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ABSTRACT

An understanding of existing ecosystem conditions is necessary for planning efforts that include formulation of landscape conservation goals and implementation strategies. In support of a landscape planning effort for a 946,000-ac mixed-ownership area in eastern Wyoming, we used remote sensing and field sampling to assess existing ecosystem conditions of terrestrial ecological sites. We used SPOT 5, 33-ft (10-m) multi-spectral satellite imagery combined with NRCS ecological sites to create a geographic information system layer of vegetation cover by ecological site. We then integrated the remote sensing information with field data (571 plots) collected from a stratified random design from 2003 through 2005. The integration of the field data with the satellite mapping provided specific information about each terrestrial ecological site including species composition, productivity, structure, and shrub cover. Western wheatgrass was the most dominant species across all of the terrestrial ecological sites followed by big sagebrush, needle and thread, blue grama, annual brome species and to a lesser extent threadleaf sedge, and six weeks fescue. We found species that typically decrease with grazing (for example green needlegrass, bluebunch wheatgrass, Indian ricegrass) to be lacking or entirely absent from plant communities. Introduced species, especially the annual bromes, were prevalent across all ecological sites. Over 55 percent of the terrestrial ecosystems we sampled had greater than five percent relative cover of introduced plant species. Current ecosystem conditions for many wildlife of the area, as identified by our assessment, had generally lower habitat quality than desired and treatments to improve these conditions are planned.

INTRODUCTION

A clear understanding of existing ecosystem conditions is necessary to formulate conservation objectives that include managing for ecosystem diversity and wildlife in working landscapes. 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 and others 2004). The region supports plant and animal communities that include grassland and sagebrush obligate species that have been identified as species of concern. 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. Although the dominant land use in Thunder Basin is ranching, energy production plays a key economic role. In fact, some of the largest coal mines in the world are located in Thunder Basin and the area also supports substantial oil and gas production.

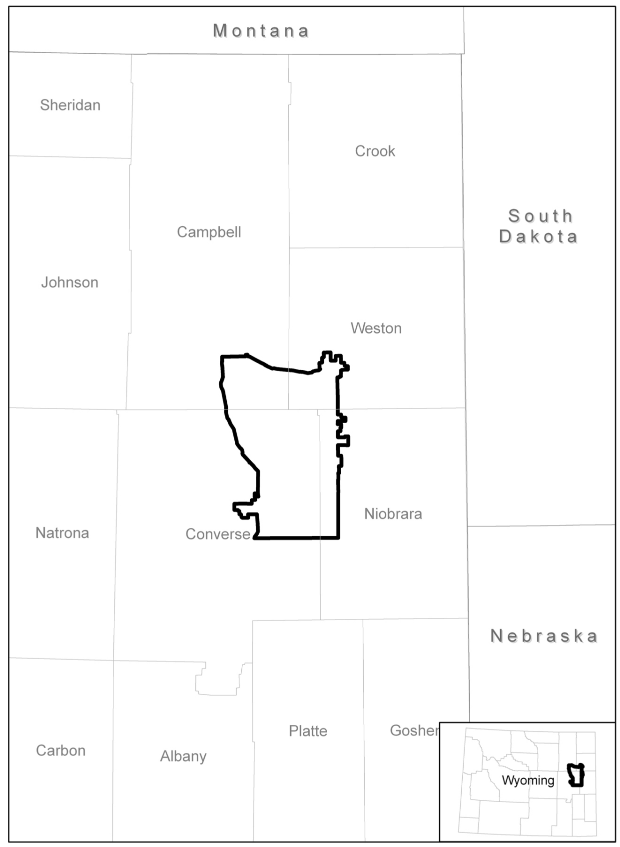

Figure 1–Location of the Thunder Basin planning area in Converse, Campbell, Niobrara, and Weston Counties of eastern Wyoming.

Thunder Basin is often identified as a key area of native grasslands, having substantial areas that have not been tilled or converted to other uses. However, to understand the actual conditions present in the landscape, an assessment of actual plant communities that currently exist was needed. The dominant land uses of the landscape are ranching and energy production, which have resulted in different disturbance pressures placed on the landscape than what occurred historically. The ecosystem diversity of this landscape prior to European settlement was primarily a function of the different types of soils, other site factors, as well as historical disturbance regimes. The primary

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historical disturbances were fire, grazing especially by bison, and drought events (Knight 1994). Although wildfires still occur, and a few ranchers have tried an occasional prescribed burn, fire suppression activities and other landscape conditions have substantially reduced the role of fire in the landscape (Fisher and others 1987; Perryman 1996; Perryman and Laycock 2000). Grazing today is by cattle, sheep, and horses, with relatively uniform grazing levels applied across the landscape as compared with estimates of historical grazing patterns and pressure of bison (Ganguli and others 2008; Fuhlendorf and Engle 2001). Hydrology within the planning area has been altered by construction of numerous water catchments. In addition, some streams have been re-routed to provide irrigation and in some cases water has been added to streams as a byproduct of energy production activities. Infrastructure for transportation has been established including railroad and roads. Another modern feature of the Thunder Basin landscape is the presence of introduced plant species.

As part of a landscape assessment aimed at identifying and quantifying the cumulative changes to native terrestrial ecosystem diversity within the Thunder Basin planning area, the goal of this study was to identify existing terrestrial ecosystem conditions. We used remote sensing and conducted plant community field sampling in the 946,000 ac planning area from 2003 through 2005 to characterize the existing terrestrial ecosystem conditions present within the Thunder Basin planning area.

STUDY AREA

This study was located in a portion of the Thunder Basin National Grasslands in northeastern Wyoming (figure 1). The area is characterized by tablelands and high open hills with occasional rock outcrops and elevations ranging from 4,000 to 5,300 ft (1,219 to 1,615 m). Bedrock geology of the area is dominated by sandstone and shale from the Fort Union and Wasatch formations. Climate of the Thunder Basin region is broadly characterized as interior continental with hot summers and cold winters. Average annual precipitation is 12.4 in (31.5 cm) with approximately 80 percent of the precipitation each year falling between April and October as rain. Terrestrial ecological sites occurring in the study area include loamy (268,298 ac; 108,578 ha), shallow clayey (224,360 ac; 90,796 ha), clayey (125,637 ac; 50,844 ha), sands/sandy (64,683 ac; 26,177 ha), shallow loamy (62,541 ac; 25,310 ha), saline upland (45,902 ac; 18,576 ha), badlands/gullied land (35,560 ac; 14,391 ha), shallow sandy (35,190 ac; 14,241 ha), shallow hilly (30,269 ac; 12,250 ha), and very shallow (2,791 ac; 1,129 ha).

METHODS

We used a combination of remote sensing and field sampling to assess the existing ecosystem conditions of the TBGPEA planning area. Remote sensing using SPOT 5 multi-spectral satellite imagery was combined with NRCS delineated ecological sites to create a geographic information system layer of vegetation classes by ecological site. The remote sensing was used to broadly characterize the landscape into land cover classes of interest, such as plant communities with greater or less than 10 percent big sagebrush cover, riparian zones, ponderosa pine woodlands, sparsely vegetated areas, and disturbed areas. We then integrated this information with field data sampled from 2003 through 2005. Field sampling provided specific information about the existing vegetation conditions of each combination of vegetation and ecological site.

Remote Sensing Vegetation Classification

We used 33ft (10 m) resolution multi-spectral imagery from the SPOT 5 satellite to classify the TBGPEA planning landscape into vegetation classes. We obtained SPOT 5 satellite images of the Thunder Basin area from iCubed Technologies (Fort Collins, CO), who worked in conjunction with the SPOT Corporation for image acquisition. Image interpretation was conducted by Symmetry, Inc. The interpretation used image analysis software to perform both unsupervised and supervised image classifications. The unsupervised classification resulted in each 33ft (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 we identified based on training points delineated in the field. Following classification of the SPOT image into land cover types we assessed image classification accuracy 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 characteristics during the 2006 growing season. SPOT 5 classification accuracy was summarized in an omission/commission matrix. We then stratified the SPOT 5 classified imagery by ecological site to obtain a landscape characterization of dominant land cover classes.

Vegetation and Ecological Site Sampling

We conducted vegetation sampling in the Thunder Basin planning area from 2003 through 2005. Sampling plots were distributed on public lands and participating private lands using a stratified random design. We stratified across

NRCS ecological sites as well as dominance of shrub cover, dominance of ponderosa pine, and dominance of prairie dog towns. Mapping errors or inconsistencies identified in the field were subsequently corrected in our analysis of plant community existing conditions.

We sampled the vegetation on each plot for cover, productivity, and structure and used the PLANTS database as a taxonomic reference (USDA, NRCS 2006). Sampling crews were trained in the same way each year to provide for consistent application of methods. A 164-ft (50 m) vegetation transect was placed in a randomly determined direction from the designated plot location and 15 quadrats, 8 in x 20 in (20 cm x 50 cm) were sampled. Canopy cover of plant species occurring in the quadrats was estimated using the following cover classes (0.01 to 1 percent, 1 to 10 percent, 10 to 20 percent, 20 to 30 percent, 30 to 40 percent, 40 to 50 percent, 50 to 60 percent, 60 to 70 percent, 70 to 80 percent, 80 to 90 percent, 90 to 99 percent, and 99 to 100 percent). For subsequent analysis we used cover class midpoints and converted absolute cover values to relative cover values for each plot and used these values in our assessment of existing conditions. Productivity of grasses and forbs were estimated by species on the first 10 quadrats sampled using double sampling (Pechanec and others 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 (USDA/NRCS 2003). In addition, we recorded the canopy cover of species not encountered in the quadrat sampling in a 82.0 ft x 49.2 ft (25 m x 15 m) or 4,036 ft^2 (375 m^2) area. Canopy cover of all species of woody vegetation was sampled along the 164 ft (50 m) transect using the line intercept method (Canfield and others 1941). Vegetation structure was determined by making 12 Robel pole measurements along the plot transect. Robel measurements were made by determining the highest 1-in (2.5 cm) band on the Robel pole that was totally or partially visible when viewed from a distance of 13.1ft (4 m) and a height of 3.3ft (1 m) (Robel 1970).

RESULTS

Remote Sensing Vegetation Classification

Accuracy assessment of the SPOT 5 land cover classification indicated that the overall accuracy was 81.6 percent (table 1). The riparian, water, sparsely vegetated, and disturbed cover classes had the highest classification accuracy. Due to the timing of SPOT 5 image acquisition, greasewood presence could not be distinguished. That is, the spectral reflectance of greasewood could not be distinguished from the surrounding vegetation. The percentage of sagebrush and other shrub cover occurred along a continuous gradient, making the determination of <10 percent and >10 percent categories difficult. Correct classification of grassland (in other words, shrub cover <10 percent) was 54 percent and grassland with shrubs (in other words, shrub cover >10 percent) was 73 percent, with most classification errors resulting from misclassification of the amount of sagebrush. Generally, accuracy of the detection of stands with either high amounts of sagebrush or 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.

The numbers of ac found in each land cover class are summarized by Ecological Site and are presented in table 2. Grasslands and shrublands occupied 68.8 percent of the terrestrial ecosystems in the Thunder Basin planning area. Further examination of the big sagebrush cover for grasslands and shrublands on the primary terrestrial Ecological Sites (in other words, Clayey, Shallow Clayey, Loamy, Shallow Loamy, Sands/Sandy, and Shallow Sandy), which occupied 62.4 percent of the landscape revealed that 52.4 percent of the planning area was grassland with less than 10.0 percent big sagebrush canopy cover and 10.0 percent of the planning area was grasslands with greater than 10.0 percent big sagebrush canopy cover. Ponderosa pine and sparsely vegetated sites occupied approximately 2.8 percent and 10.8 percent of the planning area, respectively. Other land cover conditions occupied 17.6 percent of the planning area and was dominated by human disturbed areas (13.6 percent), riparian areas or water (2.8 percent), and areas that could not be classified (1.2 percent).

Vegetation and Ecological Site Sampling

The vegetation sampling conducted in 2003 to 2005 included 571 plots sampled in terrestrial ecosystems. In addition 18 plots were visited but rejected because they contained over 75 percent canopy cover by exotic species. Average annual precipitation during the years of this assessment was slightly above the long-term average (12.4 in; 31.5 cm) in 2003 (14.6 in; 37.1 cm) and in 2005 (13.4 in; 34.0 cm), however, the annual precipitation in 2004 was below average (9.9 in; 25.1 cm). Growing season precipitation (in other words, April through August) was below the long term average (8.5 in; 21.6 cm) in 2003 (7.6 in; 19.3 cm) and 2004 (5.1 in; 13.0 cm), but was slightly above average in 2005 (9.7 in; 24.6 cm).

Table 1—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	**Land Cover Class** Grassland	Sagebrush > 10%	Sparsely Vegetated	Disturbed	Ponderosa Pine	Water	Riparian	**Classification Accuracy** 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

Canopy Cover

Within each ecological site the mean canopy cover varied in each year we sampled (figure 2), 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 (figure 2), likely a result of the drought conditions that occurred throughout that growing season. The canopy cover variation we 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. This variation in canopy cover cannot be readily explained. Therefore, we used relative cover for analyses of plant community dominance to reduce the effects of annual variation in canopy cover.

Western wheatgrass was the most dominant species occurring across all of the terrestrial ecological sites followed by big sagebrush, needle and thread, blue grama, annual brome species and to a lesser extent threadleaf sedge and six weeks fescue (table 3). Annual brome, which includes cheatgrass (*Bromus tectorum*) and field brome (*Bromus arvensis*) were dominant species across several of the ecological sites we sampled, especially in saline upland sites. However, annual brome was not as prevalent on sandy and shallow sandy ecological sites. Other site preferences we observed included soapweed yucca and needle and thread preference for sandy sites, greasewood preference for saline upland, and big sagebrush preference for all ecological sites except for shallow sandy and saline upland.

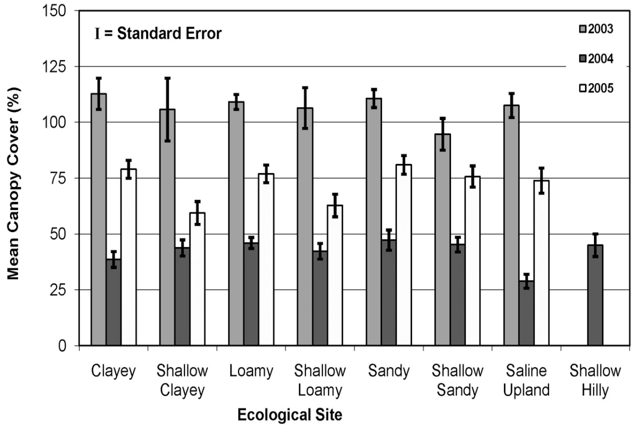

Figure 2–Mean understory canopy cover (+/- standard error of the mean) from 2003 through 2005 on terrestrial ecological sites in the Thunder Basin planning area.

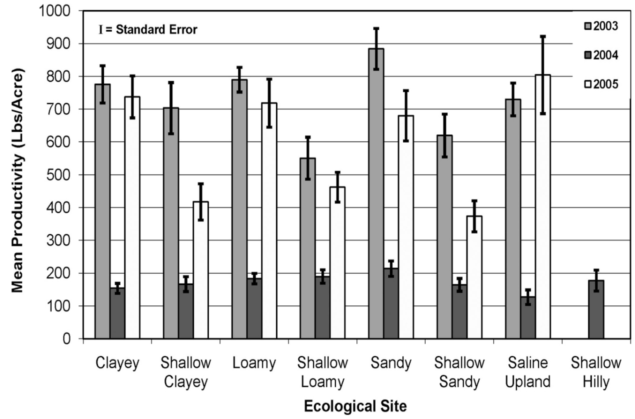

Figure 3—Productivity by ecological site (+/- standard error of the mean) from 2003 through 2005 on terrestrial ecological sites in the Thunder Basin planning area.

Productivity

Productivity, measured as the dry weight of grasses and forbs differed varied across and within terrestrial ecological sites from 2003 through 2005 (figure 3). Drought conditions resulted in 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 little variation 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.

Vegetation Structure

Vegetation structure also varied across terrestrial ecological sites from 2003 through 2005 (figure 4). 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, with the exception of the shallow hilly ecological site, and showed little variation compared to 2003 and 2005. Vegetation structure was generally greater in 2005 than 2003, however, there was little variation 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 greater structure than shallow clayey, shallow loamy, shallow sandy, and saline upland ecological sites.

Exotic Species and Noxious Weeds

Exotic species were found in every ecological site we sampled. In fact, 57.4 percent of the plots sampled had greater than five percent relative cover of exotic plant species and 22.8 percent of the plots we sampled had over 20 percent relative cover of exotic species. Six of the exotic species sampled 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 we found one native species, skeletonleaf burr ragweed (*Ambrosia tomentosa*), which is also listed as a noxious weed by the Wyoming Department of Agriculture.

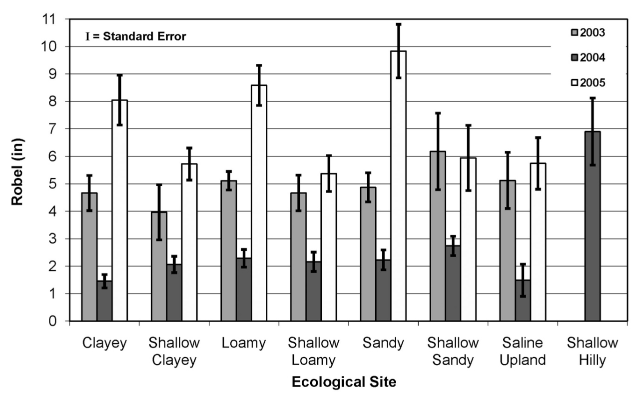

Figure 4—Vegetation structure measurements based on Robel pole readings (+/- standard error of the mean) from 2003 through 2005 on terrestrial ecological sites in the Thunder Basin planning area.

Table 2—Summary of acres within land cover classification categories identified with SPOT 5 satellite imagery for terrestrial ecological sites in the Thunder Basin region.

	SPOT 5 Satellite Imagery Land Cover Classification Categories				
Ecological Site	**Grassland (ARTR2[1] <10%)**	**Grass & Shrubland (ARTR2 >10%)**	**Ponderosa Pine**	**Sparsely Vegetated**	**Other[2]**
	------------------------	------------------------	acres	------------------------	------------------------
Clayey	76,147	14,362	213	6,606	24,933
Shallow Clayey	118,883	15,518	351	51,811	35,620
Loamy	163,862	37,913	589	9,745	47,661
Shallow Loamy	39,419	5,331	299	6,041	10,890
Sands/Sandy	38,096	10,612	258	1,490	12,754
Shallow Sandy	21,651	4,186	87	4,270	4,228
	Site Based Classification[2]				
	Grass and Shrubland		**Ponderosa Pine**	**Sparsely Vegetated**	**Other**
Shallow Hilly	—		22,540	4,348	3,341
Very Shallow	1,810		2	189	787
Saline Upland	29,914		77	3,456	9,202
Badlands/ Gullied Lands	23,553		106	6,499	4,699

[1] Big sagebrush (*Artemisia tridentata*)
[2] Other includes riparian, water, disturbed, and unclassified land cover classes.
[3] Site based classification indicates land cover classes that were classified based on topo-edaphic properties, independent of shrub cover.

The introduced species of greatest concern in the Thunder Basin planning area are cheatgrass and field brome, collectively referred to as annual brome (figure 5a, b). Annual brome occurred in 91 percent of the terrestrial plots we sampled and comprised a majority of the introduced species canopy cover. In most cases the relative proportion of annual brome did not differ within terrestrial ecological sites across the three years we sampled (figure 5a). 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, absolute cover of annual brome (figure 5b) was lower in 2004 in most of the ecological sites we sampled, and with the exception of sandy sites, annual brome cover did not vary between 2003 and 2005 on the other terrestrial ecological sites. The absolute cover patterns of annual brome essentially mirror the patterns we observed in total cover (figure 2). In general we found annual brome 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.

DISCUSSION

Grassland ecosystems of the Thunder Basin Region were historically dependent on grazing by native herbivores and fire as disturbance factors that shaped ecosystem diversity (Fuhlendorf and Engle 2001; Knapp and others 1999; Knight 1994,). Historically, grazing by native herbivores, especially bison, played a significant role in shaping and maintaining terrestrial grass and shrub ecosystems (Hart and Hart 1997; Knapp and others 1999) and interacted with fire to create a shifting mosaic of conditions (Fuhlendorf and Engle 2001; Knapp and others 1999). Although grazing by domestic animals is currently the primary use of grass and shrub ecosystems, the foraging ecology of grazers that historically occupied the Great Plains differed from those used today (Plumb and Dodd 1993) and current grazing practices in grassland ecosystems have generally been found to dramatically 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, which produces relatively uniform or homogeneous vegetation conditions (Fuhlendorf and Engle 2004). Today, plant communities that have species compositions characteristic of light grazing regimes are nearly absent in terrestrial ecological sites within the Thunder Basin planning area. For example, species that typically decrease with increasing grazing pressure, like green needlegrass (*Nassella viridula*), bluebunch wheatgrass (*Pseudoroegneria spicata*), and Indian ricegrass (*Achnatherum hymenoides*) were rarely found in this landscape. Past and current grazing practices coupled with recent drought conditions have resulted in the current distribution of plant communities with plant species compositions indicative of moderate and heavy grazing regimes dominating terrestrial ecological sites, and plant communities with plant species compositions indicative of light grazing regimes almost totally lacking in the landscape.

Table 3—Dominant plant species in terrestrial ecological sites sampled in Thunder Basin, WY in from 2003 through 2005. Dominance is based on understory (vegetation <1m in height) quadrat sampling in each plot.

	Relative Cover (%) of the 10 Most Dominant Plant Species by Ecological Site							
Plant Species	**Clayey**	**Shallow Clayey**	**Loamy**	**Shallow Loamy**	**Sandy**	**Shallow Sandy**	**Saline Upland**	**Shallow Hilly**
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	0.0
Needle and thread	3.4	3.8	6.3	7.7	11.6	13.4	1.1	6.0
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	0.0
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	0.0
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
Average Absolute Cover (%)	**76.8**	**69.7**	**77.4**	**70.5**	**79.6**	**71.9**	**70.1**	**40.0**

Without fire as a disturbance process, many of these ecosystems would succeed to shrub or tree-dominated areas (Archer 1994). Despite a documented frequently occurring fire regime in the Thunder Basin region (Fisher and others 1987; Knight 1994; Perryman 1996; Perryman and Laycock 2000), public and private land management policy in the Thunder Basin planning area has encouraged and employed fire suppression programs in the surrounding grassland and shrubland areas since the 1940s (Perryman 1996). Although wildfires still occur within the landscape, and a few ranchers have tried an occasional prescribed burn, the extent of these fires and their scattered use have reduced the influence of this disturbance process in the landscape. The implications of the loss of this natural disturbance process on ecosystem diversity within Thunder Basin is poorly understood and not well documented. However, the role of fire throughout the Great Plains, with rare exceptions, has been eliminated which has modified species compositions and altered ecosystem function (Sieg and others 1999).

Introduced exotic plant species have been identified as one of the greatest threats to the integrity and productivity of native rangeland ecosystems and conservation of indigenous biodiversity (DiTomaso 2000; Mack and others 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 (Pimental and others 2000). Although a number of exotic species occur in the Thunder Basin region, cheatgrass and field brome are the most dominant and frequently occurring species. Cheatgrass and field brome, are non-indigenous annual brome grasses that have invaded rangeland ecosystems of the western United States. Anthropogenic activities have been the primary contributors to the introduction and spread of annual brome (Gelbard and Belnap 2003; Mack 1981).

Invasion of rangeland ecosystems by annual brome has long been considered a point of contention in North America (Young and Allen 1997). 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 and others 2001a) and wildlife (Austin and others 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) especially its relatively short growing season (Ganskopp and Bohnert 2001) and its poor forage quality and palatability outside of the growing season. Annual bromes can substantially reduce the vigor of native plant communities through competitive reduction of water and nitrogen availability (Lowe and others 2003; Young and Evans 1978). 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 and others 2001b), producing higher livestock gains (Haferkamp and others 2001a), and converting degraded annual brome dominated areas back to native-dominated perennial grass communities (Evans and Young 1977).

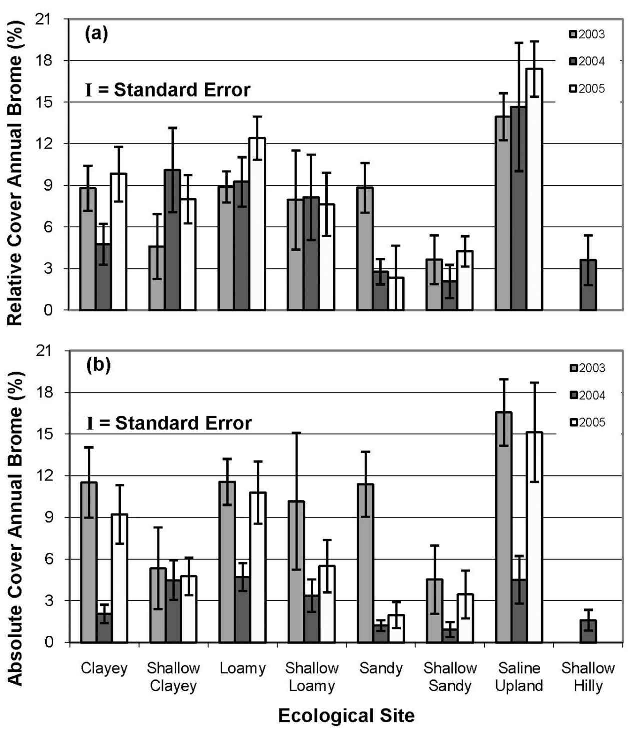

Figure 5—Relative cover +/- standard error of the mean (a) and absolute cover +/- standard error of the mean (b) of annual brome species (cheatgrass and field brome) from 2003 through 2005 on terrestrial ecological sites in the Thunder Basin planning area.

Annual brome invasion 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 and others 2003; Norton and others 2004), and the ability to compete for water (Young and Evans 1977). 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 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 and others 2005), reductions in plant community richness (Belnap and others 2005), and increases in wildfire frequency (Whisenant 1990).

MANAGEMENT IMPLICATIONS

Extractive activities associated with the rich natural resources of this area (for example coal bed methane, coal, and oil) have resulted in direct land conversions of some of the Thunder Basin area, but the area has not seen extensive direct conversion to other land uses. Despite the lack of direct conversion, grass and shrub ecosystems in the Thunder Basin planning area appear to have been influenced by fire regime modification, modification of historical grazing regimes, and the spread of introduced species. Conservation planning efforts aimed at improving ecosystem diversity and wildlife habitat in this working landscape should strategically target degraded ecosystems with modest re-introductions of prescribed fire, chemical control of the annual brome species, augmentative seeding to re-establish desirable grass and forb species and improve species diversity, and grazing modifications designed to promote healthy plant communities and wildlife habitat for species of concern. This assessment has identified ecosystems in need of improvement and could be further integrated with wildlife habitat objectives for this planning area to identify the specific locations best suited for ecosystem improvement treatments. For the Thunder Basin region to remain an ecologically significant grassland, greater attention must be paid to retaining and restoring functional native ecosystem diversity.

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