National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Vegetation Composition, Structure and Soils Monitoring at Grant-Kohrs Ranch National Historic Site

2009 Annual Data Report

Natural Resource Data Series NPS/ROMN/NRDS—2010/087

ON THE COVER
VCSS monitoring site at Grant-Kohrs Ranch National Historic Site, June, 2009
Photograph by: Justina Gray

Vegetation Composition, Structure and Soils Monitoring at Grant-Kohrs Ranch National Historic Site

2009 Annual Data Report

Natural Resource Data Series NPS/ROMN/NRDS—2010/087

Donna Shorrock, Isabel Ashton, Michael Britten, Jennifer Burke, David Pillmore, and E. William Schweiger

National Park Service
Rocky Mountain Inventory and Monitoring Network
1201 Oakridge Dr, Suite 200
Fort Collins, CO 80525

September 2010

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

This report is available from http://www1.nrintra.nps.gov/im/units/romn/ReportsPublications.cfm and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/NRPM).

Please cite this publication as:

Shorrock, D. E., I. Ashton, M. Britten, J. Burke, D. Pillmore, and E. W. Schweiger. 2010. Vegetation composition structure and soils monitoring at Grant-Kohrs Ranch National Historic Site 2009 annual data report. Natural Resource Data Series NPS/ROMN/NRDS—2010/087. National Park Service, Fort Collins, Colorado.

NPS 451/105622, September 2010

Contents

Executive Summary

The Rocky Mountain Network has identified the condition of vegetation composition, structure, and soils (VCSS) in terrestrial systems as one of its high priority vital signs. Using this protocol, we monitor the status and trend in grassland, shrubland, and woodland ecosystems as they are affected by natural and anthropogenic disturbance over time. Grant-Kohrs Ranch National Historic Site (GRKO), a small, accessible park established to preserve and demonstrate historic ranching life, is characterized by grasslands and perfect for implementing a three-year VCSS pilot study beginning in 2006. 2009 is the first year of sampling post-pilot and the data are summarized here.

The VCSS protocol uses a probability survey design allowing us to estimate measures of vegetation composition and structure along with multiple soil parameters across the entire park. Sample frames used within the design were derived from a Natural Resources Conservation Service (NRCS) GIS layer of Soil Survey Geographic Database (SSURGO) soil types. To refine this sample frame, we removed sensitive sites (e.g., cultural resources), developed park infrastructure, wetlands, and areas with greater than 50% tree cover. We are exploring possible post-hoc allocation of sites to park defined internal management zones that prioritize different resources.

In 2009, crews sampled eight sites at GRKO, revisiting one of these sites, which contributes to ongoing estimates of within-season variation. The sites fell into four internal management zones: upland pasture, pasture/hayfield, riparian area/woodland, and railroad bed and barrow pit/wetland. At each site, we used a variety of cover estimation techniques in plots and along transects. Additionally, we collected frequency data, landscape context (disturbance) data, soil cores for laboratory analyses, and performed soil aggregate stability tests. Crews found 104 vascular plant species at GRKO monitoring sites, 30 of which are non-native. Almost half of the 10 most abundant species are exotic; at least two of these species are harvested for hay. Overall community diversity proved to be lower than expected for similar community types in western Montana and markedly lower when looking strictly at the native component. The most abundant species documented at the sites included native grasses such as bluebunch wheatgrass (*Pseudoroegneria spicata*) and needle and thread grass (*Hesperostipa comata*). Equally common were exotic grasses, namely smooth brome (*Bromus inermis*), quack grass (*Elymus repens*), *and* Kentucky bluegrass (*Poa pratensis*). Spiny phlox (*Phlox hoodii*), was the only abundant perennial forb recorded.

Crews noted and recorded both anthropogenic and natural disturbance using two different indices, a modified version of the Human Disturbance Index (HDI) developed by the Colorado Natural Heritage Program and the Natural Disturbance Index, which is modeled after standard qualitative, categorical disturbance indices such as HDI and the California Rapid Assessment Method for Wetlands. These indices provide contextual information about the history of the landscape and aid interpretation of ecological variables. The scale for both indices ranges from 0-100 with lower scores indicating less impact from disturbance. Human disturbance scores at GRKO were moderate, ranging from 28 to 58, while natural disturbance scores were lower, ranging from 3-35. In preliminary work, we found no first order relationships among these coarse measures of disturbance and vegetation or soil characteristics.

Survey design-based VCSS monitoring will continue at GRKO in future years. When enough plots have been sampled, we will conduct design-based estimates of core vegetation and soil parameters and model-based trend analyses.

Acknowledgments

Thanks to the staff at Grant-Kohrs Ranch National Historic Site for their help during the 2009 field season. Special thanks to Jason Smith and Chris Ford for helping to arrange logistics, providing orientation and safety training while we were on site, and reviewing this document. We are also very appreciative of the fine work that our seasonal staff, Kyle Motley and Nina Gray, did for the park and the network. Comments and suggestions from Dana Witwicki, vegetation ecologist for the Northern Colorado Plateau I&M Network, who graciously agreed to peer review this report, were very helpful and used to improve report content.

Introduction

The purpose of the National Park Service (NPS) Inventory & Monitoring (I&M) Program is to develop and provide scientifically credible information on the current status and long-term trends of the composition, structure, and function of key park ecosystems. Having this information will assist park managers and scientists with assessing the efficacy of management practices and restoration efforts and receive early warning of impending threats to park resources. The Rocky Mountain I&M Network (ROMN), which encompasses six parks in the northern and central Rocky Mountain region, has identified vegetation composition, structure, and soils (VCSS) as a high priority vital sign that can be used to better understand the condition of park ecosystems (Britten et al. 2007). The ROMN VCSS small park protocol is designed to monitor grassland, shrubland, and woodland systems and how these systems are potentially affected by natural and anthropogenic disturbance over time. The network implements the protocol in three small ROMN parks (Florissant Fossil Beds NM (FLFO), Little Bighorn Battlefield NM (LIBI), and Grant-Kohrs Ranch NHS (GRKO)) as grassland, shrubland, and woodland systems are the dominant habitat types in these parks and (especially for GRKO and LIBI) key components of the cultural landscapes the parks were established to protect. For example, GRKO commemorates the Western cattle industry from the 1850s inception through recent times. Today, the site is still an active ranch and is managed to preserve and demonstrate ranching life as it once was. This includes irrigating, haying, and grazing hundreds of acres of native and non-native pastureland. Exotic species, such as timothy and Kentucky bluegrass, are intentionally maintained as part of the historic landscape. GRKO resource managers are charged with the challenging task of managing the ranch to preserve both cultural (ranching) and natural resources. Toward that end, GRKO's Cultural Landscape Report (2004) delineates the Ranch into nine component landscapes with varying treatment recommendations. VCSS 2009 monitoring sites occurred in four component landscapes: upland pasture, pasture/hayfield, riparian area/woodland, and railroad bed and barrow pit/wetland.

The Network began VCSS monitoring pilot work at GRKO and LIBI in 2006. After completion of this initial pilot study period, full implementation of a refined VCSS monitoring protocol commenced in the summer of 2009. The purpose of this report is to document 2009 vegetation and soils monitoring efforts in Grant-Kohrs Ranch NHS and summarize the collected data. We will publish a separate pilot summary report of our field findings and methods used in 2006-2008 in 2010.

Given that this was our first year of post-pilot data collection, this report summarizes only the status of GRKO grasslands and shrublands and does not explore trends. Moreover, given small sample sizes, we do not include any design-based estimation in this report and all results are valid only at the individual site. However, the long-term objectives of the VCSS monitoring include both design-based park-scale status and model-based trend estimation and future efforts will include these forms of analysis.

Specifically, our long-term objectives are to:

1. Determine status and trend in vegetation structure, species composition, and diversity in grassland, shrubland, and woodland ecosystems within network small parks.

2. Determine status and trends in abundance of invasive/exotic plant taxa in these areas based on park-specific lists of likely and ecologically significant invaders at each park.
3. Determine the status and trend in soil condition in grassland, shrubland, and woodlands of each park based on measures of surface stability, extent of non-vegetated soils, physical properties of the soil, and soil chemistry.

Methods

The VCSS protocol (Manier et al. in review) provides detailed descriptions of the field and analytical techniques used for VCSS monitoring in 2009. Brief synopses of core methods follow.

Logistics

The 2009 field season began May 18^{th}, the start date of the seasonal staff, which allowed two weeks for training, office, and field preparation time. We hired two seasonal, GS-05, Student Temporary Employment Position (STEP) biological technicians to travel to and conduct fieldwork for VCSS at GRKO. We tried to coordinate the new staff members' standard NPS training (e.g., first aid, safe driving) with training at Rocky Mountain National Park, with limited success. Crew members were able to participate in backcountry briefings and general NPS informational sessions, but timing and availability of first aid and defensive driving classes did not work out for ROMN seasonal crew members. Instead, crew members completed on-line first aid training, which is perhaps less useful than hands-on training. It is recommended that classroom training be offered in future years.

While working at GRKO, the crew stayed in a cabin at the KOA in Deer Lodge. The cabin sleeps 3-4 friendly people comfortably, but it was barely adequate to accommodate living, work, and storage space for the three people who stayed in the cabin in 2009. The network rented a vehicle from Enterprise Rent-a-Car for the crew to use for the duration of the summer. This arrangement did not work well when the ecologist was not present since the biotechs were not issued government credit cards. Consequently, they had to pay for gas out-of-pocket, and reimbursements severely lagged behind submission of requests in 2009. Additionally, any fines for driving infractions were automatically charged to the individual leasing the car or the network. Lastly, there were issues with using and storing the leased vehicle when the crew was not in travel status. In future years, we will equip seasonal employees with government credit cards (as is mandated as of 2010) and lease vehicles on a trip-by-trip basis.

Sample timing

We timed our visit to GRKO to sample during peak phenology while taking into consideration crew schedules and sampling at other network parks as well as maintaining consistency of timing from one year to the next.

Site Selection

The VCSS protocol used a Generalized Random Tessellation Stratified (GRTS) design and variable probability sampling across areas (subpopulations) delineated by five ecological site and soil types within a GIS layer using soil geodata (SSURGO; NRCS). We omitted points that fell in park-identified sensitive areas (e.g., cultural resources) or developed infrastructure. Additionally, we removed wetlands and areas with greater than 50% tree cover from consideration because these habitats will likely be addressed in other ROMN protocols. The designs have 300 sites allocated equally among soil types (this sample size is not the same final implemented sample size) with 50 base and 250 oversample sites. The oversample sites followed the same proportional allocation to subpopulations as the primary sites.

How VCSS sites are visited through time (known as either the revisit design or panel structure) is based on pilot research and power analysis of the ability of various alternatives to detect trend and minimize standard error around status estimates. These designs include operational constraints and are not solely based on the statistical optimum for trend detection or for the most precise status estimates. The VCSS panel structure is designed so that crews sample eight sites in the initial year and ten thereafter. The revisit design is a split panel, partially augmented serially alternating form. This design combines two panel types: one with smaller sample sizes that are resampled in consecutive years as a way to account for annual variability and one with larger sample sizes sampled infrequently to establish status. The benefit of this structure is that it provides a temporal link from the smaller sample size without overburdening sites by visiting all sites, all years, in perpetuity. The specific revisit schedule followed by VCSS is illustrated in Table 1.

Table 1. Draft panel structure of site visits to be used in GRKO VCSS survey design. Total unique sample size = 32 over 4 years; sample events accrued during this period = 42 (including within season revisits).

	Year									
Panel	1	2	3	4	5	6	7	8	9	10
GRKO1	6				6				6	
GRKO2		6				6				6
GRKO3			6				6			
GRKO4				6				6		
GRKO5	2	2			2	2			2	2
GRKO6		2	2			2	2			2
GRKO7			2	2			2	2		
GRKO8				2	2			2	2	
WithinSeason	1	1	1	1	1	1	1	1	1	1
Total#Events	9	11	11	11	11	11	11	11	11	11

Field Methods

In 2009, the field crew sampled eight sites at GRKO (Figure 1); six of these were new and two sites crews sampled in the pilot phase. The crew revisited one of these sites as part of an effort to quantify within-season variability (to be presented in future reports). Two sites, GRKO-001 and GRKO-029 sit directly in the river floodplain and close to a ditch/secondary channel connected to the river, respectively. Despite their locations, these two sites still met the criteria established for site selection based upon hydrology and vegetation composition and were not rejected.

Site Attributes

At each site, crews recorded features such as location (UTM coordinates), site description, dominant aspect, slope, topographic position, and hydrologic environment. Physical data are often useful in interpretation of vegetation data because these attributes influence vegetation distribution and growth patterns and often can account for some variation found in response measures. Crews also photographed each site following set photo point procedures for future

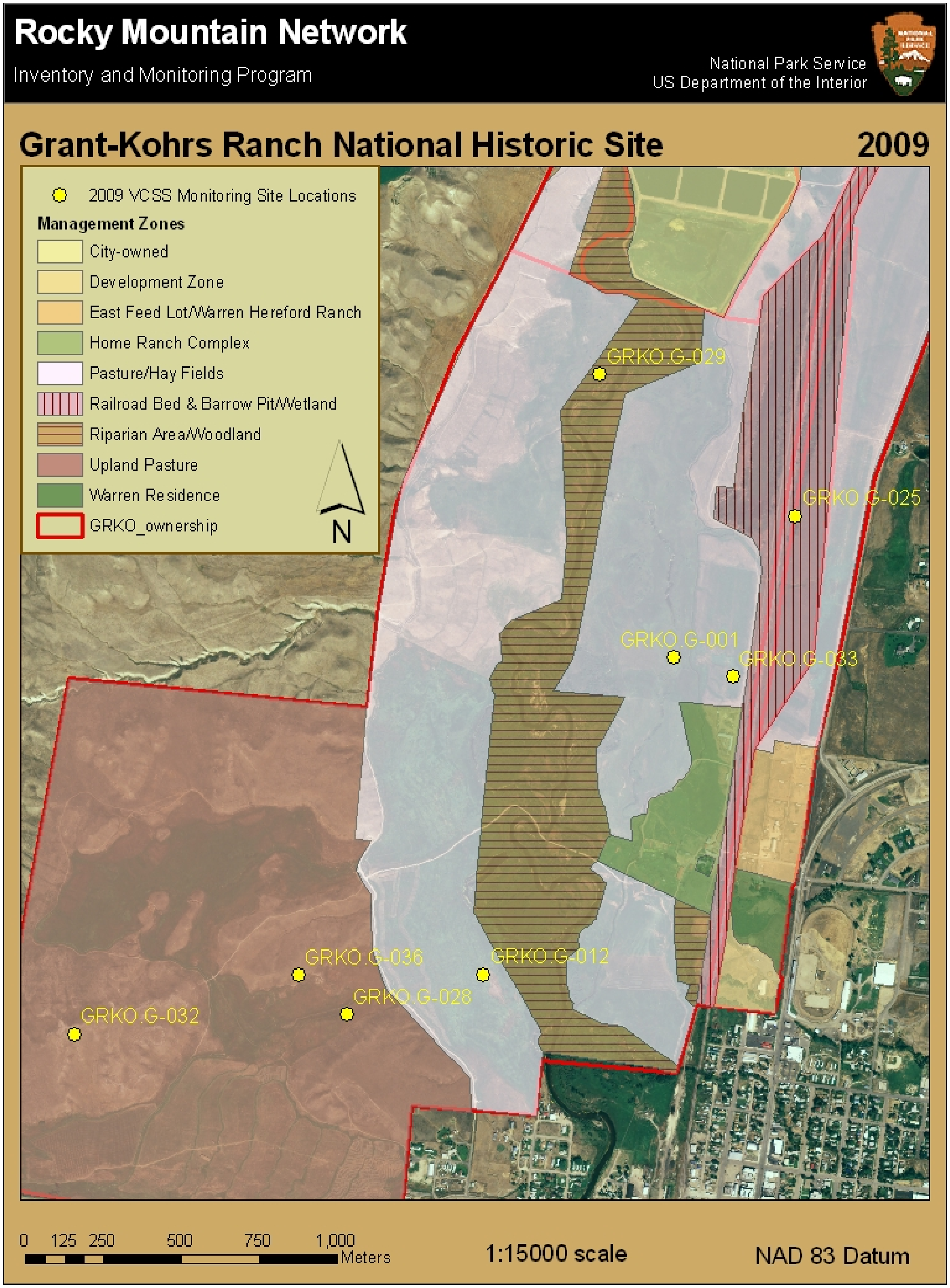

Figure 1. VCSS monitoring site locations at GRKO in 2009

comparison of changes in vegetation structure and land use; site photos are also useful for site relocation.

Shrub and Herbaceous Vegetation

2009 was the first year that we documented species rather than functional group/life form. We thought that recording species would provide additional information useful for community analyses. Plus, from a practical perspective, one often needs to identify species in order to make a functional group determination.

Crews used transect and plot methods to collect data on shrub and herbaceous vegetation. Along three 36-meter transects radiating out from site center (Figure 2), crews used a point-intercept method (thought to be most objective) to gather cover information on canopy and surface features. At 0.5m intervals, the data collector dropped a pin and recorded the species and surface type that the pin hit. These "hits" were later converted into percent cover.

In addition to transect-based measures, crews collected data in 10 1-m^2 plots. Three plots are situated near the end of each transect (5m away from each transect end at 0˚, 120˚, and 240˚ bearings) with the 10^{th} plot located near the plot center (Figure 2). At each plot, crews used ocular estimates to record absolute percent cover of each species canopy and surface feature (e.g., coarse gravel, litter). Estimating cover in small quadrats complements transect measurements by detecting rarer occurring taxa. At these same plots, crew members also documented frequency of each species in nested 0.01-m^2, 0.1-m^2, and 1-m^2 quadrats. Species may occur in a maximum of 30 plots at each site (3 quadrat sizes * 10 (the number of plots at each site) = 30). Frequency is useful for detecting changes in spatial arrangement, is an objective measure, and is largely insensitive to seasonal canopy growth, creating a larger window for sampling times. Nomenclature for all vegetation data follows the Integrated Taxonomic Information System.

Trees

No trees grew at any of the 2009 monitoring plots so crews did not use the VCSS tree sampling methods. Annual reports in years when trees are sampled will describe the ROMN VCSS tree monitoring methodology.

Soils

ROMN used the soil stability test described in Herrick et al. (2005) to provide an indicator of the extent of soil structural development and susceptibility to erosion. The measure estimates the integrity of the soil from the level of cohesiveness in the soil resulting from organic materials binding soil particles. Soil texture affects the outcome of this test, so comparisons are made only between soils of similar ratios of sands, silts, and clays.

Crews collected six surface and six subsurface soil samples from each of the three transects (36 total samples). At each collection site, the person sampling the soil also documented cover type (e.g., grass, nonvascular, bare soil). Individual soil samples measured 6-8 mm in diameter and 2-3 mm thick; subsurface samples were removed from 3-4cm below location of the corresponding surface sample. Crews submerged each of these samples in water in a field soil kit. Each sample was assigned a stability class score based upon the length of time aggregate (group of soil particles cohered to one another) structural integrity was maintained after immersion.

The crew used a second measure to assess erosion susceptibility and extent at the site level. The observer noted the extent of site erosion indicators using ratings ranging from none to extreme. Indicators include presence of rills and gullies, pedestals, and evidence of surface flow.

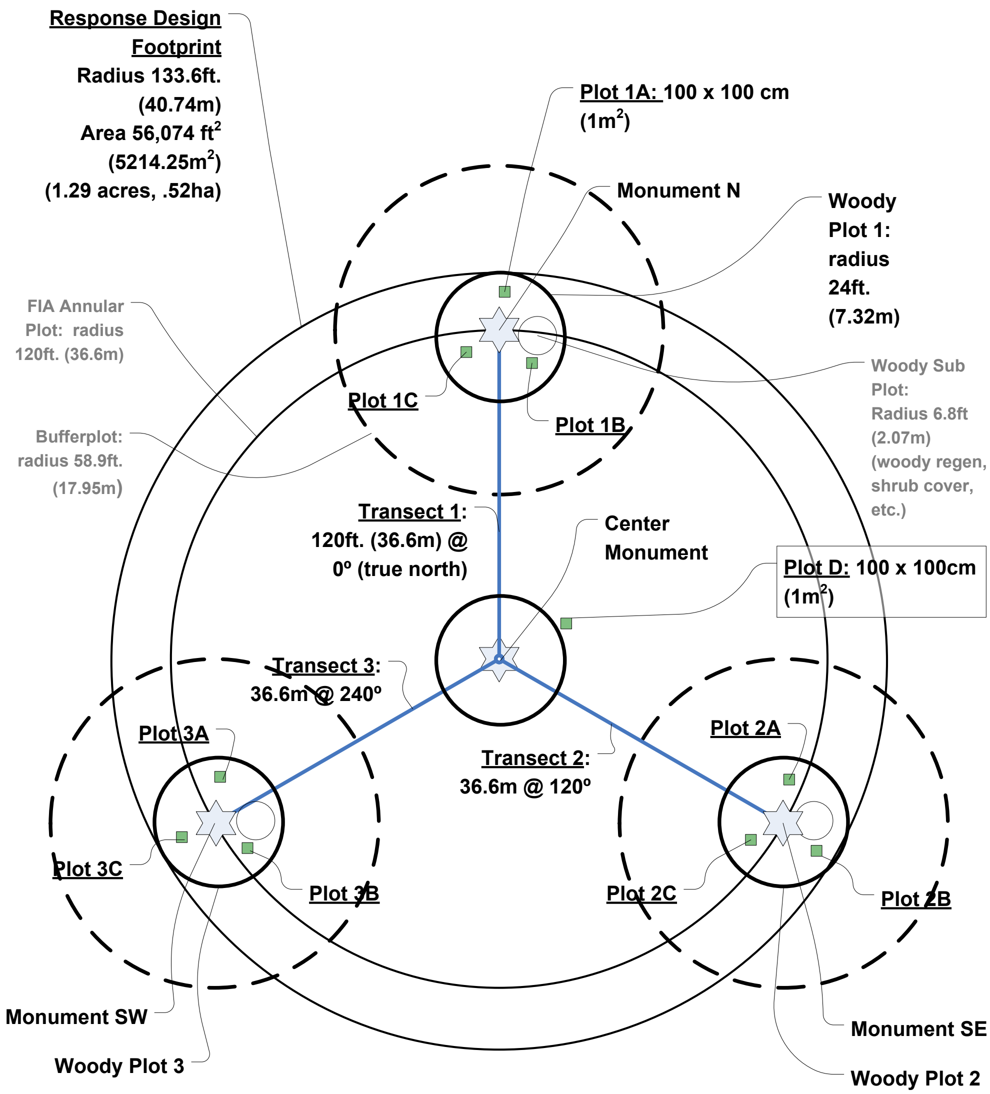

Figure 2. VCSS Monitoring Site Layout

Crews also collected four soil samples along each transect for laboratory analyses. Three samples were composited for chemistry analysis. The fourth sample was kept intact and used to measure bulk density. Crews collected each individual 20-cm deep sample using a 2-cm diameter core sampler (60.28 cm^3). Soil characteristics measured in the lab included texture, bulk density, pH, cation exchange capacity, soil organic matter content, total nitrogen and carbon content, and the concentration of mineral nutrients.

Anthropogenic and Natural Disturbance

2009 was the first year in which crews observed and documented disturbance within and surrounding the monitoring sites. Crew members rated the level of human-caused disturbance using modified Colorado Natural Heritage Program's Human Disturbance Index (HDI) (Rocchio 2007) metrics separated into three categories: Buffers/Landscape Context, Hydrological Alterations, and Physical Disturbance; these were later combined into a single metric. Using the Natural Disturbance Index (NDI), a tool modeled after standard qualitative, categorical disturbance indices such as HDI and the California Rapid Assessment Method for Wetlands (Collins et al. 2008), crews evaluated natural disturbance by observing signs of use and/or disturbance from more natural processes (e.g., fire). For example, if >50% of a site has recent evidence of rodent use (extensive castings, burrows, etc.), the observer would give the rodent category a "1-High" score. In contrast, a site with no evidence of rodent use would receive a "4-None" score. All submetrics were later combined into a single Natural Disturbance Index (NDI).

Analytical Methods

The 2009 effort at GRKO was the first year of data collection after the 2006-2008 pilot work. The focus of the pilot work was primarily on finalizing field methodology. Moreover, the pilot work treated all vegetation data only at the life form level *in the field* and 2009 was the first year that species data were collected (in addition to life form data). We therefore analyzed the 2009 data largely independently from the pilot data.

As noted earlier, given small sample sizes, we do not include any design-based estimation in this report and all results are valid only at the individual site.

Shrub and Herbaceous Vegetation

Calculated metrics for shrubby and herbaceous vegetation included absolute canopy cover by taxa averaged from plots and transects within each site. Plot frequency data were reported as a percentage of how many times the taxa occurred out of the total number of possible occurrences (number of nested plots). Using the US Department of Agriculture (USDA) PLANTS database, we assigned each species a nativity status and life form with cover and frequency also expressed for these subsets. From these data, we identified the most abundant taxa and life forms, the most frequently occurring species, and generated a list of all of the exotic species found within each plot. Finally, we explored community characteristics at the site level for all taxa and for native species only. We determined species evenness, which indicates the distribution of species at a site, (scores may range between 0 and 1, where 1 indicates equal abundance of species within a population or community). We used the Shannon Index to describe beta diversity, a measure of diversity *between* sites or communities and alpha diversity a measure of diversity *within* a community. Lastly, we calculated species richness as another important measure of community diversity.

We made comparisons of the above results across management types, but because the 2009 sample size was so small (eight sites), and there was only one site each in two of the management types, the analyses were strictly qualitative.

Soils

Staff averaged aggregate stability scores by site and by cover type with separate calculations for surface and subsurface data. We assessed soil characteristics and overall soil condition using surface erodibility ratings and physical and chemical properties including nutrients, cation exchange capacity, pH, organic matter content, and bulk density.

Anthropogenic and Natural Disturbance

HDI and NDI values were calculated based upon modified Colorado Natural Heritage Program's algorithms (Rocchio 2007) and ROMN methods, respectively. We applied index values to vegetation and soil metrics via simple linear Pearson correlations.

Assessment

We conducted a summary literature search in an effort to find similar studies in the area with which we may compare our results. These comparisons provide context for our work and increase the meaningfulness of our results. We found three studies to help assess our findings. Comparisons were simple and qualitative, but provided perspective.

Results

Shrub and Herbaceous Vegetation

Crews found a total of 104 vascular plant taxa at GRKO in 2009. Of these, 30 (29%) were exotic (see Appendix A for a complete list of species).

Cover and Frequency

A mixture of native and exotic perennial grasses and forbs dominated sites at GRKO in 2009. Table 2 provides a list of the ten most abundant species as measured by mean plot cover. Table 3 lists the ten most abundant species found on transects using point-intercept methods. The two lists share seven species in common.

Species with the greatest mean cover are also broadly distributed. Including plot and transect data, no species occurred at every site, but smooth brome, (*Bromus inermis*) and Kentucky bluegrass, (*Poa pratensis*), came very close. Crews documented these two species at seven out of eight sites. Quackgrass (*Elymus repens*) and needle-and-thread grass (*Hesperostipa comata*), two additional species with high canopy cover, were found at five sites and four sites, respectively.

The abundance and distribution of these and other species are reflected in the frequency data that were measured in nested plots at each site. Most frequently occurring species largely matched those with highest mean cover (Table 2).

Life Form-based Metrics

We converted species cover data into life form (or functional group) cover data post hoc to capture a broader ecological view of our sites. Figure 3 illustrates life form distribution at the site level two ways. The first is based on abundance as measured by percent cover and the second is based on numbers of individuals of each type. We converted absolute cover to relative cover for ease of comparison. Of the species recorded, forb species slightly outnumbered graminoid species in the 1-m^2 quadrats (Figure 3). However, graminoids (83% perennial grasses) comprised 81% (+/-15) of site canopy cover in plots and 73% (+/-7.19) along transects. Life form community composition looks different when representation is based on numbers of individuals rather than cover (Figure 3). The representation of forbs by number is far greater than that by cover.

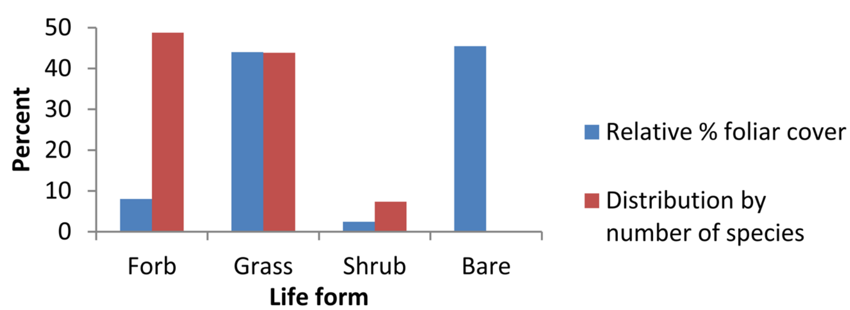

Figure 3. Life form distribution at GRKO vegetation and soil monitoring plots in 2009. Blue bars represent mean site foliar cover. Red bars represent mean number of species per life form group across sites. Both datasets were normalized to fit scale ranging 0-100 (percent). “Bare” conditions (unvegetated areas) exist in all plots.

Exotics

The mean percentage of exotic species found at each site was 54% (+/-18). The fewest number of exotic taxa at a site was four and the highest eighteen. The lowest and highest exotic canopy cover at a site (using plot data) was 2.2% and 62%, respectively. Exotic species comprise 40% of the ten most common plot species and 50% of the most abundant transect species.

Table 2. Cover and frequency of the ten most abundant species detected in 1-m^2 plots at Grant-Kohrs Ranch NHS, 2009. Exotic species are indicated by an asterisk. Minimum values displayed are the lowest value where species occurs. No species occurred at all sites. Null values were included in plot analyses.

Species Name	Mean Cover (%)	Standard Deviation	Min Value	Max Value	Freq (%)
*Bromus inermis**	12.99	13.92	4.53	40.56	34.58
*Elymus repens**	9.66	12.71	0.21	36.00	30.00
*Poa pratensis**	6.72	8.75	0.25	20.58	32.50
Hesperostipa comata	4.71	7.92	3.14	23.03	18.33
*Bromus tectorum**	3.69	6.86	13.81	15.74	12.92
Pseudoroegneria spicata	2.39	4.45	0.89	13.03	9.58
Juncus arcticus ssp.*littoralis*	2.12	5.12	2.33	14.64	16.25
Phlox hoodii	2.08	3.94	0.10	10.08	10.00
Poa secunda	1.79	3.31	0.06	9.30	8.00
Koeleria macrantha	1.78	2.88	0.22	8.10	10.00

Table 3. Cover of the most abundant species detected in transects at Grant-Kohrs Ranch NHS, 2009. Exotic species are indicated by an asterisk.

Transect Species Name	Mean Cover (%)
*Bromus inermis**	20.66
*Poa pratensis**	11.74
Hesperostipa comata	10.06
*Elymus repens**	9.78
Juncus arcticus ssp. *littoralis*	4.52
*Bromus tectorum**	3.67
*Agropyron cristatum**	2.82
Pseudoroegneria spicata	2.17
Pascopyrum smithii	1.64
Carex duriuscula	1.20

Community Metrics

Mean species richness across all sites (including unique unknowns and genera level taxa) was 20.25 (+/-7.8) and ranged from five to thirty-one. Individual 1-m^2 plots averaged 5.7 (+/-2.96) species. Mean native species richness was 10.38 (+/-6.3) and ranged from one to twenty. Native species averaged 2.13 (+/-1.4)/m^2. Shannon diversity indices for all species ranged from 0.9-2.23 and 0.04-1.38 for native communities. Total species evenness scores ranged from 0.41-0.72 with native species evenness lower at 0-0.46. Both Shannon beta diversity scores were larger than mean alpha diversity (Table 4).

Table 4. Species diversity measures of 2009 Grant-Kohrs Ranch NHS plot data (ten 1-m^2 plots).

Table 4a. All species

Diversity Metrics	Mean	Range
Species Richness	20.25	5-31
Shannon Diversity	1.50	0.9-2.23
Maximum Diversity	2.90	1.61-3.43
Species Evenness	0.52	0.41-0.72
Beta diversity		4.57

Table 4b. Native species

Diversity Metrics	Mean	Range
Species Richness	10.38	1-20
Shannon Diversity	0.70	0.04-1.38
Maximum Diversity	2.06	0-3
Species Evenness	0.28	0-0.46
Beta diversity		4.69

Soils

Interpretation of the soils data and comparative statements made are based upon information supplied by the Colorado State University Soils Lab regarding expected soil characteristics. Analysis of soil cores collected at GRKO in 2009 revealed sandy clay soils with average pH values of 6.9 ranging from 6.2-8.1 (Table 5). Soil nutrients ran normal to somewhat high with a few outliers. Elevated values included potassium (K) at all sites; calcium (Ca), magnesium (Mg) and sulfate-sulfur (SO_4-S) values were higher at sites closest to the main and secondary river channels (GRKO-001 and GRKO-029). GRKO-033 was irrigated with effluent water, but nutrient levels at this site were mid-range for all values. Bulk density numbers did not indicate that any soils were compacted. Cation exchange capacity values ranged between 12.5 and 39. Sites closest to the river channels had the highest values (39, 33.5) versus the lower values, which tended to be at sites with sandier (e.g., clay loam) soils (12.5, 13.8).

Table 5. Range of mean soil property values from cores collected at Grant-Kohrs Ranch NHS, 2009.

pH	6.2 - 8.1
NH_4-N*	3.9 - 44.8
NO_3-N*	5.9 - 143.1
P*	0.09 - 0.87
K*	256.6 - 858.7
Ca*	1888.3 - 5417.3
Mg*	219.4 - 858.7
SO_4-S*	24.4 - 808.1
CEC (meq/100g)	12.5 - 39
Bulk Density (g/cm^3)	0.87 - 1.44
N (%)	0.02 - 0.87
C (%)	0.2 - 11.8

Results from the soil aggregate stability test showed that most of the soils were stable and not likely to be susceptible to erosion. Soils with scores 5.5 and higher are generally resistant to erosion (Herrick et al. 2005). Six sites had mean surface stability scores with scores greater than 5.5 and all but one site had scores higher than 5.0. With few exceptions, scores were lower when no canopy was present at the collection site. Values for these surface layers started as low as 3.33 (Table 6). Because soils were similar in texture, we conducted all analyses of aggregate stability without factoring in texture types.

Table 6. Ranges and mean soil aggregate stability scores from samples taken at Grant-Kohrs Ranch NHS, 2009.

Soil layer	Canopy cover		No canopy cover	
	Range	Mean	Range	Mean
Surface	4.93 - 6.00	5.6	3.33 - 6	4.72
Subsurface	4.33 - 5.83	5.26	1 - 5.37	3.66

Six sites had little evidence of soil erosion based on presence of rills and gullies, pedestals or evidence of surface flow. However two sites, GRKO-028 and GRKO-036, exhibited signs of erosion. One of these, GRKO-028, had the lowest soil aggregate stability scores for surface layers regardless of cover (4.93, and 3.33, respectively).

Anthropogenic and Natural Disturbance

In 2009, crews collected both natural and anthropogenic disturbance data at each site (Table 7). Each index produces one disturbance score for every site. Scores for both indices range from 0 to 100; lower scores signify less disturbance. NDI scores were low across the board. The NDI score at GRKO-036 was somewhat higher due to evidence of rodent use and a previous fire. At all other sites, NDI scores did not exceed 1. HDI scores were clumped together at moderate levels of disturbance. The exception is GRKO-025, a site that sits in a barrow pit, which scored a 67.00.

Table 7. Disturbance Indices. Human and natural disturbance scores are shown as HDI and NDI. Scores range from 0-100, 100 being highest level of disturbance. Data were collected at Grant-Kohrs NHS, 2009.

Site ID	HDI	NDI
GRKO.G-001	51.35	0.00
GRKO.G-012	56.10	0.00
GRKO.G-025	67.00	0.00
GRKO.G-028	51.35	0.43
GRKO.G-029	51.15	0.00
GRKO.G-032	57.95	0.14
GRKO.G-033	51.35	0.14
GRKO.G-036	57.95	5.14

Discussion

GRKO VCSS monitoring sites are characterized by a mixture of native and exotic perennial grasses. Interspersed amongst the perennial grasses, we found a populous, but more sparsely distributed mixture of native and exotic perennial forbs and shrubs and exotic annual grasses. Of these, 15 were without diagnostic characters (e.g., reproductive parts) present at the time of our surveys and were classified as "unidentified." The number of unknowns should dwindle as we collect additional data in subsequent years of sampling at varying phenological stages.

Shrub and Herbaceous Vegetation

Cover and Frequency

Our findings showed forb cover and frequency to be much lower than grasses. When looking at functional group richness, these two life form groups were almost equal. At least one study has found similar, but less dramatic differences in relative cover of forbs and grasses (14% forbs vs. 19% grasses (Stohlgren 1999). Many other studies (Pokorny et al. 2004, Sims and Risser 2000, Mueggler and Stewart 1980, and Daubenmire 1970) have shown forb biomass and richness to be higher than grasses in surrounding grasslands. Network crews sampled at GRKO in 1-2 week windows in late June – early July every year, so many spring ephemerals or annual forbs may be missed. Forbs may be more variable in changes in biomass over any given season and sampling later in the summer may show the disparity between forb and grass cover shrink. Additionally, GRKO is a heavily manipulated system and may not follow common patterns found in less altered grasslands.

Exotics

Exotic species comprised 29% of all taxa recorded in 2009 and more than half of species recorded in plots. However, many are not widely distributed. In fact, almost half occur solely at one site. Even though sparsely distributed and few in number, there are species of concern to park managers present. Attention should be paid to these species because they are listed on state noxious weed lists and are quite invasive. Species to be monitored closely include leafy spurge (*Euphorbia esula*), yellow toadflax (*Linaria vulgaris*), Canada thistle (*Cirsium arvense*), and spotted knapweed (*Centaurea stoebe*). Exotic species of note due to their abundance and distribution include smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), quackgrass (*Elymus repens*), and cheatgrass (*Bromus tectorum*). Note that two of these species are intentionally maintained by park managers in pastures and hayfields.

To compare our findings with a comprehensive study conducted by Stohlgren et al. (1999) at several federal land sites across the Rocky Mountains, we analyzed our data at the individual 1-m^2 plot scale and used standard error to report deviance from the mean. When compared with Stohlgren et al. (1999) findings, GRKO 1-m^2 plot exotic species *cover* was considerably higher than a number of other Rocky Mountain grasslands (34% +/-3.1 vs. 5.4% +/-0.7). The *number* of exotic species in GRKO was also higher than the mean number of exotic species found in 1-m^2 plots in the Stohlgren et al. (1999) study (2.1 +/- 0.15 vs. 0.9 +/-0.1). GRKO is a working ranch surrounded by private ranchland and developed areas; the ten sites in the comparison study are found in grazed, but protected areas that may sit in more natural settings.

Community Metrics

Native species richness was lower at GRKO than at other public lands in the region (Stohlgren et al. 1999, 2002). The mean $1m^2$ richness at nine other federally protected sites in the Rockies was 8.5 (+/-0.3) (Stohlgren et al. 1999) and 2.94 (+/-0.29) at GRKO.

Exotic species significantly contribute to community diversity as evidenced by the precipitous drop in species richness and diversity with the removal of exotic species from consideration. Both β diversity scores are quite high, which indicates that, while community diversity is low, diversity among sites is considerable.

These are not overly surprising findings since GRKO is an active ranch and half of the 2009 monitoring sites are located in hay/pasture fields. Hay species at GRKO are not native and the primary management goal is to produce high quality forage, not maximize diversity. That said, there were not obvious differences in community metrics among management zones as defined in the GRKO cultural landscape report (John Milner Assoc., Inc. et al. 2004), but meaningful, quantitative comparisons will have to wait until we increase our sample size in future years in zones outside of the hayfields.

Soils

Soils at GRKO in 2009 are generally stable and in good condition according to guidance provided by the Colorado State University soils lab. Soil aggregate stability scores were notably lower in non-vegetated sampling areas. Often stability figures start to decline first in non-vegetated areas, followed by vegetated areas if conditions continue to degrade (Herrick et al. 2005). The network will continue to monitor these sites for changes in soil aggregate stability and signs of surface erosion.

Two sites, GRKO-001 and GRKO-029, sit in a riparian-like setting. Floodplain or transition area soils can often be nutrient rich as a result of organic inputs and flux of the system. Nutrient values at these two sites were considerably higher than at other sites. This could be a result of being set in a depositional or organic matter rich setting or alternatively, these sites could be exhibiting characteristics that are influenced by proximity to a nutrient/metal laden river. The North Fork of the Clark Fork River, which bisects the park, is a designated Superfund site as a result of pollution from copper mining upstream. River water quality is impaired and this altered chemistry may be affecting soil chemistry in surrounding floodplain areas (Rice 2003).

Neither human nor natural disturbance appeared to play a significant role in influencing site vegetation or bare soil cover. Perhaps over time, with additional analyses, especially those of soil properties and potential for erosion, we may yet see patterns arise.

Disturbance

All GRKO sites in 2009 scored HDI values in the 50s (with one exception), a narrow range, when possible scores range from 1-100. There are at least a few potential reasons to explain this cluster. One is the small size of GRKO; multiple sites are subjected to the same disturbance (most commonly land use in surrounding area). A second contributing factor might be that the data were collected by someone unfamiliar with history of land use at GRKO. The park resource manager, who is knowledgeable about historic land use of the sites, but not rigorously trained in the evaluation process, has independently applied the HDI and NDI to our 2009 sites to compare variation in interpretation. Results varied considerably from those obtained by the field crew. So far, a GRKO resource manager has evaluated human disturbance for one site and the difference in scoring (51 vs. 69) would likely alter interpretation. This is the first year that we have used these indices and we are working on improving ways to reduce variability through improvements to the datasheets themselves (e.g., clarify exactly what is being asked), calibrating scoring across crew members and park staff, and applying institutional knowledge from the park that will better inform the interpretation process.

Future reporting

The findings presented in this report are preliminary analyses; additional, more in-depth analyses will follow as time allows, as we acquire more data with subsequent sampling, and as we process all of our data from 2009.

In future annual data reports, we will present status of sites monitored that year and make comparisons with data collected in previous years. After we have accumulated 5 years of data, we will evaluate whether there are sufficient data to analyze and report on VCSS trends.

Literature Cited

Britten, M., E. W. Schweiger, B. Frakes, D. Manier, and D. Pillmore. 2007. Rocky Mountain Network vital signs monitoring plan. Natural Resource Report NPS/ROMN/ NRR-2007/010. National Park Service, Fort Collins, Colorado, USA.

Collins, J.N., E.D. Stein, M. Sutula, R. Clark, A.E. Fetscher, L. Grenier, C. Grosso, and A. Wiskind. 2008. California rapid assessment method (CRAM) for wetlands. Version 5.0.2. 151 pp.

Daubenmire, R. 1970. Steppe vegetation of Washington. Washington State University Cooperative Extension, Pullman.

Herrick, J.E., J.W. Van Zee, K.M. Havstad, L.M Burkett and W.G. Whitford. 2005. Monitoring manual for grassland, shrubland and savanna ecosystems. USDA-ARS Jornada Experimental Range, Las Cruces, New Mexico and University of Arizona Press, Tucson, Arizona. 2 vol., 236 pp. available online at http://usda-ars.nmsu.edu/.

John Milner Associates, Inc., Rivanna Archeological Consulting, & Susan Maxman & Partners Architects. 2004. Grant-Kohrs Ranch National Historic Site, Deer Lodge, Montana cultural landscape report part one: l*andscape history, existing conditions, and analysis and evaluation*. Report prepared for the National Park Service, Deer Lodge, Montana.

Manier, D., D. Shorrock, E.W. Schweiger, I. Ashton, B. Frakes, M. Britten, D. Pillmore. and J. Burke. In review. Vegetation Composition Structure and Soils: Small Park Grasslands, Shrublands, and Woodlands. Version 1.0. National Park Service, Rocky Mountain Inventory and Monitoring Network, Fort Collins, CO, 53 pp., plus appendices.

Mueggler, W.F. and W.L. Stewart. 1980. Grassland and shrubland habitat types of western Montana. Inter-mountain Forest and Range Experimental Station, Ogden, UT.

Natural Resources Conservation Service (NRCS). SSURGO data found at the Soil Data Mart. http://soildatamart.nrcs.usda.gov/State.aspx.

Pokorny, M.L, R.L. Sheley, J.J. Svejcar, and R.E. Engel. 2004. Plant species diversity in a grassland plant community: evidence for forbs as a critical management consideration. Western North American Naturalist 64(2): 219-230.

Rice, P.M. 2003. Baseline vegetation types for Grant-Kohrs Ranch. University of Montana, Missoula, MT. 24 pp.

Rocchio, J. 2007. Floristic quality assessment indices for Colorado plant communities. Unpublished report prepared for the Colorado Department of Natural Resources and US EPA Region 8. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Sims, P.L., and P.G. Risser. 2000. Grasslands. Pages 323-395 in M.G. Barbour and W.D. Billings, editors, North American terrestrial vegetation. Volume 2. Cambridge University Press, Cambridge.

Stohlgren, T.J., G.W. Chong, L. D. Schell, K.A. Rimar, Y. Otsuki, M. Lee, M.A. Kalkhan, C. A. Villa. 2002. Assessing vulnerability to invasion by nonnative plant species at multiple spatial scales. Environmental Management 29(4): 566–577.

Stohlgren, T.J., L.D. Schell, and B. Vanden Heuvel. 1999. How grazing and soil quality affect native and exotic plant diversity in Rocky Mountain grasslands. Ecological Applications 9(1): 45-64.

Appendix A

Complete list of species and corresponding life forms documented at GRKO in 2009. Nomenclature follows the Integrated Taxonomic Information System. Asterisks denote non-native species. The list does not include unknown species.

Achillea millefolium L. var. *occidentalis* DC.	Perennial forb
Agropyron cristatum (L.) Gaertn.*	Bunch graminoid
Agrostis gigantean Roth*	Rhizomatous graminoid
Allium L.	Forb
Alopecurus aequalis Sobol.	Bunch graminoid
Alyssum alyssoides (L.) L.*	Annual forb
Arabis holboellii Hornem.	Perennial forb
Artemisia campestris L.	Perennial forb
Artemisia frigida Willd.	Shrub
Astragalus laxmannii Jacq.	Perennial forb
Astragalus purshii Douglas ex Hook.	Perennial forb
Bouteloua gracilis (Willd. ex Kunth) Lag. ex Griffiths	Bunch graminoid
Bromus inermis Leyss.*	Rhizomatous graminoid
Bromus tectorum L.*	Annual graminoid
Calamagrostis stricta (Timm) Koeler	Rhizomatous graminoid
Camelina microcarpa Andrz. ex DC.*	Annual forb
Carex douglasii Boott	Rhizomatous graminoid
Carex duriuscula C.A. Mey.	Rhizomatous graminoid
Carex L.	Graminoid
Carex nebrascensis Dewey	Rhizomatous graminoid
Carex praegracilis W. Boott	Rhizomatous graminoid
Centaurea stoebe L*	Perennial forb
Cerastium fontanum Baumg.*	Perennial forb
Cirsium arvense (L.) Scop.*	Perennial forb
Convolvulus arvensis L.*	Perennial forb
Cryptantha interrupta (Greene) Payson	Perennial forb
Dactylis glomerata L.*	Bunch graminoid
Deschampsia caespitosa (L.) P. Beauv.	Bunch graminoid
Descurainia sophia (L.) Webb ex Prantl *	Annual forb
Elymus lanceolatus (Scribn. & J.G. Sm.) Gould	Rhizomatous graminoid
Elymus repens (L.) Gould*	Rhizomatous graminoid
Equisetum laevigatum A. Braun	Perennial forb
Erigeron L.	Forb
Erysimum inconspicuum (S. Watson) MacMill.	Perennial forb
Euphorbia esula L.*	Perennial forb
Festuca campestris Rydb.	Bunch graminoid
Galium boreale L.	Perennial forb
Gutierrezia sarothrae (Pursh) Britton & Rusby	Shrub

Hesperostipa comata (Trin. & Rupr.) Barkworth	Bunch graminoid
Heterotheca villosa (Pursh) Shinners	Perennial forb
Heuchera parvifolia Nutt. ex Torr. & A. Gray	Perennial forb
Iris missouriensis Nutt.	Perennial forb
Juncus arcticus Willd. ssp. *littoralis* (Engelm.) Hultén	Rhizomatous graminoid
Koeleria macrantha (Ledeb.) Schult.	Bunch graminoid
Krascheninnikovia lanata (Pursh) A. Meeuse & Smit	Shrub
Lactuca serriola L.*	Annual forb
Lepidium latifolium L.*	Perennial forb
Lesquerella alpine (Nutt.) S. Watson	Perennial forb
Lewisia rediviva Pursh	Perennial forb
Linaria vulgaris Mill.*	Perennial forb
Lupinus sericeus Pursh	Perennial forb
Lygodesmia juncea (Pursh) D. Don ex Hook.	Perennial forb
Maianthemum stellatum (L.) Link	Perennial forb
Medicago lupulina L.*	Biennial forb
Melilotus officinalis (L.) Lam.*	Biennial forb
Musineon divaricatum (Pursh) Raf.	Perennial forb
Nassella viridula (Trin.) Barkworth	Bunch graminoid
Opuntia polyacantha Haw.	Shrub
Pascopyrum smithii (Rydb.) A. Löve	Rhizomatous graminoid
Penstemon eriantherus Pursh	Perennial forb
Phlox hoodii Richardson	Perennial forb
Phleum pratense L.*	Bunch graminoid
Plantago L.	Forb
Poa L.	Graminoid
Poa pratensis L.*	Rhizomatous graminoid
Poa secunda J. Presl	Bunch graminoid
Potentilla gracilis Douglas ex Hook.	Perennial forb
Potentilla hippiana Lehm.	Perennial forb
Pseudoroegneria spicata (Pursh) A. Löve	Bunch graminoid
Ranunculus cymbalaria Pursh	Perennial forb
Ribes oxyacanthoides L.	Shrub
Rumex crispus L.*	Perennial forb
Salix boothii Dorn	Shrub
Salix exigua Nutt.	Shrub
Silene antirrhina L.	Annual forb
Silene latifolia Poir.*	Perennial forb
Sisymbrium altissimum L.*	Annual forb
Solidago canadensis L.	Perennial forb
Sphaeralcea coccinea (Nutt.) Rydb.	Perennial forb
Taraxacum officinale F.H. Wigg.*	Perennial forb

Tetradymia canescens DC.	Shrub
Thlaspi arvense L.*	Annual forb
Thlaspi L.	Forb
Tragopogon dubius Scop.*	Annual forb
Trifolium longipes Nutt.	Perennial forb
Trifolium pretense L.*	Perennial forb
Trifolium repens L.*	Perennial forb
Vicia americana Muhl. ex Willd.	Perennial forb

Appendix B.

2009 VCSS sampling information

Site ID	Sample date	Crew
GRKO.G-001	6/30/2009	DS, KM, JG
GRKO.G-012	6/29/2009	DS, KM, JG
GRKO.G-025	6/22/2009	DS, KM, JG
GRKO.G-025	7/1/2009	DS, KM, JG
GRKO.G-028	6/23/2009	DS, KM, JG
GRKO.G-029	6/24/2009	DS, KM, JG
GRKO.G-032	6/26/2009	DS, KM, JG
GRKO.G-033	6/30/2009	DS, KM, JG
GRKO.G-036	6/25/2009	DS, KM, JG
Crew members included: Donna Shorrock, Kyle Motley, and Justina Gray (NG on field forms)		