



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

Data Report 2010-2014

Natural Resource Report NPS/ROMN/NRR—2016/1211



ON THE COVER

Photograph of the field crew monitoring vegetation at Grant-Kohrs Ranch National Historic Site
Photograph courtesy of the National Park Service

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Executive Summary

In 2006, the Rocky Mountain Inventory and Monitoring (I&M) Network began an effort to determine status and trends in upland vegetation structure, species composition, and soil condition (VCSS) at Grant-Kohrs Ranch National Historic Site (NHS). After three pilot years, a set of 32 long-term sites were established in the park using a spatially-balanced probability survey design. We visited a subset of these sites each year to document and better understand the condition of upland vegetation and soils at Grant-Kohrs Ranch NHS. This report presents summary data and information from Rocky Mountain Network monitoring between 2010 and 2014. It is not an in-depth analysis of ecological condition or trend in condition. We focus on simple summaries of sample effort and a few select patterns in specific responses.

Key results include the following:

- Vegetation community composition differed from other public lands in Montana and Wyoming; Network crews found a higher relative cover of graminoids and less forbs and shrubs.
- Native species richness and cover were greater than richness and cover of exotic species. Many exotic species found in Grant-Kohrs Ranch NHS are present for a specific purpose (e.g. smooth brome and meadow foxtail are used for cattle forage) and are not of management concern to the park. However, eight species of exotic invasives from the Montana noxious weed list were found at VCSS sites.
- The low cover of bare soil, high litter cover, and high soil aggregate stability suggest low erosion potential at sites. The highest cover of bare ground was found at non-irrigated upland sites.
- Soil quality was comparable to other published sources. However, copper levels in park soils were high compared to a baseline before historic mining activity. Despite copper levels being on average almost three times the estimated baseline, they are still below Environmental Protection Agency (EPA) and other reported thresholds for plant and soil toxicity.

Scientifically credible information on the current status and long-term trends of the composition, structure, and function of the grasslands in Grant-Kohrs Ranch NHS is a key component for sound management. Rocky Mountain Network upland vegetation and soils monitoring will help park staff understand issues such as the impact of a changing climate on park ecosystems, the response of soils to disturbance, and changes in native and non-native species composition. After two full cycles of our panel design and when ecological site descriptions have been developed by the Natural Resources Conservation Service, we will have sufficient data to determine the ecological condition of vegetation and soils at Grant-Kohrs Ranch NHS. At that point, we can evaluate the monitoring design to ensure it is effective in determining condition and trend in a way that is useful to park management.

Introduction

Grant-Kohrs Ranch National Historic Site (NHS) is a 655 hectare (1,618 acre) park with 90 structures located in western Montana. Established in 1972, the park promotes an understanding of the nation's frontier cattle era, commemorating cowboys and cattlemen through the preservation, interpretation, and operation of an intact ranch with more than 150 years of unbroken history. It is sustained as a working ranch, maintaining roughly 100 animal units (cattle and horses) annually. The Clark Fork River runs through the park and has been designated by the Environmental Protection Agency (EPA) as a Superfund site due to contamination from historic mining and smelting operations upstream at Butte and Anaconda (EPA 2004). The landscape is typical of a mixed-grass prairie grassland with riparian plants along the floodplains and both tall and short grasses in the uplands. Changing climate, exotic invasive species, development, and altered fire and grazing regimes influence vegetation and soils. The natural features and systems of Grant-Kohrs Ranch NHS are managed as an integral part of the cultural landscape commemorating the history of the frontier cattle industry (NPS 2014).

Scientifically credible information on the current status and long-term trends of the composition, structure, and function of the uplands in Grant-Kohrs Ranch NHS is a key component for sound management. In 2006, the Rocky Mountain Inventory & Monitoring

(I&M) Network began an effort to determine status and trends in upland vegetation structure, species composition, and soil condition in the park (Manier et al. 2011). This protocol directly addresses two high priority vital signs in Rocky Mountain Network small parks – vegetation composition, structure, and soils and invasive/exotic plants – and is linked to three other vital signs – landscape dynamics, weather and climate, and wet and dry deposition (Britten et al. 2007). A set of 32 long-term plots were established in the park using a spatially-balanced probability survey design. A subset of these plots was visited each year to help understand the condition of upland vegetation.

This report presents a summary of network sampling at Grant-Kohrs Ranch NHS from 2010-2014. We focus on simple summaries of sample effort and a few select patterns in specific responses. Future reports will include more detail and interpretation, including park-scale estimates of ecological condition, change in select responses and, with sufficient samples, statistical estimates of trend. The pilot years of protocol development (2006-2008) were not included because different methods were still under development and some are not compatible with those used to collect data presented here. Data from the 2009 field season are summarized in Shorrock et al. (2010).

Methods

Manier et al. (2011) provides detailed descriptions of the field and analytical techniques used for monitoring vegetation composition, structure, and soils (VCSS) in Grant-Kohrs Ranch NHS and other Rocky Mountain Network parks. The VCSS protocol used a probability (random) sampling design (Stevens and Olsen 2004) with 32 sample sites (Figure 1) within five soil types. These sites loosely fall within management zones of irrigated pasture/hay fields (15 sites), riparian (8 sites), and non-irrigated upland (9 sites). These management zones roughly delineate which areas of the park are managed for hay production, are along the Clark Fork riparian corridor, and are managed for periodic cattle grazing. There are other easements, in-holdings, and special use permits within park boundaries that are honored as well (NPS 2014). Site groupings were done by park resource management staff based on expert knowledge of land management practices. Note that the study was not designed to group the data in this way and that these are not exact groupings. Nevertheless, we hope that grouping the data in this way will provide a useful context for summarizing findings.

The target resource sampled by the design was all terrestrial vegetation and soil, excluding areas in park-identified sensitive areas (e.g., cultural resources) or developed infrastructure. We visited ten sites each year following a paneled structure that repeats every five years. We revisited a subset of two sites every year to help estimate inter-annual variation. The design also included a large oversample to replace sites determined to be not sampleable or to validly expand the survey in the future. The study design was developed and field methods refined during three pilot years (2006-2008). During this time, plants were identified by their lifeform category, not to the species level. Field methods have been consistent from 2009 to present.

Field crews measured vegetation composition using both transect and plot-based methods. Along three 36-m transects radiating out from site center (Figure 2), crews used a point-intercept method to gather cover information on canopy and surface features. At 0.5-m intervals, the data collector dropped a pin and recorded the species and surface type that touched the pin. These “hits” were later converted into percent cover. Transect sampling is a fairly objective method for estimating cover (Barbour et al. 1987) and can be used for larger areas. In addition to transect-based measures, crews collected data in ten 1-m² plots (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 lower cover species (Elzinga et al. 1998). At these same plots, crew members also documented frequency of each species in nested 0.01-m², 0.1-m², and 1-m² quadrats.

During the first pilot years, plants were not identified to the species level. Rather, they were identified by their lifeform group, such as forb, perennial graminoid, annual graminoid, etc. Beginning in 2009, all plants were identified to the species level. Nomenclature for all vegetation data follow the Integrated Species Taxonomic Information System (www.itis.gov), which can be crosswalked to multiple other nomenclature schemata used in Montana. Life and natural history attributes (i.e., nativity and lifeform) were assigned using the USDA Plants database (USDA, NRCS 2014) and an attribute table was provided by the Colorado Natural Heritage Program (Lemly and Gilligan 2013).

Field methods

Vegetation composition and structure

VCSS sites were sampled during peak vegetation phenology. Crew availability and consistency of timing from one year to the next caused some variation in the date of some sample events (Table 1).

Table 1. Dates of vegetation composition, structure, and soils monitoring from 2010-2014.

Year	Date visited	Core field crew	Sites visited
2010	June 13-25	Asebrook, Hintz	1, 4, 5, 12, 37, 40, 41, 43, 44
2011	June 19-24	Asebrook, Hintz	7, 8, 9, 10, 11, 15, 16, 20, 40, 40
2012	June 17-22	Asebrook, Hintz	14, 15, 16, 17, 18, 19, 21, 22, 24, 27
2013	June 16-20	Asebrook, Hintz	1, 12, 24, 25, 27, 28, 29, 32, 33, 36
2014	June 16-21	Asebrook, Hintz	1, 4, 5, 12, 37, 40, 41, 43, 44, 45

Grant-Kohrs Ranch National Historic Site

Vegetation structure, composition, and soils
Monitoring sites 2010-2014

National Park Service
U.S. Department of the Interior



Legend

Park Boundary

Management Zones

- Irrigated Pasture/HayFields
- No-Irrigated Upland
- Riparian

Map created March 2016. Background
imagery from USDA National Agriculture
Imagery Program, 2013

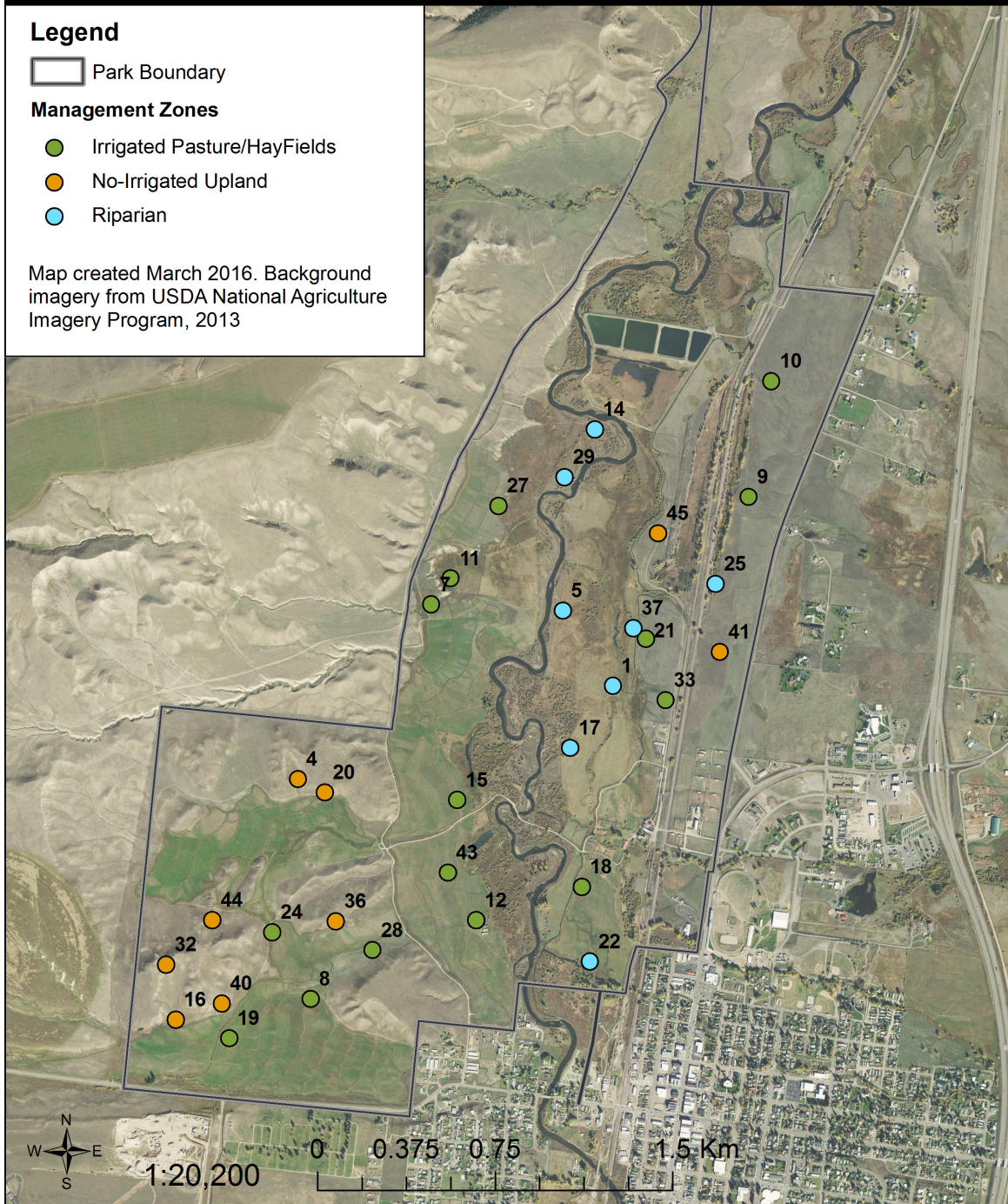


Figure 1. Vegetation composition, structure, and soil sites visited from 2010-2014 at Grant-Kohrs Ranch National Historic Site in each management zone. Numbers next to each site are the site names.

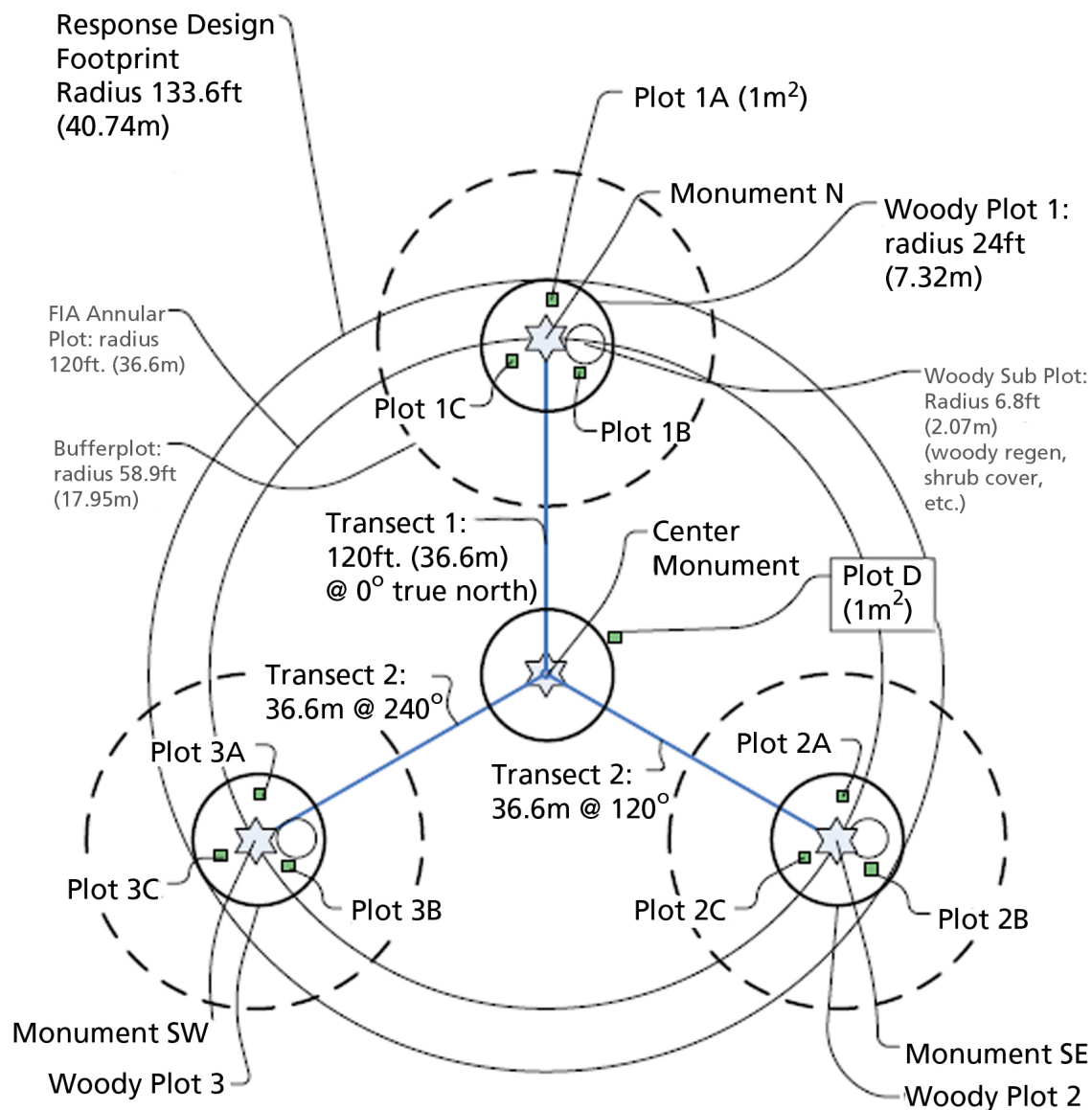


Figure 2. Rocky Mountain Network vegetation composition, structure, and soils (VCSS) plot layout.

Soils

Collection of samples to estimate soil stability (the ability of particles of soil to adhere to each other) and susceptibility to erosion followed Herrick et al. (2005). Crews collected six surface and six subsurface soil samples from each of the three transects (36 total samples) and submerged each in water in a field soil kit. They assigned samples a stability class score based upon the length of time the group of soil particles cohered to one another after immersion. At the site level, crews assessed rills and gullies, pedestals, and evidence of surface flow using ratings ranging from none to extreme.

Crews also collected four, 20-cm deep soil samples along each transect (12 samples/site) for laboratory analyses during the first visit to a new site (Robertson et al. 1999). They combined three samples for chemistry analysis while the fourth sample was kept intact and used to measure bulk density. Soil characteristics measured include pH, cation exchange capacity, total nitrogen and carbon content, and the concentration of mineral nutrients.

We sent soil samples to the Soil, Water and Plant Testing Laboratory at Colorado State University at the close of each field season. This laboratory uses

internal quality control standards that meet or exceed all standards required by the network.

Disturbance and Context

Crews observed and documented disturbance within and surrounding each site. Crew members rated the level of human-caused disturbance by observing features like distance to nearest road, presence of buildings, nativity of vegetation cover in the area surrounding the site, hydrological alterations, and physical disturbance. Crews also evaluated natural disturbance by observing signs of use and/or disturbance from natural processes (e.g., fire or disturbance from rodents). All metrics were later combined into a Human Disturbance Index (HDI) or Natural Disturbance Index (NDI) following a standardized set of algorithms (modified from Rocchio 2007).

Finally, crews recorded site location, a general site description, the dominant aspect/slope, the site's topographic position, and its hydrologic context. Crews also photographed each site following set photo point procedures.

Data management

The goal of Rocky Mountain Network information management is to develop high-quality VCSS datasets according to standards established in the network's Data and Information Management Plan and Standard Operation Procedures (NPS 2007). The data management system that supports the VCSS protocol ensured that all data collected and used in analysis and reporting were subject to quality control verification and validation processes to establish data integrity.

After we digitally compiled and reviewed all monitoring data, we used multiple quality assurance tools to verify the logical consistency of the data. We equipped the VCSS database with a user interface to execute error reports designed to identify missing data and data that are outside conditional ranges of variability. The protocol lead and the data management team collaborated to address each data issue.

All digital data acquired and derived were archived annually according to the procedures and standards in NPS National Data Management Plan and the network Data Management Plan, Rocky Mountain Network SOP: Archive Format Standards for Network Data (NPS 2008, NPS 2007). These archives included monitoring data, data processed in the laboratory,

field sheet scans, and photographs. During the spring of each year, the annual archive of these products was made available through the Integrated Resource Management Applications (IRMA) portal (<https://irma.nps.gov/App/Reference/Profile/2204154>).

Analysis

The sample unit for most analyses was the site (i.e., all subsamples within a site were composited) with data summarized as a mean and its standard deviation across management zones (Figure 1). There was minimal inter-annual variation, enabling us to average across all years. We used plot data to estimate species richness (the mean number of species per site) and the cover of exotic species. We used transect data to estimate lifeform abundance (e.g., relative cover of forbs), species level abundance (e.g., relative cover of *Bromus inermis*), and frequency. We used data from the most recent event (between 2010-2014) to determine the cover of exotic invasive species at each site, as these can change on an annual basis due to active weed management by park staff. Unless otherwise noted, samples sizes were 21 for irrigated pasture/hay sites, 16 for non-irrigated upland sites, and 12 for riparian sites.

For soil aggregate stability, we averaged the 18 surface and 18 sub-surface samples from each site to produce one estimate of stability per site. We used a soil quality index (SQI; Amacher et al. 2007; Equation 1) from the U.S. Forest Service (USFS) to interpret park soil chemistry data. The SQI combines index values for soil chemistry parameters into an overall indicator of soil quality. The original SQI included 19 parameters while the network treatment included 14. The index accounts for the fact that not all 19 parameters may be measured, so missing properties do not contribute to the index. Though it is not recommended to use this index if only a few measured properties are included (Amacher et al. 2007), this index was developed to account for several missing parameters, as is the case here. Each soil parameter was assigned an index value based on whether the level of each

$$SQI = \frac{\sum \text{individual soil index values}}{\text{maximum index values possible for properties measured}} \times 100$$

Equation 1. The USFS soil quality index (SQI; Amacher et al. 2007).

parameter was at, above, or below what was deemed ideal by expert opinion. For example, an optimal soil pH level between 5.51 and 7.2 would receive the highest possible index value while levels above or below that threshold would receive a lower index value. See Amacher et al. (2007) for a more detailed rationale for soil property threshold levels. Crews did not take soil samples in 2013 and we do not have a complete suite of soil parameters from each site or even each management zone. Given these missing data, the SQI was summarized across all sites.

Assessment

All results and their assessment in this report apply only to the specific sites sampled (or the mean of these sites within management zones). While we minimize

involved interpretation in this report, where possible we qualitatively compare results to other published sources (Amacher et al. 2007; Bird et al. 2007; EPA 2007; Bestelmeyer et al. 2006; Moore et al. 2002; Moore and Woessner 2001; Stohlgren et al. 1999; Brady and Weill 1996). Future reports will include design-based methods that statistically infer responses at a site to the entirety of sampleable upland vegetation and soils at Grant-Kohrs Ranch NHS. Future reports will also include other metrics and more involved interpretation in the context of expected ecological reference conditions and resource management needs of the park.

Results

Vegetation composition and structure

Between 2010 and 2014, field crews identified 207 vascular plant species (56 of which were exotic). Of these, 130 were forbs, 56 were graminoids (grasses, sedges, and rushes), 19 were shrubs, one was a tree, and one a vine (Appendix A).

Graminoids were on average the lifeform with the highest percent relative cover in all management zones with a mean relative cover across all years of 88.7% (standard deviation of 7.8). Forbs had a mean cover of 10.1% (7.9), shrubs had a mean cover of 2.4% (1.5), and trees and vines had covers of less than 1% (Figure 3).

The most abundant species found at irrigated pasture/hay field sites across all years were *Poa pratensis* (Kentucky bluegrass) with a mean cover of 34.5% (14.0), *Elymus repens* (quackgrass) at 24.9% (7.6), and

Bromus inermis (smooth brome) at 24.0% (16.2). The most abundant species found at non-irrigated upland sites were *Hesperostipa comata* (needle and thread) at 25.6% (10.3), *Pseudoroegneria spicata* (bluebunch wheatgrass) at 17.7% (13.1), and *Bromus tectorum* (cheatgrass) at 11.5% (12.8). The most abundant species found in riparian sites were *Poa pratensis* at 22.2% (6.6), *Juncus balticus* (Baltic rush) at 17.0% (8.0), and *Elymus repens* at 14.2% (9.7; Table 2).

Community composition included a mixture of native and exotic plants. Mean native species richness in irrigated pasture/hay field sites was 8.6 (5.1), in non-irrigated upland sites was 20.9 (5.8), and in riparian sites was 21.5 (5.2) across all years. Mean non-native species richness in irrigated pasture/hay field sites was 7.8 (3.2), in non-irrigated upland sites was 5.7 (2.4), and in riparian sites was 6.9 (2.2) across all years. Non-native species richness

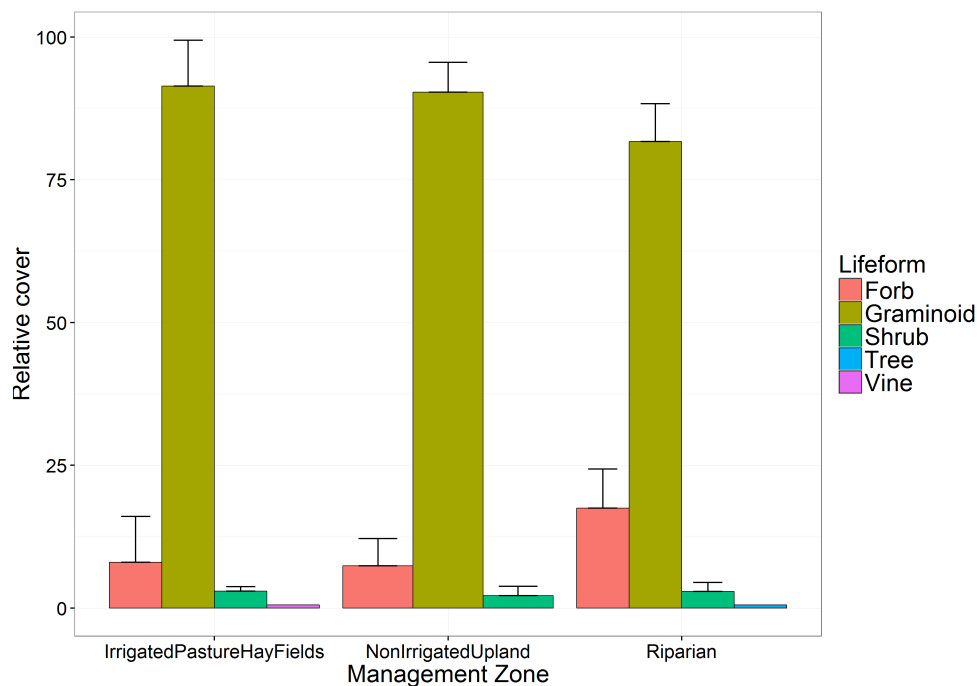


Figure 3. Mean relative cover and standard deviation of vascular plant species by life-form for each management zone (irrigated pasture/hay field, non-irrigated upland, and riparian) between 2010-2014 with forbs (red), graminoids (olive green), shrubs (bright green), trees (blue), and vines (purple). Sample sizes were 21 for irrigated pasture/hay sites, 16 for non-irrigated upland sites, and 12 for riparian sites.

Table 2. The ten most abundant species found in transects averaged over all sites for each management zone from 2010-2014. The mean frequency of each species is also shown. A standard deviation (SD) of "NA" indicates that species was found at only one site.

Management zone	Scientific name	Common name	Cover mean (%)	Cover SD (%)	Frequency mean (%)	Frequency SD (%)
Irrigated Pasture/Hay Field	<i>Poa pratensis</i> *	Kentucky bluegrass*	34.5	14.0	74.5	23.4
Irrigated Pasture/Hay Field	<i>Elymus repens</i> *	Quackgrass*	24.9	7.6	81.4	17.2
Irrigated Pasture/Hay Field	<i>Bromus inermis</i> *	Smooth brome*	24.0	16.2	64.3	20.7
Irrigated Pasture/Hay Field	<i>Carex simulata</i>	Analogue sedge	19.4	NA	41.5	44.5
Irrigated Pasture/Hay Field	<i>Alopecurus pratensis</i> *	Meadow foxtail*	10.2	9.9	31.7	34.3
Irrigated Pasture/Hay Field	<i>Carex duriuscula</i>	Needleleaf sedge	8.3	10.3	45.8	34.4
Irrigated Pasture/Hay Field	<i>Trifolium pratense</i> *	Red clover*	5.7	5.3	32.8	23.4
Irrigated Pasture/Hay Field	<i>Koeleria macrantha</i>	Prairie Junegrass	5.4	1.2	16.2	12.6
Irrigated Pasture/Hay Field	<i>Carex praegracilis</i>	Clustered field sedge	4.5	5.7	18.6	11.8
Irrigated Pasture/Hay Field	<i>Hesperostipa comata</i>	Needle and thread	4.5	4.1	34.2	19.2
Non-Irrigated Upland	<i>Hesperostipa comata</i>	Needle and thread	25.6	10.3	50.6	9.6
Non-Irrigated Upland	<i>Pseudoroegneria spicata</i>	Bluebunch wheatgrass	17.7	13.1	38.7	32.6
Non-Irrigated Upland	<i>Bromus tectorum</i> * [◊]	Cheatgrass* [◊]	11.5	12.8	36.6	22.2
Non-Irrigated Upland	<i>Pascopyrum smithii</i>	Western wheatgrass	10.9	8.3	46.6	27.1
Non-Irrigated Upland	<i>Festuca campestris</i>	Rough fescue	9.5	6.9	15.4	10.7
Non-Irrigated Upland	<i>Agropyron cristatum</i> *	Crested wheatgrass*	9.2	8.9	15.0	11.3
Non-Irrigated Upland	<i>Koeleria macrantha</i>	Prairie Junegrass	7.9	10.0	39.1	32.2
Non-Irrigated Upland	<i>Carex duriuscula</i>	Needleleaf sedge	7.8	5.8	48.7	21.2
Non-Irrigated Upland	<i>Poa secunda</i>	Sandberg bluegrass	6.5	5.6	32.9	18.0
Non-Irrigated Upland	<i>Carex douglasii</i>	Douglas' sedge	4.2	4.6	37.4	27.7
Riparian	<i>Poa pratensis</i> *	Kentucky bluegrass*	22.2	6.6	69.6	27.0
Riparian	<i>Juncus balticus</i>	Baltic rush	17.0	8.0	63.6	28.7
Riparian	<i>Elymus repens</i> *	Quackgrass*	14.2	9.7	73.6	18.9
Riparian	<i>Bromus tectorum</i> * [◊]	Cheatgrass* [◊]	14.1	NA	35.0	45.3
Riparian	<i>Pseudoroegneria spicata</i>	Bluebunch wheatgrass	12.6	NA	43.0	NA
Riparian	<i>Schedonorus pratensis</i> *	Meadow fescue*	9.7	NA	53.0	NA
Riparian	<i>Trifolium hybridum</i> *	Alsike clover*	8.3	4.9	22.2	12.3
Riparian	<i>Bromus inermis</i> *	Smooth brome*	7.8	6.0	36.3	23.8
Riparian	<i>Carex praegracilis</i>	Clustered field sedge	6.6	4.8	43.6	18.8
Riparian	<i>Pascopyrum smithii</i>	Western wheatgrass	4.9	NA	23.5	23.3

* Exotic species.

◊ Exotic species that are considered detrimental to resource management goals.

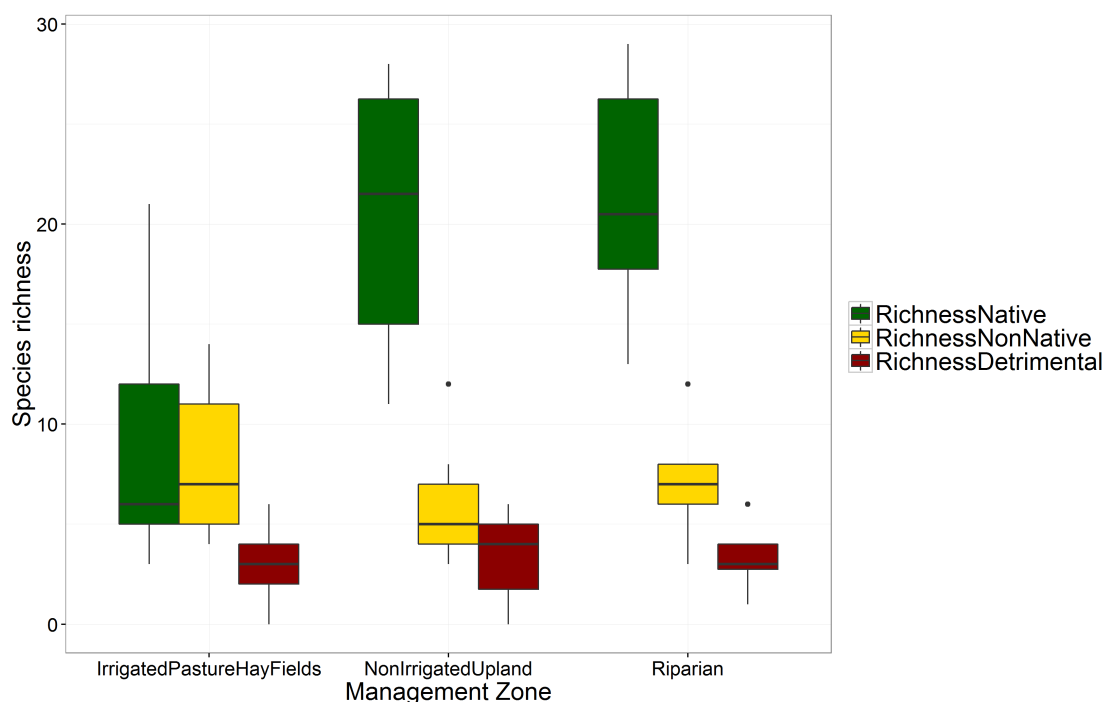


Figure 4. Native (green), non-native (yellow), and non-native and considered detrimental by the park (red) plant species richness by management zone, 2010-2014. Horizontal lines within each box represent the median; boxes extend to the upper 75th and lower 25th quartile. Vertical lines extend to the maximum and minimum observed values. Dots represent outliers. Sample sizes for irrigated pasture/hay sites was 21, for non-irrigated upland sites was 16, and for riparian was 12.

considered detrimental by the park was 2.9 (1.6) in irrigated pasture/hay fields, 3.5 (1.9) in non-irrigated pasture sites, and 3.1 (1.4) in riparian areas (Figure 4). The exotic species with the highest relative cover across all sites were *Poa pratensis* at 23.4% (16.4), *Elymus repens* at 18.2% (11.2), and *Bromus inermis* at 16.6% (15.6), none of which are considered detrimental to resource management goals.

Crews identified eight species found on the Montana noxious weeds list (Figure 5). Listed as priority 2A (common in isolated areas of Montana) was *Lepidium latifolium* (broadleaved pepperweed), found in trace amounts at three sites. Listed as priority 2B (abundant in Montana) with relative covers of less than 2% were *Euphorbia esula* (leafy spurge) found at three sites, *Centaurea stoebe* (spotted knapweed) found at five sites, *Linaria vulgaris* (yellow toadflax) found at one site, and *Cardaria draba* (whitetop) found at three sites. Also listed as priority 2B were *Convolvulus arvensis* (field bindweed) at seven sites with a relative cover of 0.13-5.68% and *Cirsium arvense* (Canada thistle) found at 13 sites with a relative cover of 0.15-12.21%. Listed as priority 3 (not noxious, but has the

potential to have significant negative economic and ecological impacts) was *Bromus tectorum* found at 15 sites with a relative cover of 0.05-50% (Figure 5). See Appendix B for a full table of these exotic invasive species and their relative covers as well as a description of each priority class.

Anthropogenic and natural disturbance

Crews collected both natural and anthropogenic disturbance data each year (Table 3). Scores for both indices range from 0 to 100; lower scores signify less

Table 3. Mean and standard deviation (SD) for the Human Disturbance Index (HDI) and Natural Disturbance Index (NDI) for each management zone, 2010-2014.

Management Zone	HDI		NDI	
	Mean	SD	Mean	SD
Irrigated Pasture/Hay Fields	70.9	14.4	7.4	4.8
Non-irrigated Upland	46.5	16.4	9.7	5.7
Riparian	56.3	13.5	15.4	2.6

Grant-Kohrs Ranch National Historic Site

Cover of select invasive species at VCSS sites 2010-2014

National Park Service
U.S. Department of the Interior

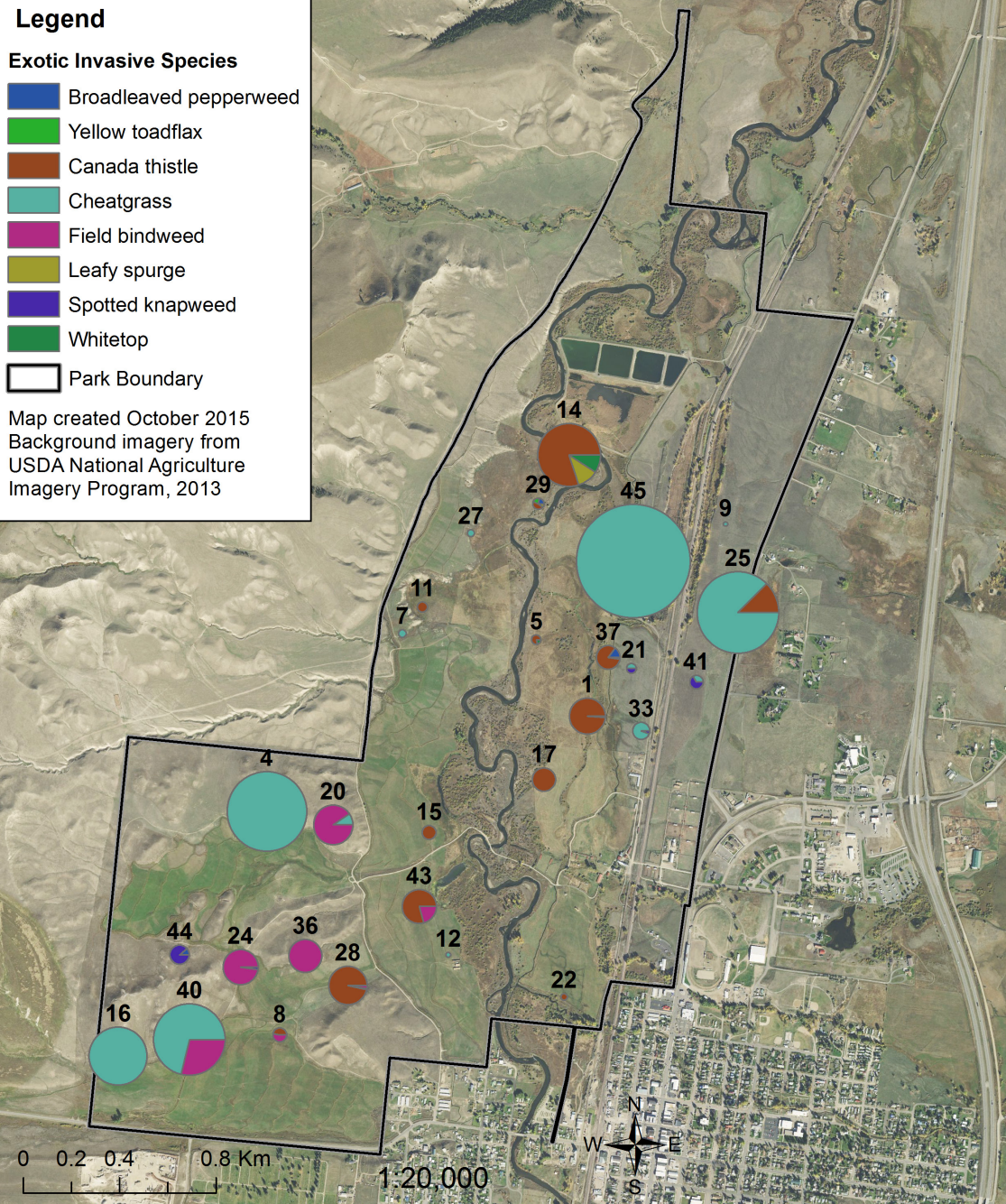


Figure 5. Relative cover of select exotic invasive species at sites 2010-2014; broadleaved pepperweed (*Lepidium latifolium*; blue), yellow toadflax (*Linaria vulgaris*; green), Canada thistle (*Cirsium arvense*; brown), cheatgrass (*Bromus tectorum*; teal), field bindweed (*Convolvulus arvensis*; pink), leafy spurge (*Euphorbia esula*; olive), spotted knapweed (*Centaurea stoebe*; purple), and whitetop (*Cardaria draba*; dark green). The size of each circle represents the relative abundance of exotic invasive species compared to other sites. To prevent overlap the location of some sites is shifted slightly. Numbers above each site are site names. Where sites had been visited more than once, data from the most recent visit (between 2010-2014) was used. See Appendix B for a full table of these exotic invasive species and their relative covers.

disturbance. NDI scores were low, relative to its scale, and HDI scores showed a moderately high level of human disturbance (Table 3).

Erosion potential and soil chemistry

Erosion potential is, in part, a function of soil aggregate stability (or the ability of particles of soil to adhere to each other) and the percent cover of bare ground. We used modified methods from Herrick et al. (2005) to create a soil aggregate stability metric. The metric ranges from 1 to 6, with lower values indicating lower stability. Mean surface soil aggregate stability was 5.0 (0.8) across all management zones. Mean subsurface soil aggregate stability was 4.4 (0.9) across all management zones (Table 4). The mean cover of litter across all years for irrigated pasture/hay field sites was 81.9%

Table 4. Soil aggregate stability mean and standard deviation (SD) for surface and sub-surface soil samples for each management zone, 2010-2014. Index ranges from 1 to 6 with lower numbers indicating lower soil stability.

Management Zone	Surface Stability		Sub-surface Stability	
	Mean	SD	Mean	SD
Irrigated Pasture/Hay Fields	5.0	0.9	4.7	0.8
Non-irrigated Upland	4.9	0.6	3.7	0.5
Riparian	5.0	1.1	5.0	1.0

(15.3), for non-irrigated uplands was 52.5% (15.9), and for riparian sites was 84.2% (11.8; Table 5). The mean cover of bare soil for irrigated pasture/hay field sites was 6.3% (6.7), for non-irrigated uplands was 21.8% (7.8), and for riparian sites was 4.2% (7.3; Table 5).

Table 5. Mean percent cover with standard deviation (SD) of bare ground and litter for each management zone, 2010-2014.

Management Zone	Bare Ground Cover (%)		Litter Cover (%)	
	Mean	SD	Mean	SD
Irrigated Pasture/Hay Fields	6.3	6.7	81.9	15.3
Non-irrigated Upland	21.8	7.8	52.5	15.9
Riparian	4.2	7.3	84.2	11.8

Using the soil quality index developed by the USFS, the overall soil quality index at Grant-Kohrs Ranch NHS between 2010 and 2014 was 14 out of 21 possible points, or 67% (Table 6; Amacher et al. 2007). This index is a percentage of 100, with lower values indicating lower soil quality. Copper levels ranged from 22.6 mg/kg at site 7 to 101.8 mg/kg at site 15, with a mean of 44.96 mg/kg (32.29; Figure 6).

Table 6. Mean soil parameters with standard deviation across all sites and years 2010-2014 (not summarized by year or site type, see text). Index value was assigned based on whether the level of each parameter was at, above, or below what was deemed ideal by expert opinion. For a full list of potential index values and interpretation, see Amacher et al. 2007. Sample size ~18.

Parameter	Mean	Standard deviation	Level	Interpretation	Index value	Maximum index value
Aluminum (mg/kg)	3.70	3.69	1 to 10	Low - adverse effects unlikely	2	2
Bulk Density (g/cm ³)	1.13	0.16	≤ 1.5	Adverse effects unlikely	1	1
Calcium (mg/kg)	2919.64	1264.32	>1000	High - excellent reserve, probably calcareous soil	2	2
Cation Exchange Capacity (meq/100g)	20.00	7.77	> 15	High – sodic soil with associated problems	0	1
Copper (mg/kg)	44.96	32.29	>1	High – possible toxicity to Cu sensitive plants, may indicate mining areas or industrial sources of Cu	0	1
Iron (mg/kg)	16.04	7.83	> 10	High – effects unknown	1	1
Potassium (mg/kg)	335.04	178.17	100 to 500	Moderate - adequate levels for most plants	1	2
Magnesium (mg/kg)	336.09	183.75	50 to 500	Moderate - adequate levels for most plants	1	2
Manganese (mg/kg)	2.36	1.47	1 to 10	Low – adverse effects unlikely, possible deficiencies	1	1
pH	6.97	0.43	6.81 to 7.2	Near neutral – optimum for many plant species except those that prefer acid soils	2	2
Soil sulfur (mg/kg)	73.00	85.16	1 to 100	Moderate - adverse effects unlikely	1	1
Zinc (mg/kg)	45.07	55.15	>10	High – possible toxicity to zinc sensitive plants, may indicate mining areas or industrial sources of zinc	0	1
Total Carbon (%)	3.52	3.36	1 to 5	Moderate - adequate levels	1	2
Total Nitrogen (%)	0.36	0.41	0.1 to 0.5	Moderate - adequate levels	1	2
Sum of index values					14	21
SQI (%)					67	

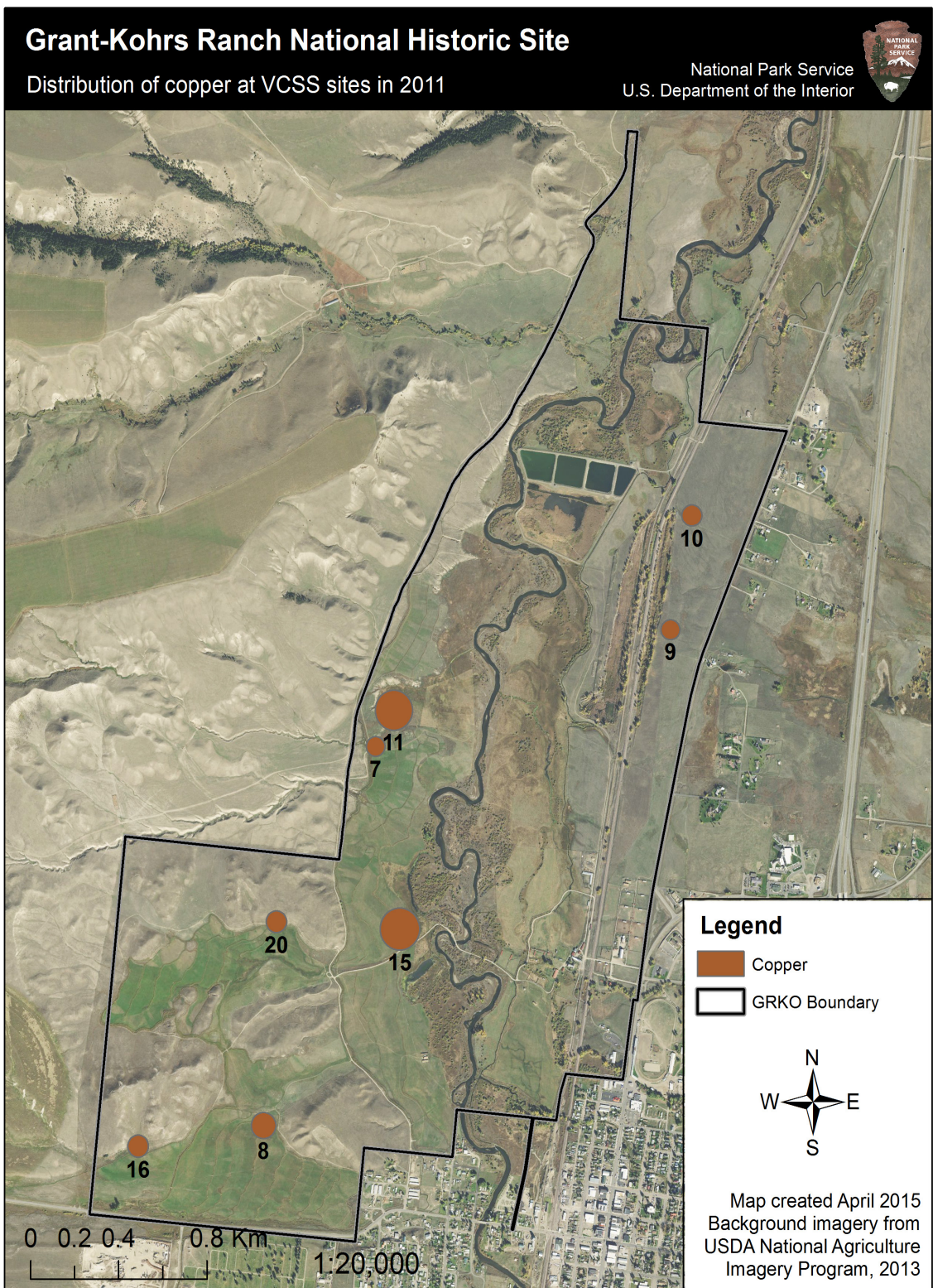


Figure 6. Relative distribution of copper measured in 2011. The size of each circle represents the relative amount of copper compared to other sites. Values ranged from 22.6 mg/kg at site 7 to 101.75 mg/kg at site 15, with a mean of 44.96 mg/kg.

Discussion

The results presented here comprise a data summary report of monitoring data for Rocky Mountain Network VCSS at Grant-Kohrs Ranch NHS. We present simple comparisons of a few vegetation and soil indicators with other published information for the region to provide context. This is not a thorough analysis of the condition of park vegetation and soils and our results and interpretation are provisional. After two full cycles of our panel design and when ecological site descriptions have been developed by the Natural Resources Conservation Service, we will have sufficient data to determine the ecological condition of vegetation and soils at the park.

Shrub and herbaceous vegetation

Plant structure differed from other public lands in Montana and Wyoming, based on a study of both grazed and ungrazed (though not managed for hay production) grasslands in Colorado, Wyoming, Montana, and South Dakota (Stohlgren et al. 1999). Network crews found a higher relative cover of graminoids and less forbs and shrubs. Possible explanations for the abundance of graminoids are the encouragement of grass species for haying or the success of some invasive grass species favored by drought. The lowest median native richness was in pasture/hay fields, with higher medians in riparian and upland pasture sites (Figure 4). This pattern is not surprising given how pasture/hay fields are managed for specific plant species suitable for haying.

Though native species richness and cover were greater than richness and cover of exotic species, there was a considerable presence of exotics. Many widespread exotic species found are present for specific purposes (e.g. smooth brome and meadow foxtail used as cattle forage) and are not of management concern to the park. There were however eight species of exotic invasives from the Montana noxious weed list found in varying degrees at plots. Two of the more widespread of these exotic invasives were *Cirsium arvense* and *Bromus tectorum* (Figure 5). Cheatgrass is not considered noxious by the state of Montana, but rather is a regulated species due to its potential to cause significant impacts. It is an annual grass that grows quickly early in the growing season, outcompeting native species and forming invasive monocultures (Harris 1967, Vasquez et al. 2008). It can also

shift plant community composition from a perennial to an annual grass driven system (Vasquez et al. 2008). Cattle will utilize cheatgrass early in the spring when it is green and before it turns purple. Livestock grazing of cheatgrass must be intensively managed to avoid damage to desirable perennial plant species. The period that cheatgrass is palatable and nutritious for herbivore consumption is considerably shorter than for most native herbaceous plants (Klemmedson and Smith 1964). Canada thistle is listed as priority 2B, meaning it should be eradicated or contained where less abundant (Table B2). It spreads quickly through horizontal roots (Moore 1975) and can limit forage (Grekul and Bork 2004). Recent active weed management at Grant-Kohrs Ranch NHS may be helping keep noxious weed abundance low; continued weed management will be needed to limit the effects of exotic invasive species.

Disturbance

Natural disturbance index (NDI) scores were low (relative to its scale); the most common sources of natural disturbance were herbivory and rodent activity, with some evidence of old beaver activity nearby. Human disturbance index (HDI) scores indicate a moderately high degree of human disturbance in or near Grant-Kohrs Ranch NHS sites (Table 4). Human disturbance was mainly due to the presence of grazing, haying, and hydrological alterations, all common aspects of an operating ranch. The clustering of disturbance scores can be explained by the small size of the park; multiple sites are subjected to the same disturbance (most commonly land use in the surrounding area).

One caveat to interpreting disturbance data is that the data were collected by crews unfamiliar with the history of land use at the park. 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. Additionally, we have not rigorously tested the NDI to see if it appropriately captures the effect of natural disturbance on the landscape or if it is confounded by HDI and its component metrics.

Soil and erosion potential

The low cover of bare soil, high litter cover, and high soil aggregate stability suggest low erosion potential. The relatively high soil aggregate stability (Bird et al. 2007 and Bestelmeyer et al. 2006) could be associated with the high cover of litter at monitoring sites (Table 5). The presence of litter provides material for soil building and moisture retention and can lower the level of soil compaction (O'Neill et al. 2005). The less vegetated upland pasture sites had the highest bare ground cover and could be more susceptible to erosion.

Despite high levels of copper, soil quality was comparable to another published source. The soil quality index at Grant-Kohrs Ranch NHS was 67% (Table 7), compared to a mean of 66% in Forest Service plots in the Interior West between 2000 and 2004 (Amacher et al. 2007). Bulk density across all sites was 1.1, which is in the expected range of 0.9-1.6 for cultivated clay and silt loam soils (Brady and Weill 1996). However, copper levels were high compared to the baseline before historic mining activity. The

pre-mining baseline representing natural levels of copper, determined by taking deep (up to 120 cm) soil cores to test older layers of soil, was estimated to be 16 mg/kg (Moore and Woessner 2001). Copper at all Rocky Mountain Network sites was above this baseline, with a mean of 44.96 mg/kg (Table 7; Figure 6). Copper toxicity thresholds in the literature vary. The toxicity threshold for plants is between 60-150 mg/kg as reported by Moore et al. (2002). The EPA sets a threshold of 95 mg/kg, below which levels are intended to be safe for soils (EPA 2007). Copper levels found at network sites were below both of these thresholds. Given the mining history upstream and the designation of sections of the Clark Fork River as a Superfund site (EPA 2004), high levels of certain metals are not unexpected. High copper at sites near the floodplain are likely from hydrologic deposition while atmospheric deposition likely contributed to levels in upland pasture sites. Copper levels measured by network crews in 2011 were lower than found in 2001 (Moore and Woessner 2001) and may decrease more at Rocky Mountain Network sites on the floodplain with planned remediation.

Conclusion

Further monitoring of Rocky Mountain Network upland vegetation and soils will continue to help Grant-Kohrs Ranch NHS staff understand park-wide vegetation and soils relative to issues such as climate change, herbivory, disturbances such as fire or superfund remediation, and change in cover or abundance

of exotic invasive species. As more data are collected over the next several years and we complete two cycles of the panel design, it may be possible to recognize patterns and trends that could indicate a change in the ecological integrity of park vegetation and soil.

Literature Cited

- Amacher, M. C., K. P. O'Neil, and C. H. Perry. 2007. Soil vital signs: A new soil quality index (SQI) for assessing forest soil health. Res. Pap. RMRS-RP-65WW. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado.
- Barbour, M. G., J. H. Burk, and W. D. Pitts. 1987. Terrestrial plant ecology. The Benjamin/Cummings Publishing Company, Inc. Menlo Park, California.
- Bestelmeyer, B. T., J. P. Ward, J. E. Herrick, and A. J. Tugel. 2006. Fragmentation effects on soil aggregate stability in a patchy arid grassland. *Rangeland Ecology & Management* 59(4):406-415.
- Bird, S. B., J. E. Herrick, M. M. Wander, and L. Murray. 2007. Multi-scale variability in soil aggregate stability: Implications for understanding and predicting semi-arid grassland degradation. *Geoderma* 140:106-118.
- Brady, N. C. and R. R. Weil. 1996. The nature and properties of soils. Prentice-Hall Inc., Upper Saddle River, New Jersey.
- Britten, N., E. W. Schweiger, B. Frakes, D. Manier, and D. Pilmore. 2007. Rocky Mountain Network vital signs monitoring plan. Natural Resource Report NPS/ROMN/NRR—2007/010. National Park Service, Fort Collins, Colorado.
- Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Measuring & monitoring plant populations. BLM Technical Reference 1730-1. Bureau of Land Management, Denver, Colorado.
- Environmental Protection Agency (EPA) 2007. Ecological soil screening levels for copper: Interim final. 2007. U.S. Environmental Protection Agency. OSWER Directive 9285.7-68. Washington, D.C.
- Environmental Protection Agency (EPA) 2004. Superfund program revised proposed clean-up plan: Milltown Reservoir sediments operable unit of the Milltown Reservoir/Clark Fork River Superfund Site (Revised Proposed Plan). May.
- Grekul, C. W. and E. W. Bork. 2004. Herbage yield losses in perennial pasture due to Canada thistle (*Cirsium arvense*). *Weed Technology* 18(3):784-794.
- Harris, G. A. 1967. Some competitive relationships between *Agropyron spicatum* and *Bromus tectorum*. *Ecological Monographs*. 37:89-111.
- 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. Volume 2 USDA-ARS Jornada Experimental Range, Las Cruces, New Mexico and University of Arizona Press, Tucson, Arizona. Available at: <http://usda-ars.nmsu.edu/>.
- Klemmedson, J. O. and J. G. Smith. 1964. Cheatgrass (*Bromus tectorum*). *Botanical Review* 30:226-262.
- Lemly, J. and L. Gilligan. 2013. Ecological integrity assessment (EIA) for Colorado wetlands field manual, version 1.0 – REVIEW DRAFT. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.
- Manier, D., D. Shorrock, E. W. Schweiger, I. Ashton, B. Frakes, M. Britten, D. Pilmore, and J. Burke. 2011. Rocky Mountain Network vegetation composition structure and soils monitoring protocol: Small park grasslands, shrublands, and woodlands, version 1.0. Natural Resource Report NPS/ROMN/NRR—2011/383. National Park Service, Fort Collins, Colorado.
- Moore, R. J. 1975. The biology of Canadian weeds: 13. *Cirsium arvense* (L.) Scop. *Canadian Journal of Plant Science* 55(4):1033-1048.
- Moore, J. N. and W. W. Woessner. 2001. Geologic, soil water and groundwater report – 2000 Grant-Kohrs Ranch National Historic Site. National Park Service, Department of the Interior.
- Moore, J., W. Woessner, J. Gannon, M. Rillig, P. Rice, D. Bedunah, and L. Kapustka. 2002. Natural resource injury report on riparian areas of the Bureau of Land Management within the Clark Fork River Basin, Montana. National Park Service. Missoula, Montana.

- National Park Service – Rocky Mountain Network (NPS). 2007. Data and information management plan, version 1.0, Rocky Mountain Network. Published Report – 2184222. National Park Service, Fort Collins, Colorado.
- National Park Service (NPS). 2008. Data management guidelines for inventory and monitoring networks. Natural Resource Report NPS/NRPC/NRR—2008/035. National Park Service, Fort Collins, Colorado.
- National Park Service (NPS). 2014. Foundation document Grant-Kohrs Ranch National Historic Site. U.S. Department of the Interior. GRKO451/124638.
- O'Neill, K. P., M. C. Amacher, and C. H. Perry. 2005. Soils as an indicator of forest health: A guide to the collection, analysis, and interpretation of soil indicator data in the Forest Inventory and Analysis program. Gen. Tech. Rep. NC-258. U.S. Department of Agriculture, Forest Service, North Central Research Station, St. Paul, Minnesota.
- Robertson, G. P., P. Sollins, B. G. Ellis, K. Lajtha. 1999. Exchangeable ions, pH, and cation exchange capacity. Pages 106-114 *in* G.P. Robertson, ed., Standard soil methods for long-term ecological research. Oxford University Press. Cary, North Carolina.
- 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.
- 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.
- Stevens Jr., D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. *J. Am. Stat. Assoc.* 99:262-278.
- 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.
- U.S. Department of Agriculture, Natural Resource Conservation Service (USDA, NRCS). 2014. The PLANTS database. National Plant Data Team, Greensboro, North Carolina. 27401-490. Available at <http://plants.usda.gov>.
- Vasquez, E., R. Sheley, and T. Svejcar. 2008. Nitrogen enhances the competitive ability of cheatgrass (*Bromus tectorum*) relative to native grasses. *Invasive Plant Science and Management* 1(3):287-295.

Appendix A

Species List

Table A1. List of 207 vascular plant species found in sites between 2010 and 2014 samplings seasons. Only plants identified to the species level are included.

Scientific name	Common name
Forbs	
<i>Achillea millefolium</i> var. <i>occidentalis</i>	western yarrow
<i>Allium cernuum</i>	nodding onion
<i>Allium schoenoprasum</i>	wild chives
<i>Allium textile</i>	textile onion
<i>Alyssum alyssoides</i> *	pale madwort*
<i>Alyssum desertorum</i> *	desert madwort*
<i>Androsace occidentalis</i>	western rockjasmine
<i>Androsace septentrionalis</i>	pygmyflower rockjasmine
<i>Angelica arguta</i>	Lyall's angelica
<i>Arabis holboellii</i> var. <i>retrofracta</i>	second rockcress
<i>Arenaria capillaris</i>	slender mountain sandwort
<i>Arenaria congesta</i>	ballhead sandwort
<i>Argentina anserina</i>	silverweed cinquefoil
<i>Artemisia ludoviciana</i>	white sagebrush
<i>Astragalus laxmannii</i> var. <i>robustior</i>	prairie milkvetch
<i>Astragalus purshii</i>	woollypod milkvetch
<i>Callitriche hermaphroditica</i>	northern water-starwort
<i>Camelina microcarpa</i> *	littlepod false flax*
<i>Campanula rotundifolia</i>	bluebell bellflower
<i>Capsella bursa-pastoris</i> *	shepherd's purse*
<i>Cardaria draba</i> *	whitetop*
<i>Centaurea macrocephala</i> *	bighead knapweed*
<i>Centaurea stoebe</i> *	spotted knapweed*
<i>Centaurea stoebe</i> ssp. <i>micranthos</i> *	spotted knapweed*
<i>Cerastium fontanum</i> *	common mouse-ear chickweed*
<i>Chenopodium album</i> *	lambsquarters*
<i>Chenopodium leptophyllum</i>	narrowleaf goosefoot
<i>Cirsium arvense</i> *	Canada thistle*
<i>Cirsium flodmanii</i>	Flodman's thistle
<i>Cirsium undulatum</i>	wavyleaf thistle
<i>Convolvulus arvensis</i> *	field bindweed*
<i>Crepis runcinata</i>	fiddleleaf hawksbeard
<i>Descurainia sophia</i> *	herb sophia*
<i>Dodecatheon pulchellum</i>	darkthroat shootingstar
<i>Draba nemorosa</i> *	woodland draba*
<i>Draba verna</i> *	spring draba*
<i>Epilobium ciliatum</i>	fringed willowherb

* Non-native species (Total of 56)

Table A1. List of 207 vascular plant species found in sites between 2010 and 2014 samplings seasons. Only plants identified to the species level are included, cont.

Scientific name	Common name
Forbs cont.	
<i>Epilobium minutum</i>	chaparral willowherb
<i>Epilobium palustre</i>	marsh willowherb
<i>Equisetum arvense</i>	field horsetail
<i>Equisetum laevigatum</i>	smooth horsetail
<i>Erigeron pumilus</i>	shaggy fleabane
<i>Erysimum inconspicuum</i>	shy wallflower
<i>Euphorbia esula</i> var. <i>uralensis</i> *	Russian leafy spurge*
<i>Eurybia integrifolia</i>	thickstem aster
<i>Galium boreale</i>	northern bedstraw
<i>Gaura coccinea</i>	scarlet beeblossom
<i>Geranium viscosissimum</i>	sticky purple geranium
<i>Geum macrophyllum</i>	largeleaf avens
<i>Glycyrrhiza lepidota</i>	American licorice
<i>Gypsophila paniculata</i> *	baby's breath*
<i>Helianthus annuus</i>	common sunflower
<i>Heterotheca villosa</i>	hairy false goldenaster
<i>Heuchera parvifolia</i>	littleleaf alumroot
<i>Hippuris vulgaris</i>	common mare's-tail
<i>Ionactis alpina</i>	Lava aster
<i>Iris missouriensis</i>	Rocky Mountain iris
<i>Lactuca serriola</i> *	prickly lettuce*
<i>Lappula occidentalis</i> var. <i>occidentalis</i>	flatspine stickseed
<i>Lepidium densiflorum</i> *	common pepperweed*
<i>Lepidium latifolium</i> *	broadleaved pepperweed*
<i>Lepidium perfoliatum</i> *	clasping pepperweed*
<i>Lesquerella alpine</i>	alpine bladderpod
<i>Lewisia rediviva</i>	bitter root
<i>Linaria vulgaris</i> *	butter and eggs*
<i>Logfia arvensis</i> *	field cottonrose*
<i>Lupinus sericeus</i>	silky lupine
<i>Lygodesmia juncea</i>	rush skeletonplant
<i>Maianthemum stellatum</i>	starry false lily of the valley
<i>Medicago lupulina</i> *	black medick*
<i>Medicago sativa</i> *	alfalfa*
<i>Melilotus officinalis</i> *	yellow sweetclover*
<i>Mentha arvensis</i>	wild mint
<i>Mertensia oblongifolia</i>	oblongleaf bluebells
<i>Microsteris gracilis</i>	slender phlox
<i>Monolepis nuttalliana</i>	Nuttall's povertyweed
<i>Musineon divaricatum</i>	leafy wildparsley
<i>Myosotis verna</i>	spring forget-me-not

* Non-native species (Total of 56)

Table A1. List of 207 vascular plant species found in sites between 2010 and 2014 samplings seasons. Only plants identified to the species level are included, cont.

Scientific name	Common name
Forbs cont.	
<i>Oenothera villosa</i>	hairy evening primrose
<i>Oxytropis besseyi</i>	Bessey's locoweed
<i>Packera streptanthifolia</i>	Rocky Mountain groundsel
<i>Penstemon eriantherus</i>	fuzzytongue penstemon
<i>Phacelia linearis</i>	threadleaf phacelia
<i>Phlox hoodia</i>	spiny phlox
<i>Phlox hoodii</i> ssp. <i>muscooides</i>	musk phlox
<i>Phlox longifolia</i>	longleaf phlox
<i>Plantago patagonica</i>	woolly plantain
<i>Polygonum achoreum</i>	leathery knotweed
<i>Polygonum amphibium</i>	water knotweed
<i>Polygonum amphibium</i> var. <i>emersum</i>	longroot smartweed
<i>Polygonum aviculare</i> *	prostrate knotweed*
<i>Polygonum convolvulus</i> var. <i>convolvulus</i> *	black bindweed*
<i>Polygonum douglasii</i>	Douglas' knotweed
<i>Potentilla gracilis</i>	slender cinquefoil
<i>Potentilla pensylvanica</i>	Pennsylvania cinquefoil
<i>Ranunculus acriformis</i>	sharpleaf buttercup
<i>Ranunculus cymbalaria</i>	alkali buttercup
<i>Ranunculus sceleratus</i>	cursed buttercup
<i>Rhinanthus minor</i>	little yellow rattle
<i>Rumex crispus</i> *	curly dock*
<i>Schoenocrambe linifolia</i>	flaxleaf plainsmustard
<i>Selaginella densa</i>	lesser spikemoss
<i>Silene latifolia</i> *	bladder campion*
<i>Sisymbrium altissimum</i> *	tall tumbledustard*
<i>Sisymbrium loeselii</i> *	small tumbleweed mustard*
<i>Sisyrinchium idahoense</i>	Idaho blue-eyed grass
<i>Sisyrinchium montanum</i>	strict blue-eyed grass
<i>Solidago canadensis</i>	Canada goldenrod
<i>Solidago missouriensis</i>	Missouri goldenrod
<i>Sonchus arvensis</i> *	field sowthistle*
<i>Sphaeralcea coccinea</i>	scarlet globemallow
<i>Stellaria longipes</i>	longstalk starwort
<i>Symphyotrichum ascendens</i>	western aster
<i>Symphyotrichum falcatum</i> var. <i>falcatum</i>	white prairie aster
<i>Symphyotrichum laeve</i> var. <i>geyeri</i>	smooth aster
<i>Symphyotrichum lanceolatum</i> ssp. <i>hesperium</i> var. <i>hesperium</i>	white panicle aster
<i>Symphyotrichum spathulatum</i>	western mountain aster
<i>Taraxacum officinale</i> *	common dandelion*
<i>Thlaspi arvense</i> *	field pennycress*

* Non-native species (Total of 56)

Table A1. List of 207 vascular plant species found in sites between 2010 and 2014 samplings seasons. Only plants identified to the species level are included, cont.

Scientific name	Common name
Forbs, cont.	
<i>Tragopogon dubius</i> *	yellow salsify*
<i>Trifolium hybridum</i> *	alsike clover*
<i>Trifolium longipes</i>	longstalk clover
<i>Trifolium pratense</i> *	red clover*
<i>Trifolium repens</i> *	white clover*
<i>Urtica dioica</i>	stinging nettle
<i>Vicia Americana</i>	American vetch
<i>Vicia villosa</i> *	winter vetch*
<i>Viola nephrophylla</i>	northern bog violet
<i>Zigadenus venenosus</i>	meadow deathcamas
<i>Zizia aptera</i>	meadow zizia
Graminoids	
<i>Achnatherum hymenoides</i>	Indian ricegrass
<i>Agropyron cristatum</i> ssp. <i>pectinatum</i> *	crested wheatgrass*
<i>Agrostis idahoensis</i>	Idaho bentgrass
<i>Agrostis mertensii</i>	northern bentgrass
<i>Agrostis stolonifera</i> *	creeping bentgrass*
<i>Alopecurus aequalis</i>	shortawn foxtail
<i>Alopecurus pratensis</i> *	meadow foxtail*
<i>Beckmannia syzigachne</i>	American sloughgrass
<i>Bouteloua gracilis</i>	blue grama
<i>Bromus arvensis</i> *	field brome*
<i>Bromus inermis</i> *	smooth brome*
<i>Bromus tectorum</i> *	cheatgrass*
<i>Calamagrostis canadensis</i>	bluejoint
<i>Calamagrostis montanensis</i>	plains reedgrass
<i>Calamagrostis stricta</i>	slimstem reedgrass
<i>Carex aquatilis</i>	water sedge
<i>Carex atherodes</i>	wheat sedge
<i>Carex bebbii</i>	Bebb's sedge
<i>Carex douglasii</i>	Douglas' sedge
<i>Carex duriuscula</i>	needleleaf sedge
<i>Carex nebrascensis</i>	Nebraska sedge
<i>Carex norvegica</i>	Norway sedge
<i>Carex pellita</i>	woolly sedge
<i>Carex praegracilis</i>	clustered field sedge
<i>Carex scirpoidea</i>	northern singlespike sedge
<i>Carex simulate</i>	analogue sedge
<i>Carex utriculata</i>	Northwest Territory sedge
<i>Dactylis glomerata</i> *	orchardgrass*
<i>Deschampsia cespitosa</i>	tufted hairgrass

* Non-native species (Total of 56)

Table A1. List of 207 vascular plant species found in sites between 2010 and 2014 samplings seasons. Only plants identified to the species level are included, cont.

Scientific name	Common name
Graminoids, cont.	
<i>Elymus elymoides</i>	squirreltail
<i>Elymus glaucus</i>	blue wildrye
<i>Elymus lanceolatus</i>	thickspike wheatgrass
<i>Elymus repens</i> *	quackgrass*
<i>Elymus trachycaulus</i>	slender wheatgrass
<i>Festuca campestris</i>	rough fescue
<i>Festuca occidentalis</i>	western fescue
<i>Glyceria grandis</i>	American mannagrass
<i>Hesperostipa comata</i>	needle and thread
<i>Hierochloa hirta</i> ssp. <i>arctica</i>	northern sweetgrass
<i>Juncus balticus</i>	Baltic rush
<i>Koeleria macrantha</i>	prairie Junegrass
<i>Leymus cinereus</i>	basin wildrye
<i>Muhlenbergia asperifolia</i>	scratchgrass
<i>Nassella viridula</i>	green needlegrass
<i>Pascopyrum smithii</i>	western wheatgrass
<i>Phalaris arundinacea</i> *	reed canarygrass*
<i>Phleum pretense</i> *	timothy*
<i>Poa compressa</i> *	Canada bluegrass*
<i>Poa cusickii</i> *	Cusick's bluegrass*
<i>Poa fendleriana</i> ssp. <i>longiligula</i>	muttongrass
<i>Poa pratensis</i> *	Kentucky bluegrass*
<i>Poa secunda</i>	Sandberg bluegrass
<i>Pseudoroegneria spicata</i>	bluebunch wheatgrass
<i>Schedonorus pratensis</i> *	meadow fescue*
<i>Schoenoplectus tabernaemontani</i>	softstem bulrush
<i>Scirpus microcarpus</i>	panicked bulrush
Shrubs	
<i>Artemisia frigida</i>	prairie sagewort
<i>Atriplex gardneri</i>	Gardner's saltbush
<i>Cardaria chalapensis</i> *	lenspod whitetop*
<i>Chrysothamnus viscidiflorus</i>	yellow rabbitbrush
<i>Ericameria nauseosa</i> ssp. <i>nauseosa</i> var. <i>nauseosa</i>	rubber rabbitbrush
<i>Gutierrezia sarothrae</i>	broom snakeweed
<i>Krascheninnikovia lanata</i>	winterfat
<i>Opuntia polyacantha</i>	plains pricklypear
<i>Ribes lacustre</i>	prickly currant
<i>Ribes oxycanthoides</i>	Canadian gooseberry
<i>Rosa acicularis</i>	prickly rose
<i>Rosa woodsii</i>	Woods' rose
<i>Salix bebbiana</i>	Bebb willow

* Non-native species (Total of 56)

Table A1. List of 207 vascular plant species found in sites between 2010 and 2014 samplings seasons. Only plants identified to the species level are included, cont.

Scientific name	Common name
Shrubs, cont.	
<i>Salix boothii</i>	Booth's willow
<i>Salix exigua</i>	narrowleaf willow
<i>Salix geyeriana</i>	Geyer willow
<i>Stenotus acaulis</i>	stemless mock goldenweed
<i>Symphoricarpos occidentalis</i>	western snowberry
<i>Tetradymia canescens</i>	spineless horsebrush
Trees	
<i>Betula occidentalis</i>	water birch
Vines	
<i>Vicia cracca</i> *	bird vetch*

* Non-native species (Total of 56)

Appendix B

Table B1. Relative covers of exotic invasive species listed on the Montana noxious weed list found at Grant-Kohrs Ranch NHS sites.

Site	Species name							
	<i>Lepidium latifolium</i> (broadleaved pepperweed)	<i>Linaria vulgaris</i> (yellow toadflax)	<i>Cirsium arvense</i> (Canada thistle)	<i>Bromus tectorum</i> (cheatgrass)	<i>Convolvulus arvensis</i> (field bindweed)	<i>Euphorbia esula</i> (leafy spurge)	<i>Centaurea stoebe</i> (spotted knapweed)	<i>Cardaria draba</i> (whitetop)
1	0	0	4.92	0	0	0	0	0.05
4	0	0	0	24.53	0	0	0	0
5	0	0	0.28	0	0	0	0	0.07
7	0	0	0	0.23	0	0	0	0
8	0	0	0.35	0	0.39	0	0	0
9	0	0	0	0.07	0	0	0	0
11	0	0	0.42	0	0	0	0	0
12	0	0	0	0.1	0	0	0	0
14	0	0	12.21	0	0	1.66	0	1.38
15	0	0	0.73	0	0	0	0	0
16	0	0	0	12.94	0	0	0	0
17	0	0	2.16	0	0	0	0	0
20	0	0	0	0.57	5.43	0	0	0
21	0	0	0	0.18	0	0	0.18	0
22	0	0	0.16	0	0	0	0	0
24	0	0	0	0	4.66	0	0.11	0
25	0	0	3.25	22.63	0	0	0	0
27	0	0	0	0.19	0	0	0	0
28	0	0	5.54	0.06	0.13	0	0	0
29	0.11	0.11	0.23	0	0	0.05	0	0
33	0	0	0	1.07	0	0	0.06	0
36	0	0	0	0	4.24	0	0	0
37	0.33	0	1.8	0.05	0	0	0	0
40	0	0	0	14	5.68	0	0	0
41	0	0	0	0.23	0	0	0.47	0
43	0	0	3.54	0	0.93	0	0	0
44	0.16	0	0	0	0	0	1.3	0
45	0	0	0	50	0	0.08	0	0

Table B2. Definition of Montana weed classifications. From <http://agr.mt.gov/agr/Programs/Weeds/PDF/2015WeedList.pdf>.

Classification	Definition	Species found at GRKO 2010-2014
Priority 1A	These weeds are not present or have a very limited presence in Montana. Management criteria will require eradication if detected, education, and prevention.	None
Priority 1B	These weeds have limited presence in Montana. Management criteria will require eradication or containment and education.	None
Priority 2A	These weeds are common in isolated areas of Montana. Management criteria will require eradication or containment where less abundant. Management shall be prioritized by local weed districts.	<i>Lepidium latifolium</i>
Priority 2B	These weeds are abundant in Montana and widespread in many counties. Management criteria will require eradication or containment where less abundant. Management shall be prioritized by local weed districts.	<i>Linaria vulgaris</i> , <i>Cirsium arvense</i> , <i>Convolvulus arvensis</i> , <i>Euphorbia esula</i> , <i>Centaurea stoebe</i> , <i>Cardaria draba</i>
Priority 3	Regulated Plants: (NOT MONTANA LISTED NOXIOUS WEEDS) These regulated plants have the potential to have significant negative impacts. The plant may not be intentionally spread or sold other than as a contaminant in agricultural products. The state recommends research, education and prevention to minimize the spread of the regulated plant.	<i>Bromus tectorum</i>

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