blue grama Threadleaf sedge Prairie junegrass Rocky Mountain juniper	Greasewood Saltgrass Sandberg bluegrass Blue grama	
TOTAL ACRES IN EACH ECOLOGICAL SITE	125,637	224,360	268,298	62,541	64,683	35,190	30,269	2,791	45,902	895,231 35,560
	NRCS Range and/or Ecological Sites Included									
	Clayey Dense Clayey	Shallow Clayey	Loamy	Shallow Loamy	Sands Sandy	Shallow Sandy	Shallow Loamy soils with with slopes > 6%	Very Shallow	Saline Upland	Gullied Land

▨ Ecosystems that did not historically occur

Figure 27. The ecosystem system diversity matrix for terrestrial ecosystems of the Thunder Basin planning region.

Model Attributes and Assumptions

Model Landscape

The model landscape was created for the Thunder Basin planning area in ArcGIS. The planning area was divided into 4 units for computing feasibility. Each modeled area was delineated into 10 acre cells and each cell was identified as a specific vegetation unit based on its ecological site and by its disturbance state, which was based on its vegetation composition. Landscape features that were static components in each simulated area included ecological sites, aquatic areas, riparian areas, and an estimate of approximate locations of historical prairie dog colonies. The starting point was developed for the Thunder Basin planning landscape using general vegetation descriptions that were included in historical public land survey records (PLSRs) conducted in the 1880's and entered into a GIS database. The PLSR information was then overlayed with GIS polygons of ecological sites. The 1880 PLSR information provided very general descriptions of the dominant plant types (e.g. bunchgrass, sagebrush, etc.) and was not considered to provide accurate descriptions of plant communities at each section marker, as discussed previously. However, this information offered at least a generalized starting point for the modeling effort that was based on spatially reported data from the 1880's, even with the limitations of these data.

Landscape features that were static components in each simulated area included ecological sites (see Figure 16 for the ecosystem classifications for each Ecological Site within the Thunder Basin planning area), aquatic areas, riparian areas, proposed locations of historical prairie dog colonies, and elevation. Ecological sites were mapped using the NRCS ecological site classification applied to soils data. National Hydrography Data and NRCS ecological sites were also used to map wetland, riparian, and aquatic areas. Digital elevation models were used to map elevation within the planning area. The approximate locations of historical prairie dog colonies were derived from a prairie dog suitability assessment conducted for this area that was based on preferred soils, other terrain features, and mapping of existing locations of prairie dog colonies.

Plant Dynamics

The response of key plant species to climate (i.e., precipitation and temperature) and disturbance (i.e., fire and grazing) were tracked annually for each 10 acre cell within SIMPPLLE. Within a given year plant species within each cell were subject to change based on climate (e.g., above average, average, or below average precipitation), grazing (e.g., light, moderate, or heavy grazing), and the occurrence of fire. Subsequently each 10 acre cell was given an ecosystem classification that placed it into a disturbance state within each NRCS designated ecological site based on its species composition. That is, classification rules were developed that used percent cover of species within a cell to identify what historical state it belonged to, and over time climate and disturbance induced changes in plant species composition caused shifts among historical states. Plant species response parameters to climate and disturbance, as well as shifts among historical states were based on expert opinion from a team of rangeland ecologists, and on scientific literature.

Fire

Fire starts were caused by lightning strikes in this model and were stochastically selected, resulting in variations designed to simulate historical variations in lightning caused fires over time. The number of lightning strikes was adjusted in the model to cause increases or decreases in the number of fire starts, but the overall influence of fire was more dependent on the burn patterns than on the number of fire starts. Once a fire started in a given cell it had the opportunity to spread to adjacent cells until it encountered cells that reduced the ability of fire to spread (see below), or encountered a stochastic weather ending event. The probability of fire occurrence was influenced by the climate (precipitation and temperature) in a given year and the grazing history on individual units (e.g., a heavily grazed 10-acre unit in a given year had a lower probability of burning, whereas a lightly grazed 10-acre unit had a higher probability of burning). Fire spread probabilities were also influenced by fixed landscape features, such as prairie dog colonies, gullied land, and aquatic/riparian areas that provided natural fire breaks. Terrestrial ecological sites that had low probability of fire because of sparse fine fuel included the following ecological sites; saline upland, very shallow, badlands, and gullied land which combined represented 84,253 acres within the planning area. The remaining terrestrial ecological sites clayey, shallow clayey, loamy, shallow loamy, sands, sandy, shallow sandy, and shallow hilly representing 810,978 acres, had a fire return probability of 11 years that ranged from approximately 3 to 15 years, with some areas exhibiting low fuel levels burning infrequently or never.

Grazing

Bison grazing intensity was dependent on the proximity of the 10-acre vegetation units to water and the fire history of the vegetation units within the areas simulated. For instance, based on knowledge of bison grazing behavior it was assumed that the closer the 10-acre vegetation units were to water and the more recently burned the vegetation units were, the heavier bison would graze. Vegetation units located between 0 to 5,280 feet away from water had a higher probability of receiving heavy bison grazing, whereas vegetation units located between 5,281 to 15,840 and 15,841 or greater feet away from water had increasingly higher probabilities of receiving moderate or light grazing, respectively. Likewise, the probability of heavy grazing on 10-acre vegetation units 1 to 2 years after a fire was higher, whereas 3 to 5 years and 6 or more years after fire the vegetation units had a higher probability of moderate and light grazing, respectively.

Each of the 4 sections of the Thunder Basin planning area was initially run for 250 years of simulation to allow the model to standardize from the initial starting conditions. The output of these runs for each section was then used to simulate historical ecosystem dynamics. Five simulations, each representing 85 years, were performed in SIMPPLLE for each of the four sections of the Thunder Basin planning area. In each of the simulations, the weather patterns were varied but within the range of weather patterns recorded for the Thunder Basin area. Fire starts were also stochastic, resulting in variations designed to simulate historical variations over time. Following the simulations the data were combined from the 4 sections to reflect the entire planning area and results were summarized using the Ecosystem Diversity Matrix framework described previously.

Results of the SIMPPLLE Model Simulations

Results of the SIMPPLLE model simulation of the historical range of variability in the Thunder Basin planning area can be found in Figure 28 and includes the average, minimum, and maximum number of acres in the Thunder Basin planning area occupied by each terrestrial ecosystem. The historical range of variability simulation illustrated that the majority of the terrestrial ecosystems in this area were historically in the vegetation conditions described by the short interval fire regime and accompanying grazing levels (Table 3). Sparsely vegetated sites represent inclusions of poor soil conditions where grazing levels would not influence the spread of fire, i.e., vegetation conditions, whether grazed or ungrazed, would never carry a fire. Modeling results included historical vegetation conditions reflective of light, moderate, and heavy grazing regimes that were produced in nearly equal proportions in the Thunder Basin planning area by the SIMPPLLE model and parameter specifications.

Table 3. Summary of the results of SIMPPLLE model simulations illustrating the % of the Thunder Basin planning area with vegetation conditions described by short or long fire return intervals and light, moderate, heavy grazing, or sparsely vegetated.

	Fire Return Interval	
Grazing Regime	Short	Long
	% of the landscape	
Light	26.3	3.6
Moderate	27.4	2.0
Heavy	22.9	3.8
Sparsely vegetated	na*	13.9

* na – not applicable, vegetation conditions will not carry fire

ECOSYSTEM DIVERSITY MATRIX - WYOMING THUNDER BASIN LANDSCAPE

TERRESTRIAL ECOSYSTEMS

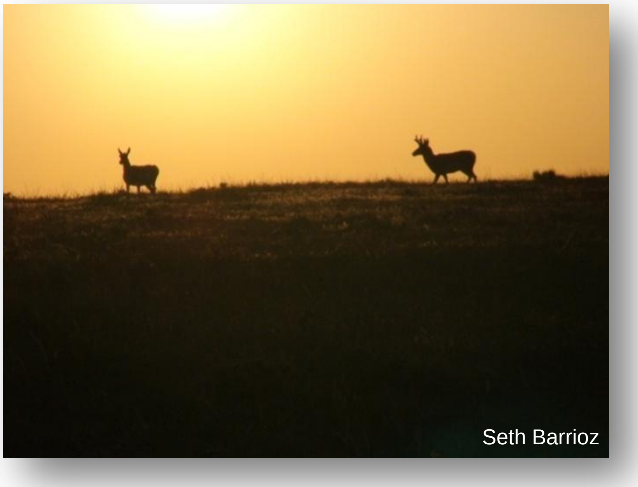
Disturbance States	Ecological Site Class									
	Clayey	**Shallow Clayey**	**Loamy**	**Shallow Loamy**	**Sands/Sandy**	**Shallow Sandy**	**Shallow Hilly**	**Very Shallow**	**Saline Upland**	**Badlands/Gullied**
	Mean Acres (HRV)	Mean Acres (HRV)	Mean Acres (HRV)	Mean Acres (HRV)	Mean Acres (HRV)	Mean Acres (HRV)	Mean Acres (HRV)	Mean Acres (HRV)	Mean Acres (HRV)	Mean Acres (HRV)
Praie Dog Colony**	HRV Unknown		HRV Unknown						HRV Unknown	
Vegetative composition/structure primarily influenced by short-interval fire regimes < 25 years										
LIGHT GRAZING	40,471 (30,710 - 47,969)	44,690 (32,612 - 53,490)	90,235 (73,170 - 102,646)	20,566 (14,125 - 25,538)	20,285 (15,545 - 25,024)	10,327 (6,308 - 13,914)	9,435 (6,480 - 11,716			
MODERATE GRAZING	44,161 (40,113 - 52,017)	65,569 (59184 - 75404)	77,307 (70,326 - 88,684)	17,628 (15,312 - 22,148)	21,043 (17,252 - 26,162)	10,575 (7,421 - 14,780)	8,087 (7,025 - 10,161)			
HEAVY GRAZING	31,543 (22,140 - 43,327)	59,357 (47106 - 76612)	70,844 (55,330 - 91,269)	16,837 (12,713 - 22,205)	12,007 (7,267 - 18,705)	7,297 (4,391 - 11,008)	7,724 (5,832 - 10,187)			
Vegetative composition/structure primarily influenced by long-interval fire regimes > 25 years										
LIGHT GRAZING	2,381 (952 - 4,642)	2,071 (690 - 3,969)	11,893 (6,981 - 17,582)	1,413 (452 - 2,995)	7,141 (3,665 - 11,880)	2,257 (155 - 6,648)	648 (207 - 1,374)	913 (518 - 1,210)	4,160 (3,353 - 5,136)	N/A
MODERATE GRAZING	357 (0 - 1,309)	518 (173 - 1,553)	7,239 (6,464 - 10,601)	17 (0 - 57)	1,959 (632 - 4,108)	340 (0 - 2,041)	8 (0 - 26)	1,007 (710 - 1,444)	7,173 (3,523 - 12,309)	N/A
HEAVY GRAZING	119 (0 - 714)	345 (0 - 1,035)	1,034 (259 - 2,844)	45 (0 - 226)	758 (126 - 2,022)	124 (0 - 1,237)	21 (0 - 104)	682 (406 - 1,056)	31,113 (25,552 - 35,230)	N/A
SPARSELY VEGETATED	6,606	51,811	9,745	6,041	1,490	4,270	4,348	189	3,456	6,499
TOTAL ACRES	**125,637**	**224,360**	**268,298**	**62,541**	**64,683**	**35,190**	**30,269**	**2,791**	**45,902**	**35,560**
	NRCS Range and/or Ecological Sites Included									
	Clayey Dense Clayey	Shallow Clayey	Loamy	Shallow Loamy	Sands Sandy	Shallow Sandy	Shallow Loamy soils with slopes > 6%	Very Shallow	Saline Upland	Gullied Land

N/A = Information not available

☐ Ecosystems that are not expected to have occurred historically

Figure 28. Results of a modeling effort to estimate Historical Range of Variability for the Thunder Basin planning area. The number in each cell represents the mean acres and the Historical Range of Variability in acres (in parenthesis). Refer to the text for a description of the methods used to obtain these results. Mean acres and HRV of prairie dog colonies were not developed through the historical modeling effort due to a lack of information on historical prairie dog distributions and population dynamics. The "Sparsely vegetated" state represents inclusions of soil conditions (i.e., slickspots, rocky sites, etc,) that are poorly vegetated and are likely not influenced by fire or grazing regimes.

5.0 TODAY'S TERRESTRIAL ECOSYSTEM DIVERSITY



Seth Barrioz

Native ecosystems and habitats have and continue to be directly and indirectly altered by human actions. Although Native Americans interacted and influenced ecosystems for thousands of years, these influences are incorporated in an historical reference. It is the extent of human influence over the last 150 years that is of primary concern to native ecosystem diversity in the Thunder Basin region. Land conversion to domestic grasslands, urban uses such as roads, and energy production are the most obvious impacts. However, there are also less obvious, yet in some instances more pervasive, human-induced changes as well. The implications of a century of alterations to and interruptions of natural disturbance regimes in the Thunder Basin region have only recently become understood. Recent studies have shown that the suppression, alteration, or cessation of natural disturbance has gradually changed ecosystem processes and ultimately the composition, structure, and function of many ecosystems (Knight 1994, Perryman 1996).

ASSESSING TODAY'S ECOSYSTEM CONDITIONS

Developing a clear understanding of the ecosystem conditions present within the planning area today is a necessary first step toward identifying and quantifying cumulative changes to native terrestrial ecosystem diversity. To develop this understanding, an intensive assessment of vegetation conditions was initiated in 2003 and completed in 2005 for the Thunder Basin planning region. The assessment utilized a combination of vegetation field surveys and remotely sensed data to identify and describe today's ecosystem conditions. The following sections provide a summary of the methods used and the results obtained from this assessment of terrestrial ecosystems.

Previous Studies

Existing vegetation in the Thunder Basin landscape has been classified or described in various reports and environmental analyses. Thilenius et al. (1995) described the vegetation types of the Cheyenne River Basin. This study placed 158 sampling plots in stands within the Basin, from which they identified 22 different existing vegetation types based on a cluster analysis of plant compositions and other information. They did not stratify stands by soils, but did describe the soils occurring across each of the 22 types, and found that soils were a key component in determining the compositions of many of the types. Thilenius et al. (1995) did not attempt to map or quantify amounts of the different vegetation types, other than to identify if each type was common or rare. Nor did the study examine the dynamics, causative drivers, and inter-relationships of the various plant communities.

The US Forest Service (USDA Forest Service 2001) prepared a Land and Resource Management Plan for the Thunder Basin National Grasslands. This plan set desired conditions based on successional stages developed by Benkobi and Uresk (Benkobi and Uresk 1996). The successional stages are based on a sagebrush dominated habitat type (Daubenmire 1968) and use three species (western wheat, blue grama, and sagebrush) as indicators of the different successional stages within this habitat type. This approach did not consider the interacting influences of fire and grazing, nor did it consider the differences caused by different ecological sites. Thus it differs substantially from the approach described in this assessment which uses ecological sites and state and transition models to characterize and identify the various historical plant communities.

Energy production activities in the Thunder Basin have resulted in a number of environmental impact analyses. Each of these described existing plant communities in the development areas. Various covertype (i.e., existing dominant vegetation not tied to an ecological site) classifications of these communities have been used over the years.

Methods

Remote sensing using SPOT 5 multi-spectral satellite imagery was combined with NRCS delineated ecological sites to create a geographic information system layer of current dominant vegetation occurring on each ecological site. This information was then integrated with field data sampled from 2003 through 2005. The EDM framework was used to stratify field sampling and develop the remote sensing data classification. Field sampling provided specific information about the existing ecosystem diversity or vegetation conditions of each combination of disturbance state and ecological site.

Remote Sensing Vegetation Classification

Ten meter resolution multi-spectral imagery from the SPOT 5 satellite was used to classify the Thunder Basin planning area into vegetation classes (Figure 29). SPOT 5 satellite images of the planning area were obtained from iCubed Technologies (Fort Collins, CO), who worked in conjunction with the SPOT Corporation for image acquisition. Image interpretation was conducted by Symmetry, Inc. of Boulder, CO. The interpretation used image analysis software to perform both unsupervised and supervised image classifications. The unsupervised classification resulted in each 10 m pixel being assigned to a class based on spectral similarity. The supervised classification then used the unsupervised classification and assigned these supervised classes to a land cover class that was identified based on training points delineated in the field. Following classification of the Spot image into land cover classes, image classification accuracy was assessed by randomly selecting ground-truthing sample points in ArcGIS. Sample points for ground-truthing were selected by land cover class and involved field measurements of shrub cover and general observations of site conditions during the 2006 growing season.

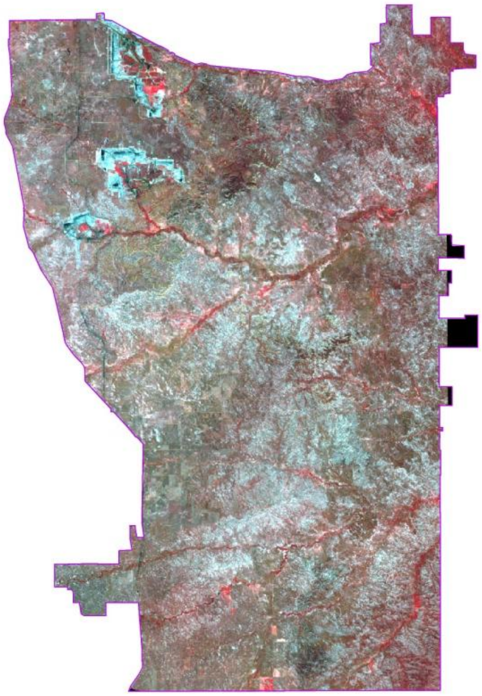


Figure 29. Unclassified SPOT 5 satellite imagery of the Thunder Basin planning area. Areas in black represent missing imagery.

Vegetation and Ecological Site Sampling

The vegetation sampling conducted in 2003-2005 included 571 plots distributed across terrestrial sites located on public and Association member lands. Plots were distributed across private Association member lands and across public lands using a stratified random design. Several plots were visited but rejected because they did not meet the specified ecological site or contained over 75% exotic species. A sampling distribution summary for the 571 plots sampled from 2003 through 2005 is presented in Table 4. Over 273 species from 48 families were identified in the sample plots. About 50% of the species found were in one of three families, Asteraceae, Fabaceae, or Poaceae.

Plots were first stratified across ecological sites, and secondarily stratified by dominance of existing vegetation. Plots were stratified and then randomly assigned for location across each of the ecological sites and by shrub cover <10%, shrub cover >10%, ponderosa pine, and prairie dog colonies. NRCS ecological site delineations, which were based on NRCS soil types, were used to determine sample locations across the ecological sites. Existing satellite and air photo imagery was used to identify areas with <10% and >10% shrub cover. Mapping errors for ecological sites or inconsistencies identified in the field were subsequently corrected for analysis of plant community existing conditions. Ecological sites for each plot were determined by examination of the soil at the plot. If the plot location was found to be a different ecological site than the targeted ecological site due to either errors in soil mapping or inclusion of different soils within mixed-soil polygons, then a new plot location was randomly selected. Plant communities were sampled at each plot, but plots were stratified into areas suspected of having <10% shrub cover as well as areas suspected of having >10% shrub cover in order to sample plant communities with both low and high levels of shrub cover across the various ecological sites. Ponderosa pine was sampled within the shallow hilly ecological site where these plant communities occurred.

Table 4. Terrestrial ecological sites sampled in the Thunder Basin planning area from 2003 through 2005.

	Number of	Number of plots sampled by year		
Ecological Site	Plots Sampled	2003	2004	2005
Clayey	79	28	24	27
Shallow Clayey	47	8	20	19
Loamy	170	97	39	34
Shallow Loamy	60	14	25	21
Sandy	77	51	15	11
Shallow Sandy	41	16	15	10
Shallow Hilly	20	-	20	-
Very Shallow	1	1	-*	-
Saline Upland	76	42	16	18
Badlands/Gullied Lands	0*	-	-	-

* No stratified sampling allocated to this ecological site

At each plot location the ecological site designation was verified as mentioned above. The elevation, slope aspect, and slope gradient were recorded. Geomorphic information was recorded including slope complexity, slope shape, hillslope profile position, and geomorphic component. Photographs of each plot were taken prior to conducting the vegetation sampling including one transect photograph and an additional photograph of a representative microplot. Vegetation on each plot was sampled for frequency, cover, productivity, and structure using the following procedures. Taxonomy used in this assessment follows the PLANTS database (USDA-NRCS 2008). A 50 m vegetation transect was placed in a randomly determined direction from the designated plot location. Beginning at 1 m from the start of the transect, microplots (standard 20 cm x 50 cm Daubenmire quadrat frames) were placed every 2 m (i.e., 1m, 3m, 5m, etc.) along the first 30m of the transect for a total of 15 quadrats (Figure 30). One side of the quadrat was consistently placed along the vegetation transect. Canopy cover of each plant species occurring in the microplots was estimated and recorded using the following cover classes (0.01-1%, 1-10%, 10-20%, 20-30%, 30-40%, 40-50%, 50-60%, 60-70%, 70-80%, 80-90%, 90-99%, and 99-100%). Canopies of plants extending over the microplot were included in the estimates even if the plant was not rooted in the microplot. For subsequent analysis absolute cover values for each plot were converted to relative cover values and used in the assessment of existing conditions. Productivity of grasses and forbs were estimated by species on the first 10 quadrats sampled using double sampling methods (Pechanec and Pickford 1937). Estimates of plant wet weight were made only on plants rooted in the microplots and were converted to dry matter estimates using conversion tables based on plant phenology. Following microplot sampling for cover and productivity, rare species and trees were assessed in a macroplot (Figure 30), which was 25m X 15m or 375m^2. The 375 m^2 area was searched for species not encountered in the microplot sampling (i.e., rare species) the cover they occupied within the macroplot was estimated in three classes (0.01-1%, 1-5%, >5%). If trees occurred within the macroplot they were counted by species and recorded by diameter class. Canopy cover of all species of woody vegetation, in addition to being estimated within the Daubenmire frames, was also sampled using the line intercept method (Canfield 1941) along the entire 50m transect. Minimum contact and gap determinations were specified for the line intercept sampling. Vegetation structure was determined by recording 12 Robel pole measurements made on each plot distributed along the plot transect. Robel measurements were made by determining the highest 1in band on the Robel pole that was totally or partially visible when viewed from a distance of 4m and a height of 1m (Robel et al. 1970).

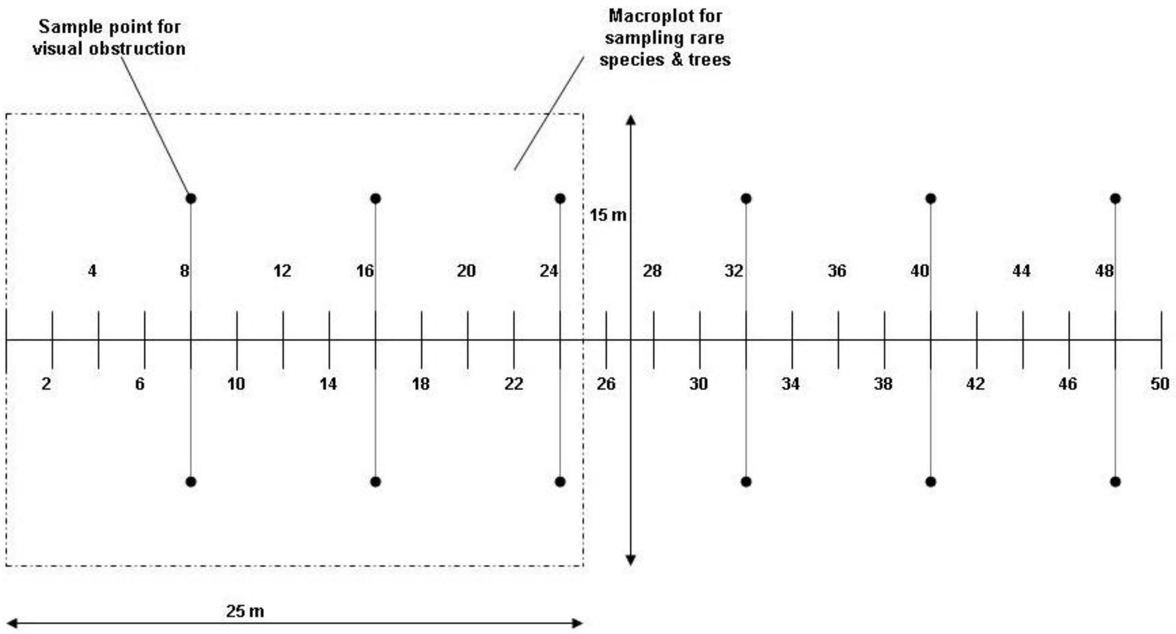


Figure 30. Vegetation plot sampling design utilized assessing existing ecological site conditions in the Thunder Basin planning area from 2003 through 2005.

Quantifying Existing Conditions

Spot imagery was used to map the amounts of various land cover classes for two primary purposes: 1) to determine the appropriate disturbance state, and 2) to help characterize existing vegetative conditions. The following land cover classes were mapped from the Spot 5 data and overlaid with a map of ecological sites to determine estimated amounts of each of these classes by ecological site:

1) Grassland – (<10% shrub cover)
2) Grassland/shrub (>10% shrub cover)
3) Ponderosa Pine
4) Sparsely Vegetated
5) Other types:
    a. Riparian vegetation – where it occurs on terrestrial ecological sites, likely due to soil mapping errors
    b. Surface water
    c. Disturbed sites – includes surface mining, gravel pits, etc.
    d. Unclassified sites – due to limitations of imagery

The Spot imagery was used to estimate the amounts of each of the above cover class/ecological site combination. Each vegetation class (grassland<10% shrub cover, grassland/shrub>10% cover, and ponderosa pine) were then evaluated as to their plant community composition relative to effects of past grazing levels based on the randomly sampled plot data. Each randomly sampled plot was evaluated relative to the primary indicators of natural disturbance regimes (see descriptions for each ecological site x disturbance state identified in Section 4). The 10% level of shrub cover was used as an estimate of shrub amounts that would have historically occurred on appropriate ecological sites (see further discussion below) if these sites did not burn in the previous 25 years. It thus serves as a determinant of amounts of existing vegetation that would be categorized as occurring in the long versus short (> or < 25 year fire return interval) irregardless of actual occurrence of fire on these sites in the previous 25 years.

An additional analysis was conducted to determine the percentage of plots that would not be considered representative of native ecosystem diversity within each cover class/ecological site combination due the presence of exotic species. Relative cover of exotic species occurring in plots was placed into 4 levels of amounts of exotic species: 5%, 10%, 15%, and 20%. Using the percentages determined from these analyses, existing acreage of each historically-occurring ecosystem type based on species compositions that currently occurred within the planning landscape was estimated. This amount was compared to the estimates of amounts that occurred historically to determine the relative level of current representation of each ecosystem type, under various levels of exotic species.

The grassland and grassland/shrub covertypes (> or < 10% shrub levels) were only applied to those ecological sites that historically were expected to have had both a short and long-fire return interval that could have influenced a site. Specifically, clayey, shallow clayey, loamy, shallow loamy, sands/sandy, and shallow sandy sites were included in this covertyping. Shallow hilly should be included with these ecological sites, but this category was identified late in the process and plot data were not stratified on this ecological site. The very shallow, saline upland, and badland/gullied lands ecological sites are expected to burn primarily under the long fire return interval, therefore, differentiating grassland from grassland/shrub covertypes was not necessary.

Results

Precipitation

Precipitation was highly variable throughout the years of the assessment (
Figure 31) (Western Regional Climate Center 2008). The average annual precipitation for the Dull Center weather station from 1949 to 2005 was 12.4in. In 2003, the annual precipitation was 14.6in. Precipitation dropped below the long term average in 2004 with only 9.9in, and was above average in 2005 with 13.4in. More important, however, was the timing of precipitation during these years. The growing season in Thunder Basin is primarily from April through August where on average about 8.5in of precipitation falls. Precipitation during the growing season in 2003 was 7.6in, slightly below the annual average, however, 2.2 inches also fell during the month of March. The driest growing season sampled was 2004, which received 5.1in of precipitation from April through August with 3.1 inches of that precipitation falling in the month of July. Precipitation during the 2005 growing season was the highest at 9.7 inches.

Remote Sensing Vegetation Classification

Analysis of the Spot 5 imagery produced a map of land cover classes for the Thunder Basin planning area (Figure 32). The numbers of acres found in each land cover class are summarized by ecological site and are presented in Table 5. Note that the objective for differentiating grassland (shrub cover < 10%) and grassland/shrub (shrub cover >10%) was to identify structural conditions similar to those exhibited on ecological sites historically influency by both short and long interval fire regimes. For those sites that were historically influenced by only the long interval fire regimes, all acres identified as grassland or grassland/shrub conditions were combined into the grassland/shrub covertype. Also, all acres identified as grassland or grassland/shrub conditions for the shallow hilly ecological site were combined into the ponderosa pine cover type, as the the land cover classes were not designed to adequately differentiate historical conditions on this ecological site. Table 6 provides more detail on the covertypes identified as “other” in Table 6, by ecological site as well. Grassland with shrub cover less than 10% was the most prevalent land cover occupying approximately 52% of terrestrial ecosystems of the planning area. The grassland/shrub cover type with greater than 10% shrub cover represented approximately 16% of the planning area. Ponderosa pine and sparsely vegetated occupied approximately 3% and 11% of the planning area, respectively. Other land cover conditions such as riparian, water, disturbed and unclassified occurred on approximately 18% of the planning area. Sample points were ground-truthed during the 2006 growing season to determine the accuracy of the land cover classification.

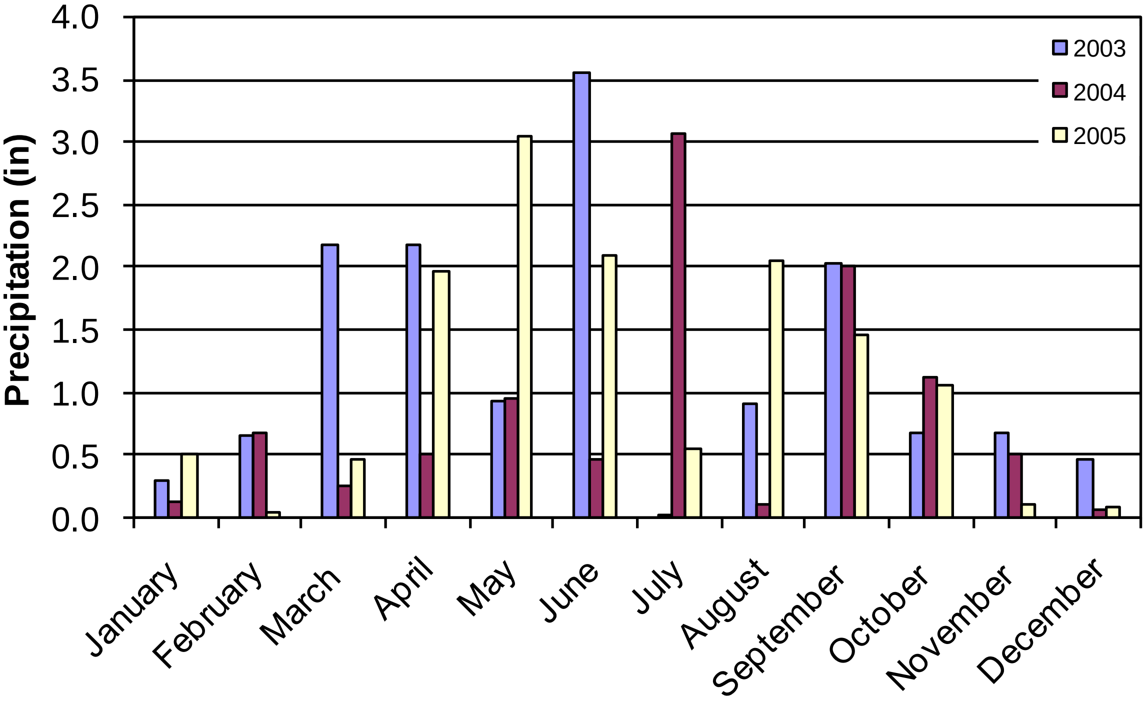


Figure 31. Monthly precipitation patterns from 2003 through 2005 (Western Regional Climate Center 2008).

Accuracy assessment of the Spot 5 land cover classification indicated that the overall accuracy was 81.6% (Table 7). The percentage of sagebrush and other shrub cover occurred along a continuous gradient, making the determination of <10% and >10% categories difficult. Correct classification of grassland was 51-74% and grassland shrub was 67-73%, with most errors resulting from misclassification of the amount of sagebrush. However, included in this error was the inability to discern the amounts of greasewood occurring on saline sites due to its having a similar spectral reflectance as various grasses. Generally, accuracy of the detection of stands with either very high amounts of sagebrush or very low amounts of sagebrush was generally good, but the intermediate levels of sagebrush were more difficult to distinguish. Ponderosa pine and other cover classes were mapped with relatively high accuracy.

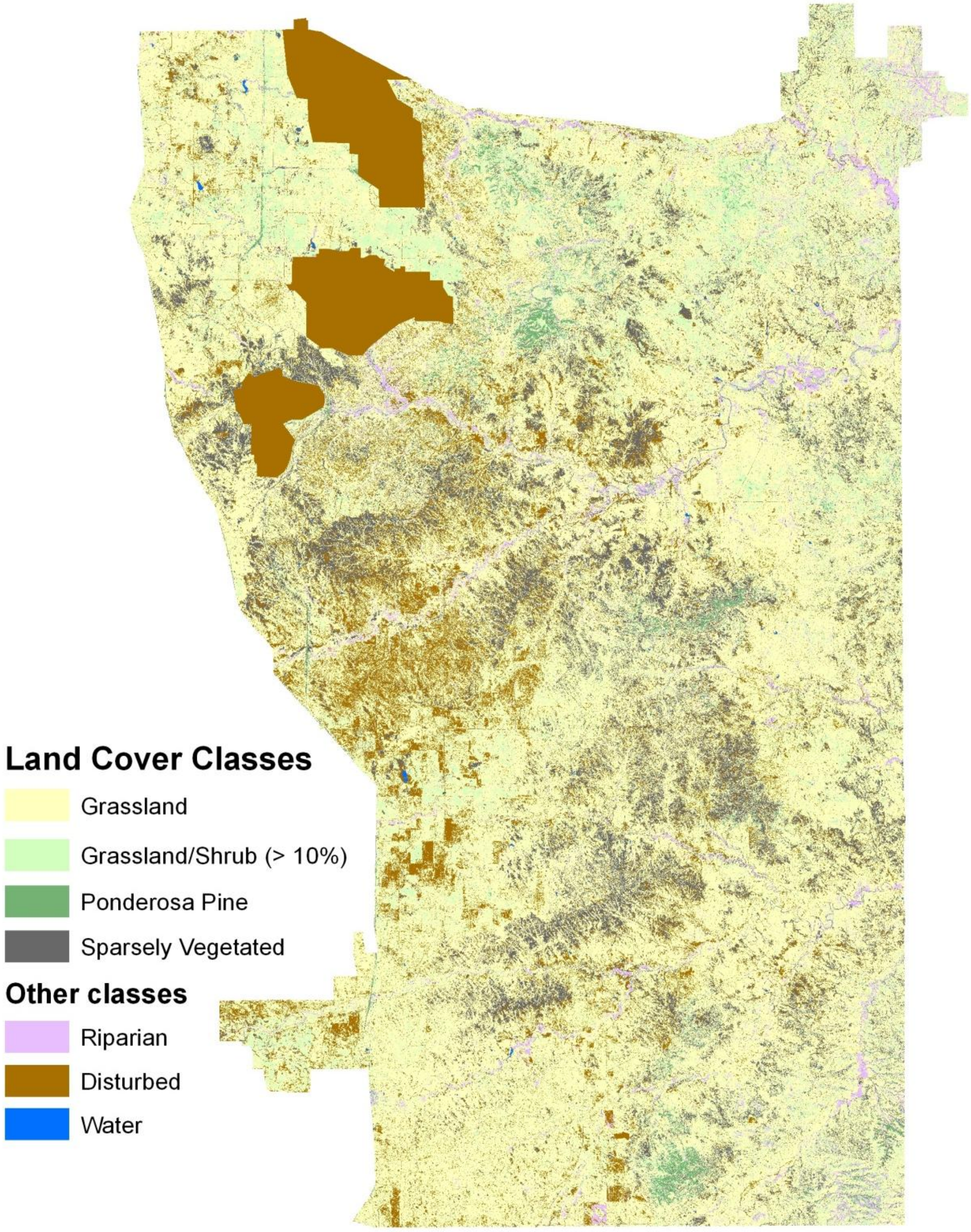


Figure 32. Map of the SPOT 5 satellite imagery land cover classification for the Thunder Basin planning area.

Table 5. Summary of acres within land cover classification categories identified with SPOT 5 satellite imagery, by ecological site.

	SPOT 5 Satellite Imagery Land Cover Classification Categories					
Ecological Site	**Grassland (shrubs <10%)**	**Grassland/ shrub (shrubs >10%)**	**Ponderosa Pine**	**Sparsely Vegetated**	**Other**	**TOTAL**
	- acres -					
Clayey	76,147	14,362	213	6,606	24,933	122,261
Shallow Clayey	118,883	15,518	351	51,811	35,620	222,183
Loamy	163,862	37,913	589	9,745	47,661	259,770
Shallow Loamy	39,419	5,331	299	6,041	10,890	61,980
Sands/Sandy	38,096	10,612	258	1,490	12,754	63,210
Shallow Sandy	21,651	4,186	87	4,270	4,228	34,422
Shallow Hilly	-	-	(22,540)**	4,348	3,341	7,689
Very Shallow	-	(1,810)	2	189	787	978
Saline Upland	-	(29,914)	77	3,456	9,202	12,735
Badlands/Gullied Lands	-	(23,553)	106	6,499	4,699	11,304

*Note – the dotted line in the table differentiates those ecological sites where both short and long fire return intervals occur within an ecological site (above dotted line) versus those ecological sites where primarily long-fire return intervals occur (below dotted line).

**Parentheses indicate where spot imagery acres were combined for grassland into the grassland/shrub cover class to represent the appropriate disturbance state or cover class for long interval fire. Also, shallow hilly acres were comined for grassland and grassland/shrub into the ponderosa pine cover class.

Table 6. Land cover class categories comprising the combined "other" cover class identified in Table 5, by ecological site.

	SPOT 5 Satellite Imagery Land Cover Classification “Other” Categories				
	Riparian	**Water**	**Disturbed**	**Not Classified**	**TOTAL**
	- Acres -				
Clayey	1,736	67	22,985	145	24,933
Shallow Clayey	2,783	99	31,857	881	35,620
Loamy	8,732	118	33,946	4,865	47,661
Shallow Loamy	1,434	19	8,448	989	10,890
Sands/Sandy	1,307	27	11,201	219	12,754
Shallow Sandy	937	5	3,043	243	4,228
Saline Upland	2,125	27	7,049	1	9,202
Very Shallow	44	0	733	10	787
Shallow Hilly	1,356	41	1,944	0	3,341
Badland/Gullied Land	1,657	32	1,791	1,219	4,699

Table 7. Omission/commission table for the assessment of land cover classification accuracy derived from SPOT 5 10-m multi-spectral imagery for the Thunder Basin planning area. Numbers in bold indicate the number of plots correctly identified, whereas non-bolded numbers in a given row indicate the number of plots omitted and the non-bolded numbers in a given column indicate the number of plots committed.

Omissions

Comissions

	Land Cover Class							**Classification Accuracy**	
Land Cover Class	Grassland	Grass/ Shrub> 10%	Sparsely Vegetated	Disturbed	Ponderosa Pine	Water	Riparian	Omissions	Commissions
	- Number of Plots -								
Grassland	**20**	11		3	2		1	71.4	54.1
Sagebrush> 10%	8	**22**						66.7	73.3
Sparsely Vegetated			**7**					100.0	100.0
Disturbed				**8**				100.0	100.0
Ponderosa Pine					**28**			93.3	100.0
Water						**26**		100.0	100.0
Riparian							**0**	0	100.0

Overall Classification Accuracy = 81.6

General Characteristics of Terrestrial Ecological Sites

Existing vegetation occurring in Thunder Basin is the product of past and on-going land uses and disturbances, both natural and antropogenic. Direct conversion of areas has occurred primarily from energy production activities. In the past following homesteading, farming converted some areas. Virtually no farming is currently being practiced today, and many previously farmed sites have revegetated to a combination of native and exotic species on these go-back lands. It was not possible to accurately map go-back lands within the landscape, although various past disturbances are noticeable from air photos. Existing vegetation is also a reponse to the changes in historical disturbance regimes. The role of fire in the landscape has been altered; a result of both an active fire suppression policy and the effects of grazing over the past 50+ years that have reduced fuels. Current grazing practices that strive to maximize the economic return from ranchlands differ from historical grazing regimes. Current grazing management improvements include water development activities to spread grazing use evenly across the landscape, and utilizing available forage to the fullest extent. The definition of using the grass resource to the fullest extent varies among ranches in the landscape.

Sampling of existing vegetation was primarily conducted using a stratified random design that randomly located plots within ecological sites. Plots were also stratified so as to occur in both stands supporting high levels of shrubs (>10% absolute shrub cover) and in stands with lower levels of shrub cover. In addition, some plots were stratified to occur on active and in-active prairie dog colonies, and recent burns, although these plots were not included in the quantification of the amounts of existing plant communities, or in the plots used to describe specific states within ecological sites. For the overall description of the existing vegetation presented below, data from all of the sampled terrestrial plots are included.

Dominant Species

Western wheatgrass is the most dominant species occurring across all of the terrestrial ecological sites followed by blue grama, big sagebrush, annual brome species (cheatgrass and Japanese brome), needleandthread, and to a lesser extent threadleaf sedge and six weeks fescue (Table 8). Several introduced species occurred with high frequency across terrestrial ecological sites. Annual brome is a dominant and frequently occurring species across several of the ecological sites sampled, especially saline upland sites. However, annual brome was not as prevalent on sandy and shallow sandy ecological sites. Other site preferences observed include soapweed yucca and needleandthread preference for sandy sites, greasewood preference for saline upland, and big sagebrush preference for all ecological sites except for shallow sandy and saline upland.

Canopy Cover

Several interesting differences in mean understory (vegetation <1 m in height) canopy cover occurred within and across terrestrial ecological sites sampled from 2003 through 2005 (Figure 33). Within each ecological site the mean canopy cover was different in each year sampled, which likely represents differences in the timing and quantity of moisture. Across ecological sites, the greatest canopy cover occurred in 2003 followed by 2005. Canopy cover was lowest in 2004, likely a result of the drought conditions that occurred throughout that growing season. Differences in canopy cover observed between 2003 and 2005 could be a function of ample spring moisture in 2003, which resulted in early plant growth during the growing season. Differences in seasonal crews might also have been a factor, although consistent training of crews was used in each of the years to minimize any observer differences, and one crew member worked in both 2003 and 2005.

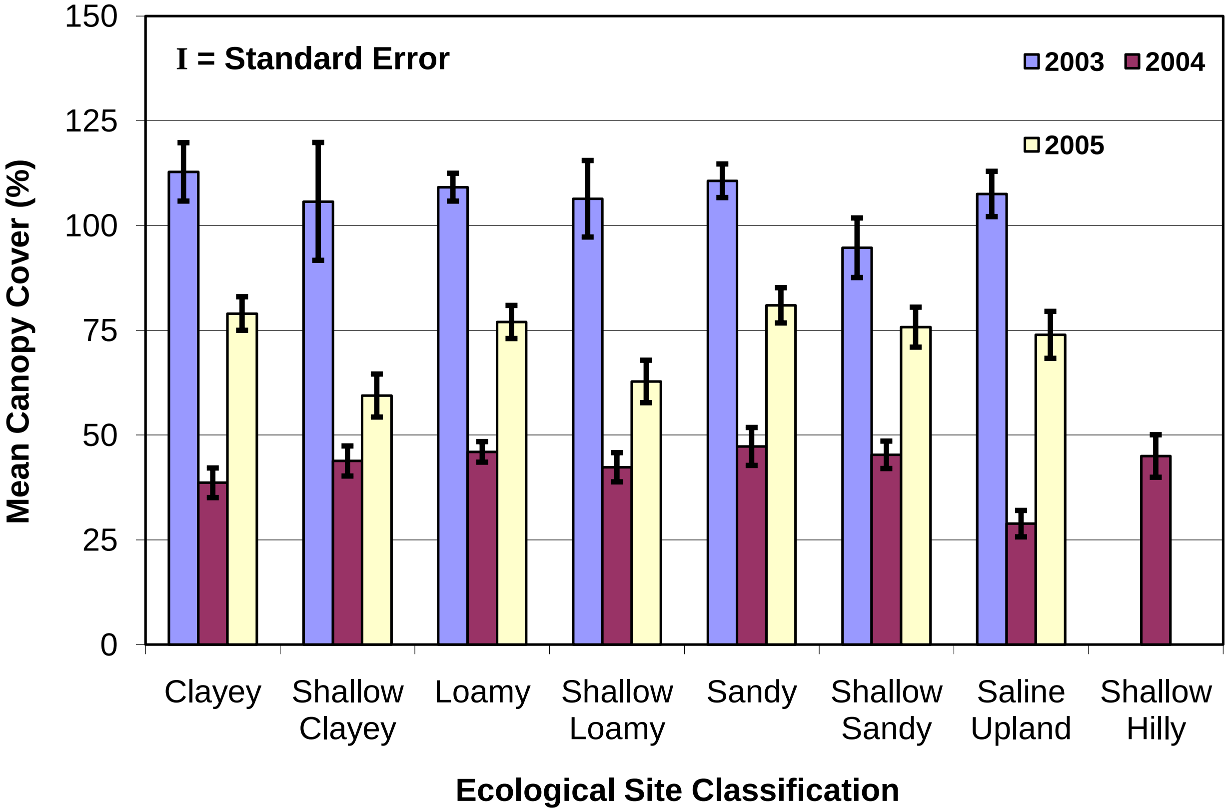


Figure 33. Mean understory canopy cover (+/- standard error of the mean) from 2003 through 2005 on terrestrial ecological sites in the Thunder Basin planning area.

Table 8. Dominant plant species expressed as relative cover in terrestrial ecological sites sampled in Thunder Basin, WY in from 2003 through 2005. Average absolute cover (%) for an ecological site is also provided in parentheses. Dominance is based on understory (vegetation <1m in height) quadrat sampling in each plot. Very Shallow and Badlands/Gullied lands ecological sites were not included in the quadrat sampling.

Plant Species	**Relative Cover (%) of the 10 Most Dominant Plant Species by Ecological Site**							
	Clayey (76.8%)	**Shallow Clayey** (69.7%)	**Loamy** (77.4%)	**Shallow Loamy** (70.5%)	**Sandy** (79.6%)	**Shallow Sandy** (71.9%)	**Saline Upland** (70.1%)	**Shallow Hilly** (45.0%)
annual brome	7.9	8.3	9.6	7.9	6.5	3.4	15.1	2.1
prairie sagewort	0.3	0.4	0.5	0.8	0.7	2.9	0.1	0.5
purple threeawn	1.4	0.5	2.4	1.2	1.6	2.8	1.8	1.3
big sagebrush	7.5	12.7	7.4	12.1	5.9	6.3	1.1	11.3
blue grama	9.6	14.8	9.5	12.6	9.2	7.4	8.5	7.2
needleleaf sedge	4.2	2.0	3.7	3.1	3.5	0.4	1.2	3.8
threadleaf sedge	0.9	3.0	3.9	5.1	11.6	21.7	0.4	0.8
slender wheatgrass	2.5	3.1	0.2	1.6	0.0	2.2	0.3	0
needle and thread	3.4	3.8	6.3	7.7	11.6	13.4	1.1	6
Rocky Mtn. juniper	0.1	0.0	0.0	0.1	0.0	0.0	0.0	3.7
prairie junegrass	1.5	2.1	1.1	2.4	1.9	2.0	0.1	2.2
common pepperweed	1.6	0.6	0.9	0.4	0.5	0.4	2.6	0
plains pricklypear	2.9	2.2	3.2	2.1	2.8	2.1	5.3	0.9
western wheatgrass	29.0	19.3	26.8	18.2	23.4	5.8	25.4	9.1
wooly plaintain	2.6	1.8	2.9	1.2	1.2	0.8	2.6	0.1
bluegrass spp.	7.2	6.7	5.1	4.1	4.7	1.5	9.4	0.3
bluebunch wheatgrass	0.2	1.3	0.0	1.7	0.0	1.2	0.0	11.6
greasewood	0.2	0.2	0.0	0.2	0.0	0.0	3.9	0
sixweeks fescue	4.1	1.8	6.3	4.2	4.5	2.6	3.8	0.3
soapweed yucca	0.3	0.3	0.1	0.5	0.9	7.2	0.0	1.2

Vegetation Structure

Vegetation structure also differed across terrestrial ecological sites from 2003 through 2005 (Figure 34). Drought conditions resulted in significantly lower vegetation structure readings across ecological sites in 2004 as compared to 2003 and 2005. Structure was uniformly low in 2004 and showed little variation compared to 2003 and 2004. Vegetation structure was generally greater in 2005 than 2003. However, there was no difference in vegetation structure between these years in shallow loamy, shallow sandy and saline upland ecological sites. Differences in vegetation structure across ecological sites within a given year were most apparent in 2005, where clayey, loamy and sandy ecological sites had significantly greater structure than shallow clayey, shallow loamy, shallow sandy, and saline upland ecological sites.

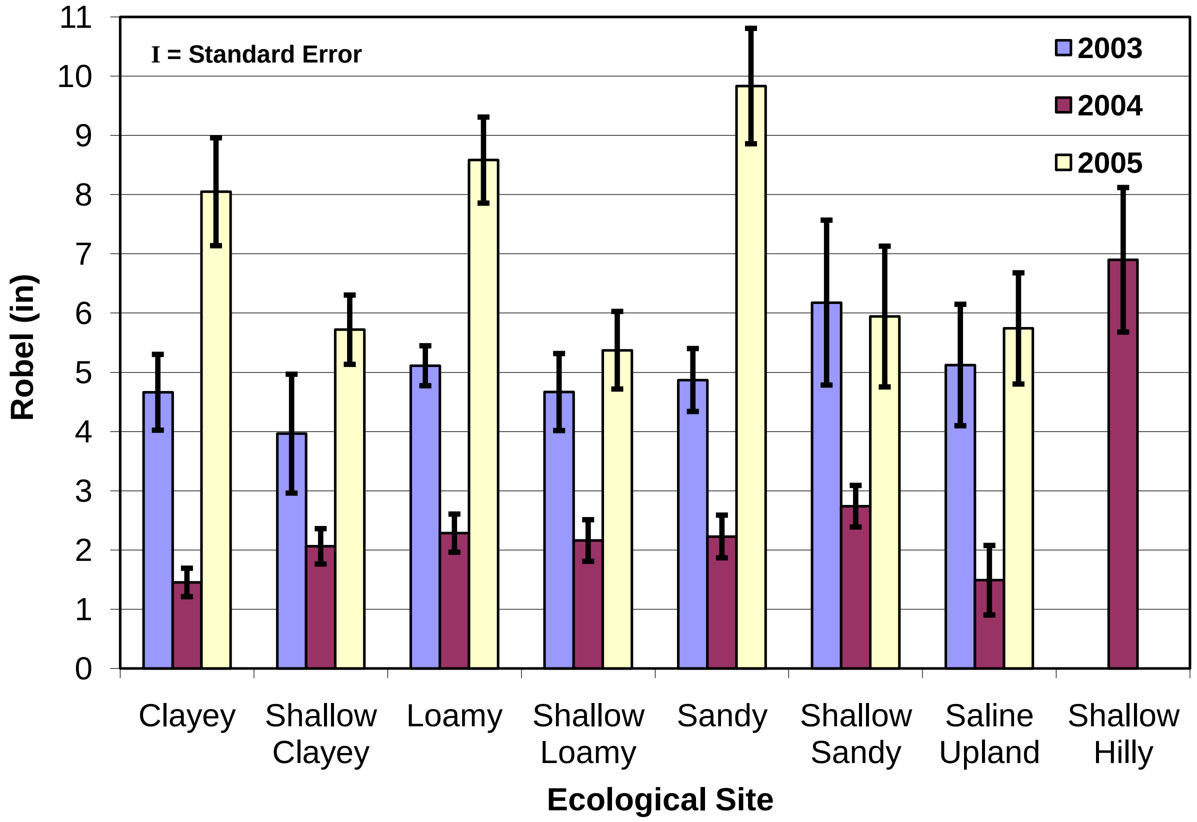


Figure 34. Vegetation structure measurements based on Robel pole readings (+/- standard error of the mean) from 2003 through 2005 on terrestrial ecological sites in the Thunder Basin planning area.

Productivity

Productivity, measured as the dry weight of grasses and Forbs differed across and within terrestrial ecological sites from 2003 through 2005 (Figure 35). Drought conditions resulted in significantly lower productivity readings across ecological sites in 2004 as compared to 2003 and 2005, and there was very little variation in productivity in 2004 across ecological sites. There was no difference in productivity between 2003 and 2005 on clayey, loamy, shallow loamy, or saline upland ecological sites. However, productivity was greater on shallow clayey, sandy, and shallow sandy ecological sites in 2003 as compared to 2005.

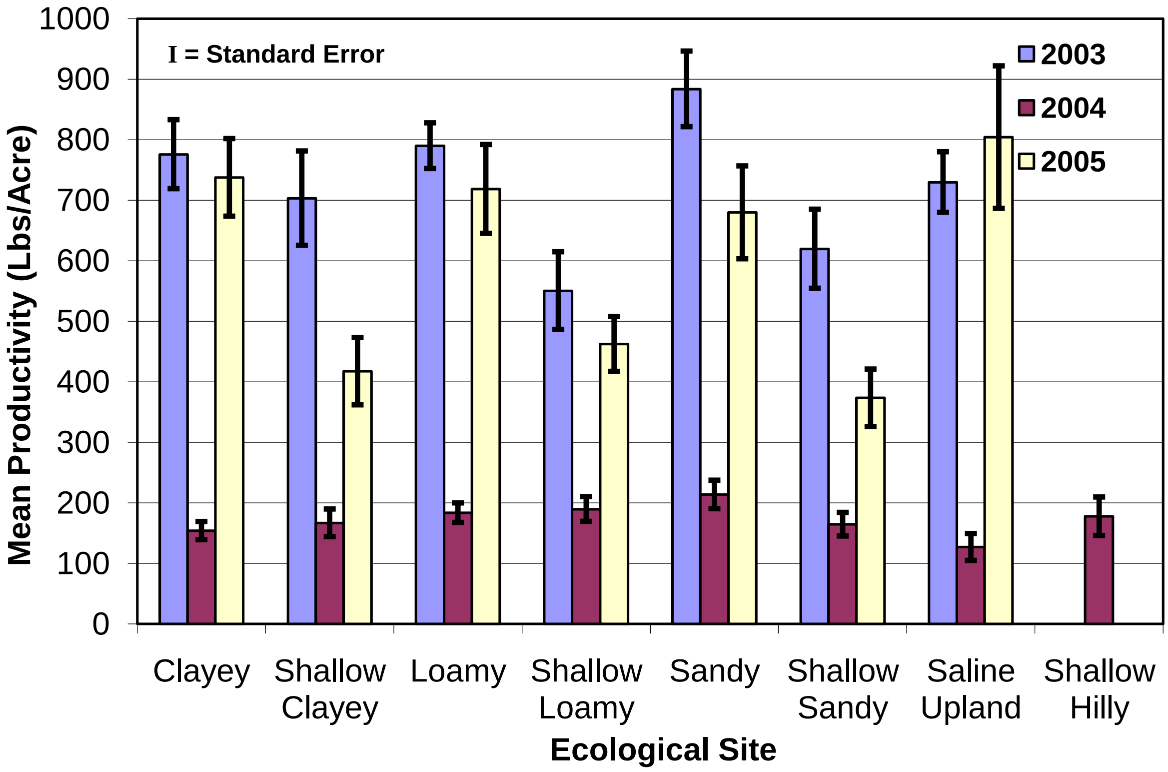


Figure 35. Productivity by ecological site (+/- standard error of the mean) from 2003 through 2005 on terrestrial ecological sites in the Thunder Basin planning area.

Characteristics of Terrestrial Ecological Sites x Disturbance States

To characterize the existing vegetation conditions of each disturbance state within each ecological site, the randomly located plots for each ecological site were allocated to a state based on the plant compositions recorded for each plot. The following descriptions are based on these results. Plots were assigned to a state based on the relative composition of native species, irregardless of the level of exotic species. Species identified as primary indicators of natural disturbance regimes were used to make the determination of the disturbance state for an individual plot. The number of plots with varying levels of exotic species is also reported.

Clayey Ecological Sites

A total of 57 random plots were used to characterize existing conditions in clayey ecological sites.

- ### Short Fire Return Interval x Light Grazing Regime

Primary indicators of natural disturbance regimes:
Short-interval fire indicator: sagebrush <10% absolute cover
Light grazing indicators: green needlegrass >20% and blue grama <30% relative cover
Number of plots classified to this disturbance state: 1
Visual Obstruction (Robel): 5.9 in
Grass and Forb Productivity: 931 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 73.9%
Absolute Big Sagebrush Canopy Cover: 5.5%
Mean Relative Cover of Exotic Species: 1.0%
Plot Summary of Exotic Species (relative cover):

<5% = 1 plot
≥5 and <10% = 0 plots
≥10% and <15% = 0 plots
≥15% and <20% = 0 plots
≥20% = 0 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
green needlegrass	20.9
western wheatgrass	17.3
needle and thread	12.7
threadleaf sedge	9.5
big sagebrush	5.9
blue grama	5.4
Nuttall’s sandwort	5.4
American vetch	4.5
prairie junegrass	3.6
bluegrass species	2.7

Other recorded species: desert madwort, milkvetch, scarlet beeblossom, leafy wildparsley, beardtongue, wooly plantain, bluegrass species, and scarlet globemallow.

- Short Fire Return Interval x Moderate Grazing Regime

Primary indicators of natural disturbance regimes:
Short fire return interval = sagebrush <10% absolute cover
Moderate grazing = green needlegrass <20% and blue grama <30% relative cover
Number of plots classified to this disturbance state: 32
Visual Obstruction (Robel): 3.3 in
Grass and Forb Productivity: 520.6 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 77.4%
Absolute Big Sagebrush Canopy Cover: 1.6%
Mean Relative Cover of Exotic Species: 14.5%
Plot Summary of Exotic Species (relative cover):
<5% = 10 plots
>5 and <10% = 4 plots
>10% and <15% = 7 plots
>15% and <20% = 2 plots
>20% = 9 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
western wheatgrass	28.2
annual brome	9.0
bluegrass species	7.7
blue grama	6.8
needleleaf sedge	5.4
sixweeks fescue	4.1
plains pricklypear	3.9
needle and thread	3.6
slender wheatgrass	3.2
big sagebrush	3.1

Other recorded species - crested wheatgrass, pale agoseris, desert madwort, textile onion, rosy pussytoes, field sagewort, prairie sagewort, birdfoot sagebrush, purple threeawn, twogrooved milkvetch, Gardner's saltbush, smooth bromegrass, threadleaf sedge, prairie sandreed, littlepod false flax, narrowleaf goosefoot, spearleaf rabbitbrush, spotted sandmat, thymeleaf sandmat, Canada thistle, Canadian horseweed, bastard toadflax, bastard toadflax, cushion cryptantha, white prairie clover, western tansymustard, draba, squirreltail, buckwheat, desert yellow fleabane, rubber rabbitbrush, scarlet beeblossom, broom snakeweed, manyflowerd stickweed, false pennyroyal, false goldenaster, Rocky Mountain juniper, prairie Junegrass, winterfat, flatspine stickseed, European stickseed, common pepperweed, clasping pepperweed, dotted blazing star, stiffstem flax, desert biscuitroot, desert parsley, rush skeleton plant, Nuttall's sandwort, leafy wildparsley, whitest evening-primrose, brittle pricklypear, silverleaf Indian breadroot, Indian breadroot, large Indian breadroot, beardtongue, Simpson hedgehog cactus, spiny phlox, oppositeleaf bahia, common plantain, woolly plantain, oval-leaf knotweed, bluebunch wheatgrass, slimflower scurfpea, skunkbush sumac, Russian thistle, greasewood, tumblegrass, little bluestem, scarlet globemallow, common dandelion, prairie thermopsis, yellow salsify, American vetch, and soapweed yucca.

- ### Short Fire Return Interval x Heavy Grazing Regime

Primary indicators of natural disturbance regimes:
Short fire return interval = sagebrush <10% absolute cover
Heavy grazing = green needlegrass <20% and blue grama >30% relative cover
Number of plots classified to this disturbance state: 6
Visual Obstruction (Robel): 2.2in
Grass and Forb Productivity: 365.0 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 56.5%
Absolute Big Sagebrush Canopy Cover: 0.5%
Mean Relative Cover of Exotic Species: 6.4%
Plot Summary of Exotic Species (relative cover):
<5% = 3 plots
≥5 and <10% = 0 plots
≥10% and <15% = 2 plots
≥15% and <20% = 0 plots
≥20% = 1 plot

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
blue grama	42.1
western wheatgrass	19.6
six weeks fescue	5.5
woolly plantain	5.1
Cusick’s bluegrass	4.7
needleleaf sedge	4.2
annual brome	3.7
big sagebrush	3.4
bluegrass species	3.1
desert madwort	2.7

Other recorded species: birdfoot sagebrush, draba, needle and thread, flatspine stickseed, common pepperweed, tansyaster, plains pricklypear, spiny phlox, scarlet globemallow, and American vetch.

- ### Long Fire Return Interval x Light Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >10% absolute cover
Light grazing = green needlegrass >20% and blue grama <30% relative cover
Number of plots classified to this disturbance state: 0
No additional information is available

- ### Long Fire Return Interval x Moderate Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >10% absolute cover
Moderate grazing = green needlegrass <20% and blue grama <30% relative cover
Number of plots classified to this disturbance state: 18
Visual Obstruction (Robel): 8.0 in
Grass and Forb Productivity: 583.9 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 95.9%
Absolute Big Sagebrush Canopy Cover: 21.3%
Mean Relative Cover of Exotic Species: 10.5%
Plot Summary of Exotic Species (relative cover):
<5% = 5 plots
≥5 and <10% = 5 plots
≥10% and <15% = 3 plots
≥15% and <20% = 2 plots
≥20% = 3 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
big sagebrush	26.3
western wheatgrass	18.4
annual brome	9.8
blue grama	6.9
poa species	5.3
needle and thread	4.8
plains prickly pear	3.6
six weeks fescue	3.1
prairie junegrass	2.8
needleleaf sedge	1.6

Other recorded species: crested wheatgrass, pale agoseris, desert madwort, textile onion, pussytoes, prairie sagewort, purple threeawn, fourwing saltbush, Gardners saltbush, threadlead sedge, prairie sandreed, mariposa lilly, littlepod false flax, narrowleaf goosefoot, astard toadflax, white prairie clover, western tansymustard, draba, slender wheatgrass, fleabane, rubber rabbitbrush, spinystar, scarlet beeblossom, broom snakeweed, false pennyroyal, winterfat, flatspine stickseed, common pepperweed, stiffstem flax, desert biscuitroot, rayless tansyaster, narrowleaf four o'clock, Nuttall's sandwort, leafy wildparsley, green needlegrass, whitest evening-primrose, brittle prickly pear, clustered broomrape, white penstemon, Indian breadroot, beardtongue, spiny phlox, oppositeleaf bahia, wooly plaintain, knotweed, bluebunch wheatgrass, slimflower scurfpea, Russian thistle, greasewood, tumblegrass, scarlet globemallow, sand dropseed, common dandelion, prairie thermopsis, yellow salsify, American vetch, and soapweed yucca.

- ### Long Fire Return Interval x Heavy Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >10% absolute cover
Heavy grazing = green needlegrass <20% and blue grama >30% relative cover
Number of plots classified to this disturbance state: 0
No additional information is available

Shallow Clayey Ecological Sites

A total of 46 random plots were used to characterize existing conditions in shallow clayey ecological sites.

Short Fire Return Interval x Light Grazing Regime

Primary indicators of natural disturbance regimes:

Short fire return interval = sagebrush <10% absolute cover
Light grazing = green needlegrass >20% and blue grama <30% relative cover

Number of plots classified to this disturbance state: 0

No additional information is available

Short Fire Return Interval x Moderate Grazing Regime

Primary indicators of natural disturbance regimes:

Short fire return interval = sagebrush <10% absolute cover
Moderate grazing = green needlegrass <20% and blue grama <30% relative cover

Number of plots classified to this disturbance state: 28
Visual Obstruction (Robel): 3.5 in
Grass and Forb Productivity: 398.6 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 59.4%
Absolute Big Sagebrush Canopy Cover: 3.1%
Mean Relative Cover of Exotic Species: 11.9%
Plot Summary of Exotic Species (relative cover):

<5% = 10 plots
>5 and <10% = 4 plots
>10% and <15% = 5 plots
>15% and <20% = 5 plots
>20% = 4 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
western wheatgrass	17.4
blue grama	12.6
annual brome	9.7
big sagebrush	7.4
bluegrass species	7.9
needle and thread	3.3
threadleaf sedge	3.3
plains pricklypear	3.1
needleleaf sedge	2.7
prairie junegrass	2.7

Other recorded species: yarrow, crested wheatgrass, pale agoseris, desert madwort, textile onion, annual ragweed, rosy pussytoes, silver sagebrush, sand sagebrush, prairie sagewort, birdfoot sagebrush, purple threeawn, milkvetch, Gardner's saltbush, sideoats grama, prairie sandreed, narrowleaf goosefoot, spotted sandmat, bastard toadflax, buttecandle, cushion cryptantha, narrowleaf hawksbeard, white prairie clover, violet prairie clover, western tansymustard, inland saltgrass, draba, slender wheatgrass, buckwheat, desert yellow fleabane, buff fleabane, fewflower buckwheat, scarlet beeblossom, broom snakeweed, false pennyroyal, false goldenaster, hairy false goldenaster, winterfat, flatspine stickseed, European stickseed, common pepperweed, stiffstem flax, desert biscuitroot, desert parsley, rayless tansyaster, lacy tansyaster, tansyleaf tansyaster, yellow sweatclover, narrowleaf four o'clock, Nuttall's sandwort, Nuttall's povertyweed, leafy wildparsley, green needlegrass, whitest evening-primrose, evening-primrose, brittle bricklypear, purple locoweed, false groundsel, white penstemon, large Indian breadroot, prairie phlox, spiny phlox, wooly plaintain, oval-leaf knotweed, knotweed, bluebunch wheatgrass, slimflower scurfpea, Russian thistle, little bluestem, alkali sacaton, scarlet globemallow, sand dropseed, common dandelion, stemless four nerve daisy, prairie thermopsis, yellow salsify, neckweed, American vetch, sixweeks fescue, and meadow deathcamus.

Short Fire Return Interval x Heavy Grazing Regime

Primary indicators of natural disturbance regimes:
Short fire return interval = sagebrush <10% absolute cover
Heavy grazing = green needlegrass <20% and blue grama >30% relative cover
Number of plots classified to this disturbance state: 3
Visual Obstruction (Robel): 2.5 in
Grass and Forb Productivity: 327.5 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 61.3%
Absolute Big Sagebrush Canopy Cover: 2.3%
Mean Relative Cover of Exotic Species: 0.3%
Plot Summary of Exotic Species (relative cover):
<5% = 3 plots
≥5 and <10% = 0 plots
≥10% and <15% = 0 plots
≥15% and <20% = 0 plots
≥20% = 0 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
blue grama	39.8
western wheatgrass	26.7
needle and thread	10.4
threadleaf sedge	4.7
big sagebrush	1.8
common pepperweed	1.7
bluegrass species	2.7
broom snakeweed	1.3
prairie sagewort	1.1
prairie Junegrass	1.1

Other recorded species: annual brome, birdfoot sagebrush, needleleaf sedge, buckwheat, buff fleabane, scarlet beeblossom, false pennyroyal, winterfat, rayless tansyaster, Nuttall's sandwort, plains pricklypear, white penstemon, prairie phlox, spiny phlox, woolly plaintain, tumblegrass, scarlet globemallow, American vetch, and sixweeks fescue.

Long Fire Return Interval x Light Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >10% absolute cover
Light grazing = green needlegrass >20% and blue grama <30% relative cover
Number of plots classified to this disturbance state: 0
No additional information is available

- ### Long Fire Return Interval x Moderate Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >10% absolute cover
Moderate grazing = green needlegrass <20% and blue grama <30% relative cover
Number of plots classified to this disturbance state: 13
Mean Relative Cover of Exotic Species: 10.3%
Visual Obstruction (Robel): 5.2 in
Grass and Forb Productivity: 319.9 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 64.8%
Absolute Big Sagebrush Canopy Cover: 17.1%
Mean Relative Cover of Exotic Species: 10.3%
Plot Summary of Exotic Species (relative cover):
<5% = 6 plots
≥5 and <10% = 2 plots
≥10% and <15% = 0 plots
≥15% and <20% = 1 plot
≥20% = 4 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
big sagebrush	25.7
western wheatgrass	18.8
blue grama	10.2
annual brome	9.0
needle and thread	3.9
bluegrass species	6.1
rubber rabbitbrush	3.1
fewflower buckwheat	2.9
threadleaf sedge	1.7
broom snakeweed	1.3

Other recorded species: Indian ricegrass, common yarrow, crested wheatgrass, desert madwort, textile onion, big bluestem, prairie sagewort, purple threeawn, saltbrush, needleleaf sedge, prairie sandreed, littlepod false flax, Nebraska sedge, narrowleaf goosefoot, spotted sandmat, Canadian horseweed, bastard toadflax, western tansymustard, draba, slender wheatgrass, hoary fleabane, fleabane, scarlet beeblossom, hairy false goldenaster, foxtail barley, prairie Junegrass, flatspine stickseed, European stickseed, common pepperweed, desert biscuitroot, desert parsley, yellow sweetclover, Nuttall's sandwort, Nuttall's povertyweed, leafy wildparsley, spring forget-me-not, green needlegrass, plains pricklypear, beardtongue, Simpson hedgehog cactus, prairie phlox, spiny phlox, woolly plaintain, oval-leaf knotweed, bluebunch wheatgrass, slimflower scurfpea, greasewood, tumblegrass, scarlet globemallow, common dandelion, goldenbanner, prairie thermopsis, yellow salsify, American vetch, sixweeks fescue, and soapweed yucca

- ### Long Fire Return Interval x Heavy Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >10% absolute cover
Heavy grazing = green needlegrass <20% and blue grama >30% relative cover
Number of plots classified to this disturbance state: 2
Mean Relative Cover of Exotic Species: 1.2%
Visual Obstruction (Robel): 4.9 in
Grass and Forb Productivity: 425.2 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 65.1%
Absolute Big Sagebrush Canopy Cover: 24.6%
Mean Relative Cover of Exotic Species: 1.2%
Plot Summary of Exotic Species (relative cover):
<5% = 2 plots
≥5 and <10% = 0 plots
≥10% and <15% = 0 plots
≥15% and <20% = 0 plots
≥20% = 0 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
blue grama	40.3
big sagebrush	23.2
western wheatgrass	11.6
threadleaf sedge	5.3
needleleaf sedge	4.4
bluebunch wheatgrass	3.8
needle and thread	2.0
prairie junegrass	1.8
scarlet globemallow	1.2
bluegrass species	1.1

Other recorded species: Indian ricegrass, desert madwort, textile onion, annual brome, prairie sagewort, cryptantha, desert yellow fleabane, scarlet beeblossom, broom snakeweed, winterfat, Nuttall's sandwort, leafy wildparsley, plains pricklypear, spiny phlox, oppositeleaf bahia, wooly plantain, Russian thistle, tumblegrass, and American vetch

Loamy Ecological Sites

A total of 115 random plots were used to characterize existing conditions in loamy ecological sites.

- ### Short Fire Return Interval x Light Grazing Regime

Primary indicators of natural disturbance regimes:
Short fire return interval = sagebrush <10% absolute cover
Light grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass >15% and blue grama <30% relative cover
Number of plots classified to this disturbance state: 0
No additional information is available

• Short Fire Return Interval x Moderate Grazing Regime

Primary indicators of natural disturbance regimes:

Short fire return interval = sagebrush <10% absolute cover

Moderate grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass <15% and blue grama <30% relative cover

Number of plots classified to this disturbance state: 64

Visual Obstruction (Robel): 4.5 in.

Grass and Forb Productivity: 611 lbs/acre

Absolute Plant Canopy Cover (less than 1m tall): 81.7%

Absolute Big Sagebrush Canopy Cover: 2.0%

Mean Relative Cover of Exotic Species: 11.6%

Mean Relative Cover of Exotic Species by range and number of plots sampled:

<5% = 25 plots
≥5 and <10% = 12 plots
≥10% and <15% = 5 plots
≥15% and <20% = 5 plots
≥20% = 17 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
western wheatgrass	24.0
annual brome	9.9
blue grama	9.6
threadleaf sedge	7.5
six weeks fescue	6.4
needleleaf sedge	5.1
bluegrass species	4.6
needle and thread	4.5
plains pricklypear	4.2
wooly plantain	3.8

Other recorded species: Indian ricegrass, crested wheatgrass, pale agoseris, desert madwort, water foxtail, annual ragweed, pussytoes, field sagebrush, silver sagebrush, prairie sagewort, birdfoot sagebrush, purple threeawn, big sagebrush, milkvetch, Gardner's saltbush, littlepod false flax, narrowleaf goosefoot, spotted sandmat, thymeleaf sandmat, Canadian horseweed, bastard toadflax, cushion cryptantha, white prairie clover, western tansymustard, herb sophia, draba, squirreltail, slender wheatgrass, wormseed wallflower, buff fleabane, fewflower buckwheat, spinystar, scarlet beeblossom, broom smakeweed, false pennyroyal, hairy false golden aster, foxtail barley, little barley, prairie Junegrass, winterfat, flatspine stickseed, European stickseed, common pepperweed, stiffstem flax, desert parsley, rush skeletonplant, rayless tansyaster, lacy tansyaster, tansyleaf tansyaster, narrowleaf four o'clock, Nuttall's sandwort, leafy wildparsley, spring forget-me-not, green needlegrass, whitest evening primrose, branched false goldenweed, brittle pricklypear, white penstemon, palmleaf Indian breadroot, large Indian breadroot, hedgehog cactus, prairie phlox, spiny phlox, oppositeleaf bahia, knotweed, slimflower scurfpea, Russian thistle, greasewood, tumblegrass, little bluestem, tall tumblemustard, scarlet globemallow, sand dropseed, common dandelion, stemless four-nerve daisy, yellow salsify, prairie spiderwort, American vetch, and meadow decathamus.

• Short Fire Return Interval x Heavy Grazing Regime

Primary indicators of natural disturbance regimes:
Short fire return interval = sagebrush <10% absolute cover
Heavy grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass <15% and blue grama >30% relative cover
Number of plots classified to this disturbance state: 18
Visual Obstruction (Robel): 4.5 in.
Grass and Forb Productivity: 573.7 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 97.5%
Absolute Big Sagebrush Canopy Cover: 1.1%
Mean Relative Cover of Exotic Species: 8.7%
Plot Summary of Exotic Species (relative cover):

<5% = 11 plots
≥5 and <10% = 1 plot
≥10% and <15% = 3 plots
≥15% and <20% = 0 plots
≥20% = 3 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
blue grama	41.9
western wheatgrass	15.8
six weeks fescue	8.5
annual brome	7.0
needleleaf sedge	6.4
wooly plantain	5.6
bluegrass species	5.2
desert madwort	1.6
scarlet globemallow	1.3
false pennyroyal	1.3

Other recorded species: textile onion, prairie sagewort, birdfoot sagebrush, big sagebrush, threadleaf sedge, goosefoot, Canadian horseweed, draba, needle and thread, false pennyroyal, prairie Junegrass, winterfat, flatspine stickseed, European stickseed, common pepperweed, desert biscuitroot, green needlegrass, whitest evening primrose, brittle pricklypear, plains pricklypear, spiny phlox, tumblegrass, sand dropseed, common dandelion, and American vetch.

• Long Fire Return Interval x Light Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >10% absolute cover
Light grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass <15% and blue grama <30% relative cover
Number of plots classified to this disturbance state: 0
No additional information is available

- ### Long Fire Return Interval x Moderate Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >10% absolute cover
Moderate grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass <15% and blue grama <30% relative cover
Number of plots classified to this disturbance state: 33
Visual obstruction (Robel): 8.9 in
Grass and Forb Productivity: 497.9 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 96.3%
Absolute Big Sagebrush Canopy Cover: 23.8%
Mean Relative Cover of Exotic Species: 19.3%
Plot Summary of Exotic Species (relative cover):
<5% = 4 plots
≥5 and <10% = 6 plots
≥10% and <15% = 5 plots
≥15% and <20% = 5 plots
≥20% = 13 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
big sagebrush	29.2
annual brome	16.9
western wheatgrass	12.1
needle and thread	8.2
blue grama	6.4
bluegrass species	5.1
plains pricklypear	3.6
six weeks fescue	3.4
needleleaf sedge	1.8
prairie Junegrass	1.8

Other recorded species: crested wheatgrass, pale agoseris, desert madwort, textile onion, rosy pussytoes, prairie sagewort, purple threeawn, Gardner's saltbush, mariposa lily, littlepod false flax, narrowleaf goosefoot, Canadian horseweed, bastard toadflax, western tansymustard, draba, squirreltail, slender wheatgrass, buff fleabane, fewflower buckwheat, broom snakeweed, false pennyroyal, foxtail barley, prairie Junegrass, winterfat, flatspine stickseed, European stickseed, tansyleaf tansyaster, Canada toadflax, threadleaf sedge, common pepperweed, rayless tansyaster, Indian breadroot, narrowleaf four o'clock, spring forget-me-not, green needlegrass, prairie spiderwort, whitest evening-primrose, brittle pricklypear prairie phlox, spiny phlox, woolly plantain, oval-leaf knotweed, bluegrass species, knotweed, bushy knotweed, greasewood, tall tumblemustard, scarlet globemallow, common dandelion, yellow salsify, neckweed, American vetch, and meadow deathcamus

- ### Long Fire Return Interval x Heavy Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >10% absolute cover
Heavy grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass <15% and blue grama >30% relative cover
Number of plots classified to this disturbance state: 0
No additional information is available

Shallow Loamy Ecological Sites

A total of 51 random plots were used to characterize existing conditions in shallow loamy ecological sites.

- Short Fire Return Interval x Light Grazing Regime

Primary indicators of natural disturbance regimes:
Short fire return interval = sagebrush <10% absolute cover
Light grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass >15% and blue grama <30% relative cover
Number of plots classified to this disturbance state: 1
Visual Obstruction (Robel): 13.8in
Grass and Forb Productivity: 711.0 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 79.5%
Absolute Big Sagebrush Canopy Cover: 0.0%
Mean Relative Cover of Exotic Species: 12.8%
Plot Summary of Exotic Species (relative cover):
<5% = 0 plots
>5 and <10% = 0 plots
>10% and <15% = 1 plot
>15% and <20% = 0 plots
>20% = 0 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
little bluestem	21.0
needleleaf sedge	15.1
bluebunch wheatgrass	13.8
crested wheatgrass	10.1
hairy false goldenaster	5.5
prairie sagewort	3.9
violet prairie clover	3.8
prairie junegrass	3.4
silverleaf Indian breadroot	2.9
annual brome	2.6

Other recorded species: common yarrow, desert madwort, purple threeawn, slender wheatgrass, broom snakeweed, needle and thread, false pennyroyal, lupine, Nuttall's sandwort, white penstemon, Indian breadroot, phlox, bluegrass species, slimflower scurfpea, Missouri goldenrod, American vetch, and sixweeks fescue.

- ### Short Fire Return Interval x Moderate Grazing Regime

Primary indicators of natural disturbance regimes:
Short fire return interval = sagebrush <10% absolute cover
Moderate grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass <15% and blue grama <30% relative cover
Number of plots classified to this disturbance state: 22
Visual Obstruction (Robel): 3.1in
Grass and Forb Productivity: 360.4 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 54.8%
Absolute Big Sagebrush Canopy Cover: 3.1%
Mean Relative Cover of Exotic Species: 9.4%
Plot Summary of Exotic Species (relative cover):
<5% = 12 plots
≥5 and <10% = 5 plots
≥10% and <15% = 0 plots
≥15% and <20% = 1 plot
≥20% = 4 plots

Ten dominant species (based on relative cover)

Species Common Name	% Relative Cover
western wheatgrass	16.6
blue grama	12.0
annual brome	7.2
needle and thread	6.9
threadleaf sedge	6.6
big sagebrush	5.5
six weeks fescue	4.9
bluegrass species	4.6
needleleaf sedge	4.4
prairie junegrass	3.2

Other recorded species: Indian ricegrass, common yarrow, crested wheatgrass, desert madwort, textile onion, pussytoes, rockcress, silver sagebrush, prairie sagewort, purple threeawn, bentflower milkvetch, Gardner's saltbush, littlepod false flax, Nebraska sedge, sego lily, bluebell bellflower, narrowleaf goosefoot, yellow rabbitbrush, wavyleaf thistle, bastard toadflax, buttecandle, cushion cryptantha, white prairie clover, western tansymustard, slender wheatgrass, buckwheat, desert yellow fleabane, rubber rabbitbrush, fewflower buckwheat, shaggy dwarf morning-glory, scarlet bee blossom, curlycup gumweed, broom snakeweed, false pennyroyal, hairy false goldenaster, winterfat, flatspine stickseed, European stickseed, common pepperweed, stiffstem flax, desert biscuitroot, desert parsley, rush skeletonplant, rayless tansyaster, tansyleaf tansyaster, Nuttall's povertyweed, leafy wildparsley, green needlegrass, whitest evening-primrose, brittle pricklypear, plains pricklypear, clustered broomrape, purple locoweed, Fendler's ragwort, white penstemon, palmleaf Indian breadroot, large Indian breadroot, spiny phlox, oppositeleaf bahia, wooly plantain, bluebunch wheatgrass, slimflower scurfpea, Russian thistle, tumblegrass, little bluestem, tall tumblemustard, scarlet globemallow, sand dropseed, common dandelion, stemless four-nerve daisy, prairie thermopsis, yellow salsify, American vetch, and soapweed yucca

- ### Short Fire Return Interval x Heavy Grazing Regime

Primary indicators of natural disturbance regimes:
Short fire return interval = sagebrush <10% absolute cover
Heavy grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass <15% and blue grama >30% relative cover
Number of plots classified to this disturbance state: 10
Mean Relative Cover of Exotic Species: 3.2%
Visual Obstruction (Robel): 3.4 in
Grass and Forb Productivity: 381.5 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 64.6%
Absolute Big Sagebrush Canopy Cover: 2.4%
Mean Relative Cover of Exotic Species: 3.2%
Plot Summary of Exotic Species (relative cover):

<5% = 7 plots
≥5 and <10% = 0 plots
≥10% and <15% = 3 plots
≥15% and <20% = 0 plots
≥20% = 0 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
blue grama	37.8
western wheatgrass	29.1
big sagebrush	13.2
plains pricklypear	4.4
bentgrass	2.4
needleleaf sedge	2.2
bluegrass species	3.8
broom snakeweed	1.0
spiny phlox	1.0
sixweeks fescue	0.8

Other recorded species: annual brome, prairie sagewort, fleabane, scarlet beeblossom, needle and thread, prairie Junegrass, leafy wildparsley, large Indian breadroot, prairie phlox, wooly plaintain, tumblegrass, scarlet globemallow, vetch species, and meadow deathcamus

- ### Long Fire Return Interval x Light Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >10% absolute cover
Light grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass >15% and blue grama <30% relative cover
Number of plots classified to this disturbance state: 2
Mean Relative Cover of Exotic Species: 0.7 %
Visual Obstruction (Robel): 4.9 in
Grass and Forb Productivity: 233.0 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 48.6%
Absolute Big Sagebrush Canopy Cover: 12.9%
Mean Relative Cover of Exotic Species: 10.5%
Plot Summary of Exotic Species (relative cover):

<5% = 2 plots
≥5 and <10% = 0 plots
≥10% and <15% = 0 plots
≥15% and <20% = 0 plots
≥20% = 0 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
bluebunch wheatgrass	28.3
big sagebrush	18.7
western wheatgrass	15.1
needle and thread	11.2
blue grama	4.9
threadleaf sedge	3.6
broom snakeweed	2.4
spearleaf rabbitbrush	2.0
American vetch	2.0
spiny phlox	1.6

Other recorded species: bluegrass species, prairie junegrass, needleleaf sedge, scarlet globemallow, Nuttall's sandwort, annual brome, prairie sagewort, western tansymustard, scarlet beeblossom, desert biscuitroot, rayless tansyaster, purple locoweed, purple threeawn, goosefoot, and common pepperweed

- Long Fire Return Interval x Moderate Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >10% absolute cover
Moderate grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass <15% and blue grama <30% relative cover
Number of plots classified to this disturbance state: 13
Visual Obstruction (Robel): 5.7in
Grass and Forb Productivity: 448.9 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 80.5%
Absolute Big Sagebrush Canopy Cover: 17.2%
Mean Relative Cover of Exotic Species: 15.3%
Plot Summary of Exotic Species (relative cover):
<5% = 6 plots
≥5 and <10% = 0 plots
≥10% and <15% = 2 plots
≥15% and <20% = 0 plots
≥20% = 5 plots

Ten most dominant species (based on relative cover).

Species Common Name	% Relative Cover
big sagebrush	26.3
western wheatgrass	15.6
annual brome	12.6
blue grama	7.5
threadleaf sedge	5.6
sixweeks fescue	2.2
prairie junegrass	2.1
bluegrass species	4.2
plains pricklypear	1.6

Other recorded species: common yarrow, pale agoseris, desert madwort, textile onion, pussytoes, prairie sagewort, purple threeawn, Gardner's saltbush, needleleaf sedge, littlepod false flax, spotted sandmat, thymeleaf sandmat, yellow rabbitbrush, wavyleaf thistle, Canadian horseweed, bastard toadflax, cushion cryptantha, western tansymustard, draba, squirreltail, fewflower buckwheat, broom snakeweed, manyflower stickseed, false pennyroyal, Rocky Mountain juniper, winterfat, flatspine stickseed, European stickseed, Great Plains bladderpod, common pepperweed, stiffstem flax, desert biscuitroot, rush skeleton plant, lacy tansyaster, tansyleaf tansyaster, Nuttall's sandwort, leafy wildparsley, green needlegrass, Canada toadflax, brittle pricklypear, large Indian breadroot, prairie phlox, spiny phlox, ponderosa pine, common plantain, woolly plantain, knotweed, bluebunch wheatgrass, Russian thistle, greasewood, tumblegrass, tall tumblemustard, scarlet, globemallow, common dandelion, yellow salsify, American vetch, and soapweed yucca

Long Fire Return Interval x Heavy Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >10% absolute cover
Heavy grazing = bluebunch wheatgrass/Indian ricegrass/green needlegrass/slender wheatgrass <15% and blue grama >30% relative cover
Number of plots classified to this disturbance state: 3
Visual Obstruction (Robel): 4.7 in
Grass and Forb Productivity: 443.9 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 61.8%
Absolute Big Sagebrush Canopy Cover: 19.5%
Mean Relative Cover of Exotic Species: 1.6%
Plot Summary of Exotic Species (relative cover):
<5% = 3 plots
>5 and <10% = 0 plots
>10% and <15% = 0 plots
>15% and <20% = 0 plots
>20% = 0 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
blue grama	38.4
big sagebrush	26.7
needle and thread	15.7
plains pricklypear	9.1
purple threeawn	4.5
bluegrass species	2.7
western wheatgrass	0.8
prairie sagewort	0.7
scarlet globemallow	0.7
prairie Junegrass	0.6

Other recorded species: annual brome.

Sands/Sandy Ecological Sites

A total of 58 random plots were used to characterize existing conditions in sands/sandy ecological sites.

Short Fire Return Interval x Light Grazing Regime

Primary indicators of natural disturbance regimes:
Short fire return interval = sagebrush <5% absolute cover
Light grazing = prairie sandreed >10% and blue grama/threaleaf sedge <30% relative cover
Number of plots classified to this disturbance state: 0
No additional information is available

- ### Short Fire Return Interval x Moderate Grazing Regime

Primary indicators of natural disturbance regimes:
Short fire return interval = sagebrush <5% absolute cover
Moderate grazing = prairie sandreed <10% and blue grama/threaleaf sedge <30% relative cover
Number of plots classified to this disturbance state: 22
Visual Obstruction (Robel): 5.4 in.
Grass and Forb Productivity: 988.2 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 103.8%
Absolute Big Sagebrush Canopy Cover: 0.9%
Mean Relative Cover of Exotic Species: 14.0%
Plot Summary of Exotic Species (relative cover):

<5%	= 10 plots
≥5 and <10%	= 3 plots
≥10% and <15%	= 2 plots
≥15% and <20%	= 0 plots
≥20%	= 7 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
western wheatgrass	21.3
needle and thread	16.3
annual brome	11.4
blue grama	7.7
bluegrass species	7.4
sixweeks fescue	6.4
needleleaf sedge	4.1
threadleaf sedge	4.0
plains pricklypear	2.2
purple threeawn	2.1

Other recorded species: prairie Junegrass, scarlet globemallow, crested wheatgrass, prairie sagewort, sand dropseed, false pennyroyal, woolly plantain, desert madwort, big sagebrush, Canadian horeseweed, common pepperweed, western tansymustard, broom snakeweed, slimflower scurfpea, flatspine stickseed, fleabane, soapweed yucca, whitest evening-primrose, false goldenaster, rush skeletonplant, fewflower buckwheat, winterfat, annual buckwheat, lemon scurfpea, little bluestem, silver sagebrush, common dandelion, tumblegrass, prickly Russian thistle, Indian breadroot, rabbitbrush, littlepod false flax, desert parsley, brittle pricklypear, white penstemon, leafy wildparsley, tansyleaf tansyaster, prairie spiderwort, large Indian breadroot, cryptantha, mariposa lily, meadow deathcamus, rubber rabbitbrush, spinystar, saltbrush, green needlegrass, Indian ricegrass, branched false goldenweed, American vetch, lupine, milkvetch, draba, narrowleaf four o'clock, field pennycress, bushy knotweed, Nuttall's sandwort, spotted sandmat, yellow salsify, scarlet beeblossom, thymeleaf sandmat, and Canada toadflax

Short Fire Return Interval x Heavy Grazing Regime

Primary indicators of natural disturbance regimes:
Short fire return interval = sagebrush <5% absolute cover
Heavy grazing = prairie sandreed <10% and blue grama/threadleaf sedge >30% relative cover
Number of plots classified to this disturbance state: 10
Visual Obstruction (Robel): 5.6 in.
Grass and Forb Productivity: 737.0 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 90.6%
Absolute Big Sagebrush Canopy Cover: 0.4%
Mean Relative Cover of Exotic Species: 1.5%
Plot Summary of Exotic Species (relative cover):
<5% = 9 plots
≥5 and <10% = 0 plots
≥10% and <15% = 1 plot
≥15% and <20% = 0 plots
≥20% = 0 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
threadleaf sedge	33.4
blue grama	16.0
western wheatgrass	12.7
needle and thread	11.3
soapweed yucca	3.9
plains pricklypear	3.4
needleleaf sedge	2.9
sixweeks fescue	2.2
bluegrass species	1.9
prairie Junegrass	1.3

Other recorded species: purple threeawn, annual brome, scarlet globemallow, woolly plantain, broom snakeweed, prairie sagewort, spiny phlox, leafy wildparsley, big sagebrush, prairie sandreed, American vetch, sand dropseed, Nuttall's sandwort, Indian breadroot, milkvetch, winterfat, common pepperweed, desert madwort, birdfoot sagebrush, bastard toadflax, tumblegrass, stiffstem flax, yellow salsify, littlepod false flax, slimflower scurfpea, prickly Russian thistle, mariposa lily, scarlet beeblossom, buttecandle, rush skeletonplant, flatspine stickseed, lacy tansyaster, draba, western tansymustard, white penstemon, green needlegrass, European stickseed, textile onion, large Indian breadroot, and bluebunch wheatgrass.

Long Fire Return Interval x Light Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >5% absolute cover
Light grazing = prairie sandreed >10% and blue grama/threadleaf sedge <30% relative cover
Number of plots classified to this disturbance state: 0
No additional information is available

Long Fire Return Interval x Moderate Grazing Regime

Primary indicators of natural disturbance regimes:

Long fire return interval = sagebrush >5% absolute cover

Moderate grazing = prairie sandreed <10% and blue grama/threadleaf sedge <30% relative cover

Number of plots classified to this disturbance state: 18

Visual Obstruction (Robel): 6.8 in.

Grass and Forb Productivity: 737.1 lbs/acre

Absolute Plant Canopy Cover (less than 1m tall): 97.1%

Absolute Big Sagebrush Canopy Cover: 13.7%

Mean Relative Cover of Exotic Species: 10.4%

Plot Summary of Exotic Species (relative cover):

<5% = 10 plots
≥5 and <10% = 1 plot
≥10% and <15% = 3 plots
≥15% and <20% = 0 plots
≥20% = 4 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
big sagebrush	20.3
needle and thread	16.7
western wheatgrass	13.9
blue grama	9.9
annual brome	7.2
needleleaf sedge	3.6
bluegrass species	4.4
plains pricklypear	3.3
crested wheatgrass	2.9
sixweeks fescue	2.8

Other recorded species: prairie Junegrass, threadleaf sedge, soapweed yucca, scarlet globemallow, woolly plantain, purple threeawn, false pennyroyal, American vetch, prairie sagewort, sand dropseed, squirreltail, green needlegrass, common pepperweed, winterfat, desert biscuitroot, spiny phlox, desert madwort, whitest evening-primrose, western tansymustard, large Indian breadroot, white penstemon, narrowleaf goosefoot, textile onion, milkvetch, slimflower scurfpea, littlepod false flax, fleabane, false goldenaster, common dandelion, broom snakeweed, Canadian horseweed, pussytoes, fewflower buckwheat, draba, scarlet beeblossom, little bluestem, leafy wildparsley, pale agoseris, yellow salsify, Canada toadflax, Nuttall's sandwort, slender wheatgrass, Indian ricegrass, narrowleaf four o'clock, Indian breadroot, Great Plains bladderpod, tumblegrass, branched false goldenweed, stiffstem flax, ponderosa pine, and brittle pricklypear.

Long Fire Return Interval x Heavy Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >5% absolute cover
Heavy grazing = prairie sandreed <10% and blue grama/threadleaf sedge >30% relative cover
Number of plots classified to this disturbance state: 8
Visual Obstruction (Robel): 3.9 in.
Grass and Forb Productivity: 625.3 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 91.2%
Absolute Big Sagebrush Canopy Cover: 8.9%
Mean Relative Cover of Exotic Species: 0.8%
Plot Summary of Exotic Species (relative cover):
<5% = 8 plots
≥5 and <10% = 0 plots
≥10% and <15% = 0 plots
≥15% and <20% = 0 plots
≥20% = 0 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
threadleaf sedge	25.3
western wheatgrass	15.0
blue grama	14.4
needle and thread	12.7
big sagebrush	9.2
sixweeks fescue	5.8
prairie Junegrass	2.8
bluegrass species	2.2
plains pricklypear	1.9
prairie sagewort	1.2

Other recorded species: needleleaf sedge, field sagewort, woolly plantain, annual brome, scarlet globemallow, broom snakeweed, silver sagebrush, common pepperweed, textile onion, purple threeawn, sand sagebrush, Nuttall's sandwort, false pennyroyal, winterfat, Indian breadroot, tansyleaf tansyaster, fleabane, squirreltail, knotweed, foxtail barley, spinystar, milkvetch, sego lily, scarlet beeblossom, white penstemon, sand dropseed, pale agoseris, mariposa lily, narrowleaf four o'clock, brittle pricklypear, locoweed, slimflower scurfpea, European stickseed, western tansymustard, and thymeleaf sandmat.

Shallow Sandy Ecological Sites

A total of 41 random plots were used to characterize existing conditions in shallow sandy ecological sites.

- ### Short Fire Return Interval x Light Grazing Regime

Primary indicators of natural disturbance regimes:
Short fire return interval = sagebrush <5% absolute cover
Light grazing = prairie sandreed >10% and blue grama/threadleaf sedge <30% relative cover
Number of plots classified to this disturbance state: 1
Mean Relative Cover of Exotic Species: 0.0 %
Visual Obstruction (Robel): 6.5 in
Grass and Forb Productivity: 411.7 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 68.5 %
Absolute Big Sagebrush Canopy Cover: 0.0%
Mean Relative Cover of Exotic Species: 0.0%
Plot Summary of Exotic Species (relative cover):
<5% = 1 plot
≥5 and <10% = 0 plots
≥10% and <15% = 0 plots
≥15% and <20% = 0 plots
≥20% = 0 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
prairie sandreed	29.2
blue grama	15.1
purple threeawn	8.8
sixweeks fescue	5.9
needleleaf sedge	4.9
sun sedge	4.9
needle and thread	4.4
slimflower scurfpea	4.4
white prairie clover	3.4
soapweed yucca	3.4

Other recorded species: common pepperweed, wooly plantain, little bluestem, prairie Junegrass, Nuttall's sandwort, scarlet globemallow, scarlet beeblossom, prairie sagewort, slender wheatgrass, broom snakeweed, lacy tansyaster, white penstemon, spiny phlox, and bluegrass species

- ### Short Fire Return Interval x Moderate Grazing Regime

Primary indicators of natural disturbance regimes:
Short fire return interval = sagebrush <5% absolute cover
Moderate grazing = prairie sandreed <10% and blue grama/threaleaf sedge <30% relative cover
Number of plots classified to this disturbance state: 19
Mean Relative Cover of Exotic Species: 4.1 %
Visual Obstruction (Robel): 5.4 in
Grass and Forb Productivity: 496.3 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 78.0 %
Absolute Big Sagebrush Canopy Cover: 0.9%
Mean Relative Cover of Exotic Species: 4.1%
Plot Summary of Exotic Species (relative cover):
<5% = 15 plots
≥5 and <10% = 1 plot
≥10% and <15% = 0 plots
≥15% and <20% = 3 plots
≥20% = 0 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
soapweed yucca	11.4
needle and thread	11.1
western wheatgrass	11.0
blue grama	7.8
sixweeks fescue	6.9
threadleaf sedge	6.6
annual brome	3.8
little bluestem	3.0
purple threeawn	3.0
prairie junegrass	2.7

Other recorded species: Indian ricegrass, pale agoseris, desert madwort, textile onion, big bluestem, pussytoes, silver sagebrush, prairie sagewort, birdfoot sagebrush, big sagebrush, milkvetch, bentflower milkvetch, silverscale saltbush, sideoats grama, needleleaf sedge, prairie sandreed, mariposa lily, littlepod false flax, rabbitbrush, Canadian horseweed, bastard toadflax, buttecandle, cryptantha, white prairie clover, western tansymustard, slender wheatgrass, fleabane, buckwheat, fewflower buckwheat, scarlet beeblossom, broom snakeweed, false pennyroyal, sunflower, false goldenaster, hairy false goldenaster, winterfat, flatspine stickseed, prickly lettuce, common pepperweed, dotted blazing star, stiffstem flax, desert biscuitroot, rush skeleton plant, yellow sweetclover, Nuttall's sandwort, leafy wildparsley, green needlegrass, whitest evening-primrose, branched false goldenweed, plains pricklypear, white penstemon, palmleaf Indian breadroot, large Indian breadroot, prairie phlox, spiny phlox, woolly plantain, bluegrass species, lemon scurfpea, slimflower scurfpea, upright prairie coneflower, skunkbush sumac, tumblegrass, nightshade, alkali sacaton, scarlet globemallow, sand dropseed, common dandelion, stemless four-nerve daisy, yellow salsify, pairie spiderwort, American vetch, and meadow deathcamus.

Short Fire Return Interval x Heavy Grazing Regime

Primary indicators of natural disturbance regimes:
Short fire return interval = sagebrush <5% absolute cover
Heavy grazing = prairie sandreed <10% and blue grama/threadleaf sedge >30% relative cover
Number of plots classified to this disturbance state: 11
Visual Obstruction (Robel): 4.1 in
Grass and Forb Productivity: 276.7 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 55.3%
Absolute Big Sagebrush Canopy Cover: 1.0%
Mean Relative Cover of Exotic Species: 2.3%
Plot Summary of Exotic Species (relative cover):
<5% = 9 plots
≥5 and <10% = 1 plot
≥10% and <15% = 1 plot
≥15% and <20% = 0 plots
≥20% = 0 plots

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
threadleaf sedge	41.9
needle and thread	16.0
blue grama	6.7
soapweed yucca	4.6
prairie sagewort	3.7
bluebunch wheatgrass	2.6
plains pricklypear	2.3
western wheatgrass	2.2
big sagebrush	2.0
annual brome	1.9

Other recorded species: Indian ricegrass, crested wheatgrass, desert madwort, textile onion, Cuman ragweed, rosy pussytoes, white sagebrush, purple threeawn, tufted milkvetch, bentflower milkvetch, needleleaf sedge, prairie sandreed, yellow rabbitbrush, wavyleaf thistle, bastard toadflax, white prairie clover, squirreltail, slender wheatgrass, desert yellow fleabane, rubber rabbitbrush, scarlet beeblossom, broom snakeweed, prairie Junegrass, common pepperweed, rush skeletonplant, lacy tansyaster, white penstemon, large Indian breadroot, prairie phlox, spiny phlox, wooly plantain, bluegrass species, slimflower scurfpea, little bluestem, scrlet globemallow, sand dropseed, and sixweeks fescue.

Long Fire Return Interval x Light Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >5% absolute cover
Light grazing = prairie sandreed >10% and blue grama/threadleaf sedge <30% relative cover
Number of plots classified to this disturbance state: 0
No additional information is available

- ### Long Fire Return Interval x Moderate Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >5% absolute cover
Moderate grazing = prairie sandreed <10% and blue grama/threadleaf sedge <30% relative cover
Number of plots classified to this disturbance state: 4
Mean Relative Cover of Exotic Species: 9.6 %
Visual Obstruction (Robel): 5.7 in
Grass and Forb Productivity: 343.8 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 86.9 %
Absolute Big Sagebrush Canopy Cover: 12.5%
Mean Relative Cover of Exotic Species: 9.6%
Plot Summary of Exotic Species (relative cover):

<5% = 2 plots
>5 and <10% = 0 plots
>10% and <15% = 0 plots
>15% and <20% = 1 plot
>20% = 1 plot

Ten most dominant species (based on relative cover)

Species Common Name	% Relative Cover
big sagebrush	25.1
needle and thread	16.4
threadleaf sedge	13.0
annual brome	9.4
blue grama	6.4
plains pricklypear	4.6
western wheatgrass	3.4
bluegrass species	3.6
purple threeawn	3.3
prairie junegrass	2.8

Other recorded species: big sagebrush, needle and thread, threadleaf sedge, annual brome, blue grama, plains pricklypear, western wheatgrass, bluegrass species, purple threeawn, prairie junegrass, prairie sagewort, sixweeks fescue, bluebunch wheatgrass, needleleaf sedge, common pepperweed, slimflower scurfpea, wooly plantain, winterfat, whitest evening primrose, broom snakeweed, false pennyroyal, prairie phlox, scarlet globemallow, yellow salsify, scarlet beeblossom, silver sagebrush, textile onion, fleabane, Canadian horseweed, large Indian breadroot, vetch, and meadow deathcamus.

- ### Long Fire Return Interval x Heavy Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = sagebrush >5%
Heavy grazing = prairie sandreed <10% and blue grama/threadleaf sedge >30% relative cover
Number of plots classified to this disturbance state: 6
Visual Obstruction (Robel): 3.8 in
Grass and Forb Productivity: 309.1 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 74.1 %
Absolute Big Sagebrush Canopy Cover: 8.9%
Mean Relative Cover of Exotic Species: 0.4%
Plot Summary of Exotic Species (relative cover):

<5% = 6 plots
≥5 and <10% = 0 plots
≥10% and <15% = 0 plots
≥15% and <20% = 0 plots
≥20% = 0 plots

Ten most dominant species (based on relative cover).

Species Common Name	% Relative Cover
threadleaf sedge	31.2
big sagebrush	14.4
needle and thread	12.4
blue grama	8.3
western wheatgrass	7.8
purple threeawn	3.6
prairie sagewort	2.5
spiny phlox	2.5
plains pricklypear	2.2
six weeks fescue	1.8

Other recorded species: annual brome, silver sagebrush, milkvetch, needleleaf sedge, cushion cryptantha, western tansymustard, squirreltail, western daisy fleabane, broom snakeweed, false pennyroyal, prairie Junegrass, winterfat, common pepperweed, whitest evening-primrose, purple locoweed, palmleaf Indian breadroot, large Indian breadroot, beardtongue, wooly plantain, bluegrass species, bluebunch wheatgrass, prickly Russian thistle, scarlet globemallow, sand dropseed, American vetch, and soapweed yucca

Shallow Hilly Ecological Site

A total of 19 random plots were used to characterize existing conditions in shallow sandy ecological sites.

Short Fire Return Interval x Light Grazing Regime

Primary indicators of natural disturbance regimes:

Short fire return interval = big sagebrush and ponderosa pine <10% absolute cover

Light grazing = bluebunch wheatgrass >10% and blue grama <30% relative cover

Number of plots classified to this disturbance state: 3

Visual Obstruction (Robel): 8.0 in

Grass and Forb Productivity: 162 lbs/acre

Absolute Plant Canopy Cover (less than 1m tall): 38.1%

Absolute Big Sagebrush Canopy Cover: 4.4 %

Absolute Ponderosa Pine Canopy Cover: 3.3 %

Mean Relative Cover of Exotic Species: 4.9%

Plot Summary of Exotic Species (relative cover):

<5% = 2 plots
≥5 and <10% = 0 plots
≥10% and <15% = 1 plot
≥15% and <20% = 0 plots
≥20% = 0 plots

Short Fire Return Interval x Moderate Grazing Regime

Primary indicators of natural disturbance regimes:

Short fire return interval = big sagebrush and ponderosa pine <10% absolute cover

Moderate grazing = bluebunch wheatgrass <10% and blue grama <30% relative cover

Number of plots classified to this disturbance state: 5

Visual Obstruction (Robel): 4.6 in

Grass and Forb Productivity: 133.7 lbs/acre

Absolute Plant Canopy Cover (less than 1m tall): 33.3%

Absolute Big Sagebrush Canopy Cover: 2.2%

Absolute Ponderosa Pine Canopy Cover: 0.4%

Mean Relative Cover of Exotic Species: 2.1%

Plot Summary of Exotic Species (relative cover):

<5% = 4 plots
≥5 and <10% = 1 plot
≥10% and <15% = 0 plots
≥15% and <20% = 0 plots
≥20% = 0 plots

Short Fire Return Interval x Heavy Grazing Regime

Primary indicators of natural disturbance regimes (% cover):

Short fire return interval = big sagebrush and ponderosa pine <10% absolute cover

Heavy grazing = bluebunch wheatgrass <10% and blue grama >30% relative cover

Number of plots classified to this disturbance state: 1

Mean Relative Cover of Exotic Species: 3.8%

Visual Obstruction (Robel): 3.6 in

Grass and Forb Productivity: 135.9 lbs/acre

Absolute Plant Canopy Cover (less than 1m tall): 37.5%

Absolute Big Sagebrush Canopy Cover: 0.9%

Absolute Ponderosa Pine Canopy Cover: 0.0%

Mean Relative Cover of Exotic Species: 3.8%

Plot Summary of Exotic Species (relative cover):

<5% = 1 plot
≥5 and <10% = 0 plots
≥10% and <15% = 0 plots
≥15% and <20% = 0 plots
≥20% = 0 plots

Long Fire Return Interval x Light Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = big sagebrush and ponderosa pine >10% absolute cover
Light grazing = bluebunch wheatgrass > 10% and blue grama <30% relative cover
Number of plots classified to this disturbance state: 5
Visual Obstruction (Robel): 6.7 in
Grass and Forb Productivity: 257.8 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 60.6 %
Absolute Big Sagebrush Canopy Cover: 9.4 %
Absolute Ponderosa Pine Canopy Cover: 18%
Mean Relative Cover of Exotic Species: 4.1%
Plot Summary of Exotic Species (relative cover):
<5% = 4 plots
≥5 and <10% = 0 plots
≥10% and <15% = 0 plots
≥15% and <20% = 0 plots
≥20% = 1 plot

Long Fire Return Interval x Moderate Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = big sagebrush and ponderosa pine >10% absolute cover
Moderate grazing = bluebunch wheatgrass <10% and blue grama <30% relative cover
Number of plots classified to this disturbance state: 6
Visual Obstruction (Robel): 9.1 in
Grass and Forb Productivity: 162.0 lbs/acre
Absolute Plant Canopy Cover (less than 1m tall): 40.8%
Absolute Big Sagebrush Canopy Cover: 3.5%
Absolute Ponderosa Pine Canopy Cover: 15.9%
Mean Relative Cover of Exotic Species: 6.9%
Plot Summary of Exotic Species (relative cover):
<5% = 4 plots
≥5 and <10% = 1 plot
≥10% and <15% = 0 plots
≥15% and <20% = 0 plots
≥20% = 1 plot

Long Fire Return Interval x Heavy Grazing Regime

Primary indicators of natural disturbance regimes:
Long fire return interval = big sagebrush and ponderosa pine >10% absolute cover
Heavy grazing = bluebunch wheatgrass <10% and blue grama >30% relative cover
Number of plots classified to this disturbance state: 0
No additional information is available

Very Shallow Ecological Sites

No plots were sampled in very shallow ecological sites.

Saline Upland Ecological Sites

A total of 56 random plots were used to characterize existing conditions in saline upland ecological sites.

- Long Fire Return Interval x Light Grazing Regime

Primary indicators of natural disturbance regimes:
Light grazing = Gardner's saltbush >30% relative cover
Number of plots classified to this disturbance state: 0
No additional information is available

- Long Fire Return Interval x Moderate Grazing Regime

Primary indicators of natural disturbance regimes:
Moderate grazing = Gardner's saltbush >10% and <30% relative cover
Number of plots classified to this disturbance state: 0
No additional information is available

Long Fire Return Interval x Heavy Grazing Regime

Primary indicators of natural disturbance regimes:

Heavy grazing = Gardner's saltbush <10% relative cover

Number of plots classified to this disturbance state: 56

Visual Obstruction (Robel): 5.6 in

Grass and Forb Productivity: 655.8 lbs/acre

Absolute Plant Canopy Cover (less than 1m tall): 88.5%

Absolute Gardners Saltbush Canopy Cover: 0.12%

Mean Relative Cover of Exotic Species: 24.7%

Plot Summary of Exotic Species (relative cover):

<5% = 6 plots
>5 and <10% = 7 plots
>10% and <15% = 5 plots
>15% and <20% = 4 plots
>20% = 34 plots

Ten most dominant species (based on relative cover).

Species Common Name	% Relative Cover
western wheatgrass	21.3
annual brome	17.8
blue grama	8.6
bluegrass species	9.9
plains pricklypear	5.0
greasewood	4.9
six weeks fescue	3.7
clasping pepperweed	2.5
common pepperweed	2.5
desert madwort	2.1

Other recorded species: crested wheatgrass, bentgrass, textile onion, Cuman ragweed, skeletonleaf burr ragweed, biennial wormwood, field sagewort, silver sagebrush, prairie sagewort, birdfoot sagebrush, purple threeawn, big sagebrush, bentflower milkvetch, Gardner's saltbush, saltbrush, buffalograss, needleleaf sedge, threadleaf sedge, littlepod false flax, pitseed goosefoot, narrowleaf goosefoot, spotted sandmat, thymeleaf sandmat, Canadian horseweed, cushion cryptantha, western tansymustard, herb sophia, saltgrass, draba, squirreltail, slender wheatgrass, spinystar, curlycup gumweed, broom snakeweed, saltlover, needle and thread, false pennyroyal, hairy false goldenaster, foxtail barley, little barley, molly, prairie Junegrass, winterfat, flatspine stickseed, European stickseed, stiffstem flax, desert biscuitroot, desert parsley, tansyleaf tansyaster, yellow sweetclover, narrowleaf four o'clock, Nuttall's sandwort, Nuttall's povertyweed, leafy wildparsley, green needlegrass, whitest evening-primrose, brittle pricklypear, Indian breadroot, Simpson hedgehog cactus, spiny phlox, ponderosa pine, common plantain, woolly plantain, oval-leaf knotweed, slimflower scurfpea, upright prairie coneflower, Russian thistle, tumblegrass, stonecrop, tall tumblemustard, alkali sacaton, scarlet globemallow, sand dropseed, common dandelion, field pennycress, yellow salsify, bigbract verbena, and American vetch.

TODAY'S TERRESTRIAL ECOSYSTEM CONDITIONS

The analysis of the satellite imagery and the random plot data were used to estimate the amounts of each disturbance state in the landscape (Figure 36). The analysis quantified current levels of representation of historically occurring states. The level of representation was based on several measures. The amounts of short versus long fire return interval stands for those ecological sites that historically experienced both types of fire regimes was estimated from the classification of big sagebrush cover greater than 10% absolute cover from the satellite imagery. The acres of each ecological site placed into the short or long fire regimes were then classified into a grazing regime (light, moderate, or heavy) based on the proportion of randomly located plots that had meet each grazing regime criteria in terms of the community composition for grazing indicator species. Finally, the percentage of plots that had less than 5% relative cover of exotics species were considered to be representative of each ecosystem. From this, we estimated the amounts of each ecosystem that occurred historically (ecological site x fire regime x grazing regime) with less than 5% exotics that was currently present in the landscape. It should be noted that this quantification is based entirely on the composition of the existing vegetation. The occurrence of disturbance factors including fire and grazing levels in the recent past was not factored into this quantification, only that the existing plant community had a composition most resembling the indicated historical state. Incorporating the appropriate disturbance factors for any areas identified as representative of the historical state is an important consideration for the representative areas to function effectively as a coarse filter for conservation.

ECOSYSTEM DIVERSITY MATRIX - WYOMING THUNDER BASIN LANDSCAPE

Terrestrial Ecosystems

		Ecological Site Class									
		Clayey	Shallow Clayey	Loamy	Shallow Loamy	Sands/Sandy	Shallow Sandy	Shallow Hilly	Very Shallow	Saline Upland	Badlands/Gullied
		Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres
Prairie Dog Colonies Active or Inactive		Unknown		Unknown						Unknown	
Vegetative composition/structure primarily influenced by short-interval fire regimes < 25 years											
Light Grazing	≤ 5% exotics	1,952	0	0	0	0	698	2,932			
	> 5% exotics	0	0	0	1,195	0	0	1,466			
Moderate Grazing	≤ 5% exotics	19,525	38,349	49,958	14,334	11,905	10,476	5,864			
	> 5% exotics	42,955	69,029	77,934	11,945	14,286	2,794	1,466			
Heavy Grazing	≤ 5% exotics	5,857	11,505	21,981	8,362	10,715	6,286	1,466			
	> 5% exotics	5,857	0	13,988	3,584	1,191	1,397	0			
Vegetative composition/structure primarily influenced by long-interval fire regimes > 25 years											
Light Grazing	≤ 5% exotics	0	0	0	626	0	0	5,478	N/A	0	N/A
	> 5% exotics	0	0	0	0	0	0	1,369		0	
Moderate Grazing	≤ 5% exotics	4,049	6,348	4,667	1,877	4,181	855	4,108	N/A	0	N/A
	> 5% exotics	10,526	7,406	33,835	2,189	3,345	855	2,739		0	
Heavy Grazing	≤ 5% exotics	0	2,116	0	938	3,345	2,564	0	N/A	3,213	N/A
	> 5% exotics	0	0	0	0	0	0	0		26,778	
Sparsely Vegetated		6,606	51,811	9,745	6,041	1,490	4,270	4,348	189	3,456	6,499
Other		24,933	35,620	47,661	10,890	12,754	4,228	3,341	787	9,202	4,699
TOTAL ACRES IN ECOLOGICAL SITE		122,260**	222,183	259,772	61,979	63,211	34,422	30,229	2,789	42,648	34,858
NRCS Range and/or Ecological Sites Included		Clayey Dense Clayey	Shallow Clayey	Loamy	Shallow Loamy	Sands Sandy	Shallow Sandy	Shallow Loamy with slopes > 6%	Very Shallow	Saline Upland	Gullied Land

🟪 conditions do not represent historical ecosystems- see text for a description

⬜ ecosystems that are not expected to have occurred historically

** Ecological site acreage totals vary slightly from other matrices due to missing imagery for portions of the landscape as well as differences in source data and mapping methodologies

N/A - information was not collected

Figure 36.Results of an ecological assessment to quantify today's terrestrial ecosystem diversity relative to the historical or native ecosystem diversity for the Thunder Basin planning area. The number in each cell represents the estimated acres of conditions with <5% exotics and >5% exotics. Refer to the text for a description of the methods used to obtain these results. The estimated acres of prairie dog colonies were not quantified through this assessment process – see the Species Diversity section for an estimate of prairie dog colony acres for portions of the landscape.

6.0 CUMULATIVE CHANGES TO NATIVE ECOSYSTEM DIVERSITY

There are two primary types of native ecosystem conversion or alteration within the Thunder Basin planning region that have contributed to the cumulative changes to native ecosystem diversity observed in the landscape today. These two primary conversions or alterations include: 1) the direct conversion of terrestrial native ecosystems to some other land type or use; and 2) the indirect alteration of terrestrial ecosystems through suppression of natural disturbance processes or alteration of species compositions, structures, or functions resulting from human activities. The primary causative agents for direct conversion of terrestrial ecosystems within the Thunder Basin planning area include roads, railroads, agriculture, and energy development. The primary causative agents for indirect alteration of terrestrial ecosystems include fire suppression, altered grazing regimes, and reduced numbers and distribution of prairie dog colonies across the landscape as well as accidental or intentional introduction of non-native species that cause changes to native species habitats and native ecosystems.

CONVERSION OF TERRESTRIAL ECOSYSTEMS

Overall land conversion that can be documented with remote sensing within terrestrial ecosystems within the Thunder Basin planning area is relatively low at 5% of the total acres. Table 9 identifies a breakdown of the acres converted by ecological site and type of conversion including primary and secondary roads, surface coal mining, and well pads associated with coal bed natural gas, natural gas, and oil production. Sands/Sandy and clayey ecological sites have received the highest amounts of conversion at 13 and 8%, respectively. The majority of the acres converted within the planning area have resulted from surface coal mining at 80.5% of the acres converted, followed by roads at 9%, railroads at 6.5% and well pads at 4% of the total converted acres. Conversion estimates were roughly based on a 4 m wide average surface impact for primary and secondary roads, a 50 m wide average surface impact associated with railroad tracks, and a 1 ac surface impact associated with a well pad location.

Surface mining of coal requires numerous permits from state and federal agencies. The most significant of which is the “permit-to-mine” required by the Federal Surface Mine Control and Reclamation Act. This permit requires a mine to extensively describe pre-mine environmental baseline conditions and develop mitigation plans as part of the mine and reclamation planning process. The primary objective of this permit is to return the surface of the mined land to a use equal to or higher than, the pre-mine land use. In the Thunder Basin planning area, the reclamation objectives usually target livestock grazing and wildlife habitat as the post-mine use on the landscape (Burget 2001).

Table 9. The number of acres and percentage of each terrestrial ecological site within the Thunder Basin planning area converted to roads, coal mining, or well pads (i.e., coal bed natural gas, oil, or natural gas).

	Clayey	Shallow Clayey	Loamy	Shallow Loamy	Sands/ Sandy	Shallow Sandy	Very Shallow	Saline Upland	Shallow Hilly	Badland/ Gullied	Riparian/ Wetland	Unkown Ecosite**	TOTAL
Roads	786	760	1,564	251	313	140	19	304	64	46	154	37	4,438
Railroad	486	316	1,082	325	481	16	29	266	0	19	154	0	3,174
Mining	8,109	3,668	11,157	546	7,214	53	153	216	0	270	1,136	6,705	39,227
Well Pads	306	179	693	124	429	40	1	24	18	42	54	11	1,921
TOTAL	**9,687**	**4,923**	**14,496**	**1,246**	**8,437**	**249**	**202**	**810**	**82**	**377**	**1,498**	**6,753**	**48,760**
% of Ecological Site conversion	**8%**	**2%**	**5%**	**2%**	**13%**	**1%**	**7%**	**2%**	**<1%**	**1%**	**4%**	**100%**	**5%**

**Unknown ecosite – represents areas where the ecological site was not classified prior to site conversion for other uses

Acres under active mining are clearly converted from historical ecosystem conditions. However, analysis of reclaimed lands in terms of their plant community compositions and other factors, and relative to their inclusion in representation calculations for historically-occurring ecosystem states, was not conducted as part of this assessment.

Primary and secondary roads are, in practical terms, a permanent conversion of native ecosystem conditions. In addition to the direct loss of habitat, roads may also fragment existing habitat, contribute to direct mortality for some wildlife species, and are a mechanism for the spread of exotic species of plants. Nearly 2,800 miles of mapped primary and secondary roads occur within the Thunder Basin planning area (Figure 37). This number and the number of acres identified in Table 9 are considered conservative estimates of the surface impacts of roads as not all two track roads associated with ranch access and energy development, are included in this estimate.

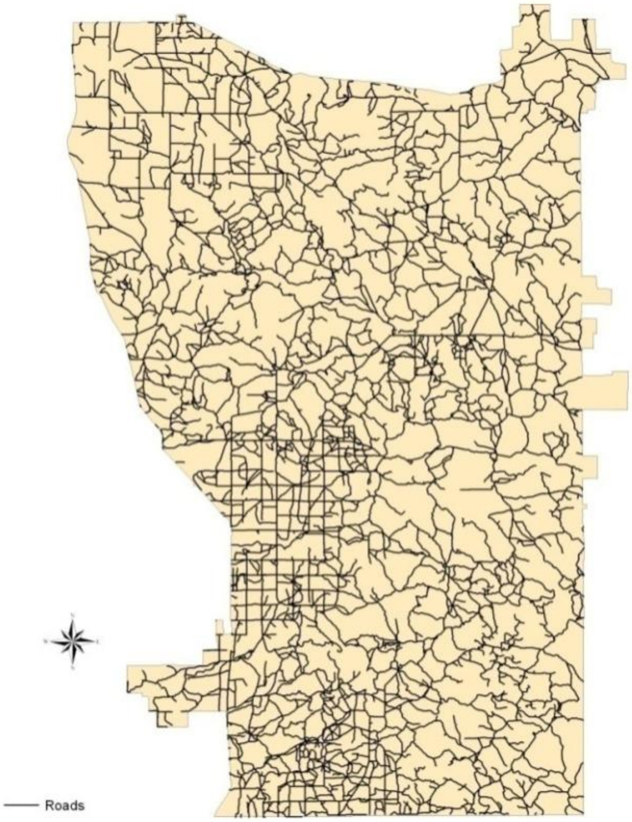


Figure 37. Primary and secondary roads found within the Thunder Basin planning area. Due to mapping resolution, many ranch roads and energy production roads (i.e., "two-tracks") are not included in this map.

In addition to roads, there are currently 68 miles of railroad track occurring as either single track, double track, or, to a lesser extent, triple track or more, within the planning area. The impacts of railroads on native species and ecosystems are similar but more substantial than roads.

Oil and gas production has produced some direct effects on native species and ecosystems. Recent coal bed natural gas production has generated concerns over realized and potential environmental impacts (Rice 1997). These well pads are often placed in a higher density connected by a network of roads, pipelines, and compressor stations. Production also requires utility lines and water containment or disposal systems. In addition to the direct impacts of this development on ecosystems and habitats, concerns also exist over the potential for fragmentation of additional habitat and displacement of local wildlife populations due to increased human and mechanical activity. Disturbance from and use of roads and well pads can make sites vulnerable for the spread of noxious weeds into native ecosystems. Extracting the gas requires water to be pumped to the surface in order to release the gas trapped in the coal seam. There has been considerable debate and disagreement on how to best manage these waters.

Other human alterations of sites including past efforts at growing crops, planting of exotic grass species such as crested wheatgrass, scraping the surface to discourage sagebrush or pricklypear cactus, and other disturbances have not been mapped or quantified. While some of these past disturbances can be partially discerned on air photos, many others cannot be readily identified. Some of these disturbed areas have now reverted back to a mix of native and exotic species of vegetation, and any lasting effects on soils or other ecosystem elements are unknown.

■ INDIRECT ALTERATION OF TERRESTRIAL ECOSYSTEMS

Native Ecosystem Diversity

While the direct conversion of ecosystem conditions is relatively low at 5% when compared to other Great Plains ecoregions (Vodehnal and Haufler 2008), the number of acres present today that represent native ecosystem conditions is a concern. Currently, lands within the Thunder Basin planning area are predominantly used for livestock ranching and energy production. These land uses exhibit different types and levels of disturbance relative to natural disturbance regimes resulting in different ecosystem compositions and structures from what occurred historically.

Table 10 provides an estimate of the percentage of each natural disturbance state (e.g., fire regime x grazing intensity), as identified using the EDM framework, that remains today compared to the mean historical range of variability, for seven of the ecological sites occurring in the planning area. Three of the ecological sites - Very Shallow, Shallow Hilly, and Badlands/Gullied Lands - were not included in this comparison due to their more extreme soil and topographical conditions that limit management or restoration opportunities.

It is important to note that while the EDM framework characterizes native ecosystem diversity relative to the natural disturbance processes of short and long-interval fires as well as the light, moderate, and heavy grazing by native herbivores, the conditions present on the landscape today are, for the most part, no longer influenced by these same disturbance processes. Although, wildfires still occur, and a few ranchers have incorporated an occasional prescribed burn into their management toolbox, the extent of these fires and their scattered use have not produced the large scale effects of nutrient cycling and plant species influences that occurred historically (Perryman and Laycock 2000). Grazing today is primarily by cattle, sheep, and horses, with relatively uniform grazing levels applied across the landscape as compared with estimates of historical grazing patterns and pressure by bison and other herbivores (Fuhlendorf and Engle 2001). However, to evaluate the cumulative impacts of Euro-American settlement, today's conditions were assessed relative to species compositions that most closely resemble native ecosystem conditions as influenced by natural disturbance processes. Ecosystems present today that are relatively similar in species compositions to those present historically, are assumed for the purposes of this assessment, to provide similar habitat benefits to the wildlife species they historically supported. However, it is also acknowledged that the reduction of fire and changes from grazing by native herbivores may have resulted in more profound effects on ecosystem conditions relative to historical conditions that have not been quantified in this assessment.

The results presented in Table 10 demonstrate that the percentage of the landscape that is still similar to native ecosystem conditions (i.e., has similar structure and species compositions) has in most instances been reduced significantly from the percentage of the landscape represented by the mean historical range of variability. A comparison of the historical role of fire for clayey, shallow clayey, loamy, shallow loamy, sands/sandy, and shallow sandy ecological sites determined that historically, 6% of the area of these sites (that weren't sparsely vegetated due to inclusions of other soil conditions) occurred within the long fire-return interval and would have supported >10% sagebrush cover, while today the percentage of this area with >10% sagebrush cover has increased to 16%. This indicates that the amount of sagebrush with >10% sagebrush cover has increased by approximately 280%, although this is only a 10% increase in actual acres within the landscape. At present, for the overall landscape, this assessment has estimated that 18.6% of the landscape supports plant communities indicative of a long fire-return interval (>25 years), while 81.4% of the existing landscape supports plant communities more indicative of a short fire-return interval (<25 years).

Grazing practices in use today also show changes from those estimated to have occurred historically. Historical plant communities were modelled to represent a relatively even distribution in grazing regimes within the short fire-return interval among plant communities resulting from light, moderate, and heavy grazing influences. Today, plant communities that would be present under light grazing conditions are nearly absent from the landscape. Grazing of the landscape over the past 50 or more years has generally focused on maximizing financial returns from ranching operations. Many ranchers have tried to manage their grasslands to maintain the long-term productivity of their ranches, striving to spread out grazing through better distribution of water sources and monitoring numbers of animals using each pasture. Other ranchers manage the use of their pastures by observing available remaining grass prior to shifting use to other pastures. These practices as well as prior grazing practices have resulted in the current distribution of plant communities in the landscape, with nearly all plant communities indicative of moderate and heavy grazing regimes (Tables 10 and 11).

Perhaps the greatest difference in today's ecosystem conditions versus historical conditions in the Thunder Basin planning area is the widespread presence of exotic species. Over 41% of the terrestrial ecosystems in this planning area were estimated to have greater than 5% cover of exotic plant species. Plant communities indicative of heavy grazing regimes show the greatest impacts from the presence of these exotic species, but substantial amounts of plant communities indicative of the moderate grazing regime also show significant levels of exotic species.

The percentage of today's ecosystem conditions classified as "other" was 14.8% (see Table 6 for more a more detailed description of "other" category). Where direct conversion has not occurred within this category, the loss of natural disturbance processes may have altered vegetation conditions to the point that they no longer represent historical ecosystem structure or species conditions. However, native ecosystem restoration that approximates historical conditions may still be possible for these areas.

The comparison of today's percentages with the historical mean percentage is also of interest relative to ecological sites (Table 11). Cumulative changes are more apparent for some ecological sites than others and for some disturbance states than others. All but one of these ecological sites, Shallow Sandy, has realized a loss of native ecosystem conditions by greater than 50% when compared to the mean HRV value. Native ecosystems occurring on the Saline Upland ecological site have been reduced by 93%, whereas Shallow Loamy ecological sites have been reduced by 40%. Table 12 represents the percent change of native ecosystem diversity, expressed as ecological site x disturbance state, relative to the amount of today's ecosystems that are similar (representative) to historical conditions.

The historical extent of prairie dog colonies in the planning landscape is not known, but based on mapping of highly suitable soil and terrain features, is expected to have been significantly higher than the amounts present today. The suppression of prairie dog colonies within the planning area has likely reduced the amounts of these native ecosystem conditions. The current lack of information on their historical distribution and stochastic events that would influence population dynamics within their colonies makes it impossible to estimate their historical range of variability at this time. For this reason they were not included in the comparison of today's conditions versus historical conditions.

Table 10. A comparison of today's ecosystem conditions to the historical or native ecosystem conditions, using mean historical range of variability (HRV), and compared relative to natural disturbance states resulting from the interaction of short and long fire regimes and native herbivore grazing intensity. Today's ecosystem conditions are described relative to the percent of the landscape characterized as meeting the conditions of the natural disturbance states in terms of species compositions and further by the percentages of the landscape that had plant communities with <5, <10, <15, or <20% exotic species. The "High Exotics" category is the percentage of the landscape containing plant communities with higher amounts than the indicated level of exotic species for that column. "Other" conditions are the percentage of the landscape that did not occur historically (see Table 6 for more detail on "other" category). Note – this table excludes the badland/gullied lands and very shallow ecological sites from the percentages (representing 3.8% of the total acres), as vegetation samples were not collected on these sites.

Natural Disturbance States	% of the landscape				
	Mean HRV	Today's conditions compared among 4 levels of exotic species (% relative cover)			
		<5%	<10%	<15%	<20%
Short-Interval Fire Regime					
Light Grazing	27.4	0.3	0.3	0.6	0.6
Moderate Grazing	28.6	18.8	26.3	32.7	37.0
Heavy	23.9	8.4	9.8	11.8	10.8
High Exotics	-	32.1	23.2	16.9	11.5
Long-Interval Fire Regime					
Light	3.8	0.1	0.1	0.1	0.1
Moderate	2.1	2.9	4.6	5.9	7.0
Heavy	4.0	1.6	2.0	2.4	2.6
High Exotics		11.1	8.7	7.0	5.7
Sparsely Vegetated	10.1	10.1	10.1	10.1	10.1
"Other" conditions	-	14.8	14.8	14.8	14.8

Table 11. A comparison of today's ecosystem conditions to the historical or native ecosystem conditions by ecological site, using the mean of the historical range of variability (HRV), and compared relative to natural disturbance states resulting from the interaction of short and long fire regimes and native herbivore grazing intensity. Today's ecosystem conditions also include the percent of the landscape characterized by >5% exotic species and "other" conditions that did not occur historically (see Table 6 for more detail).

	CLAYEY		SHALLOW CLAYEY		LOAMY		SHALLOW LOAMY		SANDS/ SANDY		SHALLOW SANDY		SALINE UPLAND	
	Today	Mean HRV	Today	Mean HRV	Today	Mean HRV	Today	Mean HRV	Today	Mean HRV	Today	Mean HRV	Today	Mean HRV
	%													
Short-Interval Fires														
Light Grazing	1.6	32.2	0.0	19.8	0.0	33.5	0.0	32.8	0.0	31.4	2.1	29.2	-	-
Moderate Grazing	16.2	35.1	17.6	29.1	20.3	28.7	24.1	28.1	19.3	32.4	31.6	29.9	-	-
Heavy Grazing	4.9	25.1	5.3	26.2	8.9	26.3	14.1	26.9	17.4	18.5	18.9	20.6	-	-
Long Interval Fires														
Light Grazing	0.0	1.9	0.0	0.9	0.0	4.4	1.1	2.2	0.0	11.0	0.0	6.4	0.0	8.9
Moderate Grazing	3.4	0.3	2.9	0.2	1.9	2.7	3.2	0.0	6.8	3.0	2.6	0.9	0.0	15.3
Heavy Grazing	0.0	0.1	1.0	0.2	0.0	0.4	1.6	0.1	5.4	1.2	7.7	0.3	9.1	66.2
Sparsely Vegetated	5.5	5.3	23.6	23.6	4.0	4.0	9.9	9.9	2.5	2.5	12.7	12.7	9.6	9.6
>5% Exotics	49.3	-	35.0	-	51.1	-	31.8	-	30.5	-	15.2	-	75.8	-
Disturbed conditions	19.1	-	14.6	-	13.8	-	14.2	-	18.1	-	9.2	-	5.5	-

Table 12. The % change of native ecosystem diversity from today's ecosystem diversity.

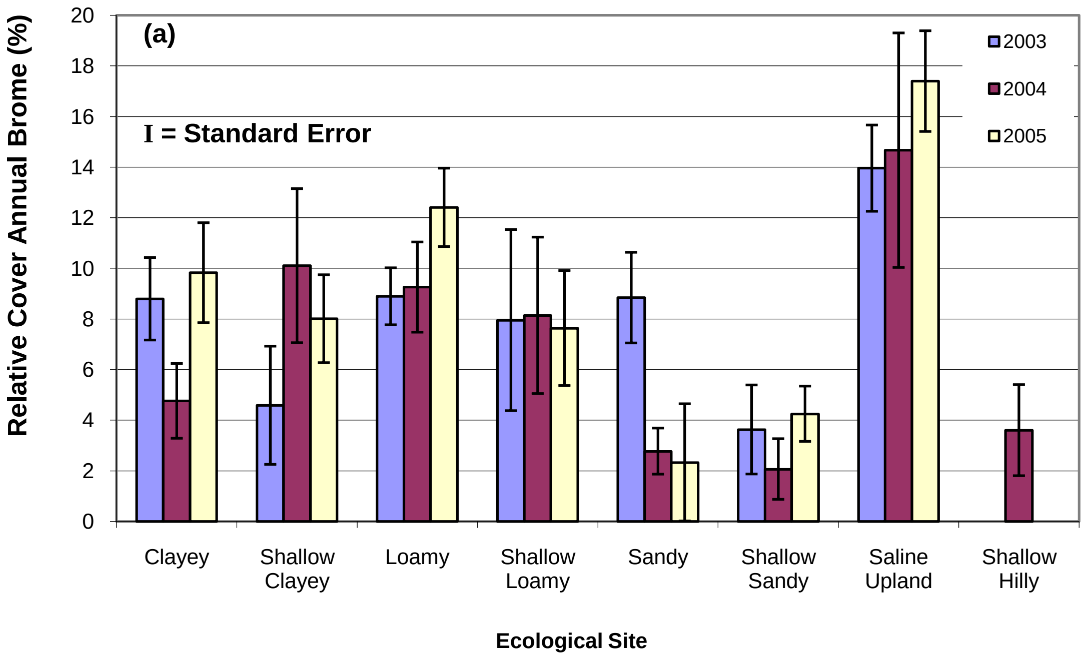
	CLAYEY	SHALLOW CLAYEY	LOAMY	SHALLOW LOAMY	SANDS/ SANDY	SHALLOW SANDY	SALINE UPLAND
	% Change						
Short-Interval Fires							
Light Grazing	-95	-100	-100	-100	-100	-93	-
Moderate Grazing	-54	-40	-29	-14	-40	105	-
Heavy Grazing	-82	-80	-66	-48	-6	-8	-
Long Interval Fires							
Light Grazing	-100	-100	-100	-52	-100	-100	-100
Moderate Grazing	+1133	+1450	-30	+3200	+227	+260	-100
Heavy Grazing	-100	+500	-100	+1600	+450	+1925	-86

Exotic Species

One of the primary causes for indirect alteration of terrestrial ecosystems has been the accidental or intentional introduction of non-native species that can negatively impact native species and ecosystems. In three years of vegetation sampling in the Thunder Basin planning area, 39 introduced (i.e. non-native) species were identified. Of the 39 introduced species, 24 were forbs, 10 were grasses, 3 were legumes, and 2 were trees (see Appendix A for a complete listing). Seven of these introduced species are also designated by the Wyoming Department of Agriculture as noxious weeds. The noxious weeds include nodding plumeless thistle (*Carduus nutans*), Canada thistle (*Cirsium arvense*), field bindweed (*Convolvulus arvensis*), gypsyflower (*Cynoglossum officinale*), leafy spurge (*Euphorbia esula*), field sowthistle (*Sonchus arvensis*), and saltcedar (*Tamarix* spp.). In addition one native species was found, skeletonleaf burr ragweed (*Ambrosia tomentosa*), which is also listed as a noxious weed by the Wyoming Department of Agriculture. Introduced species were found in every ecological site sampled, however, certain terrestrial ecological sites, such as saline upland, had considerably higher proportions of introduced species.

The introduced species of greatest concern in the Thunder Basin planning area are cheatgrass and Japanese brome, collectively referred to as annual brome (Figure 38a and 38b). On most ecological sites, annual brome comprises a majority of the introduced species and occurred in approximately 91% of the plots sampled. In most cases the relative proportion of annual brome did not differ within terrestrial ecological sites across the three years sampled (Figure 38a). However, differences do exist across some of the ecological sites, mainly a result of high proportions of annual brome on saline upland sites and relatively low proportions of annual brome on sandy and shallow sandy ecological sites. However, the absolute cover of annual brome (Figure 38b) was significantly lower in 2004 in most of the ecological sites sampled, and with the exception of sandy sites, annual brome cover did not differ between 2003 and 2004 on the other terrestrial ecological sites. The absolute cover patterns of annual brome (Figure 38b) essentially mirror the patterns observed in relative cover (Figure 38a). This suggests that annual brome is found in fairly constant proportions across ecological sites from year to year, but annual brome responds favorably when the timing and quantity of precipitation is adequate and less favorably when precipitation is not adequate.

Introduced exotic plant species have been identified as one of the greatest threats to the integrity and productivity of native ecosystem diversity and conservation of indigenous biodiversity (Mack 1981, DiTomaso 2000, Mack et al. 2000). In addition to environmental consequences, the damages caused and the costs incurred to control invasive plants are several billion dollars each year in wild and working landscapes of the United States



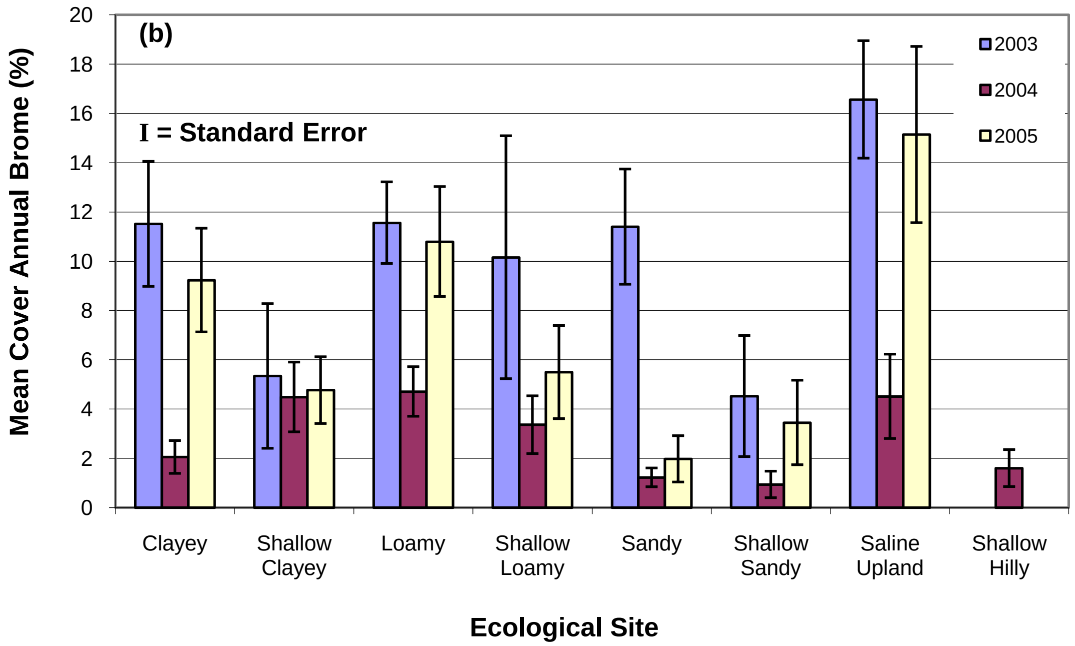


Figure 38 a,b. Relative cover +/- standard error of the mean (a) and absolute cover +/- standard error of the mean (b) of annual brome species (cheatgrass and Japanese brome) from 2003 through 2005 on terrestrial ecological sites in the Thunder Basin planning area.

(Pimentel et al. 2000). Cheatgrass and Japanese brome are non-indigenous annual grasses that have invaded rangeland ecosystems of the western United States. Originally from Europe and Asia, annual brome grasses are currently found in every state within the contiguous United States, and are considered to be among the most problematic invasive species in rangeland ecosystems (DiTomaso 2000, USDA-NRCS 2008). Human activities have been the primary contributors to the introduction and spread of annual brome (Mack 1981, Gelbard and Belnap 2003).

Invasion of rangeland ecosystems by annual brome has long been considered a point of contention in North America (Young and Allen 1997). Annual brome was initially introduced to the United States through accidental means (Mack 1981), however, rapid range expansion of annual brome throughout the United States has been attributed to repeated accidental introductions (Novak and Mack 2001), as well as, intentional introductions for livestock forage (Young and Allen 1997, Mack 1981). Thus, contention regarding annual brome stemmed from scientists and land managers who disagreed about the potential impacts of annual brome invasion on native ecosystem structure and function and the potential of annual brome to provide a desirable forage resource for livestock (Young and Allen 1997).

Annual brome is consumed by both livestock (Murray 1971, Haferkamp et al. 2001a) and wildlife (Austin et al. 1994), and at certain times of the year annual brome can provide high quality forage (Ganskopp and Bohnert 2001). However, annual brome has many attributes that make it an undesirable forage (Young and Allen 1997) including its relatively short growing season (Ganskopp and Bohnert 2001) and the fluctuations in annual brome production from year to year (Murray 1971, Haferkamp et al. 2001b). Furthermore, controlling annual brome has been shown to result in several livestock production benefits including improving the forage quality of perennial native grass species (Haferkamp et al. 2001b), producing higher livestock gains (Haferkamp et al. 2001a), and converting degraded annual brome dominated areas back to native-dominated perennial grass communities (Evans and Young 1977).

Invasion of rangeland ecosystems by annual brome has been fueled by its competitive nature and has been associated with several negative environmental and economic consequences. Competitive attributes of annual brome include the ability to rapidly establish and attain community dominance following disturbances such as wildfire (Young and Evans 1978), the ability to rapidly respond to increases in resource availability (Lowe et al. 2003, Norton et al. 2004), and the ability to compete for water (Young and Allen 1997). Invasion by annual brome has resulted in alterations of rangeland ecosystem function and structure. These alterations include reductions in above and below ground biomass (Ogle et al. 2003), increases in plant litter (Belnap and Phillips 2001), changes in plant community canopy architecture (Belnap and Phillips 2001), reductions in soil biota richness and abundance (Belnap et al. 2005), reductions in plant community richness (Belnap et al. 2005), and increases in wildfire frequency (Whisenant 1990).

7.0 SPECIES DIVERSITY

Prior to Euro-American settlement of eastern Wyoming, wildlife species dependent on the shortgrass and mixed-grass ecosystems of the of the Great Plains were expected to have been common to the Thunder Basin planning area including American bison, black-tailed prairie dogs, pronghorn antelope, elk, mule deer, grizzly bear, grey wolf, swift fox, and meadowlark. Additionally, due to the location of the planning area along the western edge of the Great Plains, some species more commonly associated with sagebrush dominated or co-dominated systems likely occurred within the planning area. This transition zone may have provided varying amounts of suitable habitat for species on the fringe of their range depending on climatic cycles of drought and above average precipitation. Species more commonly associated with sagebrush systems included greater sage-grouse, sage thrashers, vesper sparrows, and others. Several of the species likely present in this region prior to settlement have since been extirpated including the American bison, grizzly bear, gray wolf, and black-footed ferret.

Wildlife species diversity is presented in this document to address three primary purposes:

1) Facilitate a check of the Coarse Filter using a fine filter –species assessment
2) Identify non-habitat limited species
3) Identify current Species of Greatest Conservation Need

FINE FILTER – SPECIES ASSESSMENT

The niche of a species is defined by the specifc habitat conditions it selects and how it uses this habitat. The disturbance state(s) that comprised the historical and existing ecosystem diversity in the planning landscape have provided the diversity of habitat conditions for wildlife species, and the resulting selected niches of each species. The historical states described those conditions available to species under the historical disturbance regimes, and define the historical capability of the landscape to support each species. Maintaining or restoring an appropriate level of native ecosystem diversity throughout the Thunder Basin planning area is the goal of the coarse filter, and a primary focus of the Thunder Basin planning effort. The assumption of this approach is that by providing this representation, not only will ecosystem integrity be maintained, but the habitat needs and future persistence of all native species and their genetic heterozygosity will also be provided. However, simply providing specified amounts of each native ecosystem may not be sufficient without considering the sizes and distribution of the representation areas. Further, while the coarse filter is designed to provide sufficient amounts to maintain all native species if placed in appropriate sizes and distributions, the selected level of representation should be assessed for its abilities to meet these needs by checking whether various species that are good indicators of various types of ecosystems have high probabilities of persistence into the future. Thus, the approach of providing representation of native ecosystems (coarse filter) combined with the assessment of the habitat needs of selected focal species (fine filter) will check the adequacy of the coarse filter as the primary conservation strategy.

To evaluate the adequacy of the coarse filter, focal species will be selected that each have habitat requirements clearly linked to a combination of ecological site and disturbance states identified in the ecosystem diversity framework. The goal will be to select species that will encompass the full array of native terrestrial ecosystem diversity identified by the coarse filter framework. To accomplish this, the species selected must also have sufficient information available on each of their habitat requirements and characteristics to facilitate the evaluation effort. After completion of the terrestrial ecosystem diversity assessment and careful review of the species occurring within the planning area, six focal species were selected for the fine-filter species assessment and include:

1) Grasshopper Sparrow
2) Chestnut-collared Longspur
3) Lark Bunting
4) McCown's Longspur
5) Mountain Plover
6) Greater Sage-grouse

The expected distribution of each of these species within the native grassland ecosystem diversity framework is identified in Figure 39. Population viability will be evaluated for each of these six species using a habitat-based species viability approach. These models and processes have been developed and will be used to evaluate the adequacy of the coarse filter relative to the representation goals identified by the project participants during Phase 2 of the project -development of the Ecosystem Management Plan. The habitat-based species viability approach maps and compares the quality of individual home ranges for these selected species under historical, current, and proposed future conditions using methods described by (Roloff and Haufler 1997, Roloff and Haufler 2002). These results will then be used to evaluate whether proposed levels of representation are sufficient to provide an acceptable probability of viability for the focal species, thus serving as a check on the coarse filter or ecosystem diversity approach to biodiversity conservation.

NON-HABITAT LIMITED SPECIES

As discussed previously, wildlife species that are not habitat limited will require consideration of additional non-habitat related factors, such as direct mortality, to ensure their continued persistence in the planning area. The primary species occurring in the planning area that requires the development of a separate conservation strategy to address these concerns is the black-tailed prairie dog. Black-tailed prairie dogs are not generally habitat limited within this landscape but their populations are limited primarily due to human control of their populations as well as the occurrence of sylvatic plague. To address this concern, a separate Prairie Dog Conservation Strategy has been developed for the Thunder Basin planning area (Carnwath and Haufler 2008). The goal of the Strategy is to ensure the long-term persistence and viability of the prairie dog ecosystem. The prairie dog ecosystem is considered to include the ecological processes, ecosystem conditions, and assemblage of species historically associated with prairie dog colonies.

ECOSYSTEM DIVERSITY MATRIX - WYOMING THUNDER BASIN LANDSCAPE

TERRESTRIAL ECOSYSTEMS

Disturbance States	Ecological Site Class									
	Clayey	Shallow Clayey	Loamy	Shallow Loamy	Sands/ Sandy	Shallow Sandy	Shallow Hilly	Very Shallow	Saline Upland	Badlands/Gullied Land
Prairie Dog Town, active	MOPL	░	MOPL	░	░	░	░	░	MOPL	░
Prairie Dog Town, inactive		░		░	░	░	░	░		░
Vegetative composition/structure primarily influenced by short-interval fire regimes <25 year										
LIGHT GRAZING	GRSP	GRSP	GRSP	GRSP	GRSP	GRSP		░	░	░
MODERATE GRAZING	CCLO	CCLO	CCLO	CCLO	CCLO	CCLO		░	░	░
HEAVY GRAZING	MOPL MCLO	MCLO MOPL	MCLO MOPL	MCLO MOPL	MCLO MOPL	MCLO MOPL		░	░	░
Vegetative composition/ structure primarily influenced by long-interval fire regimes > 25 years										
LIGHT GRAZING	SAGR, LABU	SAGR, LABU	SAGR, LABU	SAGR, LABU	SAGR, LABU	LABU		LABU	LABU	
MODERATE GRAZING	SAGR, LABU	SAGR, LABU	SAGR, LABU	SAGR, LABU	SAGR, LABU	LABU		LABU	LABU	
HEAVY GRAZING										
SPARSELY VEGETATED			MOPL	MOPL						
TOTAL ACRES	125,637	224,360	268,298	62,541	64,683	35,190	30,269	2,791	45,902	35,560

░ Ecosystems that did not historically occur

KEY

CCLO – Chestnut-collared Longspur	LABU – Lark Bunting	MOPL – Mountain Plover
GRSP – Grasshopper Sparrow	MCLO - McCown's Longspur	SAGR – Greater Sage Grouse

Figure 39. Expected habitat distributions of species selected for the fine-filter assessment relative to native ecosystem diversity of the Thunder Basin planning ar

SPECIES OF GREATEST CONSERVATION NEED

In 2005, the Wyoming Wildlife Action Plan (Wyoming Game and Fish Department 2005) identified 21 mammal species, 18 bird species, 6 reptile species and 2 amphibian species as "Species of Greatest Conservation Need" (SGCN) that may occur in terrestrial ecosystems of the Thunder Basin planning area. Table 13 identifies these 47 species. The list of SGCN was developed by the Wyoming Game and Fish Department using a matrix of habitat population variables that help to determine the conservation priority of all native species in the state. Six classes are recognized, of which classes NSS1, NSS2, and NSS3 are considered the highest priorities for conservation attention. Refer to the following section on SGCN – key habitat protection status for specific conservation priority designations for each SGCN and definitions of these codes.

For the majority of the SGCN identified, existing habitat quality or quantity is a recognized concern for the future persistence of the species. For eleven of the SGCN, a lack of data or information on their population status is the primary reason for inclusion as a species of concern.

The following section presents a summary of the key habitat needs (Wyoming Game and Fish Department 2005) and causes for concern identified for each Species of Greatest Conservation Need presented in Table 13 and their expected distributions relative to the coarse filter or native ecosystem diversity (Figures 44-46). It is important to note that the distributions of SGCN relative to native ecosystem diversity were developed using existing information on key habitat needs. However, very few studies have described key habitat conditions in terms of native ecosystem diversity as influenced by ecological sites and historical disturbance regimes. For this reason, the key habitat needs of a species were interpreted and extrapolated to represent the current understanding of native ecosystems and may therefore reflect over-estimations or under-estimations of a species distribution. This information gap has been identified as a key future research priority for SGCN within the planning region and will require re-evaluation as better information becomes available.

Table 13. Wyoming's Species of Greatest Conservation Need as identified for the Wyoming Wildlife Action Plan (WY Game and Fish Dept. 2005), which may occur in the Thunder Basin planning area.

Common Name	Scientific Name	Common Name	Scientific Name
Mammals		**Birds**	
Big Brown Bat	*Sciurus aberti*	Bobolink	*Dolchonyx oryzivorus*
Black-footed Ferret	*Mustela nigripes*	Brewer's Sparrow	*Spizella breweri*
Black-tailed Prairie Dog	*Cynomys ludovicianus*	Burrowing Owl	*Athene cunicularia*
Fringed Myotis	*Myotis thysanodes*	Chestnut-collared Longspur	*Calcarius ornatus*
* Hispid Pocket Mouse	*Chaetodipus hispidus*	Dickcissel	*Spiza americana*
Hoary Bat	*Lasiurus cinereus*	Ferruginous Hawk	*Buteo Regalis*
Little Brown Myotis	*Myotis lucifugus*	Grasshopper Sparrow	*Ammodramus savannarum*
Long-eared Myotis	*Myotis evotis*	Greater Sage Grouse	*Centrocercus urophasianus*
* Olive-backed Pocket Mouse	*Perognathus fasciatus*	Lark Bunting	*Calamospiza melanocorys*
Pallid Bat	*Antrozous pallidus*	Long-billed Curlew	*Numenius americanus*
* Prairie Vole	*Microtus ochrogaster*	McCown's Longspur	*Calcarius mccownii*
* Sagebrush Vole	*Lemmiscus curtatus*	Merlin	*Falco columbarius*
* Silky Pocket Mouse	*Perognathus flavus*	Mountain Plover	*Charadrius montanus*
Silver-haired Bat	*Laionycteris noctivagans*	Pygmy Nuthatch	*Sitta pygmaea*
Spotted Bat	*Euderma maculatum*	Sage Sparrow	*Amphispiza belli*
* Spotted Ground Squirrel	*Spermophilus spilosoma*	Sage Thrasher	*Oreoscoptes montanus*
Swift Fox	*Vulpes velox*	Short-eared Owl	*Asio flammeus*
Townsend's Big-eared Bat	*Corynorhinus townsendii*	Swainson's Hawk	*Buteo swainsoni*
Western Small-footed Myotis	*Myotis ciliolabrum*	Upland Sandpiper	*Bartrania longicauda*
Wyoming Ground Squirrel	*Spermophilus elegans*		
Reptiles		**Amphibians**	
* Bullsnake	*Pituophis melanoleucas sayi*	Great Plains Toad	*Bufo cognatus*
* Greater Short-horned Lizard	*Phrynosoma hernandesi hernandesi*	Plains Spadefoot	*Spea bombifrons*
* Northern Sagebrush Lizard	*Sceloporus graciosus graciosus*		
* Plains Gartersnake	*Thamnophis radix*		
Plains Hog-nosed Snake	*Heterodon nasicus nasicus*		
* Prairie Rattlesnake	*Crotalus viridis viridis*		

* Species listed as SGCN entirely due to the absence of data

Each species summary contains the following information:

Protection Status – State and Federal designations and codes for protection of a species.

Code	Code Definition
Federal Status	
	Endangered
	Threatened
	Candidate - information indicates that listing is justified
State Status	
	Endangered
	Threatened
Species of Greatest Conservation Need	
NSS1	Species with on-going significant loss of habitat and populations greatly restricted or declining; extirpation appears possible
NSS2	Habitat is restricted or vulnerable and populations are declining; or habitat loss is significant and on-going and populations are declining; extirpation is not imminent
NSS3	habitat is not restricted but populations are declining; or habitat loss is on-going but population trends appear stable
NSS4	Habitat is vulnerable but no loss; and populations appear stable but status is unknown
NSS5	Habitat is stable; and populations appear to be stable but status is unknown
NSS6	population status is unknown
NatureServe Global (G) & State (S) Rank	
G1 S1	Critically imperiled because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction
G2 S2	Imperiled because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extinction throughout its range
G3 S3	Either very rare and local throughout its range, or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction throughout its range because of other factors; in the range of 21 of 100 occurrences
G4 S4	Apparently secure, though it may be quite rare in parts of its range, especially at the periphery. Cause for long term concern
G5 S5	Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery

Key Habitat - Physical description of the known primary habitat features required for a species to survive and persist in a defined region

Linkage to Native Ecosystem Diversity - Specifies the appropriate ecosystem diversity matrix to view a species expected occurrence within native ecosystems, as predicted from the current understanding of key habitat needs. The ecosystem diversity matrix represents the coarse filter for identifying native ecosystem diversity at the landscape scale. Ecosystem diversity is also mapped using a Geographic Information System (GIS). Expected historical/current species distributions relative to native ecosystem diversity can also be mapped using the ecosystem diversity matrix linked to the GIS data. It is important to note that a species link to ecosystem diversity is based on the historical distribution of a species as influenced by natural disturbance processes.

Causes of Concern – known or expected causes of concern are based on the best knowledge of the species; these concerns are recognized range-wide and may or may not affect the species in the Thunder Basin planning area

Mammals

BIG BROWN BAT (BBBA)

SCIENTIFIC NAME: *Eptisicus fuscus*

PROTECTION STATUS

Federal: None

State: Species of Greatest Conservation Need, NSS3

NatureServe: G5, S5

KEY HABITAT NEEDS

Requires sagebrush, juniper woodlands, and conifer forests; also uses rock crevices and caves

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Population status, trends, and distribution are unknown; removal of snags may result in loss of roosting habitat; broad scale insect control may impact prey base

BLACKFOOTED FERRET (BFFE)

SCIENTIFIC NAME: *Mustela nigripes*

PROTECTION STATUS

Federal: Endangered

State: Endangered; Species of Greatest Conservation Need, NSS1

NatureServe: G1, S1

KEY HABITAT NEEDS

Requires black-tailed prairie dog colonies; estimates of 100 to 150 acres of prairie dog colony are required to support one ferret

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Reduced number and size of prairie dog colonies from control programs and/or sylvatic plague; canine distemper; predation by coyotes and badgers, and barriers to dispersal.

BLACK-TAILED PRAIRIE DOG (BTPD)

SCIENTIFIC NAME: *Cynomys ludovicianus*

PROTECTION STATUS

Federal: None

State: Species of Greatest Conservation Need, NSS3

NatureServe: G3- G4, S2

KEY HABITAT NEEDS

Requires dry, flat, open shortgrass and mixedgrass prairie with low, sparse vegetation; fine to medium textured soils

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Sylvatic plague; intensive landowner eradication programs; population trends and status not well documented; and recreational shooting.

FRINGED MYOTIS (FRMY)

SCIENTIFIC NAME: *Myotis thysanodes*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS2
NatureServe: G4-G5, S2

KEY HABITAT NEEDS

Prefers dry coniferous forests; roosts in loose bark on large snags, rock crevices (particularly badlands), and caves; forages over grasslands

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Loss of large trees and snags; disturbance of roost sites; pesticides that reduce prey items.

HISPID POCKET MOUSE (HPMO)

SCIENTIFIC NAME: *Chaetodipus hispidus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS3
NatureServe: G5, S2

KEY HABITAT NEEDS

Prefers dry shortgrass and open bunchgrass prairie; may prefer sandy soils and rocky or gravelly areas with heavy soils

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Population status, trends, and distribution are unknown.

HOARY BAT (HOBA)

SCIENTIFIC NAME: *Lasiurus cinereus*

PROTECTION STATUS

Federal: None
State: Species of Special Need, NSS4
NatureServe: G5, S4

KEY HABITAT NEEDS

Prefers conifer and deciduous forests with small openings intermixed or nearby

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Population status, trends, and distribution are unknown; insect control programs may impact prey base

LITTLE BROWN MYOTIS (LBMY)

SCIENTIFIC NAME: *Myotis evotis*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS2

NatureServe Rank: G4, S4

KEY HABITAT NEEDS

Prefers dense coniferous forests and woodland including juniper and ponderosa pine; forages over rivers, streams, and ponds within the forest-woodland complex; roosts in snags, under loose bark

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Population status, trends, and distribution are unknown; insect control programs may impact prey base

OLIVE-BACKED POCKET MOUSE (OBPM)

SCIENTIFIC NAME: *Perognathus fasciatus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS3
NatureServe Rank: G5, S4

KEY HABITAT NEEDS

Prefers sparsely vegetated grasslands and sagebrush grasslands; loose sandy to clay soils for burrowing

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Population status, trends, and distribution are unknown

PALLID BAT (PABA)

SCIENTIFIC NAME: *Antrozous pallidus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS2
NatureServe Rank: G5, S1

KEY HABITAT NEEDS

Inhabits juniper woodlands, low shrublands, and grasslands; prefers rocky outcroppings particularly near water; roosts in rock crevices, rock piles, tree cavities, and shallow caves

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Population status, trends, and distribution are unknown; insect control programs may impact prey base; sensitive to human disturbance; recreational activities may impact roosting sites; insect control programs may impact prey base

PRAIRIE VOLE (PRVO)

SCIENTIFIC NAME: *Microtus ochrogaster*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS3
NatureServe Rank: G5, S5

KEY HABITAT NEEDS

Inhabits dense grasslands with few or no shrubs

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Population status, trends, and distribution are unknown

SAGEBRUSH VOLE (SAVO)

SCIENTIFIC NAME: *Lemmiscus curtatus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S5

KEY HABITAT NEEDS

Inhabits areas dominated by sagebrush and rabbitbrush mixed with bunchgrass

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Population status, trends, and distribution are unknown

SILKY POCKET MOUSE (SPMO)

SCIENTIFIC NAME: *Perognathus flavus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS3
NatureServe Rank: G5, S2

KEY HABITAT NEEDS

Inhabits a variety of arid, sometimes barren habitats, including grasslands, shrublands, and juniper woodlands; prefers low, thin grasses and a minimum of bare soil; loose, friable soils such as sandy and loamy

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Population status, trends, and distribution are unknown

SILVER HAIRED BAT (SHBA)

SCIENTIFIC NAME: *Laionycteris noctivagans*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S3

KEY HABITAT NEEDS

Inhabits relatively open coniferous forests and woodlands, including juniper and ponderosa pine; prefers late successional conditions and may be reliant on older forests for roost trees; roosts exclusively in trees, usually in cavities in trees or snags but also under loose bark/crevices

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Population status, trends, and distribution are unknown; timber harvest and the removal of snags may result in loss of roosting habitat; insect control may impact prey base

SPOTTED BAT (SPBA)

SCIENTIFIC NAME: *Euderma maculatum*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS2
NatureServe Rank: G4, S3

KEY HABITAT NEEDS

Inhabits juniper woodlands and coniferous forest; roosts in caves, rock crevices and cliffs

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Population status, trends, and distribution are unknown; recreational activities may impact roost sites; insect control programs may reduce prey base

SPOTTED GROUND SQUIRREL (SPGS)

SCIENTIFIC NAME: *Perognathus flavus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS3
NatureServe Rank: G5, S3

KEY HABITAT NEEDS

Inhabits sagebrush-grasslands, grasslands, and sand dunes; prefers dry, deep, sandy soils in sparse vegetation

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Population status, trends, and distribution are unknown

SWIFT FOX (SWFO)

SCIENTIFIC NAME: *Vulpes velox*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G3, S2

KEY HABITAT NEEDS

Inhabits short, mixed and sagebrush grasslands; closely associated with prairie dog colonies and uses underground dens year round; selects habitat with low-growing vegetation, flat terrain, and friable soils

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Loss or degradation of native grasslands, unregulated trapping and hunting; rodent control programs; vulnerable to death on highways; population trends and distributions poorly known

TOWNSEND'S BIG EARED BAT (TBEB)

SCIENTIFIC NAME: *Corynorhinus townsendii*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS2
NatureServe Rank: G4, S2

KEY HABITAT NEEDS

Inhabits a variety of xeric to mesic habitats including open pine/coniferous forests, juniper woodlands, and shrublands; roosts in caves and rocky outcrops

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Population status, trends, and distribution are unknown; sensitive to disturbance at the roost site; insect control projects may impact prey base

WESTERN SMALL-FOOTED MYOTIS (WSFM)

SCIENTIFIC NAME: *Myotis ciliolabrum*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS3
NatureServe Rank: G5, S3

KEY HABITAT NEEDS

Inhabits arid rocky areas such as canyons, cliffs, rock outcrops, and badlands adjacent to forest, juniper woodlands, sagebrush steppe, and shortgrass prairie; roosts in rock crevices, overhangs, cliffs, under rocks, and caves; requires caves for hibernation

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Population status, trends, and distribution are unknown; roost sites are sensitive to disturbance; insect control programs may impact prey base

WYOMING GROUND SQUIRREL (WGSQ)

SCIENTIFIC NAME: *Spermophilus elegans*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS6
NatureServe Rank: G5, S3-4

KEY HABITAT NEEDS

Inhabits a variety of habitats including valley bottoms and foothills, and rocky slopes; usually found above 1500 m

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 40

CAUSES OF CONCERN

Population status, trends, and distribution are unknown; rodent eradication programs; sylvatic plague; recreational shooting

ECOSYSTEM DIVERSITY MATRIX - WYOMING THUNDER BASIN LANDSCAPE

TERRESTRIAL ECOSYSTEMS

Disturbance States	Ecological Site Class Clayey	Shallow Clayey	Loamy	Shallow Loamy	Sands/ Sandy	Shallow Sandy	Shallow Hilly	Very Shallow	Saline Upland	Badlands/Gullied Land
Prairie Dog Town, active	BTPD, BFFE, SWFO	▨	BTPD, BFFE, SWFO	▨	▨	▨	▨	▨	BTPD, BFFE, SWFO	▨
Prairie Dog Town, inactive	SWFO	▨	SWFO	▨	▨	▨	▨	▨	SWFO	▨
Vegetative composition/structure primarily influenced by short-interval fire regimes < 25 years										
LIGHT GRAZING	PRVO		PRVO		PRVO		FRMY, HOBA, SPBA SHBA, BBBA, PABA TBEB	▨	▨	▨
MODERATE GRAZING	PRVO, SWFO	OBPM, SWFO	HPMO, PRVO, SPMO SWFO	HPMO, OBPM SWFO	HPMO, PRVO, SPMO SPGS, SWFO	OBPM, HPMO SWFO	FRMY, HOBA, SPBA SHBA, BBBA, PABA TBEB	▨	▨	▨
HEAVY GRAZING	SWFO	OBPM, SWFO	HPMO, SPMO, SWFO	HPMO, OBPM, SWFO	HPMO, SPMO, SPGS SWFO	OBPM, HPMO SWFO	FRMY, HOBA SHBA, BBBA, PABA TBEB	▨	▨	▨
Vegetative composition/ structure primarily influenced by long-interval fire regimes >25 years										
LIGHT GRAZING	SAVO		SAVO		SAVO		FRMY, SPBA LEMY, TBEB	PABA, TBEB		FRMY, LBMY PABA, SPBA WSFM
MODERATE GRAZING	SAVO	OBPM	SAVO	OBPM	SAVO	OBPM	FRMY, SPBA LEMY, TBEB	PABA, TBEB	OBPM	
HEAVY GRAZING		OBPM		OBPM		OBPM	FRMY, SPBA LEMY, TBEB	PABA, TBEB	OBPM	
SPARSELY VEGETATED										
TOTAL ACRES	125,637	224,360	268,298	62,541	64,683	35,190	30,269	2,791	45,902	35,560

▨ Ecosystems that did not historically occur

KEY

BBBA - Big Brown Bat
BFFE – Black-footed Ferret
BTPD – Black-tailed Prairie Dog
FRMY – Fringed Myotis
HPMO – Hispid Pocket Mouse
HOBA – Hoary Bat
LEMY – Long-eared Myotis
OBPM–Olive Backed Pocket Mouse
PABA - Pallid Bat
PRVO - Prairie Vole
SAVO - Sagebrush Vole
SPMO–Silky Pocket Mouse
SHBA – Silver Haired Bat
SPBA – Spotted Bat
SPGS – Spotted Ground Squirrel
SWFO – Swift Fox
TBEB – Townsend’s Big-eared Bat
WSFM – Western Small-footed Myotis
WGSQ – Wyoming Ground Squirrel

Figure 40. Expected distribution of mammal Species of Greatest Conservation Need (WY Game and Fish Dept. 2005) relative to native ecosystem diversity of the Thunder Basin planning area.

Birds

BOBOLINK (BOBO)

SCIENTIFIC NAME: *Dolichonyx oryzivorus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S2

KEY HABITAT NEEDS

Inhabits ungrazed to lightly grazed grasslands; prefers large expanse of grasslands

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Loss of grassland habitat; impacts and disturbance to ground nests during incubation and early nestling stages

BREWER'S SPARROW (BRSP)

SCIENTIFIC NAME: *Spizella breweri*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S5

KEY HABITAT NEEDS

Considered a sagebrush obligate species with abundant sagebrush and shortgrass; can also be found in rabbitbrush, juniper, and bunchgrass grasslands

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Loss of sagebrush habitat

BURROWING OWL (BUOW)

SCIENTIFIC NAME: *Athene cunicularia*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S3

KEY HABITAT NEEDS

Occurs in colonies using burrows excavated by black-tailed prairie dogs or ground squirrels for cover; prefers burrows in heavily grazed grasslands that provide good horizontal visibility; forage in grasslands with low to moderate grass cover to aid prey detection

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Rodent control programs; conversion of native grasslands to croplands or taller, non-native grasslands

CHESTNUT-COLLARED LONGSPUR (CCLO)

SCIENTIFIC NAME: *Calcarius ornatus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S1

KEY HABITAT NEEDS

Inhabits shortgrass and open mixed-grass prairies; prefers moderately to heavily grazed areas; sparse cover; avoids excessively shrubby areas

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Loss or degradation of native grasslands

DICKCISSEL (DICK)

SCIENTIFIC NAME: *Spiza americana*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S1

KEY HABITAT NEEDS

Inhabits taller grasslands and shrublands; prefers dense vegetation, high abundance of forbs, moderately deep litter, and singing perches

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Impacts or disturbance to ground nests; Loss or degradation of native grasslands

FERRUGINOUS HAWK (FEHA)

SCIENTIFIC NAME: *Buteo regalis*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS3
NatureServe Rank: G4, S4-5

KEY HABITAT NEEDS

Diversity of grassland and shrubland habitats supporting a diversity and abundance of prey such as ground squirrels, jackrabbits, and prairie dogs; forages in open, short-statured grasslands; nests within a short distance of abundant prey sources; prefers to nest in trees but will also nest in shrubs and tall, clumpy grasses on the ground

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Loss or degradation of native grasslands; rodent control programs that reduce prey base

GRASSHOPPER SPARROW (GRSP)

SCIENTIFIC NAME: *Ammodramus savannarum*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe: G5, S4

KEY HABITAT NEEDS

Prefers lightly grazed shortgrass systems; prefers continuous grassland areas >30 ha for breeding; avoids areas with shrubs

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Loss or degradation of native grasslands

GREATER SAGE GROUSE (SAGR)

SCIENTIFIC NAME: *Centrocercus urophasianus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS2
NatureServe Rank: G4, S4

KEY HABITAT NEEDS

Mixture of sagebrush and grassland habitats in close proximity

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Decline in quality and quantity of sagebrush habitats; possible impacts from West Nile virus

LARK BUNTING (LABU)

SCIENTIFIC NAME: *Calamospiza melanocorys*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S4

KEY HABITAT NEEDS

Prefers native grasslands of low to moderate stature (24 in. or less) with relatively high vegetative cover (45%); an overstory of shrubs may be present; may nest in colonies with birds roughly distributed every 100 ft.

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See
Figure 41

CAUSES OF CONCERN

Loss or degradation of native grasslands

LONG-BILLED CURLEW (LBCU)

SCIENTIFIC NAME: *Numenius americanus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS3
NatureServe Rank: G5, S3

KEY HABITAT NEEDS

Prefers short grasslands; may use prairie dog colonies for foraging

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Population may be declining significantly

MCCOWN'S LONGSPUR (MCLO)

SCIENTIFIC NAME: *Calcarius mccownii*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G4, S2

KEY HABITAT NEEDS

Inhabits open, dry, sparsely vegetated areas; prefers short grasslands and shrubland habitats; prefers 45 - 80% grass cover and 15 - 25% bare ground

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Loss of habitat due to fire suppression and conversion

MERLIN (MERL)

SCIENTIFIC NAME: *Falco columbarius*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS3
NatureServe Rank: G5, S4

KEY HABITAT NEEDS

Inhabits open woodlands, savannah, grasslands and shrublands; nests in large trees, commonly ponderosa pine

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Population status and trends are unknown; Loss or degradation of native grassland and shrubland ecosystems

MOUNTAIN PLOVER (MOPL)

SCIENTIFIC NAME: *Charadrius montanus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G2, S2

KEY HABITAT NEEDS

Inhabits low (4 in. or less), open habitats such as shortgrass and mixed-grass prairies dominated by blue grama and buffalograss with scattered clumps of cacti and Forbs; adapted to areas disturbed by prairie dogs, heavy grazing, or fire.

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Population status and trends are not well documented; Loss or degradation of native grassland ecosystems; high nest site fidelity increases its vulnerability to disturbance

PYGMY NUTHATCH (PYNU)

SCIENTIFIC NAME: *Sitta pygmaea*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S2

KEY HABITAT NEEDS

Considered a pine specialist; restricted primarily to ponderosa pine forests; prefers old-growth stands that are fairly open with high numbers of large snags

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Population status, trends, and distribution are unknown; timber harvest that removes older trees and snags

SAGE SPARROW (SASP)

SCIENTIFIC NAME: *Amphispiza belli*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S3

KEY HABITAT NEEDS

Considered a sagebrush obligate species; prefers tall sagebrush and low grass cover; requires large expanses of habitat to breed successfully

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Loss or degradation of native sagebrush ecosystems

SAGE THRASHER (SATH)

SCIENTIFIC NAME: *Oreoscoptes montanus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S5

KEY HABITAT NEEDS

Considered a sagebrush obligate; prefers tall sagebrush and low grass cover

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Loss of sagegrush ecosystems

SHORT-EARED OWL (SEOW)

SCIENTIFIC NAME: *Asio flammeus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S2

KEY HABITAT NEEDS

Occupies broad expanses of open grasslands and sagebrush habitat; strongly associated with ungrazed and undisturbed native grasslands that support small mammal populations; dependent on the meadow vole, which represents at least 90% of its diet

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Loss or degradation of native ecosystems; impacts on prey populations

SWAINSON'S HAWK (SWHA)

SCIENTIFIC NAME: *Perognathus flavus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S4

KEY HABITAT NEEDS

Inhabits semi-open grasslands and shrublands, savannahs, and open pine-juniper woodlands; nests in isolated trees of suitable size – taller than 10 ft. and diameter of at least 2 in.

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Loss or degradation of native grasslands and nest trees; direct mortality due to pesticide use and shooting

UPLAND SANDPIPER (UPSA)

SCIENTIFIC NAME: *Bartrania longicauda*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S3

KEY HABITAT NEEDS

Inhabits open grassland habitats; requires large areas of short grasses for foraging and courtship, interspersed with or adjacent to taller grasses for nesting and short to medium grasses for brood cover

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

See Figure 41

CAUSES OF CONCERN

Loss or degradation of native grasslands

ECOSYSTEM DIVERSITY MATRIX - WYOMING THUNDER BASIN LANDSCAPE

TERRESTRIAL ECOSYSTEMS

Disturbance States	Ecological Site Class									
	Clayey	Shallow Clayey	Loamy	Shallow Loamy	Sands/ Sandy	Shallow Sandy	Shallow Hilly	Very Shallow	Saline Upland	Badlands/Gullied Land
Prairie Dog Town, active	BUOW, FEHA, LBCU MOPL	▨	BUOW, FEHA, LBCU MOPL	▨	▨	▨	▨	▨	BUOW, FEHA, LBCU MOPL	▨
Prairie Dog Town, inactive	BUOW	▨	BUOW	▨	▨	▨	▨	▨	BUOW	▨
Vegetative composition/structure primarily influenced by short-interval fire regimes <25 years										
LIGHT GRAZING	BOBO, DICK, GRSP SEOW, UPSA	BOBO, SEOW, GRSP UPSA	BOBO, DICK, GRSP SEOW, UPSA	BOBO, SEOW, GRSP UPSA	BOBO, DICK, GRSP SEOW	BOBO, SEOW, GRSP	PYNU, MERL SWHA	▨	▨	▨
MODERATE GRAZING	CCLO, DICK, UPSA FEHA, LBCU, SEOW	CCLO, FEHA FEHA, LBCU, SEOW UPSA	CCLO, DICK, SEOW FEHA, GRSP, LBCU UPSA	CCLO, FEHA, SEOW GRSP, LBCU, UPSA	CCLO, DICK, SEOW FEHA, GRSP, LBCU	CCLO, FEHA, SEOW GRSP, LBCU	PYNU, MERL SWHA	▨	▨	▨
HEAVY GRAZING	BUOW, FEHA, MOPL LBCU, MCLO	LBCU, MCLO BUOW, FEHA, LBCU MOPL	BUOW, FEHA, MCLO GRSP, LBCU, MOPL	GRSP, MCLO BUOW, FEHA, LBCU MOPL	BUOW, FEHA, MCLO GRSP, LBCU, MOPL	GRSP, MCLO BUOW, FEHA, LBCU MOPL	PYNU, MERL SWHA	▨	▨	▨
Vegetative composition/ structure primarily influenced by long-interval fire regimes >25 years										
LIGHT GRAZING	BRSP, DICK, SATH SAGR, LABU, SASP	SAGR, LABU SASP, SATH	BRSP, DICK SAGR, LABU, SATH	SAGR, LABU SATH	BRSP, DICK SAGR, LABU	LABU	MERL	LABU, SWHA	LABU	
MODERATE GRAZING	BRSP, DICK, SATH SAGR, LABU, SASP	SAGR, LABU SASP, SATH	BRSP, DICK, SATH SAGR, LABU, SASP	SAGR, LABU SASP, SATH	BRSP, DICK SAGR, LABU, SASP	LABU	MERL	LABU, SWHA	LABU	
HEAVY GRAZING							MERL	SWHA		
SPARSELY VEGETATED										
TOTAL ACRES	**125,637**	**224,360**	**268,298**	**62,541**	**64,683**	**35,190**	**30,269**	**2,791**	**45,902**	**35,560**

▨ Ecosystems that did not historically occur

KEY

BOBO– Bobolink
BRSP – Brewer's Sparrow
BUOW – Burrowing Owl
CCLO – Chestnut-collared Longspur
DICK – Dicksissel
FEHA – Ferruginous Hawk
GRSP – Grasshopper Sparrow
SAGR - Greater Sage Grouse
LABU – Lark Bunting
LBCU – Long-billed Curlew
MCLO – McCown's Longspur
MERL – Merlin
MOPL – Mountain Plover
PYNU – Pygmy Nuthatch
SASP – Sage Sparrow
SATH – Sage Thrasher
SEOW –Short-eared Owl
SWHA – Swainson's Hawk
UPSA – Upland Sandpiper

Figure 41. Expected distribution of bird Species of Greatest Conservation Need (WY Game and Fish Dept. 2005) relative to native ecosystem diversity of the Thunder Basin planning area.

Reptiles and Amphibians

BULLSNAKE (BULL)

SCIENTIFIC NAME: *Pituophis melanoleucas sayi*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS3
NatureServe Rank: G5, S2

KEY HABITAT NEEDS

Inhabits grasslands, sagebrush, sandhills, rocky canyons, and woodlands

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

*S*ee Figure 42

CAUSES OF CONCERN

Population status, trends, and distribution are unknown; poor understanding of habitat requirements

GREAT PLAINS TOAD (GPTO)

SCIENTIFIC NAME: *Bufo cognatus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S3

KEY HABITAT NEEDS

Inhabits grasslands and sandhills

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

*S*ee Figure 42

CAUSES OF CONCERN

Loss or degradation of habitat

GREATER SHORT-HORNED LIZARD (GSLI)

SCIENTIFIC NAME: *Phrynosoma hernandesi hernandesi*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4
NatureServe Rank: G5, S4

KEY HABITAT NEEDS

Inhabits grassland and sagebrush habitats

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

*S*ee Figure 42

CAUSES OF CONCERN

Population status, trends, and distribution are unknown; poor understanding of habitat needs

NORTHERN SAGEBRUSH LIZARD (NSLI)

SCIENTIFIC NAME: *Sceloporus graciosus graciosus*

PROTECTION STATUS

Federal: None
State: Species of Greatest Conservation Need, NSS4

NatureServe Rank: G5, S5

KEY HABITAT NEEDS

Inhabits rock outcrops in sagebrush and juniper communities;

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

*S*ee Figure 42

CAUSES OF CONCERN

Population status, trends, and distribution are unknown

PLAINS GARTERSNAKE (PLGA)

SCIENTIFIC NAME: *Thamnophis radix*

PROTECTION STATUS

Federal: None

State: Species of Greatest Conservation Need, NSS4

NatureServe Rank: G5, S5

KEY HABITAT NEEDS

Inhabits dry grasslands and sandhills near water

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

*S*ee figure xx

CAUSES OF CONCERN

Population status, trends, distribution, and habitat data are lacking

PLAINS HOG-NOSED SNAKE (PHNS)

SCIENTIFIC NAME: *Heterodon nasicus nasicus*

PROTECTION STATUS

Federal: None

State: Species of Greatest Conservation Need, NSS4

NatureServe Rank: G5, S4

KEY HABITAT NEEDS

Inhabits grasslands and sandhills; burrows into loose soils

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

*S*ee Figure 42

CAUSES OF CONCERN

Population status, trends, distribution and habitat data are lacking; direct mortality due to resemblance to the rattlesnake

PLAINS SPADEFOOT (PLSP)

SCIENTIFIC NAME: *Spea bombifrons*

PROTECTION STATUS

Federal: None

State: Species of Greatest Conservation Need, NSS4

NatureServe Rank: G5, S4

KEY HABITAT NEEDS

Inhabits grasslands and sagebrush communities; burrows deeply to hibernate

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

*S*ee Figure 42

CAUSES OF CONCERN

Loss or degradation of habitat

PRAIRIE RATTLESNAKE (RATT)

SCIENTIFIC NAME: *Crotalus viridis viridis*

PROTECTION STATUS

Federal: None

State: Species of Greatest Conservation Need, NSS3

NatureServe Rank: G5, S5

KEY HABITAT NEEDS

Inhabits grasslands and woodlands, preferring areas near granite or limestone outcrops; prefers black-tailed prairie dog towns as habitat

LINKAGE TO NATIVE ECOSYSTEM DIVERSITY

*S*ee Figure 42

CAUSES OF CONCERN

Population status, trends, distribution, and habitat data are lacking; direct mortality

ECOSYSTEM DIVERSITY MATRIX - WYOMING THUNDER BASIN LANDSCAPE

TERRESTRIAL ECOSYSTEMS

Disturbance States	Ecological Site Class									
	Clayey	Shallow Clayey	Loamy	Shallow Loamy	Sands/ Sandy	Shallow Sandy	Shallow Hilly	Very Shallow	Saline Upland	Badlands/Gullied Land
Prairie Dog Town, active	RATT	▨	RATT	▨	▨	▨	▨	▨	RATT	▨
Prairie Dog Town, inactive	RATT	▨	RATT	▨	▨	▨	▨	▨	RATT	▨
Vegetative composition/structure primarily influenced by short-interval fire regimes <25 years										
LIGHT GRAZING					BUSN, PLSP, PHNS GPTO, PLGA	BUSN, PLSP, PHNS GPTO, PLGA	NSLI	▨	▨	▨
MODERATE GRAZING					BUSN, PLSP, PHNS GPTO, PLGA	BUSN, PLSP, PHNS GPTO, PLGA	NSLI	▨	▨	▨
HEAVY GRAZING					BUSN, PLSP, PHNS GPTO, PLGA	BUSN, PLSP, PHNS GPTO, PLGA	NSLI	▨	▨	▨
Vegetative composition/ structure primarily influenced by long-interval fire regimes <25 years										
LIGHT GRAZING					BUSN, PLSP, PHNS GPTO, PLGA	BUSN, PLSP, PHNS GPTO, PLGA	NSLI	NSLI	GSLI	GSLI, NSLI, PHNS
MODERATE GRAZING					BUSN, PLSP, PHNS GPTO, PLGA	BUSN, PLSP, PHNS GPTO, PLGA	NSLI	NSLI	GSLI	
HEAVY GRAZING					BUSN, PLSP, PHNS GPTO, PLGA	BUSN, PLSP, PHNS GPTO, PLGA	NSLI	NSLI	GSLI	
SPARSELY VEGETATED										
TOTAL ACRES	125,637	224,360	268,298	62,541	64,683	35,190	30,269	2,791	45,902	35,560

▨ Ecosystems that did not historically occur

KEY

BULL – Bullsnake	GSLI – Greater short-horned lizard	PLGA – Plains gartersnake	PLSP – Plains spadefoot
GPTO – Great Plains toad	NSLI - Northern sagebrush lizards	PHNS – Plains hog-nosed snake	RATT – Rattlesnake

Figure 42. Expected distribution of reptile and amphibian species of special needs (WY Game and Fish Dept. 2005) relative to native ecosystem diversity of the Thunder Basin planning area.

8.0 KEY FINDINGS AND RECOMMENDATIONS

Current ecosystem conditions, as identified by the ecosystem assessment, have been influenced by fire regime modification, the modification of historical grazing regimes, and the spread of introduced species. Grassland ecosystems were historically dependent on grazing by native herbivores and fire as disturbance factors that shaped ecosystem diversity. Without fire as a disturbance process, many of these ecosystems move toward shrub or tree-dominated areas (Archer 1994, Knapp et al. 1999, Fuhlendorf and Engle 2001). The role of fire in many grasslands including Thunder Basin has been reduced. This has modified species compositions of plant communities, altered nutrient cycling processes, and influenced grazing patterns, which in turn has influenced vegetation compositions and structure. Historically, grazing by native herbivores, especially bison, played a significant role in shaping and maintaining terrestrial ecosystems (Hart and Hart 1997, Knapp et al. 1999) and interacted with fire to create a shifting mosaic of conditions (Knapp et al. 1999, Fuhlendorf and Engle 2001). Although grazing by domestic animals is currently the primary use of grasslands, the foraging ecology of grazers that historically occupied the Great Plains differed from those used today (Plumb and Dodd 1993) and the current grazing practices in grassland ecosystems have been found to differ from the historical role of herbivores (Fuhlendorf and Engle 2001). Existing livestock grazing practices have been focused on achieving even distribution of animals and even utilization of grass resources, which produces relatively uniform or homogeneous vegetation conditions; a condition referred to by Fuhlendorf and Engle (Fuhlendorf and Engle 2004) as “management to the middle”.

This ecological assessment was conducted to obtain a thorough understanding of the ecological characteristics of the planning area prior to developing specific conservation and management plans. Vegetation sampling occurred from 2003 through 2005 to characterize ecosystem diversity in the area. This assessment compared existing ecosystem diversity in the planning area to an historical reference and provided the information needed to develop conservation objectives for the planning area. The comparison of historical and existing ecosystem conditions revealed many differences including an increase in the ecosystems characterized as having long-fire return intervals, lack of representation of ecosystems characterized by light grazing, and the widespread presence of exotic plant species (Tables 10 and 11).

It should be noted that the current conditions described for the landscape have considered a plant community to be representative of historical conditions if it meets the composition specified through the development of primary indicators of disturbance states. For short-return fire communities, a recent fire was not a prerequisite for designation to this category, even though a fire in the recent past would stimulate various community responses that would make the community more suitable as a representative site. This is primarily true for the moderate grazing-level sites. Compositions produced or resulting from light-grazing conditions, as mentioned, were almost completely absent from the landscape. Considerable acreage of moderate grazing conditions existed, a number of which had low enough levels of exotic species to qualify as representative of historical conditions in our assessment. However, these stands would be improved for representation if fire was reinstated as a disturbance regime. Areas containing plant communities with compositions that indicate a history of heavy grazing occur across the landscape. A fairly high percentage of these sites are not considered representative of historical conditions because of the high levels of exotic species found on many of these areas. Those sites that have low enough levels of exotic species should be fairly representative of historical heavily grazed grassland communities, as fire was less of a factor in the shortgrass dominated plant communities as compared to the mixed grass dominated communities resulting from past moderate or light grazing levels.

The long fire-return interval, for most ecological sites, refers to sagebrush communities having >10% sagebrush cover. Most of these sites historically received relatively light grazing, as bison would prefer recently burned sites for grazing to obtain higher nutritional-quality forage. However, as in the short fire-return interval plant communities, communities representative of light grazing regimes are almost totaling lacking in the landscape today (Tables 10 and 11). Much of the sagebrush occurring today still appeared to be fairly healthy and vigorous, but lacked an understory of native grass and forb species likely due to the moderate or heavy levels of livestock grazing that have occurred on this landscape for >50 years. Many stands also had high levels of exotic species, especially annual bromes in the understory. Denser stands of sagebrush occurring in the landscape, particularly near sage-grouse leks, appear to be particularly important to sagebrush-associated species. It is important to maintain the sagebrush component of these stands, while striving to increase the quality of the understory vegetation. This may present a management challenge, as any significant disturbance to the sagebrush will reduce the amounts of this plant community that are needed by sagebrush-associated species in this landscape.

At present, this assessment has determined that the landscape supports more sagebrush than occurred historically, albeit with different understory conditions than occurred historically. The estimate of 16% of the landscape with >10% sagebrush cover compared to 6% historically demonstrates this 2.8 fold increase. The historical estimates of the amounts of sagebrush with >10% sagebrush cover appear to be well supported by the existing conditions, that with even a modest amount of fire in the landscape would be reduced in amounts.

While wildfires still occur within the landscape the extent of these fires has not produced good representation of the fire-maintained grassland conditions that occurred historically. Current fire control policies as well as the levels of livestock grazing applied to the landscape have reduced the role of this disturbance factor.

Grazing was an important disturbance that affected ecosystem diversity across the landscape, with bison being the primary historical grazer. Grazing today is by cattle, sheep, and horses with relatively uniform grazing levels applied across the landscape as compared with estimates of historical grazing pressure. Providing for a greater range, specifically focusing on plant communities characteristic of light grazing regimes is needed if the full spectrum of native ecosystem diversity is to be represented in the landscape.

Current ecosystem conditions have also been heavily influenced by the spread of exotic species. A particular concern is the spread of cheatgrass, an exotic annual grass that competes with native species for moisture and nutrients, and can dramatically alter ecosystem compositions, structures, and functions. Controlling this species, and filling in the areas it has taken over with desired native species is an important objective for a conservation and management plan for the Thunder Basin.

A native species that has increased as a result of fire exclusion and moderate to heavy grazing regimes is the pricklypear cactus. Many ranchers desire to reduce the amounts of this species in the landscape. Complicating its reduction is that many of the plant communities indicative of heavy grazing regimes have lower production of grasses and forbs, and reduced abilities to carry fires that could be used to control pricklypear occurrence. Pricklypear can be chemically controlled, but this will also control most of the broad-leaved plants, reducing the potential occurrence of many desired native forbs and potentially making the site inappropriate for representation of native ecosystem diversity.

This assessment has documented both the historical ecosystem diversity and existing ecosystem diversity of the Thunder Basin planning landscape. It provides the information needed to identify desired representation goals, and describes the specific plant communities that would need to be maintained or restored to achieve the representation goals.

9.0 ADDITIONAL INFORMATION NEEDS

This assessment has produced many insights into the ecology of the Thunder Basin as well as information on its past and current conditions that will assist in managing the area for multiple objectives. However, many questions remain that will only be answered with additional research. Several key information needs are discussed here.

This ecological assessment only addressed the terrestrial ecosystems in Thunder Basin. While some work on aquatic, riparian, and wetland ecosystems has been conducted, sufficient knowledge of and data from these ecosystems does not currently exist to conduct a similar assessment. State and transition models that address historical disturbance regimes for these ecosystems have not been developed, and the response of these ecosystems to specific disturbance factors and the resulting changes in compositions and functions of plant communities is poorly understood. For these ecosystems, in addition to the role of fire, grazing, and drought, additional disturbance factors that need to be considered and understood include floods and the role of beaver. Even the descriptions of existing ecosystem compositions and structures across different ecological sites, is poorly understood. Thus, much new research will be needed before a coarse filter approach to aquatic, riparian, and wetland ecosystems can be completed for the Thunder Basin.

This assessment has expanded the data and knowledge concerning the terrestrial ecosystems of the Thunder Basin. However, much remains unknown about these ecosystems, their dynamics, and their responses to management activities. Well planned management activities, applied using adaptive management could provide needed information in an efficient and effective manner. For example, Figure 43 shows an adaptive management design applied to proposed rangeland improvement treatments. Use of such a design would provide information on how each treatment individually and in combination was influencing plant community responses. If experimental designs such as this or even of a more simple framework were applied to replicated treatments, knowledge about effectiveness of various rangeland practices and plant community dynamics could be rapidly gained. Treatments that consider an appropriate experimental design, factor in the consideration of possible sources of variance, and that conduct baseline and post-treatment monitoring would add significant reproducible results on the ecology and management of the Thunder Basin. Unfortunately, funding for needed longer-term monitoring is typically not well supported by agencies and other funding sources. While landowners can do some monitoring on their own in a coordinated manner, the complexity, required time commitment, and technical capabilities required for many important monitoring tasks limits the extent of information that such citizen-contributed approaches can provide.

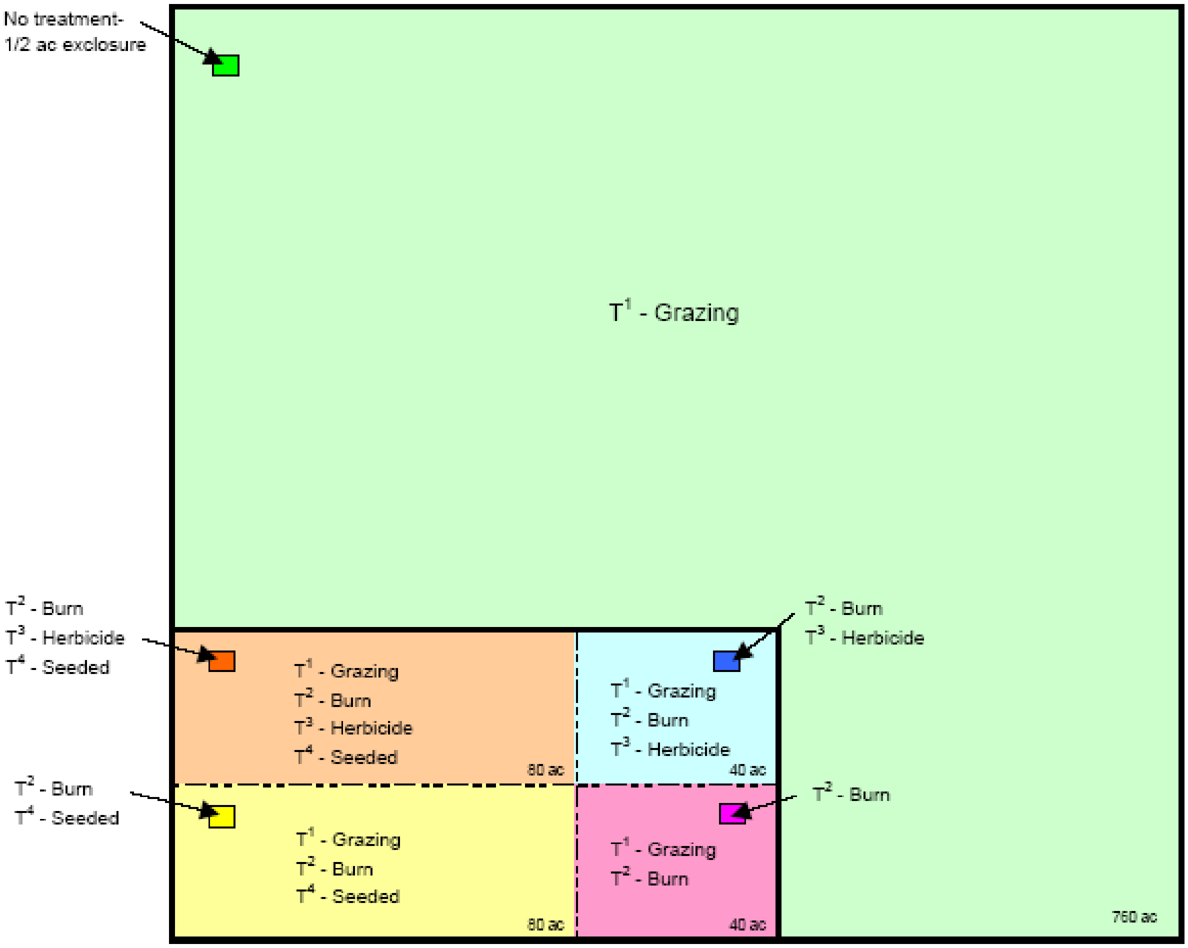


Figure 43. An adaptive management design used in Thunder Basin for evaluating the effectiveness of several rangeland improvement treatments and their combinations including prescribed burning, herbicide control of cheatgrass, interseeding with desired species of native grasses and forbs, and selected grazing regimes. Exclosures are used to monitor the longer term responses to grazing compared to ungrazed areas for each treatment combination. This design should be replicated across different ecological sites, and for different grazing regimes to determine the influence of all treatment variables in a heterogeneous environment, as described in Franklin et al. (2007).

The work of this assessment concentrated on understanding and quantifying plant communities and their dynamics in terms of compositions, structures, and relationships to ecological sites, and historical and existing disturbance factors. No research was conducted on the below ground differences or responses to these factors, nor to the functioning of the plant communities in terms of such things as nutrient dynamics, carbon sequestration, or soil characteristics. Information on such topics would enhance our abilities to understand such related effects, and to incorporate this understanding into our planning and management to produce more predictable and desirable outcomes. Broader knowledge of these relationships would expand the ability to address additional ecosystem services that could be provided through a implementation of a conservation strategy.

The work conducted for this assessment produced state and transition models that explain, based on our current understanding, the historical and existing responses of terrestrial plant communities to disturbance factors. The modeling work that was completed included the quantification of plant species responses to historical disturbances, and in aggregate for a site, these plant species responses allow for modeling of the community and resulting plant community dynamics. This work could be readily expanded to evaluate possible changes that could result from climate change. The Thunder Basin is an ecotonal area, transitioning from the Great Plains to the Great Basin to the west. It is also an ecotonal area were moisture and grazing levels can push plant communities to be dominated by either short-grass or mixed-grass plant communities, and where fire regimes interacting with grazing regimes can allow varying amounts of sagebrush to occur. Understanding how potential climate change might influence such dynamics from both the ecological and economic perspective would be valuable information for future planning.

Finally, the coarse filter approach emphasized in this assessment is based on the assumption that representation of native ecosystem diversity will provide for the habitat needs of native species. The characterization of this coarse filter in terms of the classification system used for identifying ecosystems and the levels of representation selected for management should be monitored and evaluated over time. While a properly constructed coarse filter does not need to demonstrate its effectiveness for each and every species in the landscape, it should still be evaluated for its effectiveness in meeting the needs of various species selected as focal species to represent the range of ecosystem conditions produced under historical disturbance regimes. While this component of monitoring and adaptive management has been identified as an important part of this conservation planning strategy (Figure 3), it is still worth re-emphasizing in this discussion on future information and research needs.

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APPENDIX A

Plant species identified during the 2003 through 2005 field sampling seasons in the Thunder Basin Planning Area located in eastern Wyoming. Nomenclature follows The PLANTS Database (http://plants.usda.gov; accessed 12/2006) where Origin I = Introduced, N = Native, N/A = Information is not available.

FAMILY/ SYMBOL	SCIENTIFIC NAME	COMMON NAME	ORIGIN
Agavaceae			
YUGL	*Yucca glauca*	soapweed yucca	N
Anacardiaceae			
RHTR	*Rhus trilobata*	skunkbush sumac	N
Apiaceae			
LOFO	*Lomatium foeniculaceu*	desert biscuitroot	N
MUDI	*Musineon divaricatum*	leafy wildparsley	N
Asclepiadaceae			
ASIN	*Asclepias incarnata*	swamp milkweed	N
ASSP	*Asclepias speciosa*	showy milkweed	N
ASSU2	*Asclepias subverticillata*	horsetail milkweed	N
Asteraceae			
ACMI2	*Achillea millefolium*	common yarrow	N
AGGL	*Agoseris glauca*	pale agoseris	N
AMAR2	*Ambrosia artemisiifolia*	annual ragweed	N
AMPS	*Ambrosia psilostachya*	Cuman ragweed	N
AMTO3	*Ambrosia tomentosa*	skeletonleaf burr ragweed	N
ANPA4	*Antennaria parvifolia*	small-leaf pussytoes	N
ANRO2	*Antennaria rosea*	rosy pussytoes	N
ARAB3	*Artemisia absinthium*	absinthium	I
ARBI2	*Artemisia biennis*	biennial wormwood	N/I
ARCA12	*Artemisia campestris*	field sagewort	N
ARCA13	*Artemisia cana*	silver sagebrush	N
ARFI2	*Artemisia filifolia*	sand sagebrush	N
ARFR4	*Artemisia frigida*	prairie sagewort	N
ARLU	*Artemisia ludoviciana*	white sagebrush	N
ARPE6	*Artemisia pedatifida*	birdfoot sagebrush	N
ARTR2	*Artemisia tridentata*	big sagebrush	N
BIDEN	*Bidens* spp	beggarticks	N
CANU4	*Carduus nutans*	nodding plumeless thistle	I
CHLI3	*Chrysothamnus linifolius*	spearleaf rabbitbrush	N
CHVI8	*Chrysothamnus viscidiflorus*	yellow rabbitbrush	N
CIAR4	*Cirsium arvense*	Canada thistle	I
CICA11	*Cirsium canescens*	prairie thistle	N
CIUN	*Cirsium undulatum*	wavyleaf thistle	N
COCA5	*Conyza canadensis*	Canadian horseweed	N
CRTE3	*Crepis tectorum*	narrowleaf hawksbeard	I
DYPA	*Dyssodia papposa*	fetid marigold	N
ERNA10	*Ericameria nauseosa*	rubber rabbitbrush	N
ERBE2	*Erigeron bellidiastrum*	western daisy fleabane	N
ERCA4	*Erigeron canus*	hoary fleabane	N
ERGL2	*Erigeron glabellus*	streamside fleabane	N

Appendix A. Continued.

FAMILY/ SYMBOL	SCIENTIFIC NAME	COMMON NAME	ORIGIN
ERLI	*Erigeron linearis*	desert yellow fleabane	N
EROC	*Erigeron ochroleucus*	buff fleabane	N
ERST3	*Erigeron strigosus*	prairie fleabane	N
ERIOG	*Eriogonum* spp	buckwheat	N
EUGR5	*Euthamia graminifolia*	flat-top goldenrod	N
GRSQ	*Grindelia squarrosa*	curlycup gumweed	N
GUSA2	*Gutierrezia sarothrae*	broom snakeweed	N
HELIA3	*Helianthus* spp	sunflower	N
HEVIV	*Heterotheca villosa var. villosa*	hairy false goldenaster	N
HIUM	*Hieracium umbellatum*	narrowleaf hawkweed	N
HYMEN4	*Hymenopappus spp*	hymenopappus	N
LASE	*Lactuca serriola*	prickly lettuce	I
LATAP	*Lactuca tatarica var. pulchella*	blue lettuce	N
LIPU	*Liatris punctata*	dotted blazing star	N
LYJU	*Lygodesmia juncea*	rush skeletonplant	N
MAGR2	*Machaeranthera grindelioides*	rayless tansyaster	N
MAPI	*Machaeranthera pinnatifida*	lacy tansyaster	N
MATA2	*Machaeranthera tanacetifolia*	tansyleaf tansyaster	N
OOMU	*Oonopsis multicaulis*	branched false goldenweed	N
PACA15	*Packera cana*	woolly groundsel	N
PAFE4	*Packera fendleri*	Fendler's ragwort	N
PAPSP2	*Packera pseudaurea*	false groundsel	N
PARO	*Palafoxia rosea*	rosy palafox	N
PAROM	*Palafoxia rosea*	rosy palafox	N
PIOP	*Picradeniopsis oppositifolia*	oppositeleaf bahia	N
RACO3	*Ratibida columnifera*	upright prairie coneflower	N
SOMI2	*Solidago missouriensis*	Missouri goldenrod	N
SOAR2	*Sonchus arvensis*	field sowthistle	I
STAR10	*Stenotus armerioides*	thrift mock goldenweed	N
SYFAF	*Symphyotrichum falcatum* var. *falcatum*	white prairie aster	N
SYLAH6	*Symphyotrichum lanceolatum ssp. hesperium* var. *hesperium*	white panicle aster	N
TAOF	*Taraxacum officinale*	common dandelion	I
TEAC	*Tetraneuris acaulis*	stemless four-nerve daisy	N
TRDU	*Tragopogon dubius*	yellow salsify	I
XAST	*Xanthium strumarium*	rough cocklebur	N
Boraginaceae			
CRCE	*Cryptantha celosioides*	buttecandle	N
CRCI2	*Cryptantha circumscissa*	cushion cryptantha	N
CYOF	*Cynoglossum officinale*	gypsyflower	I
HAFL2	*Hackelia floribunda*	manyflower stickweed	N
LAOC3	*Lappula occidentalis*	flatspine stickseed	N
LAOCC	*Lappula occidentalis* var. *cupulata*	flatspine stickseed	N
LASQ	*Lappula squarrosa*	European stickseed	I
LIIN2	*Lithospermum incisum*	narrowleaf stoneseed	N
MELA3	*Mertensia lanceolata*	prairie bluebells	N
MYVE	*Myosotis verna*	spring forget-me-not	N

Appendix A. Continued.

FAMILY/ SYMBOL	SCIENTIFIC NAME	COMMON NAME	ORIGIN
Brassicaceae			
ALDE	*Alyssum desertorum*	desert madwort	I
ARABI2	*Arabis* spp	rockcress	N/A
CAMI2	*Camelina microcarpa*	littlepod false flax	I
DEPI	*Descurainia pinnata*	western tansymustard	N
DESO2	*Descurainia sophia*	herb sophia	I
DRABA	*Draba* spp	draba	N/A
ERCH9	*Erysimum cheiranthoides*	wormseed wallflower	I
LEDE	*Lepidium densiflorum*	common pepperweed	N
LEPE2	*Lepidium perfoliatum*	clasping pepperweed	I
LEAR6	*Lesquerella arenosa*	Great Plains bladderpod	N
SIAL2	*Sisymbrium altissimum*	tall tumblemustard	I
THAR5	*Thlaspi arvense*	field pennycress	I
Cactaceae			
ESVIV	*Escobaria vivipara* var. *vivipara*	spinystar	N
OPFR	*Opuntia fragilis*	brittle pricklypear	N
OPPO	*Opuntia polyacantha*	plains pricklypear	N
PESI	*Pediocactus simpsonii*	Simpson hedgehog cactus	N
Campanulaceae			
CARO2	*Campanula rotundifolia*	bluebell bellflower	N
Capparaceae			
CLSE	*Cleome serrulata*	Rocky Mountain beeplant	N
Caprifoliaceae			
SYOC	*Symphoricarpos occidentalis*	western snowberry	N
SYMPH	*Symphoricarpos* spp	snowberry	N
Caryophyllaceae			
CEAR4	*Cerastium arvense*	field chickweed	N
MINU4	*Minuartia nuttalli*	Nuttall's sandwort	N
Chenopodiaceae			
ATAR2	*Atriplex argentea*	silverscale saltbush	N
ATCA2	*Atriplex canescens*	fourwing saltbush	N
ATGA	*Atriplex gardneri*	Gardner's saltbush	N
ATNU2	*Atriplex nuttallii*	Nuttall's saltbush	N
ATRIP	*Atriplex* spp	saltbrush	N
CHBE4	*Chenopodium berlandieri*	pitseed goosefoot	N
CHLE4	*Chenopodium leptophyllum*	narrowleaf goosefoot	N
CHGLS3	*Chenopodium salinum*	Rocky Mountain goosefoot	N
HAGL	*Halogeton glomeratus*	saltlover	I
KOCHI	*Kochia* spp	molly	N/A
KRLA2	*Krascheninnikovia lanata*	winterfat	N
MONU	*Monolepis nuttalliana*	Nuttall's povertyweed	N
SATR12	*Salsola tragus*	prickly Russian thistle	I
SAVE4	*Sarcobatus vermiculatus*	greasewood	N
Commelinaceae			
TROC	*Tradescantia occidentalis*	prairie spiderwort	N
Convolvulaceae			
COAR4	*Convolvulus arvensis*	field bindweed	I
EVNU	*Evolvulus nuttallianus*	shaggy dwarf morning-glory	N

Appendix A. Continued.

FAMILY/ SYMBOL	SCIENTIFIC NAME	COMMON NAME	ORIGIN
Crassulaceae			
SEDUM	*Sedum* spp	stonecrop	N/A
Cupressaceae			
JUSC2	*Juniperus scopulorum*	Rocky Mountain juniper	N
Cyperaceae			
CABR10	*Carex brevior*	shortbeak sedge	N
CADU6	*Carex duriuscula*	needleleaf sedge	N
CAFI	*Carex filifolia*	threadleaf sedge	N
CAINH2	*Carex inops ssp. Heliophila*	sun sedge	N
CANE2	*Carex nebrascensis*	Nebraska sedge	N
CAST5	*Carex stipata*	owlfruit sedge	N
CAUT	*Carex utriculata*	Northwest Territory sedge	N
ELEOC	*Eleocharis* spp	spikerush	N
SCPU10	*Schoenoplectus pungens*	common threesquare	N
SCTA2	*Schoenoplectus tabernaemontani*	softstem bulrush	N
Elaeagnaceae			
ELAN	*Elaeagnus angustifolia*	Russian olive	I
Equisetaceae			
EQLA	*Equisetum laevigatum*	smooth horsetail	N
Euphorbiaceae			
CHMA15	*Chamaesyce maculata*	spotted sandmat	N
CHSE6	*Chamaesyce serpyllifolia*	thymeleaf sandmat	N
EUES	*Euphorbia esula*	leafy spurge	I
Fabaceae			
ASAG2	*Astragalus agrestis*	purple milkvetch	N
ASBI2	*Astragalus bisulcatus*	twogrooved milkvetch	N
ASGI5	*Astragalus gilviflorus*	plains milkvetch	N
ASLAR	*Astragalus laxmannii*	prairie milkvetch	N
ASADR	*Astragalus laxmannii* var. *robustiar*	prairie milkvetch	N
ASMO7	*Astragalus mollissimus*	woolly locoweed	N
ASSP6	*Astragalus spatulatus*	tufted milkvetch	N
ASVE5	*Astragalus vexilliflexus*	bentflower milkvetch	N
DACA7	*Dalea candida*	white prairie clover	N
DAPU5	*Dalea purpurea*	violet prairie clover	N
GLLE3	*Glycyrrhiza lepidota*	American licorice	N
HEBO	*Hedysarum boreale*	boreal sweetvetch	N
LUPIN	*Lupinus* spp	lupine	N/A
MELU	*Medicago lupulina*	black medick	I
MEAL12	*Melilotus alba*	white sweetclover	I
MEOF	*Melilotus officinalis*	yellow sweetclover	I
OXLA3	*Oxytropis lambertii*	purple locoweed	N
PEAR6	*Pediomelum argophyllum*	silverleaf Indian breadroot	N
PEDI9	*Pediomelum digitatum*	palmleaf Indian breadroot	N
PEES	*Pediomelum esculentum*	large Indian breadroot	N
PEHY4	*Pediomelum hypogaeum*	subterranean Indian breadroot	N
PSLA3	*Psoralidium lanceolatum*	lemon scurfpea	N
PSTE5	*Psoralidium tenuiflorum*	slimflower scurfpea	N
THRH	*Thermopsis rhombifolia*	prairie thermopsis	N
VIAM	*Vicia americana*	American vetch	N

Appendix A. Continued.

FAMILY/ SYMBOL	SCIENTIFIC NAME	COMMON NAME	ORIGIN
Grossulariaceae			
RIAU	*Ribes aureum*	golden current	N
RICE	*Ribes cereum*	wax current	N
Hydrophyllaceae			
PHLI	*Phacelia linearis*	threadleaf phacelia	N
Iridaceae			
SIMO2	*Sisyrinchium montanum*	strict blue-eyed grass	N
Juncaceae			
JUDU2	*Juncus dudleyi*	Dudley's rush	N
JUNO2	*Juncus nodosus*	knotted rush	N
JUTO	*Juncus torreyi*	Torrey's rush	N
Lamiaceae			
HEHI	*Hedeoma hispida*	rough false pennyroyal	N
LYAM	*Lycopus americanus*	American water horehound	N
MEAR4	*Mentha arvensis*	wild mint	N
Liliaceae			
ALTE	*Allium textile*	textile onion	N
CANU3	*Calochortus nuttalli*	sego lily	N
CALOC	*Calochortus* spp	mariposa lily	N/A
ZIVE	*Zigadenus venenosus*	meadow deathcamus	N
Linaceae			
LIRI	*Linum rigidum*	stiffstem flax	
Malvaceae			
SPCO	*Sphaeralcea coccinea*	scarlet globemallow	N
Nyctaginaceae			
ABFR2	*Abronia fragrans*	snowball sand verbena	N
MILI3	*Mirabilis linearis*	narrowleaf four o'clock	N
Onagraceae			
GACO5	*Gaura coccinea*	scarlet beeblossom	N
OEAL	*Oenothera albicaulis*	whitest evening-primrose	N
OECA10	*Oenothera caespitosa*	tufted evening-primrose	N
Orobanchaceae			
ORCO5	*Orobanche corymbosa*	flat-top broomrape	N
ORFA	*Orobanche fasciculata*	clustered broomrape	N
ORLU	*Orobanche ludoviciana*	Louisiana broomrape	N
Papaveraceae			
ARPO2	*Argemone polyanthemos*	crested pricklepoppy	N
Pinaceae			
PIPO	*Pinus ponderosa*	ponderosa pine	N
Plantaginaceae			
PLEL	*Plantago elongata*	prairie plantain	N
PLMA2	*Plantago major*	common plantain	N
PLPA2	*Plantago patagonica*	woolly plaintain	N
Poaceae			
ACHY	*Achnatherum hymenoides*	Indian ricegrass	N
AGCR	*Agropyron cristatum*	crested wheatgrass	I
AGST2	*Agrostis stolonifera*	creeping bentgrass	N
ALAE	*Alopecurus aequalis*	shortawn foxtail	N
ALCA4	*Alopecurus carolinianus*	Carolina foxtail	N
ALGE2	*Alopecurus geniculatus*	water foxtail	I

Appendix A. Continued.

FAMILY/ SYMBOL	SCIENTIFIC NAME	COMMON NAME	ORIGIN
ANGE	*Andropogon gerardii*	big bluestem	N
ANBR	*Annual brome*	cheatgrasses	I
ARPU9	*Aristida purpurea*	purple threeawn	N
BOCU	*Bouteloua curtipendula*	sideoats grama	N
BOGR2	*Bouteloua gracilis*	blue grama	N
BRIN2	*Bromus inermis*	smooth bromegrass	I
BUDA	*Buchloe dactyloides*	buffalograss	N
CALO	*Calamovilfa longifolia*	prairie sandreed	N
DISP	*Distichlis spicata*	Inland saltgrass	N
ELCA4	*Elymus canadensis*	Canada wildrye	N
ELEL5	*Elymus elymoides*	squirreltail	N
ELTR7	*Elymus trachycaulus*	slender wheatgrass	N
ELTR13	*Eremopyrum triticeum*	annual wheatgrass	I
HECO26	*Hesperostipa comata*	needle and thread	N
HOJU	*Hordeum jubatum*	foxtail barley	N
HOPU	*Hordeum pusillum*	little barley	N
KOMA	*Koeleria macrantha*	prairie Junegrass	N
MUAS	*Muhlenbergia asperifolia*	scratchgrass	N
MURI	*Muhlenbergia richardsonis*	mat muhly	N
NAVI4	*Nassella viridula*	green needlegrass	N
PASM	*Pascopyrum smithii*	western wheatgrass	N
PHPR3	*Phleum pratense*	timothy	I
POCU3	*Poa cusickii*	Cusick's bluegrass	N
POPA2	*Poa palustris*	fowl bluegrass	N
POPR	*Poa pratensis*	Kentucky bluegrass	I
POSE	*Poa secunda*	sandberg bluegrass	N
POMO5	*Polypogon monspeliensis*	annual rabbitfoot grass	I
PSSP6	*Pseudoroegneria spicata*	bluebunch wheatgrass	N
SCPA	*Schedonnardus paniculatus*	tumblegrass	N
SCSC	*Schizachyrium scoparium*	little bluestem	N
SPGR	*Spartina gracilis*	alkali cordgrass	N
SPPE	*Spartina pectinata*	prairie cordgrass	N
SPAI	*Sporobolus airoides*	alkali sacaton	N
SPCR	*Sporobolus cryptandrus*	sand dropseed	N
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	I
VUOC	*Vulpia octoflora*	sixweeks fescue	N
ELMA8	*xElyhordeum macounii*	Macoun's barley	N
Polemoniaceae			
COLI2	*Collomia linearis*	tiny trumpet	N
PHAL3	*Phlox alyssifolia*	alyssumleaf phlox	N
PHAN4	*Phlox andicola*	prairie phlox	N
PHHO	*Phlox hoodii*	spiny phlox	N

Appendix A. Continued.

FAMILY/ SYMBOL	SCIENTIFIC NAME	COMMON NAME	ORIGIN
Polygonaceae			
ERAN4	*Eriogonum annuum*	annual buckwheat	N
ERPA9	*Eriogonum pauciflorum*	fewflower buckwheat	N
ERUM	*Eriogonum umbellatum*	sulphur-flower buckwheat	N
POAC3	*Polygonum achoreum*	leathery knotweed	N
POAR11	*Polygonum arenastrum*	oval-leaf knotweed	I
POAV	*Polygonum aviculare*	prostrate knotweed	I
PORA3	*Polygonum ramosissimum*	bushy knotweed	N
RUAQF	*Rumex aquaticus* var. *fenestratus*	western dock	N
RUMA4	*Rumex maritimus*	golden dock	N
RUPA5	*Rumex patientia*	patience dock	I
Ranunculaceae			
RAAB	*Ranunculus abortivus*	littleleaf buttercup	N
RACY	*Ranunculus cymbalaria*	alkali buttercup	N
Rosaceae			
POCO13	*Potentilla concinna*	elegant cinquefoil	N
POPE8	*Potentilla pensylvanica*	Pennsylvania cinquefoil	N
PRVI	*Prunus virginiana*	chokecherry	N
ROACS	*Rosa acicularis* ssp. *sayi*	prickly rose	N
ROWO	*Rosa woodsii*	Woods' rose	N
Salicaceae			
POAN3	*Populus angustifolia*	narrowleaf cottonwood	N
PODEM	*Populus deltoides ssp. monilifera*	plains cottonwood	N
SAEX	*Salix exigua*	narrowleaf willow	N
SAIN3	*Salix interior*	sandbar willow	N
Santalaceae			
COUM	*Comandra umbellata*	bastard toadflax	N
Scrophulariaceae			
CAAN7	*Castilleja angustifolia*	northwestern Indian paintbrush	N
NUTE	*Nuttallanthus texanus*	Texas toadflax	N
PEAL2	*Penstemon albidus*	white penstemon	N
PEAN4	*Penstemon angustifolius*	beardtongue	N
PEER	*Penstemon eriantherus*	fuzzytongue penstemon	N
PEGR5	*Penstemon gracilis*	lilac penstemon	N
VEPE2	*Veronica peregrina*	neckweed	N
Solanaceae			
PHVI5	*Physalis virginiana*	Virginiana groundcherry	N
SOTR	*Solanum triflorum*	cutleaf nightshade	N
Tamaricaceae			
TAMAR2	*Tamarix* spp	tamarisk	I
Typhaceae			
TYLA	*Typha latifolia*	broadleaf cattail	N
Verbenaceae			
VEBR	*Verbena bracteata*	bigbract verbena	N