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Vegetation Composition, Structure, and Soils Monitoring in Grasslands, Shrublands, and Woodlands at Little Bighorn Battlefield National Monument

2009 Annual Data Report

Natural Resource Data Series NPS/ROMN/NRDS—2010/088

ON THE COVER
VCSS monitoring site at the Reno-Benteen unit at Little Bighorn Battlefield National Monument, June, 2009
Photograph by: Donna Shorrock

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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.

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Executive Summary

The Rocky Mountain Network has identified vegetation composition, structure, and soils in terrestrial systems as one of its 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. Little Bighorn Battlefield National Monument (LIBI), a small, accessible park characterized by grasslands, was 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. Pilot data collected in 2006-2008 will be reported separately.

The VCSS protocol uses variable probability sampling allowing us to characterize the vegetation and soils across the entire park. In LIBI, we developed sample frames within a GIS layer using soil geodata. 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.

In 2009, crews sampled eleven sites at LIBI, three of which are located in the Reno-Benteen unit and eight in the Custer unit. 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, tree health, density, and structural attributes, soil cores for laboratory analyses, and performed soil aggregate stability tests.

Crews found 79 vascular plant species at LIBI monitoring sites, 20 of which are non-native. In fact, five of the ten most abundant species are exotic. Overall community diversity proved to be relatively low 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 western wheatgrass (*Pascopyrum smithii*). Equally common were annual exotic grasses, namely cheatgrass (*Bromus tectorum*) and field brome (*B. arvensis*). Annual forbs and native shrubs were less abundant than the grasses.

Most trees at LIBI grow in the riparian area; consequently the upland monitoring sites visited in 2009 contained very few trees. All of the trees recorded were Rocky Mountain juniper (*Juniperus scopulorum*), one of which was alive; the remaining individuals were killed in a 1991 fire in the Reno Benteen unit.

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 fewer disturbances. Disturbance scores at LIBI were very low, the highest score being under 24 for human disturbance and under 3 for natural disturbance. Because the scores were so low and similar to one another, we were not able to discern any direct relationship between disturbance levels and vegetation characteristics. However, based on soil aggregate stability scores, we did see less stable soils at sites located in the 1991 burn areas.

VCSS monitoring will continue at LIBI in future years and when sufficient data have been collected, we will conduct a thorough trend analysis.

Acknowledgments

Thanks to the staff at Little Bighorn Battlefield National Monument for their help during the 2009 field season. Special thanks to Melana Stichman for helping to arrange logistics while field crews were at the monument and for reviewing this document, Michael Stops for providing orientation and safety training, and Shane Archuleta for his assistance in the field. We are also very appreciative of the fine work that our seasonal staff, Kyle Motley and Justina Gray, did for the park and the network. Comments and suggestions from Amy Symstad, USGS research ecologist for the Northern Great Plains 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 park ecosystems, and to determine how well current management practices are sustaining those ecosystems. The Rocky Mountain I&M Network (ROMN) identified vegetation composition, structure, and soils (VCSS) as a vital sign that can be used to better understand the condition of park ecosystems (Britten et al. 2007). The ROMN VCSS protocol is designed to monitor grassland, shrubland, and woodland systems within our three smaller Network parks. Using this protocol, we monitor the status and trend in these ecosystems as they are affected by natural and anthropogenic disturbance over the long term. We focus our monitoring in the three small ROMN parks (Florissant Fossil Beds National Monument (FLFO), Little Bighorn Battlefield National Monument (LIBI), and Grant-Kohrs Ranch National Historic Site (GRKO)) because 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. Within the ROMN, these three ecosystem types represent important habitats and resources for wildlife as well as unique assemblages of local flora.

The Network began VCSS monitoring pilot work at GRKO and LIBI in 2006. After completion of the initial pilot study period, full implementation of the refined VCSS monitoring protocol commenced in the summer of 2009. The purpose of this report is to document the 2009 upland vegetation and soils monitoring efforts in LIBI 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 Monument grassland, shrubland, and woodlands and does not explore trends. However, the long-term objectives of the VCSS monitoring effort will focus on both status and trends. Specifically, our 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 18th, 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 LIBI. 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 were unable to attend Rocky Mountain National Park's first aid and defensive driving classes due to timing and limited availability of the classes. 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 LIBI, the crew stayed in a three-bedroom cabin with its own bath and kitchen at the KOA in Hardin, a small town 13 miles northwest of the park. The cabin was somewhat pricey ($1500/mth) but was worth the expense because crews had adequate living, work, and storage space, which contributes to creating a more productive and satisfied crew. For the same price, it may be worth exploring temporary home rentals in the area that offer more comfortable accommodations and perhaps a location closer to the park.

The network rented a vehicle from Enterprise Rent-a-Car for the crew to use for the duration of the summer of 2009. 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 and lodging 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 to 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 LIBI 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. Network VCSS sampling at LIBI in 2009 occurred in June as it has in all years since 2006 when VCSS sampling began.

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.

ROMN VCSS revisit designs are based on pilot research in each park and power analysis of the ability of various alternative revisit designs to detect trend and minimize standard error around status. However, in reality, sample size and panel design are also a function of operational constraints, not solely the optimum for trend detection or for precisely estimated status. In an effort to reconcile scientific idealism with feasibility, we determined our average maximum sample size for VCSS surveys in LIBI in any given year to be nine to eleven sample events. The VCSS panel structure is designed so that crews sample eight sites in the initial year and ten thereafter (plus one within-season visit). 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 LIBI VCSS survey design. Total unique sample size of sites = 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
LIBI01	6				6				6	
LIBI02		6				6				6
LIBI03			6				6			
LIBI04				6				6		
LIBI05	2	2			2	2			2	2
LIBI06		2	2			2	2			2
LIBI07			2	2			2	2		
LIBI08				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, we sampled eleven sites at LIBI, three of which were located in the Reno-Benteen unit and eight in the Custer unit; four sites had been previously sampled in the pilot phase and seven sites we newly established. The crew revisited four of these sites in an effort to capture within-season variability. Figure 1 shows 2009 site locations.

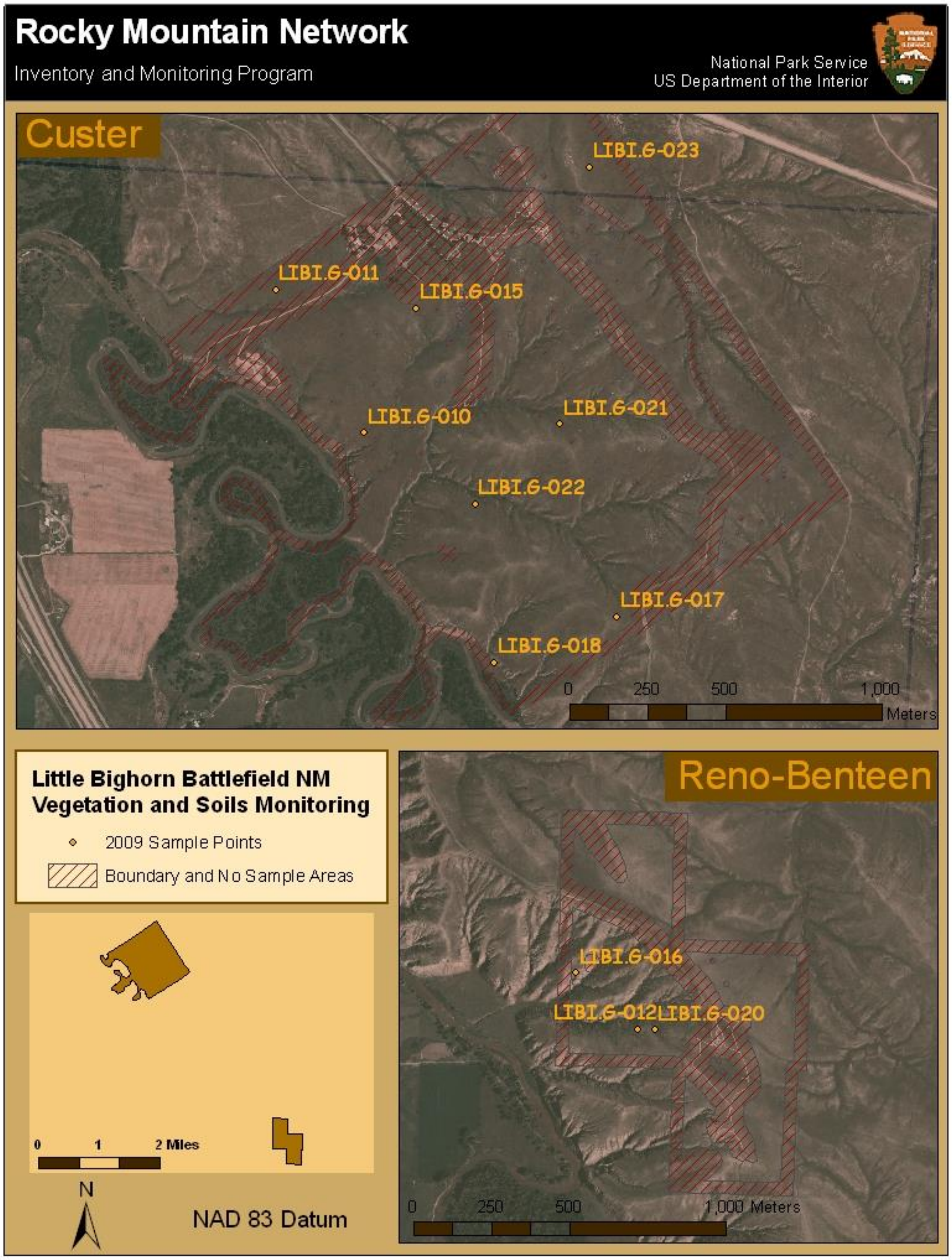

Figure 1. 2009 VCSS monitoring site locations at Little Bighorn Battlefield National Monument Reno-Benteen and Custer units

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 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 transect "spokes" radiating out from the site center (Figure 2), crews used a point intercept method 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 ten 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

Two 2009 monitoring plots at LIBI had trees present. At these sites, crews delineated one 168-m^2 circular plot at the end of each transect. Data collectors first assigned an ID code to each tree, and then recorded each tree species, distance and bearing to every individual from plot center (transect end), canopy position, health, and diameter at breast height (DBH). If tree seedlings had been found, they would have been tallied by species and size class.

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.

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.

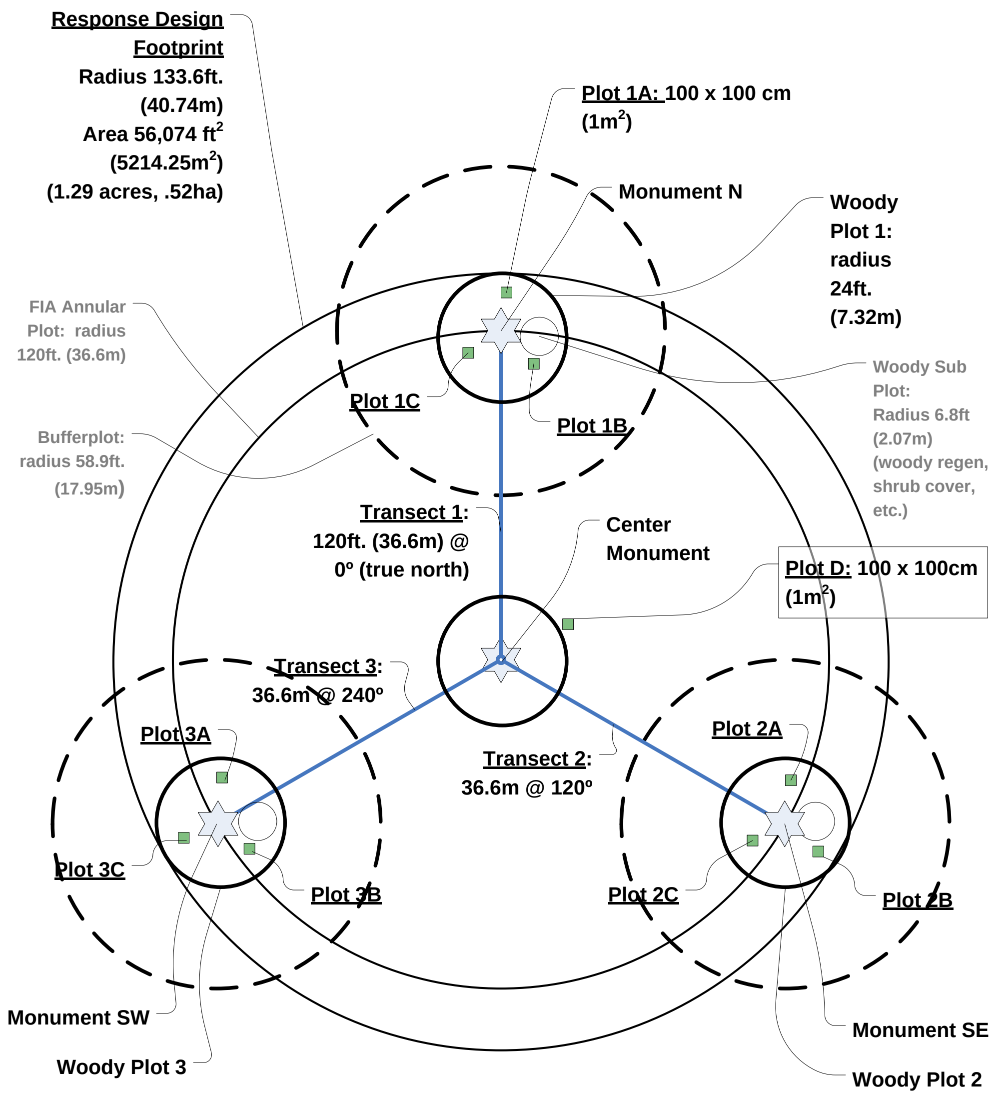

Figure 2. VCSS Monitoring Site Layout

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 LIBI 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.

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 provided context for our work and increased the meaningfulness of our results.

Results

Shrub and Herbaceous Vegetation

Crews found a total of 79 vascular plant species at LIBI in 2009. Of these, 20 were exotic species, which comprised 25% of all species found (see Appendix A for a complete list of species).

Cover and Frequency

A mixture of perennial and annual grasses and annual forbs was most commonly found at LIBI VCSS sites in 2009. Table 2 provides a list of the ten most abundant species as measured by mean plot canopy cover. By comparison, Table 3 lists the ten most abundant species found on transects. The two lists share eight species in common.

The relationship between species abundance and distribution (frequency) is strongly positive (r^2=.78, $p<.001$). In other words, species with the greatest mean cover are also typically broadly distributed, but not exclusively. Seven species with mean percent cover that did not exceed 1.4% occurred at eight or more sites (out of eleven). Crews found one of these species, prickly lettuce (*Lactuca serriola*), at all sites. One species that was abundant along transects, but not in plots, western yarrow (*Achillea millefolium* var. *occidentalis*), also grew at all sites sampled. Including all plot and transect cover data, eight species occurred at every site (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. When considering cover, the grasses were more than twice as abundant as forbs (46% vs. 19% relative cover). 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. For every 16 grass species, there are 39 forbs at LIBI sites in 2009.

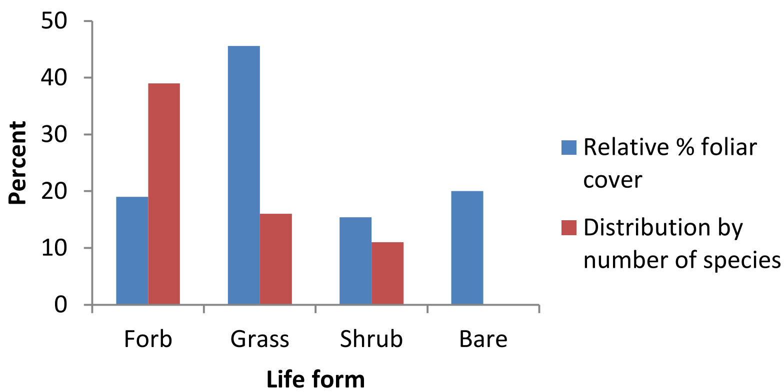

Figure 3. Life form distribution at LIBI vegetation and soil monitoring plots in 2009. Blue bars represent mean site foliar cover. Red bars represent mean number of species per life form group across sites. Both datasets were normalized to fit scale ranging 0-100 (percent).

Exotics

The mean percentage of exotic species found at each site in 2009 was 25.5 (+/-7.6 SD). The fewest number of exotic taxa at a site was seven and the highest fourteen. The lowest and highest exotic canopy cover at a site (using plot data) was 14.9% and 34.7%, respectively. Exotic species comprise 50% of the ten most common plot species and 60% of the most abundant species recorded on transects. Crews documented all exotic species found at sites in 2009; Appendix B identifies exotic species of special concern to park managers.

Table 2. Cover and frequency of the ten most abundant species detected in 1-m^2 plots at Little Bighorn Battlefield NM, 2009. Exotic species are indicated by an asterisk. Minimum values displayed are the lowest value where species occurs. Species that did not occur at all sites are indicated by ** next to the Min Value column. Null values were included in plot analyses. Number of sites found includes both plots and transects.

Species Name	Common name	Mean Cover (%)	St Dev	Min Value		Max Value	Freq (%)	#Sites where found
Pseudoroegneria spicata	bluebunch wheatgrass	12.16	7.93	0.25		27.00	35.30	11
*Bromus arvensis**	Japanese brome	7.79	4.11	2.11		13.94	62.73	11
*Bromus tectorum**	Cheatgrass	4.45	5.68	1.00	**	18.63	28.64	9
*Tragopogon dubius**	Salsify	3.44	3.13	0.19		11.39	38.18	11
Pascopyrum smithii	western wheatgrass	2.98	1.23	1.42		4.64	53.64	11
*Alyssum alyssoides**	pale madwort	2.80	2.14	0.47		6.72	46.52	11
*Poa pratensis**	Kentucky bluegrass	2.57	3.09	0.08	**	9.22	18.94	11
Yucca glauca	soapweed yucca	2.38	3.98	1.50	**	13.33	3.94	6
Symphoricarpos occidentalis	western snowberry	2.20	2.81	0.56	**	8.61	8.79	8
Artemisia cana	silver sagebrush	2.13	3.11	0.50	**	9.19	10.30	7

Table 3. Cover of the most abundant species detected along 36-m transects in Little Bighorn Battlefield NM, 2009. Exotic species are indicated by an asterisk.

Transect Species Name	Mean Cover (%)
*Bromus arvensis**	19.01
Pseudoroegneria spicata	13.81
*Bromus tectorum**	8.71
*Poa pratensis**	7.15
Pascopyrum smithii	6.64
*Tragopogon dubius**	4.99
*Bromus hordeaceus**	2.45
Symphoricarpos occidentalis	1.66
Achillea millefolium var. *occidentalis*	1.58
*Alyssum alyssoides**	1.56

Community Metrics

Mean plot species richness across all sites (including unique unknowns and genera level taxa) was 31.82 (+/-4.53 SD) and ranged from 23 to 40. Individual 1-m^2 plots averaged 9.47 (+/-2.8) species. Mean *native* species richness was 19.82 (+/-2.99) and ranged from 13 to 22. Native species averaged 5.3 (+/-2.4)/m^2. Shannon diversity indices for all species ranged from 2.19-2.9

and 1.15-1.99 for native communities. Total species evenness scores ranged from 0.64-0.83 with native species evenness lower at 0.41-0.65. Both Shannon beta diversity scores were larger than mean alpha diversity (Table 4).

Table 4. Species diversity measures of 2009 Little Bighorn Battlefield NM plot data (ten 1-m^2 plots).

Table 4a. All species

Diversity Metrics	Mean	Range	
Species Richness	31.82	23-40	
Shannon Diversity	2.57	2.19-2.9	
Maximum Diversity	3.45	3.14-3.69	
Species Evenness	0.75	0.64-0.83	
Beta diversity			2.66

Table 4b. Native species

Diversity Metrics	Mean	Range	
Species Richness	19.82	13-22	
Shannon Diversity	1.51	1.15-1.99	
Maximum Diversity	2.97	2.56-3.09	
Species Evenness	0.51	0.41-0.65	
Beta diversity			3.35

Trees

There are very few trees in our monitoring plots at LIBI. In fact, they were all found at 2 sites situated in ravines on the western slopes in the Reno-Benteen unit. All individuals are *Juniperus scopulorum* and, with one exception, are dead as a result of a 1991 fire.

Table 5. Tree species abundance and density at Little Bighorn Battlefield NM, 2009. Density is calculated as stems/ha and abundance as m^2/ha. Mean diameter at breast height (DBH) or 1.37 m above ground is presented for each category. Category types are Y = alive or N = Dead. Health is percentage of the tree canopy that is damaged. Canopy layer indicates tree stature and position in the community.

Species	Mean DBH	Live	Canopy	Health (%)	Basal area (m^2/ha)	Stem #	Density (stems/ha)
Juniperus scopulorum	35	Y	Open	50	5.94	1	59.52
Juniperus scopulorum	16.5	N	Co-dominant	100	11.07	8	476.16

Tree abundance is measured in basal area (m^2/ha) and density (stems/ha). Table 5 divides *Juniperus scopulorum* abundance and other descriptors into categories based on whether the individuals are alive or dead.

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 LIBI in 2009 revealed clayey soils that are neutral to slightly alkaline. PH values averaged 7.6 and ranged from 6.8-8.1 (Table 6). Soil nutrients at LIBI stayed within normal ranges with only a few exceptions. Some values were elevated, such as potassium (K) at all sites and calcium (Ca) and sulfate (SO_4) values at sites burned in 1991. It is worth noting that the burn sites are the only sites sampled in the Reno-Benteen unit in 2009, so they are geographically separate from the remainder of the sites, which are in the Custer unit. Bulk density numbers do not indicate that the soils at the 2009 sites are compacted. Cation exchange capacity values are in line with the clayey soils found in 2009. The lower values tended to be at sites with sandier soils (e.g., clay loam, sandy clay).

Results from the soil aggregate stability test showed that most of the soils at the 2009 sites are fairly stable and not overly susceptible to erosion. Soils with scores 5.5 and higher are generally resistant to erosion (Herrick et al. 2005). Five sites had mean surface stability scores that fit in

Table 6. Range of mean soil property values from cores collected at Little Bighorn Battlefield NM, 2009

pH	6.8 - 8.1
NH_4-N*	5.5 - 19.1
NO_3-N*	3.7 - 15.5
P*	0.06 - 0.4
K*	301 - 489.2
Ca*	1981 - 5177
Mg*	359.3 - 598.1
SO_4-S*	19.2 - 66.6
CEC (meq/100g)	14.2 - 30.2
Bulk Density (g/cm^3)	1.1 - 1.3
N (%)	0.03 - 0.22
C (%)	0.17 - 2.36

this category; seven sites had scores higher than 5.0. Scores were noticeably lower at the three burn sites, starting as low as 3.17 on the surface layer (Table 7). Because soils were similar in texture, we conducted all analyses of aggregate stability without factoring in texture types.

Many sites had little evidence of soil erosion based on surface conditions; indicators included presence of rills and gullies, pedestals, and evidence of surface flow. Four sites exhibited at least moderate signs of erosion. These include three sites subjected to the 1991 fire plus one in the Custer unit that was adjacent to the riparian area with steep slopes and extensive unvegetated areas.

Table 7. Ranges of mean soil aggregate stability scores from samples taken at Little Bighorn Battlefield NM, 2009.

	Surface	Subsurface
Canopy cover (overall)	4.64 - 5.83	3.82 - 5.75
Fire	4.64 - 4.81	3.82 - 4.5
No fire	4.94 - 5.83	4.61 - 5.75
No canopy (overall)	3.17 - 5.33	2.33 - 5.5
Fire	3.17 - 5.14	2.33 - 4.71
No fire	4.38 - 5.33	2.86 – 5.5

Anthropogenic and Natural Disturbance

In 2009, crews collected both natural and anthropogenic disturbance data at each site (Table 8). 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 LIBI-015 was somewhat higher due to more intense and extensive evidence of rodent use. At all other sites, NDI scores did not exceed 1. HDI scores were clumped together at fairly low levels of disturbance.

Table 8. Disturbance Indices. Human and natural disturbance scores are shown as HDI and NDI. Scores range from 0-100, 100 indicating highest level of disturbance. Data were collected at Little Bighorn NM, 2009.

Site ID	HDI	NDI
LIBI.G-010	16.5	0.96
LIBI.G-011	23.3	0.96
LIBI.G-012	16.5	0
LIBI.G-015	16.5	2.88
LIBI.G-016	16.5	0.96
LIBI.G-017	16.5	0.96
LIBI.G-018	21.45	0.96
LIBI.G-020	16.5	0.96
LIBI.G-021	16.5	0
LIBI.G-022	16.5	0
LIBI.G-023	16.5	0

Discussion

LIBI VCSS monitoring sites are characterized by a mixture of native perennial and exotic annual grasses and exotic annual forbs. Interspersed amongst these, we found a populous, but more sparsely distributed mixture of native perennial forbs and shrubs. Of the species documented, ten were without diagnostic characters 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 to be much lower than grasses while frequency was similar between the two dominant life forms. 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 LIBI in 1-3 week windows beginning early June every year, so we may capture a number of spring ephemerals or annual forbs that are still small in stature (cover). Total forb biomass may fluctuate more than grass biomass over any given season; multiple, within-season sampling may show the disparity between forb and grass cover shrink.

Exotics

Exotic species comprised 25% of all taxa recorded in 2009. Some of these exotic taxa were widely distributed (four taxa were found at all sites) while others were only recorded at one or two sites (six taxa). Even though some of the exotic taxa were sporadically distributed and few in number, they may be of concern to park managers due to their presence on the Montana noxious weed list or because certain taxa are quite invasive and have great potential to spread with significant ecological impact. Species on the state noxious weed list found at LIBI in 2009 were field bindweed (*Convolvulus arvensis*) and Canada thistle (*Cirsium arvense*). Populations of bulbous bluegrass (*Poa bulbosa*) were found that warrant close monitoring as these are recent newcomers in the park. Exotic species of note due to their abundance and distribution include field brome (*Bromus arvensis*) and cheatgrass (*Bromus tectorum*).

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, LIBI 1-m^2 plot exotic species *cover* was considerably higher than a number of other Rocky Mountain grasslands (25.2% +/-1.5 vs. 5.4% +/-0.7). The *number* of exotic species in LIBI was also higher than the mean number of exotic species found in 1-m^2 plots in the Stohlgren et al. (1999) study (4.1 +/- 0.17 vs. 0.9 +/-0.1). It is unclear why exotic presence at LIBI would be considerably higher than in other protected lands. LIBI is an ungrazed (except by low use of native herbivores), protected grassland; access to visitors is restricted primarily to a single road and a few trails. LIBI is also a very small park (765 acres) and is surrounded by private ranchland.

Community Metrics

Native species richness was lower at LIBI than at other public lands in the region (Stohlgren et al. 1999, 2002). The mean 1-m^2 native richness at nine other federally protected sites in the Rockies was 8.5 (+/-0.3) (Stohlgren et al. 1999) versus 5.25 (+/-0.20) at LIBI. Upon closer examination of individual parks in this study, we see that the parks are encompassed within the Rocky Mountain region, but are geographically disparate and environmentally variable in that the climate and elevations of the parks range widely. Within this range, LIBI's setting is at a lower elevation and in a drier climate. When comparing richness data from parks closest to LIBI based on these environmental variables, we see close native richness values, but still far more exotics at LIBI.

2009 results showed that exotic species significantly contributed to community diversity as evidenced by the precipitous drop in species richness and diversity with the removal of exotic species from the equation. Both β diversity scores were quite high, which indicated that, while community diversity was low, diversity among sites was considerable.

Soils

Soils at LIBI in 2009 were fairly stable and in good condition according to guidance provided by the Colorado State University soils lab. Values at three burned sites deviated from other sites in two categories: nutrients and stability. Soils at the burned sites exhibited more extensive signs of erosion and higher nutrient levels. Neither of these is surprising. After a fire, it is common for nutrients to become more readily available due to changes in physical properties of soil particles as a result of exposure to heat and subsequent cooling (Neary et al. 2005). Additionally, fire removes or reduces the vegetative and litter layers, exposing soil and increasing the potential for erosion (Neary et al. 2005).

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 LIBI sites in 2009 scored low HDI values in the upper teens and lower twenties, a narrow range, when possible scores range from 1-100. There are at least a few potential reasons to explain this cluster of lower scores. One explanation for the clustering is the small size of LIBI; multiple sites are subjected to the same disturbance (most commonly land use in surrounding area). Scores might be fairly low because the majority of the park is inaccessible to the public. LIBI is a site that preserves and commemorates a significant battle in US history and is largely left undisturbed as a place of cultural significance. Visitors are restricted to the road, a few trails, and to the visitor center area.

One caveat to interpreting 2009 disturbance data is that the data were collected by someone unfamiliar with history of land use at LIBI. This is also 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.

At GRKO, another small, network park, 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. In light of this outcome, we will go through the same exercise at LIBI in the future to compare results.

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 look to see if we have sufficient data to analyze and report on VCSS trends.

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Appendix A

Complete list of species with corresponding lifeform documented at LIBI in 2009. Asterisks denote exotic species. The list does not include unknown species.

Achillea millefolium L. var. *occidentalis* DC.	Perennial forb
Agropyron cristatum (L.) Gaertn.*	Bunch graminoid
Allium cernuum Roth	Perennial forb
Alyssum alyssoides (L.) L.*	Annual forb
Antennaria rosea Greene ssp. *rosea*	Perennial forb
Arnica sororia Greene	Perennial forb
Artemisia cana Pursh	Shrub
Artemisia frigidai Willd.	Shrub
Artemisia ludoviciana Nutt.	Perennial forb
Artemisia tridentate Nutt.	Shrub
Bouteloua curtipendula (Michx.) Torr.	Rhizomatous graminoid
Bromus hordeaceus L.*	Annual graminoid
Bromus inermis Leyss.*	Rhizomatous graminoid
Bromus arvensis L.*	Annual graminoid
Bromus tectorum L.*	Annual graminoid
Calochortus nuttallii Torr. & A. Gray	Perennial forb
Carex filifolia Nutt.	Bunch graminoid
Cirsium arvense (L.) Scop.*	Perennial forb
Collomia linearis Nutt.	Annual forb
Convolvulus arvensis L.*	Perennial forb
Crepis acuminate Nutt.	Perennial forb
Cryptantha torreya (A. Gray) Greene	Annual forb
Descurainia sophia (L.) Webb ex Prantl*	Annual forb
Dianthus armeria L.*	Annual forb
Eleocharis palustris (L.) Roem. & Schult.	Rhizomatous graminoid
Ericameria nauseosa (Pall. Ex Pursh) G.L. Nesom & Baird	Shrub
Gaura coccinea Nutt. Ex Pursh	Perennial forb
Galium aparine L.	Annual forb
Geum triflorum Pursh.	Perennial forb
Gutierrezia sarothrae (Pursh) Britton & Rusby	Shrub
Hesperostipa comata (Trin. & Rupr.) Barkworth	Bunch graminoid

Juniperus scopulorum Sarg.	Tree/Shrub
Koeleria macrantha (Ledeb.) Schult.	Bunch graminoid
Lactuca serriola L.*	Annual forb
Lesquerella montana (A. Gray) S. Watson	Perennial forb
Linum lewisii Pursh	Perennial forb
Lupinus argenteus Pursh	Perennial forb
Maianthemum stellatum (L.) Link	Perennial forb
Medicago lupulina L.*	Biennial
Melilotus officinalis (L.) Lam.*	Biennial
Musineon divaricatum (Pursh) Raf.	Perennial forb
Nassella viridula (Trin.) Barkworth	Bunch graminoid
Opuntia fragilis (Nutt.) Haw.	Shrub
Opuntia polyacantha Haw.	Shrub
Pascopyrum smithii (Rydb.) A. Löve	Rhizomatous graminoid
Phacelia linearis (Pursh) Holz.	Annual forb
Phlox hoodii Richardson	Perennial forb
Poa bulbosa L.*	Bunch graminoid
Poa pratensis L.*	Rhizomatous graminoid
Poa secunda J. Presl	Bunch graminoid
Prunus virginiana L.	Shrub
Pseudoroegneria spicata (Pursh) A. Löve	Bunch graminoid
Rhus trilobata Nutt.	Shrub
Rosa L.	Shrub
Sarcobatus vermiculatus (Hook.) Torr.	Shrub
Silene antirrhina L.	Annual forb
Sisymbrium altissimum L.*	Annual forb
Sphaeralcea coccinea (Nutt.) Rydb.	Perennial forb
Sporobolus airoides (Torr.) Torr.	Bunch graminoid
Symphoricarpos occidentalis Hook.	Shrub
Taraxacum officinale F.H. Wigg.*	Perennial forb
Thlaspi arvense L.*	Annual forb
Thermopsis rhombifolia (Nutt. ex Pursh) Nutt. ex Richardson	Perennial forb
Toxicodendron rydbergii (Small ex Rydb.) Greene	Perennial forb
Tragopogon dubius Scop.*	Annual forb
Veronica arvensis L.*	Annual forb
Vicia americana Muhl. ex Willd.	Perennial forb
Yucca glauca Nutt.	Shrub
Zigadenus elegans Pursh	Perennial forb

Appendix B

List of exotic plant taxa targeted at Little Bighorn Battlefield NM in 2009. These are species that crews searched for, but did not necessarily find.

Common Name	Scientific Name
Russian knapweed /hardhead	*Acroptilon repens*
diffuse knapweed	*Centaurea diffusa*
spotted knapweed	*Centaurea stoebe*
rush skeletonweed	*Chondrilla juncea*
Canada thistle	*Cirsium arvense*
bull thistle	*Cirsium vulgare*
common salsify	*Tragopogon dubius*
common houndstongue	*Cynoglossum officinale*
Russian thistle	*Salsola kali*
prickly Russian thistle	*Salsola tragus*
St.Johnswort	*Hypericum perforatum*
leafy spurge	*Euphorbia esula*
yellow sweet-clover	*Melilotus officinalis*
awnless brome	*Bromus inermis*
downy brome, cheatgrass	*Bromus tectorum*
curly dock	*Rumex crispus*
dalmation toadflax	*Linaria dalmatica*