

Non-Native Plant Survey at Grant-Kohrs Ranch National Historic Site



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Foreword

This report presents the results of a non-native plant survey performed in Grant-Kohrs Ranch National Historic Site (GRKO) in 2003. The purpose of the survey was to identify and map the distribution of non-native plant species that were of concern to park resource managers or were known to be potentially invasive in other areas. The survey at GRKO was part of a larger inventory and mapping project initiated by the Intermountain Region (IMR) of the National Park Service (NPS). Several cooperators mapped 19 national parks in the Intermountain Region of the western US. The goals of the IMR project were to develop a database that would assist resource managers with invasive plant management and control, provide baseline data for long term monitoring efforts, and facilitate data sharing within the NPS and with external agencies.

The specific goals of resource managers at Grant-Kohrs Ranch were:

- to develop maps of non-native plant species to assist with non-native plant management and restoration,
- to prioritize mapping in habitats with increased risk of invasion, particularly the upland ranges and the Clark Fork River riparian area,
- to search for potential new invaders.

To achieve these goals we surveyed the area of interest using three different sampling methods. In general, we demarked the area of primary interest with transects. These transects were walked and the occurrence of target non-native plants and other variables were recorded with Global Positioning System (GPS) receivers. In areas of secondary interest, or areas that were too topographically difficult to sample intensively we still used transects but targeted them to follow the landscape or geographical features. Therefore, this approach was biased, providing information around a certain feature but not at a distance from that feature. However, in combination with our primary method we are confident our survey provides representative data of the species occurrence in the environment. The third method was used on areas of least interest to the park or for non-native plants that were present in high density throughout the survey unit (i.e. Canada thistle (*Cirsium arvense*) in the riparian area) and therefore difficult to delineate accurately into distinct populations. In these situations, we sampled an area either by one of the two methods described above or by visually scanning the survey unit. This “gross area” sampling method was meant to provide only a general assessment of occurrence.

Maps of target plant species’ distributions are provided in the report, as well as tables summarizing the acres infested by each species mapped. No sampling method is completely accurate and we therefore provide an estimation of the uncertainty associated with sampling each species. The invasive plant database and maps produced from the survey of Grant-Kohrs Ranch are a singular look at the invasive plant distribution in the spring/early summer of 2003. The data should be considered baseline, or a starting point from which to monitor and assess changes in invasive plant populations in the area over time. A short discussion of the next phase, monitoring invasive plant populations, is included in the conclusion.

Introduction

Site description

Grant Kohrs-Ranch National Historic Site is administered by the NPS, U.S. Department of the Interior. It was established as a NHS by the U.S. Congress in 1972 to preserve the historical character and cultural integrity of a large western cattle ranch. Grant-Kohrs Ranch is located in Deer Lodge, Montana and occupies 1,500 acres of irrigated pasture, upland rangelands, and riparian area along the Clark Fork River. The IMR goal was to survey a selected 1,000 acres of the ranch. The site also contains numerous ranch buildings, roads, irrigation ditches, and fences. The NPS manages Grant-Kohrs as an active cattle ranch, and as an interpretive site open to the public, while preserving natural and cultural resources for future generations.

Site disturbance history

Grant-Kohrs Ranch has been a working cattle ranch since its inception in the mid-1800s as a supply source of cattle for the Oregon Trail. The current ranch consists of upland grasslands that are relatively intact and mesic pastures that are irrigated and managed for hay production and/or grazing. There are numerous ranch buildings, corrals, and roads. There are several main irrigation ditches running the length of the ranch as well numerous lateral ditches that irrigate the pastures.

Burlington Northern/Montana Western Railroad operates and maintains a railroad right-of-way through the ranch. A borrow pit at the north end of the ranch was excavated to build the railroad grade. The borrow pit currently functions as a wetland.

The Clark Fork River bisects the ranch and supports an approximately 126 acre riparian area that is fenced. The reach that flows through Grant-Kohrs Ranch is part of the Clark Fork River Operable Unit of the Milltown Reservoir Sediments National Priority List Site, which was declared a Superfund site in 1992. Natural and man-influenced hydrological processes have deposited high levels of heavy metals produced from mining and smelting in sediments in the riparian zone.

Justification for action

According to the NPS, the invasion of non-native plant species (exotics, non-indigenous species, invasive species, or weeds) is one of the most serious threats that Park Service administered lands face today, and exotic plants infest 2.6 million acres of NPS lands (National Park Service 2005). Non-indigenous species are considered the second greatest threat to biodiversity after habitat destruction (Randall 1996). When such species have characteristics that permit them to rapidly invade new areas and out-compete native plants for light, water, and nutrients they are often termed “invasive weeds” (Westerbrooks 1998).

A “noxious weed” is any plant species that has been designated by a federal, state or county government as injurious to public health, agriculture, recreation, wildlife or property (Sheley et al. 1999). Montana has defined noxious weeds to include "...any exotic plant species established or that may be introduced in the state which may render land unfit for agriculture, forestry, livestock, wildlife, or other beneficial uses or that may harm native plant communities" (County

Noxious Weed Control Act (CNWCA)). The control of “noxious weeds” is justified by the CNWCA (7-22-2101 MCA), which requires the control of designated noxious weeds within county districts. Weed management plans are required by the CNWCA to incorporate all appropriate methods, including education, prevention, mechanical methods, biological controls, cultural methods, and general land management practices. Therefore, to meet NPS objectives and to comply with state and county law it is necessary to obtain information about where target species are in the environment to be able to manage them.

The three phases of non-native species management

Management of non-native species (non-indigenous species or NIS) should be regarded as a three-phase process: inventory/survey, monitoring, and management (Figure 1). Although all three phases can be performed simultaneously, considering them as different phases is important for conceptual, theoretical, methodological, logistic and practical reasons. The first phase, inventory/survey, determines which species are present and their distribution within the environment. This is the aim of the current study. The second phase, monitoring, provides information about how patches are changing with time, their impact on the ecosystem and the impact of management on the patch. The final phase, management, is important for control of non-native patches and populations, by reducing their distribution and impact.

Under most land management scenarios, it is not possible to observe all of the plants or even plant communities in a managed area. In most cases we do not know which non-indigenous species are present within a managed area, their frequency or their distribution pattern, how much their distribution is changing and, finally, the impact they are having on the endemic ecosystem. It is only armed with all of this information that land managers can begin to make knowledgeable decisions about control or management of invasive species.

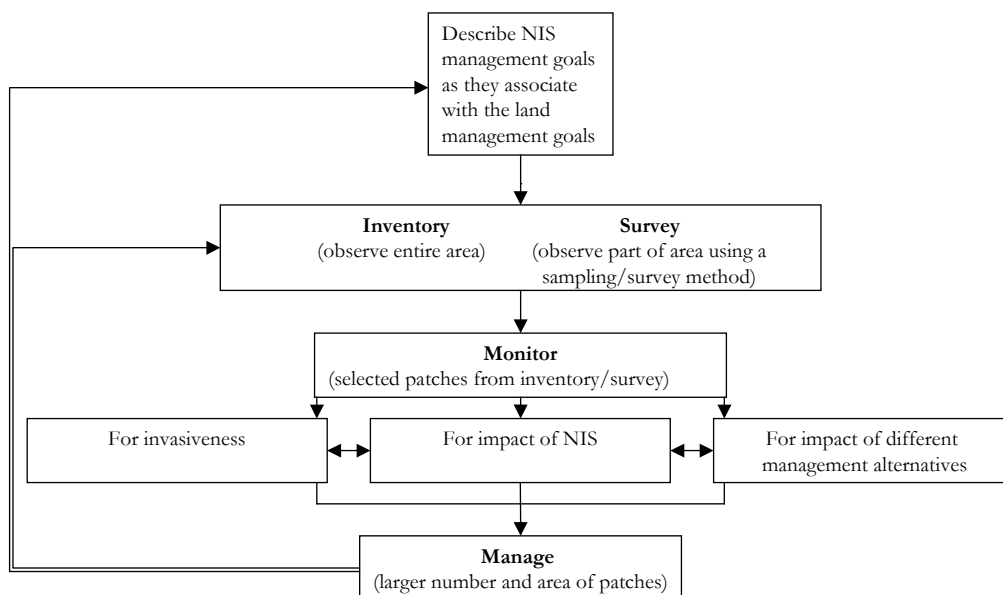


Figure 1. Three phases of non-native species management.

While researchers and managers often use the terms inventory and survey interchangeably, there are distinctions between the terms. An inventory samples the entire population within given boundaries, similar to a census. For example, an inventory of GRKO might involve the systematic search for noxious weeds along 10 m transects within the entire park boundary. For large management areas, inventories become cost-prohibitive, time-consuming, and therefore impractical. A survey samples a subset of the population within a larger boundary. Areas for survey might be selected randomly or using prior knowledge about invasive plant biology and ecological processes. Mapping records the geographic location of invasive plant infestations. Resource managers and scientists have used numerous different survey methods and Rew et al. (in press) evaluated the accuracy of seven of these methods for sampling the frequency of a species in the environment.

Non-native plant survey history

Several studies have addressed the vegetation community and the presence of non-native plants in GRKO. In 1983, the University of Montana performed an inventory of vascular plant species in GRKO. The results were compiled in a report to the NPS entitled “Baseline plant inventory of Grant-Kohrs Ranch” (Rice and Ray 1984). The study included a checklist of native and non-native plants and did not address species location or frequency. The plant inventory was part of a larger assessment of toxic metal contamination of the soil and biota of the Clark Fork River riparian system that was summarized in a report to the NPS entitled “Floral and faunal survey and toxic metal contamination study of the Grant-Kohrs Ranch National Historic Site” (Rice et al. 1984). From 2000-2002 Peter Rice and Janet Hardin of the University of Montana updated the vascular plant inventory and noted which species were native or exotic (Rice and Hardin 2002b).

A study of the Clark Fork riparian vegetation was completed by the University of Montana in 2002 (Rice and Hardin 2002a). The study used ordination to compare riparian community structure and species composition to similar uncontaminated sites in Western Montana. Riparian habitat types were classified and mapped, however, non-native plants were not specifically delineated.

As part of the Superfund litigation and planning effort, Peter Rice prepared a weed management and restoration plan in 2003 (restricted NPS document). The primary long-term objective of the plan was to restore the upland grasslands and the riparian area to pre-1900 species compositions. A major limitation identified by the plan was lack of accurate and comprehensive spatial data on weed distributions.

Montana State University (MSU) performed sampling in portions of the NHS from June 30 – July 7, and September 9 – 10, 2003. Approximately 849 acres were surveyed using 82 and 164 ft (25 and 50 m) wide transects or searching intuitively following landscape or manmade features. We developed a list of target species (Appendix 1) by consulting with NPS resource managers and Peter Rice at the University of Montana. Surveyors mapped weed infestations as points or polygons.

Methods

Targeting the survey area

Before mapping was initiated, we met with Ben Bobowski of GRKO and Peter Rice and Janet Hardin to prioritize weed-mapping areas based on GRKO management objectives. The goal of the IMR weed mapping project was to map 1,000 acres of the greater 1,500-acre ranch. The ranch is broken into units based on the management use as range or pasture. Figure 2 identifies the management units or areas we surveyed in 2003. We identified the upland ranges targeted for restoration as highest priority areas, potential sources of spread such as ditches, roads, and railroads as secondary priority areas, irrigated pastures as third priority areas, and finally weed source areas such as areas around the visitor center as fourth priority areas.

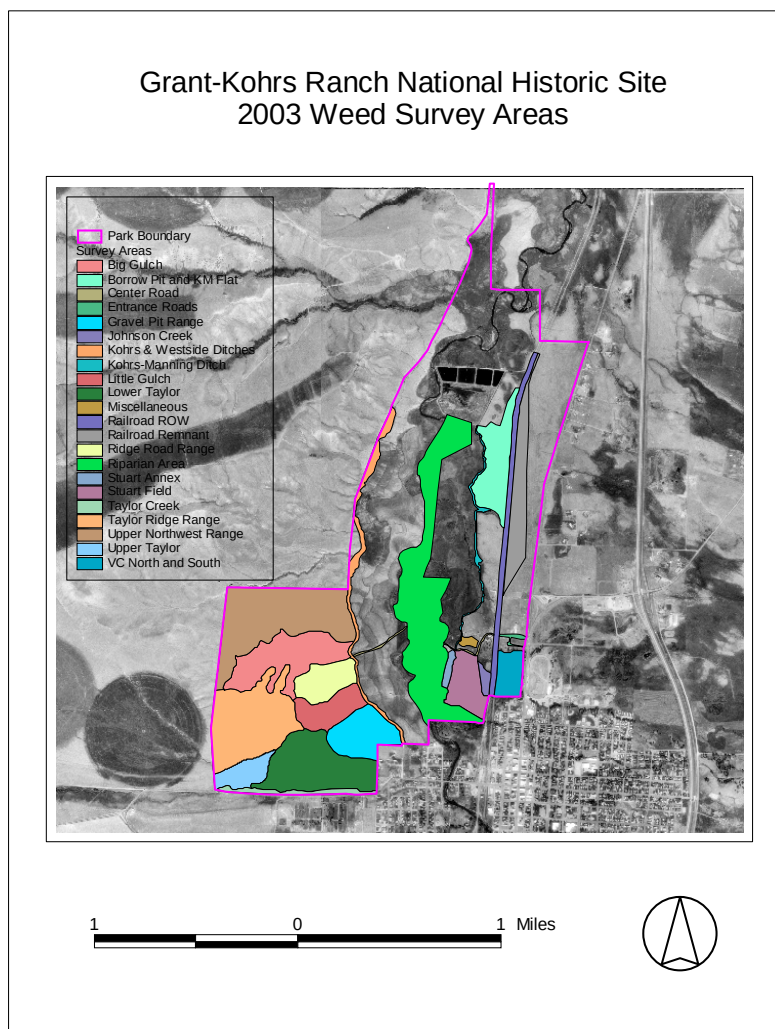


Figure 2. Map of management units and areas surveyed in 2003.

Sampling protocol

We used three sampling approaches to survey for non-native plant species. The primary method involved searching along parallel transects following a UTM northing or easting within the boundary of the search area. An alternative method was utilized if the boundary width of the search area was too narrow to warrant transects or if the search area followed a landscape or manmade feature such as an irrigation ditch, creek, or road. The third approach was termed gross area sampling and it was used for large areas where only a rough estimate of infestation was practical due to the size of the area or the complexity of the infestation. Gross area features were sampled with the primary or secondary methods described above, or in some instances with a simple visual estimation of the non-native plant occurrence in the landscape.

Transect widths for primary and secondary sampling methods were based on visibility and were generally constrained by topography and vegetation density. At GRKO we used 82 ft (25 m) and 164 ft (50 m) transect widths (distances were measured in meters for transects because UTM coordinate system units are in meters). We found 164 ft (50 m) transect widths to provide best coverage while maximizing mapping speed and efficiency in the open grasslands of the upland ranges and irrigated pastures. Along the more densely vegetated riparian area we narrowed our transect widths to 82 ft (25 m) to enable better detection of non-native plants.

When sampling along transects, the 3-member mapping crew spread out 164 ft (50 m) from each other and followed an east-west UTM northing or a north-south UTM easting. Crew members used the coordinate display window on the GPS receiver to navigate along the transect. Mappers generally stayed abreast of one another as they moved along the midpoint of the transect, visually searching an 82 ft (25 m) swath on either side. When the mapper encountered an infestation, s/he would visually assess the perimeter of the patch. If the patch was small enough that the boundary could be seen, the mapper would pace or visually estimate the length and width of the patch, then collect the remaining field attributes. If the patch continued out of vision, the mapper would use an adaptive strategy and spiral out from where the patch was first encountered to determine the extent of the infestation. If the patch continued out of the mapper's transect, s/he would communicate with other crew members via two-way radio to determine if other crew members had also encountered the same patch and how to proceed with mapping (who would map the patch). In this manner, each patch was considered unique and mapped only once. In general, if 150 ft (46 m) or more separated patches, they were considered unique metapopulations (except in some situations noted below). We found that 82 or 164 ft (25 or 50 m) was the minimum width appropriate for surveying areas where visibility was adequate, weeds were common, and patches were generally larger than 82 ft (25 m) wide. If smaller widths were used weed patches often crossed several transects, which made coordinating the mapping among surveyors more complicated.

Mapping non-native plant infestations as points, polygons, or gross area features

At GRKO, non-native plant infestations were recorded as point, polygon, or gross area features. In most cases, it is far easier in terms of time and efficiency to map a patch as a point, recording length and width attributes for calculating acreage later. For most non-native plant management objectives or baseline surveys, point data provides satisfactory resolution needed to address management planning and this is the method we used. Defining a patch's shape and size with a

polygon might be important if monitoring is the objective. However, capturing the perimeter of a non-native plant patch with mapping grade GPS receivers (even 1 m accuracy) might not be accurate enough to detect small changes in the patch shape and size, and measuring the patch with a tape measure could still be more accurate. Further, the exact perimeter drawn around a non-native plant patch is often a subjective decision of the mapper attempting to delineate diffuse or convoluted boundaries of vegetation.

When mapping a point, the surveyor stood in the approximate center of the patch and logged positions (X, Y coordinates) with the GPS receiver. Generally, 20 or more positions were logged. The GPS software averaged these positions to create a single point feature. Generally, we mapped patches less than or equal to 1.5 acres (approximately 350 ft x 350 ft) as points.

When mapping a polygon, the surveyor walked the perimeter of the patch recording a position at each vertex of the polygon, or each location where the polygon changed shape. An alternative method for capturing polygon infestations involved using point features to define the perimeter of a non-native plant patch. The points were later converted into a polygon feature in ArcView by essentially “connecting the dots”. This method was useful if the infestation was large (>3 ac) and/or convoluted, or the terrain and/or vegetation cover made it difficult to delineate the patch visually. For example, leafy spurge (*Euphorbia esula*) occurred on the floodplain of the Clark Fork River in continuous and complex patterns and through thick riparian vegetation. Instead of attempting to walk the entire perimeter of the patch, we recorded the boundary of leafy spurge with point features as we encountered it along transects. If a polygon was recorded from GPS points, we recorded this in the “Notes” field of the database. In such areas where there were large, pervasive, convoluted weed infestations the distance between clumps of weeds in the same population was increased to 250 ft (76 m). We considered large weedy areas to be essentially the same population.

Gross area data provide a very rough estimation of the distribution and abundance of non-native plants that are well established, extensive, and have a high degree of spatial complexity. These areas are not practical to map with a high degree of accuracy because they are a low priority for management. Management objectives are not aimed at eradication, rather an effective goal might be to prevent further spread. At GRKO, we used the gross area feature to describe large non-native plant infestations (+/-10 ac) that were ubiquitous in a management unit. For example, Canada thistle was scattered yet pervasive throughout the Big Gulch pasture. It was impossible and impractical to attempt to delineate Canada thistle into unique infestations. As a result, we used the management boundary of Big Gulch as a gross area feature that contained Canada thistle. Non-native plant cover was not necessarily continuous throughout the area mapped. Gross area features were recorded using hand-mapping and GPS-mapping points along the perimeter as described above or we used the park GIS layer for fields to create the gross area polygon. Mappers estimated the percent of land that was occupied by the non-native plants. This percent of infestation was used to calculate roughly the area infested within the greater gross area boundary. For example, if a 100-acre area was estimated to be 50% infested with Canada thistle, the total area infested was calculated to be 50 acres.

Mapping the survey area

Mappers recorded a transect start and end feature on each transect searched. These point features were used to generate a transect line in ArcGIS 9.0 (ArcView). The transect lines were used to calculate the project survey area.

The GPS receivers were programmed to record a position every 100 ft (30 m) along the mappers search path. These “non-feature” positions or “between-feature” positions were exported to ArcView and used to calculate the survey area in addition to areas where transects were used by on-screen digitizing around the search paths.

GPS mapping protocol

Weed infestation location and attributes were recorded with mapping grade GPS receivers. We used Trimble’s GeoExplorer XM and GeoExplorer 3 receivers, which have a manufacturer specified accuracy of 3 – 16 ft (1 – 5 m) after post-processed differential correction (+/- 1 cm per 100 km from the base station used for differential correction). The GeoExplorer XM was capable of receiving real-time differential GPS signals. All data were differentially corrected and exported to ArcView.

As a rule, in terrain with an unobstructed view of the sky mappers set the PDOP mask to 6. Trimble considers positions collected with a PDOP of 6 or less to be of excellent accuracy. A value of 7 – 8 is considered acceptable accuracy. In some areas with steep terrain features (canyons or mountain fronts) or with significant overstory vegetation, a PDOP of 6 or less could not be achieved. In addition, at certain times the satellite configuration simply prevented logging by receivers with a PDOP of 6 or less. In these instances, surveyors bumped the PDOP mask up to level where logging could continue. Of 576 non-native plant point features recorded 19 had a PDOP greater than 6, and only 4 of those points had a PDOP of greater than 8.

Database design and metrics collected

MSU utilized minimum mapping standards established by the North American Weed Management Association (NAWMA 2002), which were accepted for the project by the NPS Intermountain Region Weed Mapping Committee. We followed the database development guidelines created by the IMR Weed Mapping Committee (National Park Service 2001) as a starting point to design the field data dictionary used to collect environmental attribute data with GPS receivers. Because MSU was mapping several Rocky Mountain Network (RMN) Parks, we utilized attributes and attribute values developed by non-native plant managers at Glacier National Park. Glacier has been documenting non-native species since the early 1980s and using this historical data, developed an extensive Microsoft Access database. Managers at Glacier requested that we utilize their “Exotics” database fields and attributes for RMN parks where possible to simplify merging datasets.

In addition, Ben Bobowski requested that we record habitat type as an attribute of weed infestations to the database. Rice and Hardin (2002) mapped the riparian vegetation at GRKO and we decided their data could be used to derive habitat type for weeds we mapped in the riparian area. However, the 2002 study did not map the upland grasslands or pastures. Therefore,

as an attribute of the weed patches we determined grassland community types following Mueggler and Stewart (1980).

The data dictionary served as an interface for collecting non-native plant attributes efficiently and accurately. Spatial data were exported to ArcView in shapefile format. Additional administrative or spatially derived attributes were added to the database after field mapping was completed. The tabular dBASE files (.dbf files) were exported to Microsoft Excel format.

Field data elements

The following list reviews the field data elements captured for each non-native plant patch that was mapped and how values were assigned.

Species – A list of target species was developed by consulting with GRKO resource managers (Appendix 1). Currently accepted scientific names were recorded. The Integrated Taxonomic Information System (ITIS) was used to reference currently accepted nomenclature (<http://www.itis.usda.gov>).

Canopy Cover – Mappers visually estimated the percent canopy cover of the non-native plant patch assigning a whole number from 1 – 100. A surveyor envisioned a perimeter around the non-native plant patch and estimated the percent of ground covered by the vertical projection of the non-native plant foliage, including small gaps in the canopy. If a small patch or single species was mapped the area covered by foliage relative to the perimeter around the plant(s) was high.

Patch Length, Patch Width – Mappers either paced or visually estimated the length and width of the infestation and recorded the distance in feet.

Phenology – The growth stage of the majority of plants in the infestation. The range of values included rosette, bolt, prebud, bud, early bloom, full bloom, fruit, and fall regrowth.

Distribution – The spatial distribution or spatial pattern of the infestation. Descriptions of the values follow in Table 1.

Table 1. The range of values followed by a brief description for the distribution attribute.

Distribution value	Description
Scattered	Individual or small clusters of weeds thinly scattered with no apparent spatial pattern
Clumped	Weeds growing in distinct clusters separated by weed free areas within the larger area considered to be the patch
Continuous cover	Weeds essentially growing in a monoculture with a very distinct edge
Gradient	Weed cover dense in the center of the patch,

	thinning out toward edges of patch
Isolated individual	Single weed plant
Isolated patch	Isolated group of weeds with contiguous individuals mapped as a unique feature (used generally when no other NPP occurred within 300 ft)

Community – The dominant form of the plant community in which the infestation occurred. The range of values included forest, shrub, grass, mixed, barren, alpine, riparian, and wetland.

Habitat Type – Habitat types were determined following Mueggler and Stewart (1980) for grasslands. Rice and Hardin (2002) mapped riparian vegetation following Hansen et al. (1996). Their data can be used to derive habitat type for weed infestations we mapped in the riparian area in 2003.

Dominant Species – A list of dominant species was developed from the updated inventory of vascular plants performed at GRKO (Rice and Hardin 2002) and in consultation with resource managers (Appendix 2). Mappers visually estimated the dominant species growing in association with the non-native plant species. Dominance was determined by the species with the highest percent canopy cover. If single or few non-native plants were mapped, dominant species were determined for 0.1-acre area surrounding the plants.

Disturbance – Mappers identified the disturbance factor with the greatest apparent impact on the area infested by the non-native plants (Table 2).

Table 2. Disturbance factors adapted from the IMR weed mapping guidelines (NPS 2001).

Disturbance Factor	Comment
Ag/livestock grazing	
Animal disturbance	Not from livestock
Construction/development	
Fire suppression	Impacts resulting from active fire suppression, i.e. fireline
Geothermal	
Habitat improvement	
Hydrology	Effects from hydrologic resources; could be ground water or surface water (intermittent, ephemeral, perennial streams)
Irrigation/ditching	
Mining/quarries	
Oil/gas development	
Recreation	Impacts from developed or undeveloped recreational sites such as barren areas around picnic tables

Right-of-way	Road and roadside impacts such as ditches; roads might be surfaced or not
Trail/ORV/outfitter	
Utility	i.e., power lines or areas around transformers
Wildfire	
Wind/erosion	
Other	
None apparent	

Ecological Status – A numeric value from 1 – 4 based on a qualitative description of the level of infestation that identifies ability of site to recover to natural state once the non-native plants have been removed (Table 3).

Table 3. Ecological status classifications developed by the IMR weed mapping guidelines (NPS 2001).

Description	Class
No weeds. The management emphasis is preventing weed encroachment.	1
New and/or small infestations. These infestations have good potential for eradication because they are small and there is a good understory of desirable plants.	2
Large-scale infestation with 30% or greater understory of residual grasses and good potential productivity. Management of these sites in a way that selects for the recovery of the residual native grasses and shrubs has good potential for control but not eradication of the weeds. There may be more than one noxious weed species but the underlying biologic integrity of the unit is good.	3
Large-scale infestations with few or no (less than 30% cover) desirable grasses in the understory. Infestation often dense and/or multiple weed species. Control will require intense treatment and probably revegetation. Control may be possible but not eradication. In some areas, the infestation may have changed the character of the land so much that attempts for rehabilitation are cost prohibitive.	4

Slope – Mappers recorded the average steepness of the terrain in which the weed infestation grew in degrees. Slope categories included low (0-20°), moderate (21-45°), high (46-80°), and vertical (81-90°).

Aspect – Mappers stood in the approximate center of the weed infestation, facing down the fall line, and recorded the compass direction of the aspect in categories of north, northeast, east, southeast, south, southwest, west, northwest, and level.

Distance to Water – Mappers estimated the distance to the closest source of water from 1 to 1,000 ft. Sources of water included perennial, intermittent, and ephemeral streams and wetlands or areas saturated by groundwater. Other sources of water included irrigation ditches and stock tanks. If the source of water was greater than 300 ft, the accuracy of the estimated distance was less reliable. If the distance to the closest water source was unknown the mapper recorded 1000 ft.

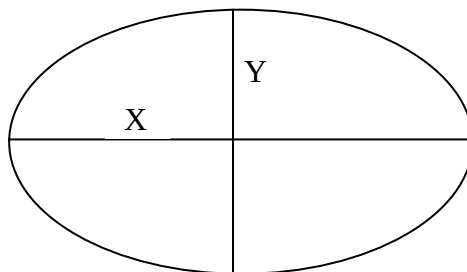
Notes – Mappers recorded any relevant notes concerning the weed infestation in the notes field. Often it was easier and quicker to record extensive notes by hand. Each mapper maintained a field notebook for recording this extra information noted while mapping and transcribed the data at days end.

Other required data elements, GIS/GPS derived

The IMR database development guidelines (National Park Service 2001) required other administrative data elements that were populated in a GIS. Some data elements were derived from the GPS settings. The following is a list of additional data elements for GRKO.

Coordinates – Embedded in GPS data and exported to GIS. Universal Transverse Mercator (UTM) northing and easting coordinates were added to the dBase table.

Area – Calculated in the GIS using the formula for the area of an ellipse (Figure 3). Field gathered length and width of patch were used as the semi-major and semi-minor axes.



$$\text{Area} = X/2 * Y/3 * \text{Pi}$$

X = semi-major axis (length)

Y = semi-minor axis (width)

Figure 3. Patch length and width was estimated and used to calculate the patch size as the area of an ellipse.

Acres – Calculated in the GIS by dividing area (ft²) by 43,560 ft² (square feet per acre).

Lifeform – Derived in the GIS and identifies the physiognomic class of the non-native plant species as a tree, shrub, grass or forb.

Elevation – Embedded in GPS data and exported to GIS. Hand mapped locations do not have an elevation value.

Maximum PDOP – Position dilution of precision (PDOP) reflects the accuracy of GPS measurements. Embedded in GPS data and exported to GIS. A value of 6 or less can indicate excellent accuracy (likely within 1-5 meters) while >6 – 8 can indicate acceptable accuracy.

Date – Embedded in GPS data and exported to GIS. Indicates date of mapping.

Surveyor – Recorded with GPS data and exported to GIS. The name of the mapper who recorded the non-native plant infestation.

Integrated Taxonomic Information System (ITIS) code – Species name of the invasive plant was based on current ITIS accepted nomenclature. The Natural Resource Conservation Service Plants database was used to derive the code for the ITIS name of the invasive plant (USDA 2004).

Datum – The datum in which the spatial data are stored. All data for the IMR mapping project are in the UTM coordinate system and the North American Datum (NAD) of 1983.

UTM zone – Zone of the spatial data. GRKO data are in UTM zone 12.

Country – United States (USA)

State – Montana (MT)

County – Powell

NPS region – NPS code for Intermountain Region (IMR)

NPS Inventory and monitoring network – NPS code for Rocky Mountain Network (RMN)

NPS unit – NPS code for park (GRKO)

Source of data – Person who manages data at GRKO (Ben Bobowski).

Results

Acres infested with non-native plant species

We surveyed approximately 849 acres of Grant-Kohrs Ranch. We fell short of the targeted acreage by 151 acres. A summary of the survey, including area surveyed, cumulative infested area and total infested area with error bars, and uninfested area with error bars, is presented in Figure 4. We calculated the total land area occupied by weeds, including overlaps in physical space (a number of species might occupy portions of the same physical space but each area is

considered a unique infestation and added separately), for a cumulative infested area of 632 acres (Table 4). Further, we calculated the total infested area of all species, (a number of species might infest the same physical space but the area infested is counted only once). Total infested area was estimated to be 550 acres. Cumulative infested area and total infested area estimates include gross areas.

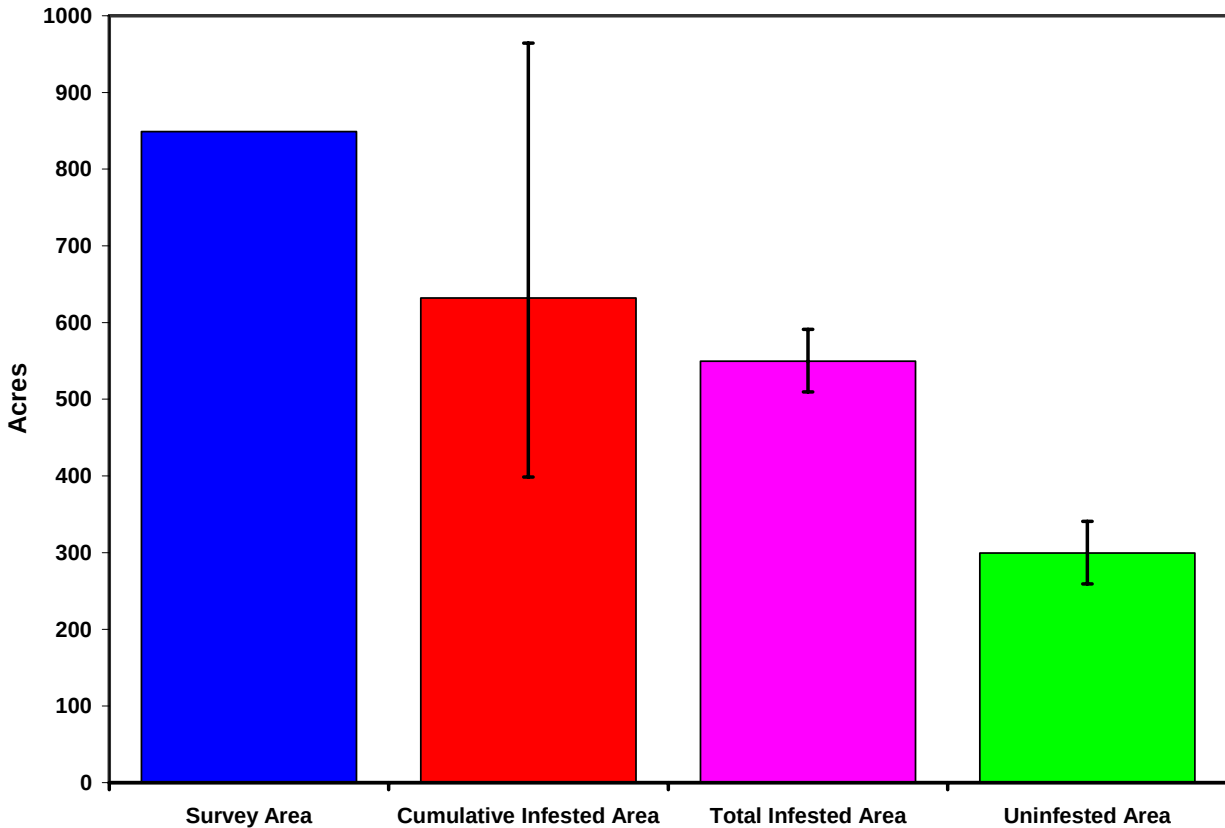


Figure 4. Area surveyed, infested, and uninfested. Cumulative infested area sums all overlapping patches. Total infested area is limited to the area occupied by any number of non-native plant species, regardless of how many might occupy the same physical site (i.e. overlapping patches are not summed separately).

Table 4. Area surveyed, infested, and uninfested.

	Estimated Acres	Estimated Acres Low	Estimated Acres High
Survey Area	848.9		
Cumulative Infested Area	631.8	398.8	964.3
Total Infested Area	549.5	509.5	591.0
Uninfested Area	299.3	339.4	257.8

Estimating error associated with mapping

When calculating the area of a weed infestation mapped as a point feature we used the estimated length and width to calculate the patch size as the area of an ellipse. When infestations were mapped as polygons, the GIS software was used to calculate the area. In each instance, a single

acreage estimate for the patch was the result. All sampling methods and mapping crews make errors. To reflect these inaccuracies we provide a potential range of acreage values that represent the potential uncertainty associated with mapping. We think this is a more accurate reflection of reality than a single acreage value. Managers should be able to more effectively plan and allocate limited resources by understanding the uncertainty associated with estimating acreage from mapping.

The two sources of error were instrument error and user error. Trimble states the GeoExplorer XM and GeoExplorer 3 receivers have an accuracy of 3 – 16 ft (1 – 5 m) under optimal conditions with post-processed differential correction. The biggest source of user error was most likely incurred when estimating size (length and width) of the non-native plant patch. We had high confidence that we correctly identified the weed species and that we located some portion of the weed patch (we might not have been standing in the exact center of the patch but we located at least some portion of the patch). However, we had less confidence in our estimates of polygon area. Therefore, we accounted for potential error by calculating a low and high acreage for each infestation.

Further, we had more confidence in locating the approximate center of the patch for point data than we had confidence in locating a point on the perimeter of a polygon. Therefore, for patches mapped as point features we simply estimated an error of +/- 10%. In practical terms, for every 10 ft (3 m) in length or width we paced or visually estimated, there was likely one foot (plus or minus) of error associated. For polygon features there was error associated with the entire perimeter of the polygon. Patches mapped as polygons were less accurate than patches mapped as points because they were generally larger and more complex and we did not stand in the center and average GPS positions. Therefore, we used a larger error estimate of +/- 100 ft (30 m) from the radius of each polygon and calculated a low and high area estimate. For gross areas we estimated an error of +/- 25%. For each non-native plant patch mapped as either point, polygon or gross area, we calculated the +/- error and thus, a low and high acreage.

Non-native plant species composition at GRKO

Twelve target non-native plant species were recorded in GRKO (Figure 5) and their infestation levels are provided in Table 5. The composition of non-native plants within the survey area is important for planning management strategies uniquely targeted to each particular species. For example, leafy spurge might be managed differently than spotted knapweed (*Centaurea biebersteinii*), even though infestations might overlap.

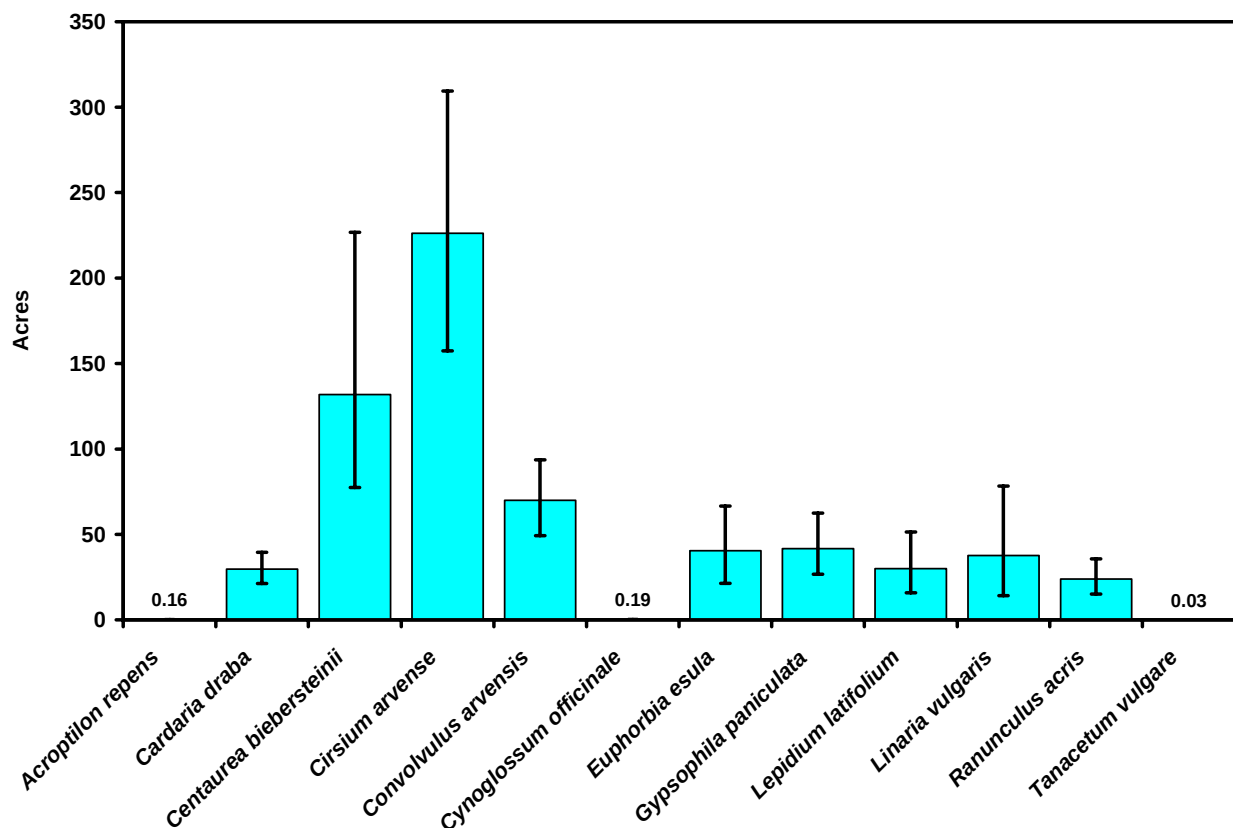


Figure 5. Non-native plant composition of survey area with accuracy of estimates shown as error bars. Where no histogram is present the value represents the estimated population acreage (with no error bars).

Table 5. Non-native plant composition of survey area.

Species	Estimated Acres	Estimated Acres Low	Estimated Acres High
<i>Acroptilon repens</i>	0.16	0.14	0.18
<i>Cardaria draba</i>	29.69	21.24	39.58
<i>Centaurea biebersteinii</i>	131.87	77.39	226.74
<i>Cirsium arvense</i>	226.19	157.36	309.45
<i>Convolvulus arvensis</i>	70.04	49.23	93.73
<i>Cynoglossum officinale</i>	0.19	0.17	0.21
<i>Euphorbia esula</i>	40.40	21.42	66.59
<i>Gypsophila paniculata</i>	41.71	26.72	62.46
<i>Lepidium latifolium</i>	30.00	15.80	51.40
<i>Linaria vulgaris</i>	37.58	14.20	78.28
<i>Ranunculus acris</i>	23.93	15.05	35.70
<i>Tanacetum vulgare</i>	0.03	0.02	0.03
SUM	631.78	398.75	964.34

RUSSIAN KNAPWEED (*Acroptilon repens*)

We mapped four small infestations of Russian knapweed, all on the west side of the Clark Fork River (Figure 6). Three of the patches were less than 0.1 acre and one was slightly over 0.1 acre (160 x 40 ft). Two patches were located in upland range habitats (Taylor Ridge Range and along the west side road), one was located in pasture (Big Gulch), and the fourth was located in the riparian area. All patches we mapped have a high potential for eradication. Care should be taken to prevent spread, especially along the Clark Fork River.

WHITETOP (*Cardaria draba*)

Most whitetop infestations were mapped in or near mesic sites such as irrigated pastures or in developed/disturbed areas as point features (Figure 7). All point features were less than 0.2 acre. We mapped a large patch (28 acres) of whitetop along the southern edge of Lower Taylor Field.

SPOTTED KNAPWEED (*Centaurea biebersteinii*)

Spotted knapweed was one of the most abundant non-native plants mapped at Grant-Kohrs Ranch in 2003. We mapped 201 point features ranging in size from a single plant to 1.5 acres (Figure 8). We mapped 16 polygon features, all but one of which was less than 7 acres. The Burlington Northern railroad and right-of-way was infested through the length of the ranch. We mapped this area as one polygon (36 acres). In addition, we mapped the Railroad Remnant and KM Flats with the gross area feature. Spotted knapweed was scattered yet pervasive throughout these two management units and therefore it was difficult to delineate unique metapopulations. As a result, we delineated the whole unit as infested. However, there were areas inside the Railroad Remnant and KM Flats where spotted knapweed grew in denser patches. We mapped these higher density patches with point features in the Railroad Remnant. In KM Flats, we mapped two disturbed sites with point features and a patch of particularly dense spotted knapweed following an old road with a polygon feature. While the acreage calculations are slightly redundant we felt it was important to provide more specific information within the gross areas when possible.

In the riparian area, spotted knapweed generally grew close to the river along gravel bars. Spotted knapweed was consistently scattered throughout the upland grasslands, but was less frequently located in the irrigated pastures.

CANADA THISTLE (*Cirsium arvense*)

Canada thistle was the most abundant non-native plant mapped at Grant-Kohrs Ranch in 2003. Canada thistle was ubiquitous along irrigation ditches, creeks, and around the borrow pit wetland (Figure 9). In the riparian area, Canada thistle was so pervasive we found it impossible to distinguish separate populations and as result, we mapped the entire survey unit as a gross area. While the area is not continuously covered with Canada thistle, patches were never separated by more than 250 feet. We mapped Canada thistle in Big Gulch and Lower Taylor Field with the gross area feature also.

FIELD BINDWEED (*Convolvulus arvensis*)

Field bindweed was abundant along the Westside Ditch and in Lower Taylor Field and Little Gulch (Figure 10). Field bindweed was difficult to detect in the moist pastures where tall grasses such as smooth brome (*Bromus inermis*) and timothy (*Phleum pratense*) dominated. Delineating unique patches was impossible in such situations; therefore, if we identified field bindweed consistently throughout a unit we mapped it as a gross area. It was likely that field bindweed infested Big Gulch yet we did not detect it there.

HOUNDSTONGUE (*Cynoglossum officinale*)

We mapped 16 houndstongue patches the majority of which were close to the railroad right-of-way or developed areas (Figure 11). All houndstongue infestations were less than 0.1 acre and consisted of one to several scattered or clumped plants.

LEAFY SPURGE (*Euphorbia esula*)

Leafy spurge was abundant in the riparian area. We mapped four nearly contiguous polygons along the Clark Fork River (Figure 12). Unlike Canada thistle, leafy spurge thinned out further from the river and did not infest the entire area we sampled. Outside the riparian area, leafy spurge was not as abundant. We mapped several small patches (less than 0.1 acre) of leafy spurge around the borrow pit and near the railroad. In addition, we found one small patch in both the Gravel Pit Range and Big Gulch. A slightly larger patch (100 ft x 85 ft or 0.15 acre) was located in Taylor Ridge Range. Two patches were mapped along the Westside road. These smaller point infestations have higher potential for eradication and should be monitored.

BABYSBREATH (*Gypsophila paniculata*)

Babysbreath is not on the Montana state noxious weed list, however, it is on county noxious weed lists for neighboring Deerlodge and Silver Bow counties. Managers were concerned about its spread on the ranch from a potential downwind source in the Deer Lodge cemetery, located to the south of the park. Babysbreath predominantly infested the upland range sites (Figure 13). The Gravel Pit Range had the greatest density of babysbreath, making it difficult to map unique patches. Therefore, we mapped the entire unit as a gross area, mapping patches inside the gross area if they had higher than average canopy cover. We mapped one polygon of 30% canopy cover spreading along the road at the south end of the range and up into the old gravel pit. We mapped two other large patches (10 and 16 acres) of babysbreath in the Taylor Ridge Range. We also located one isolated plant on a gravel bar in the riparian area and two large plants next to the walkway from the Visitor Center to the Kohrs House.

PERENNIAL PEPPERWEED (*Lepidium latifolium*)

Perennial pepperweed was mapped along ditches, in the riparian area and borrow pit wetland, and in Big Gulch (Figure 14). In the riparian area, perennial pepperweed became more abundant to the north. The infestations in Big Gulch were all very small (less than 0.01 acres).

YELLOW TOADFLAX (*Linaria vulgaris*)

Yellow toadflax was constrained to the moister areas of ranch, though it was locally abundant in the riparian area (Figure 15). We mapped several large, clumped infestations, ranging in size from 1 to 11 acres in the riparian area.

TALL BUTTERCUP (*Ranunculus acris*)

Janet Hardin discovered tall buttercup in Stuart Field (Figure 16), a non-native plant that was not previously recorded on the ranch. Tall buttercup looks very similar to native *Ranunculus* species (fortunately we had Janet's excellent botany skills to detect and identify the non-native plant), and might be very difficult to detect when not flowering. The core infestation occurred in Stuart Field proper (22 acres). A two-acre infestation was also mapped in the Stuart Field Annex. In addition, we found three small patches (less than 0.04 acre) to the south of the main infestation near Cottonwood Creek.

COMMON TANSY (*Tanacetum vulgare*)

We mapped eight infestations of common tansy in the riparian area, along the Kohrs-Manning ditch, and along Cottonwood Creek (Figure 17). All patches were very small (less than 0.01 acre), with high potential for eradication.

Russian knapweed (*Acroptilon repens*)

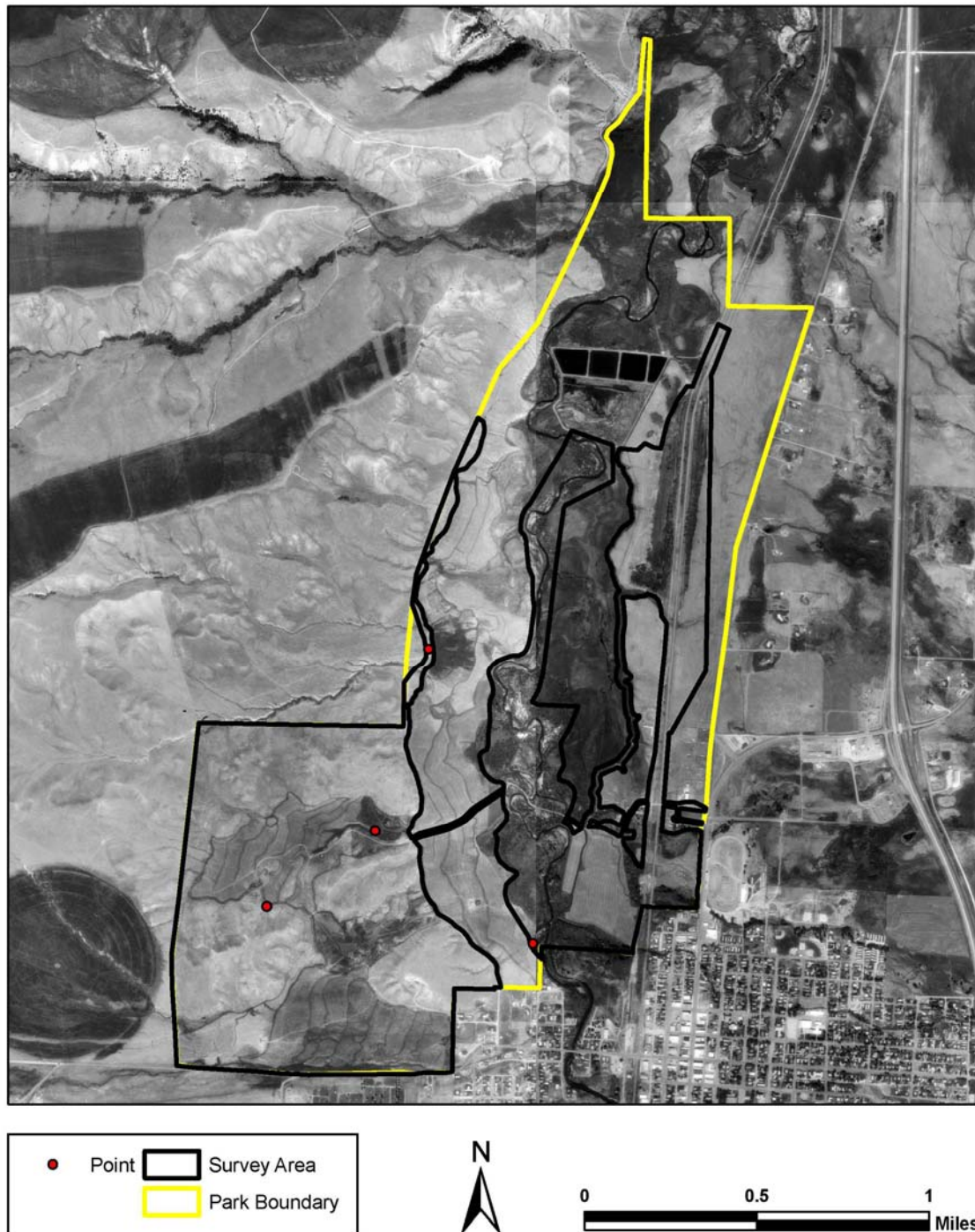


Figure 6. Map of Russian knapweed distribution in GRKO.

Whitetop (*Cardaria draba*)

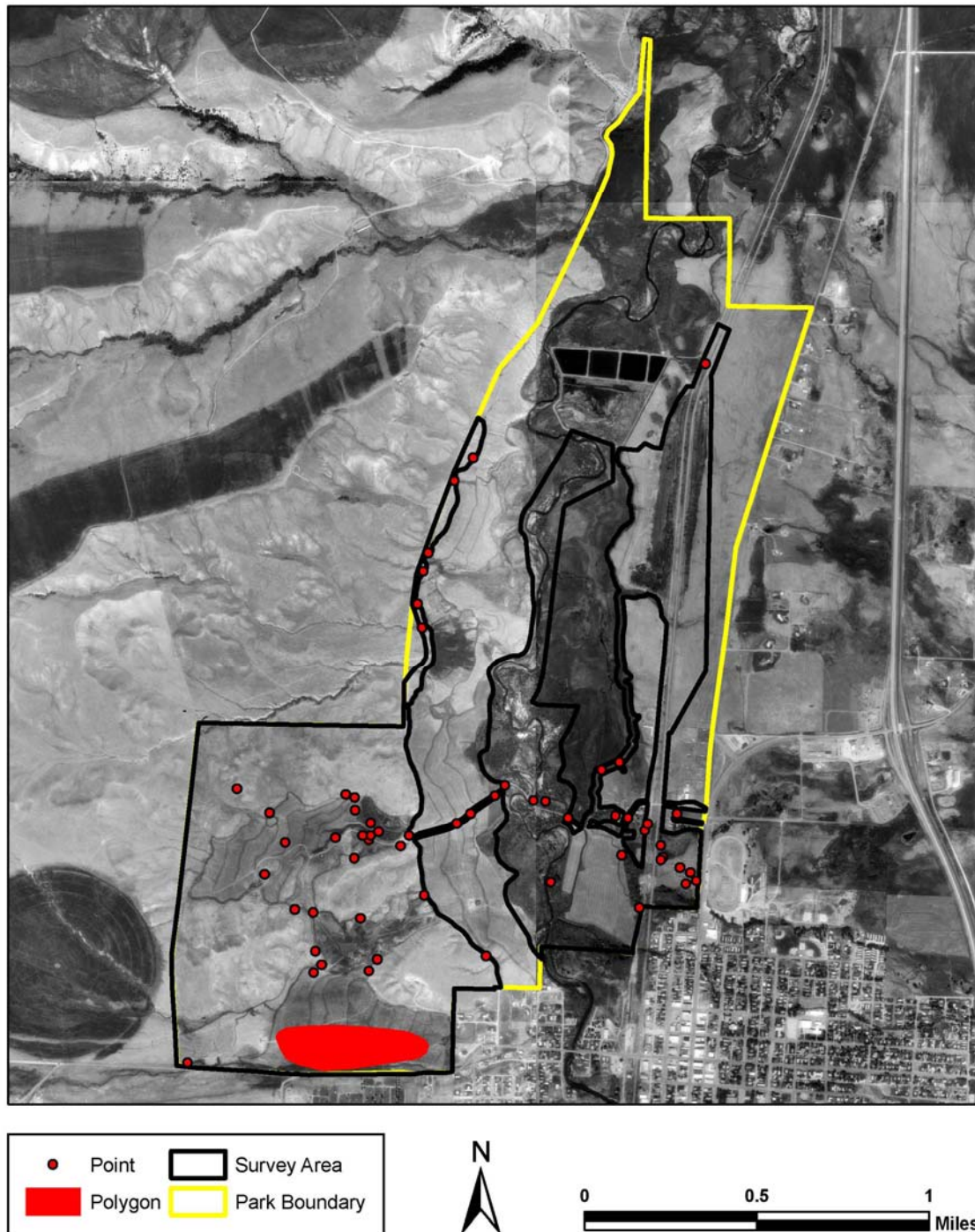


Figure 7. Map of whitetop distribution in GRKO.

Spotted knapweed (*Centaurea biebersteinii*)

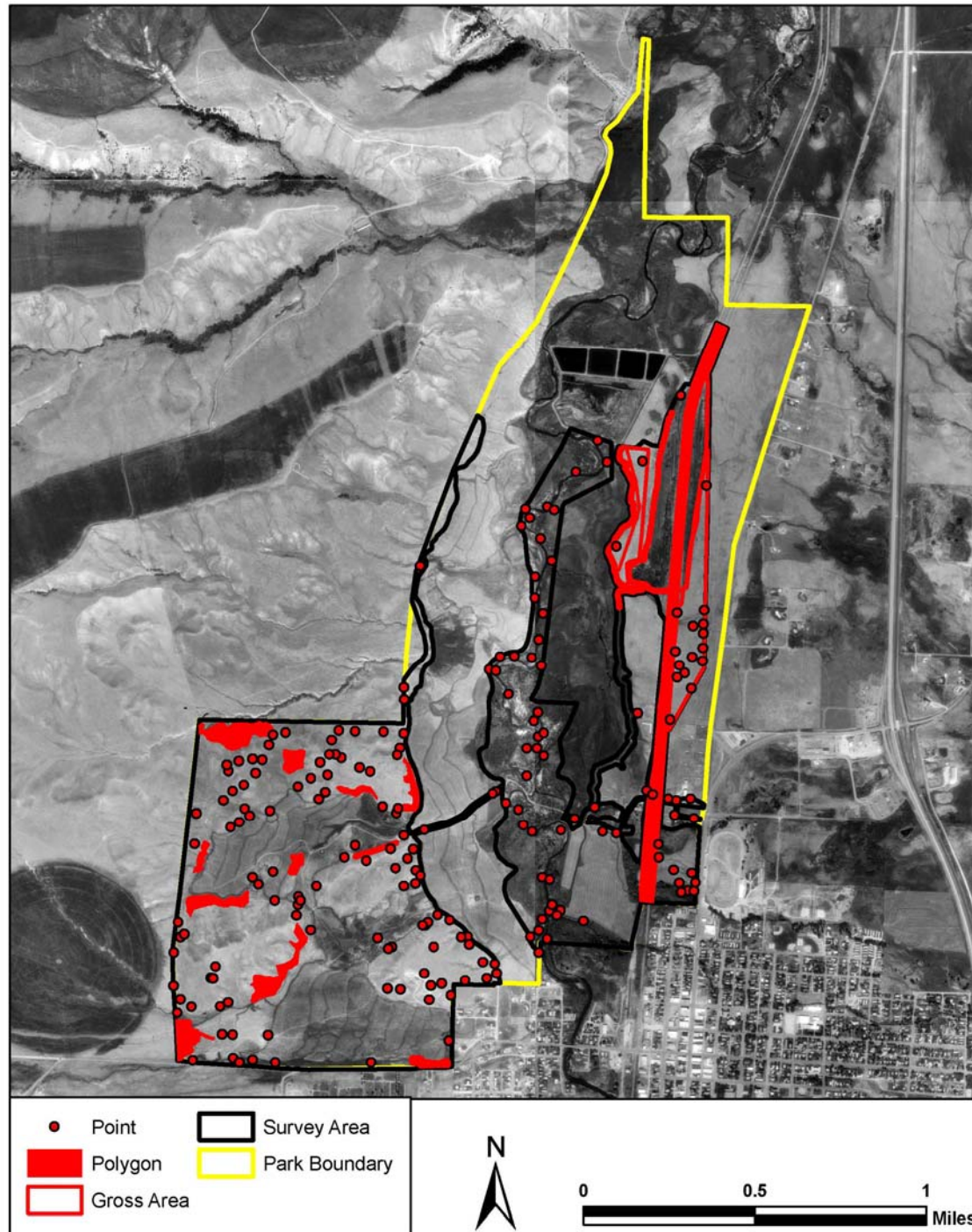


Figure 8. Map of spotted knapweed distribution in GRKO.

Canada thistle (*Cirsium arvense*)

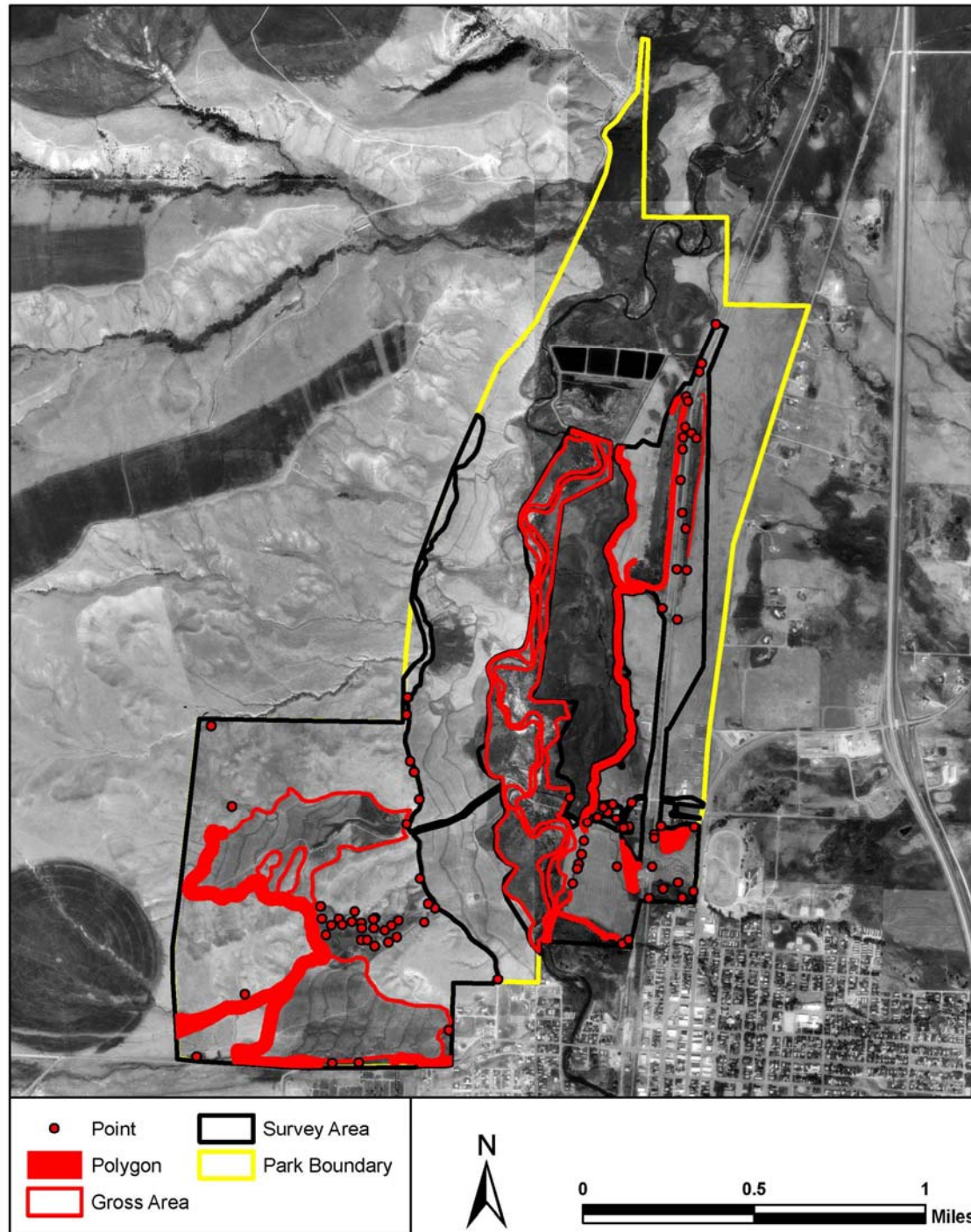


Figure 9. Map of Canada thistle distribution in GRKO.

Field bindweed (*Convolvulus arvensis*)

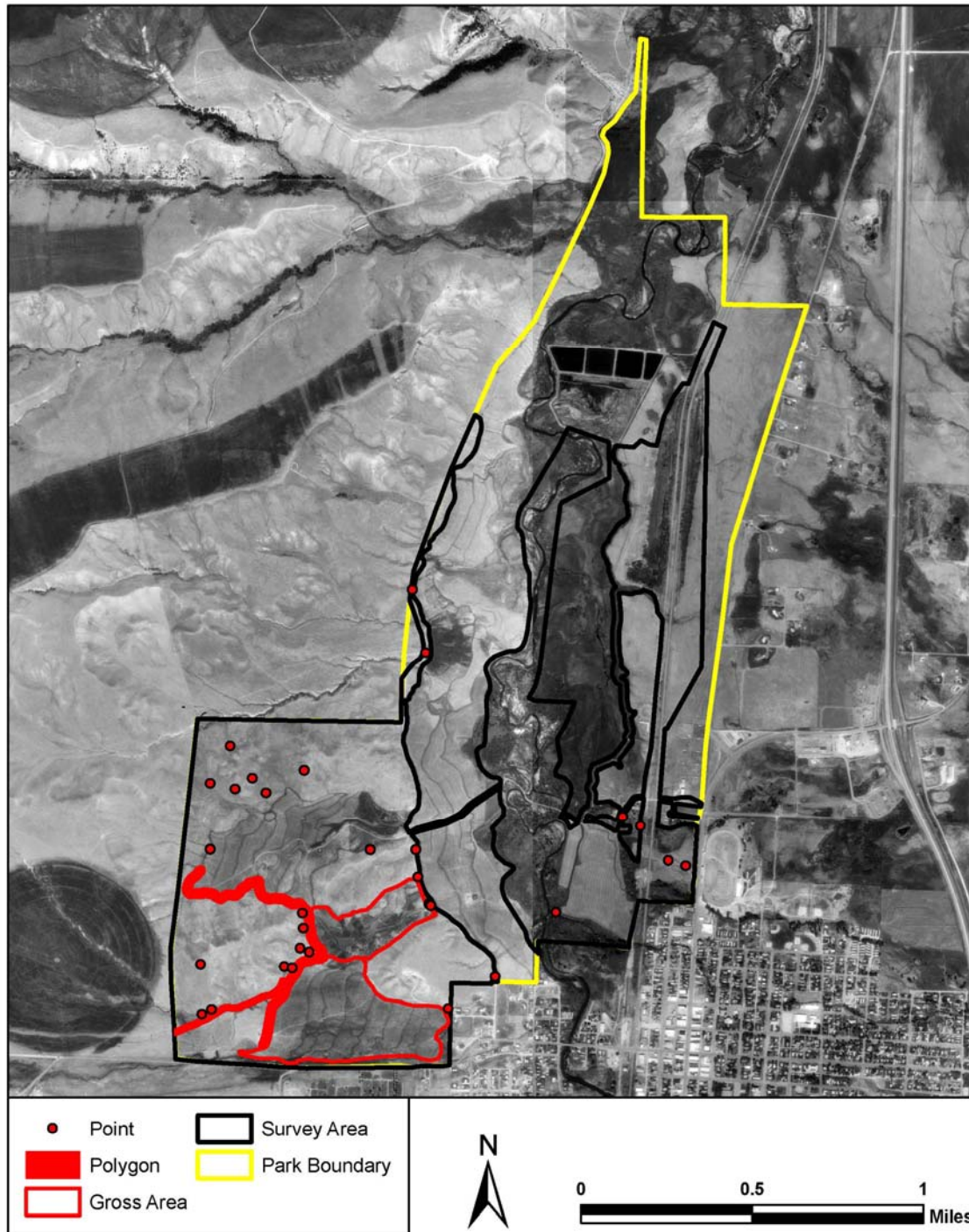


Figure 10. Map of field bindweed distribution in GRKO.

Houndstongue (*Cynoglossum officinale*)

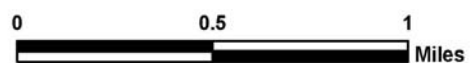
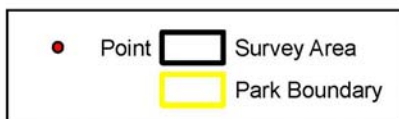
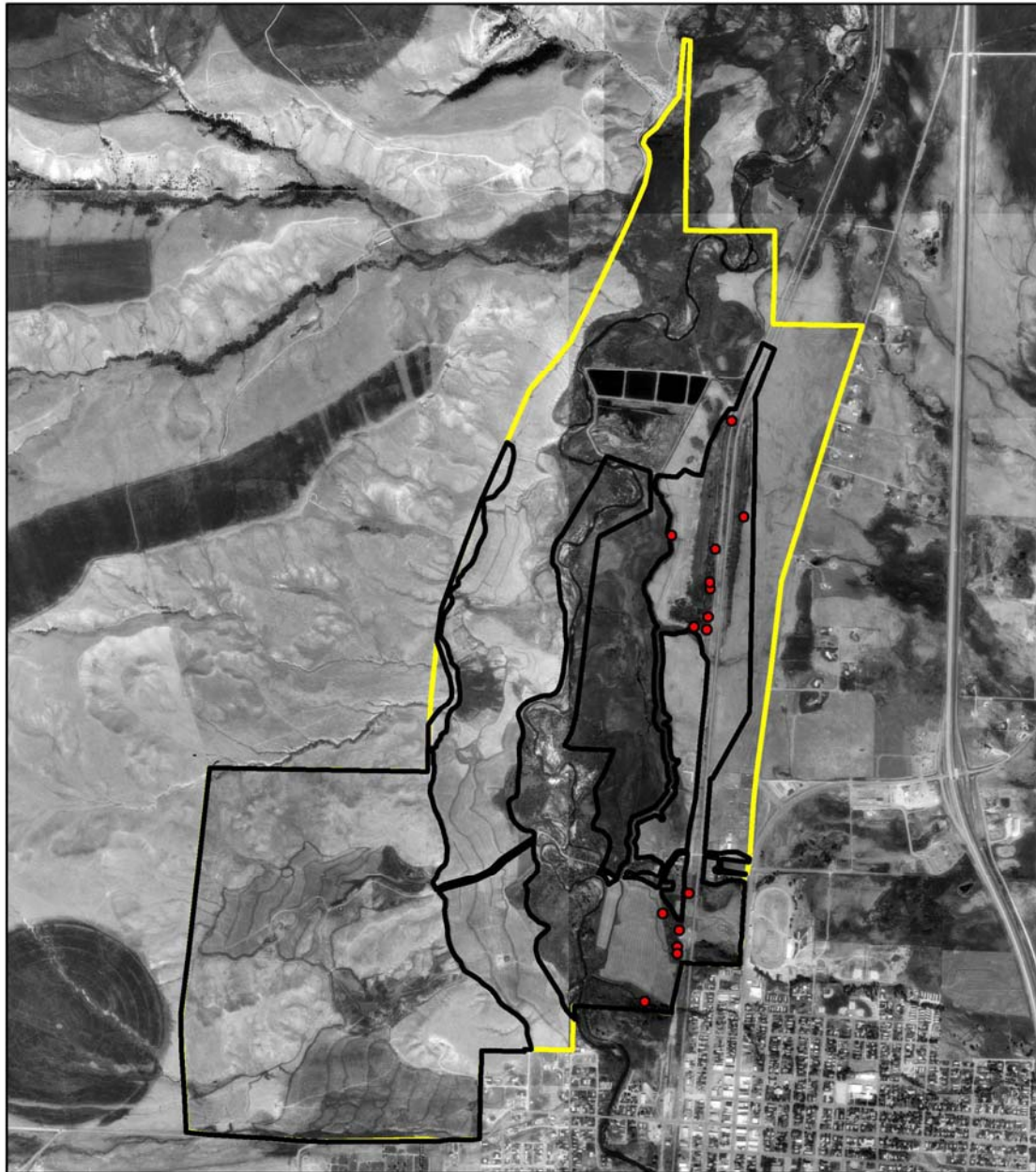


Figure 11. Map of houndstongue distribution in GRKO.

Leafy spurge (*Euphorbia esula*)

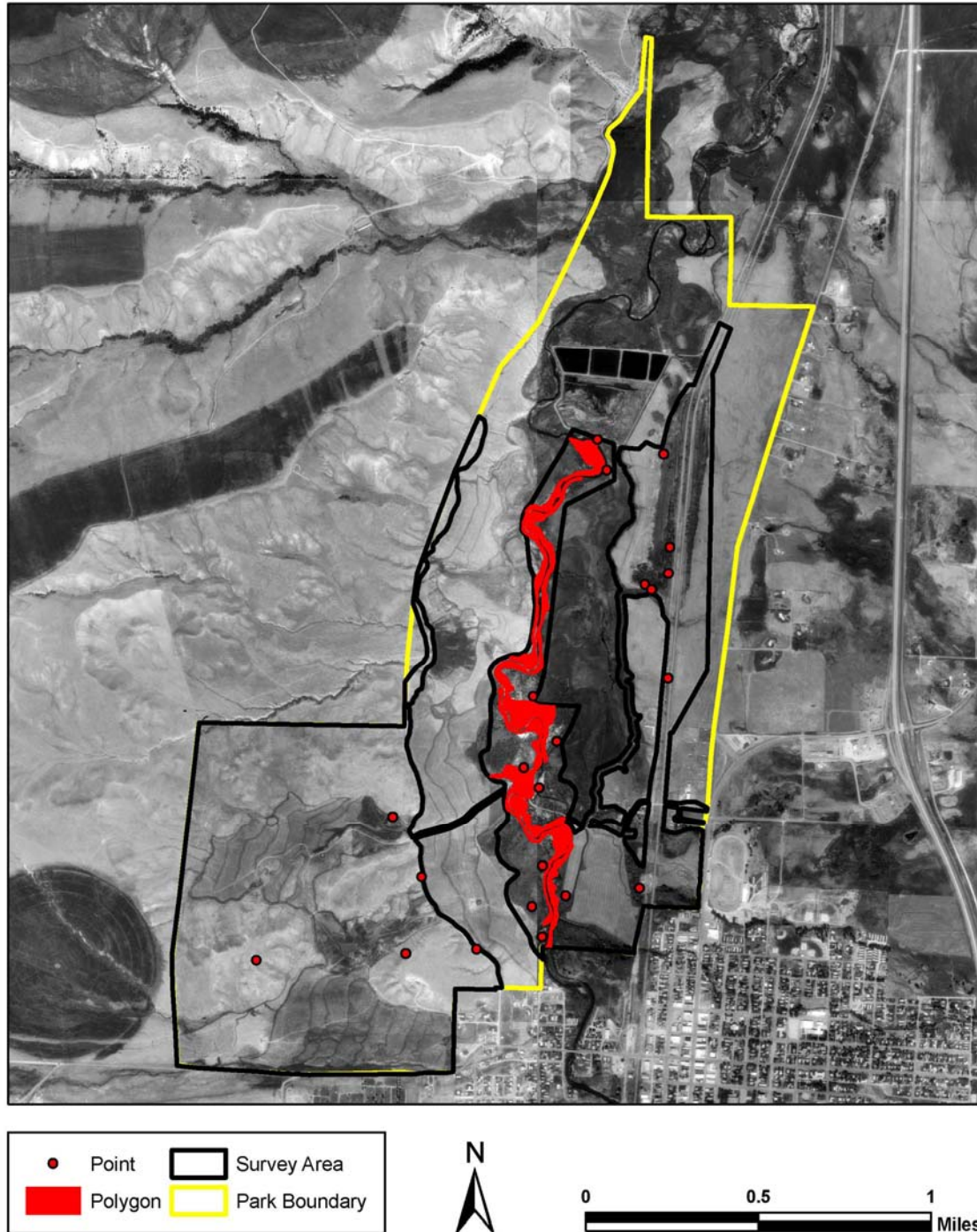


Figure 12. Map of leafy spurge distribution in GRKO.

Babysbreath (*Gypsophila paniculata*)

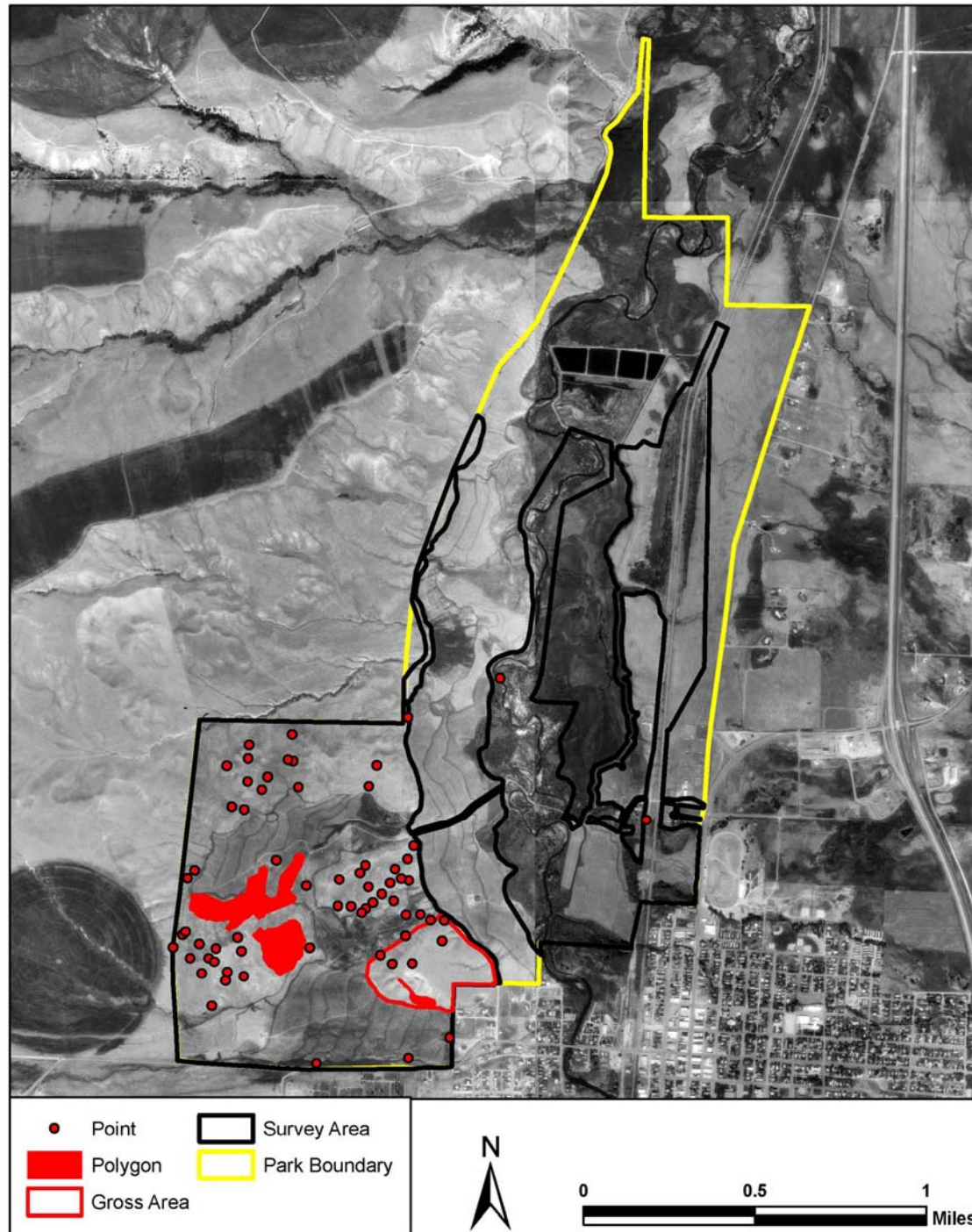


Figure 13. Map of babysbreath distribution at GRKO.

Perennial pepperweed (*Lepidium latifolium*)

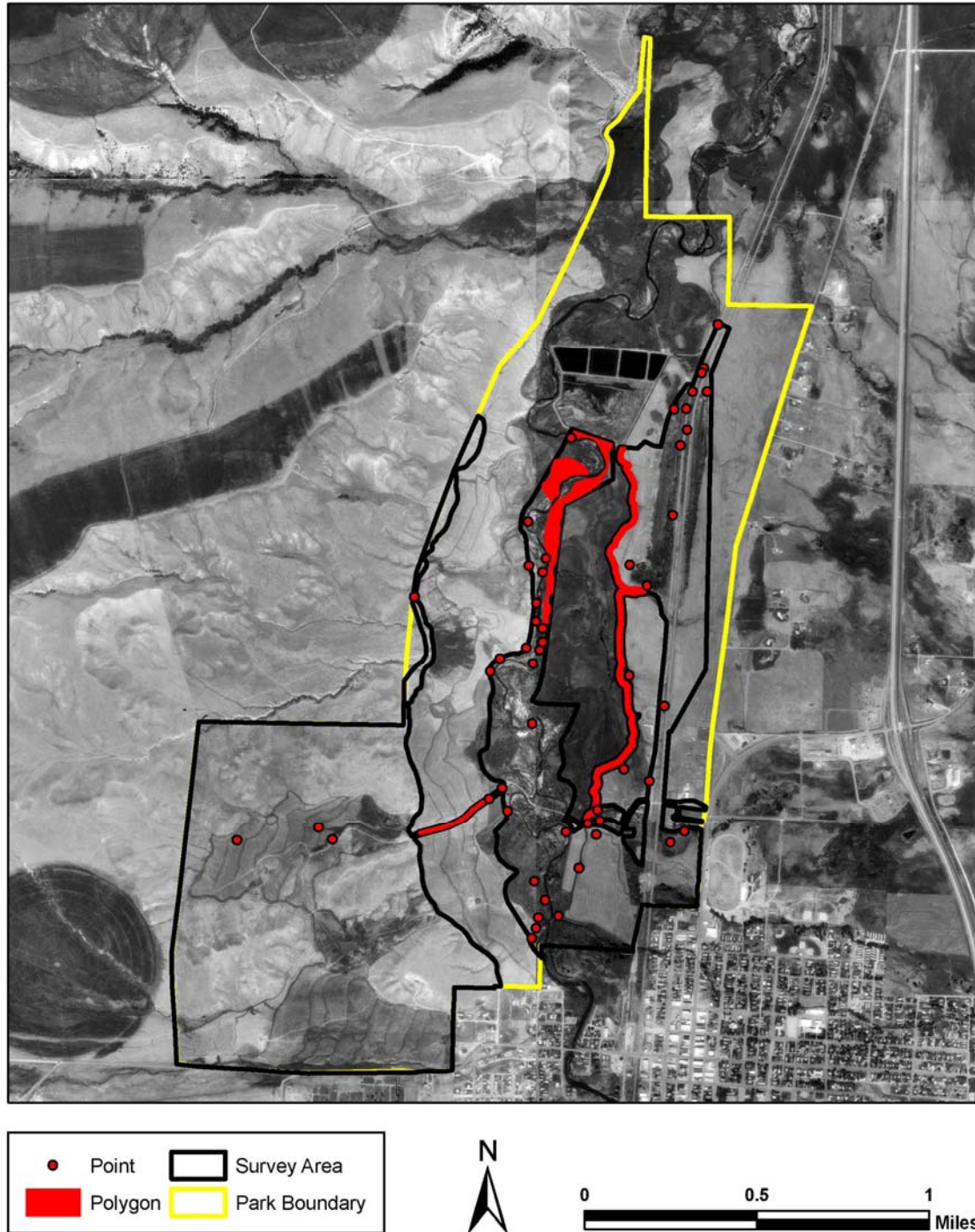


Figure 14. Map of perennial pepperweed distribution in GRKO.

Yellow toadflax (*Linaria vulgaris*)

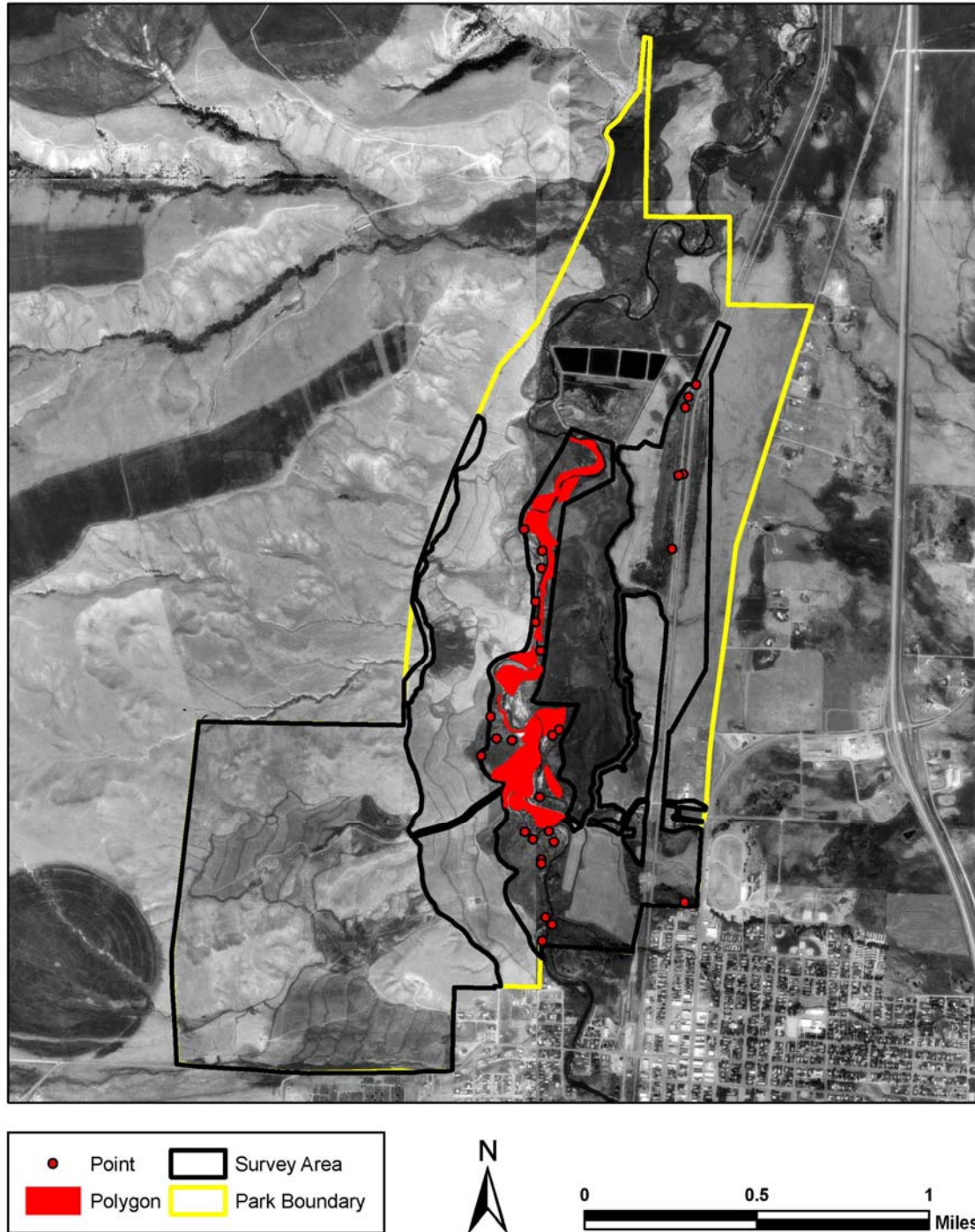


Figure 15. Map of yellow toadflax distribution in GRKO.

Tall buttercup (*Ranunculus acris*)

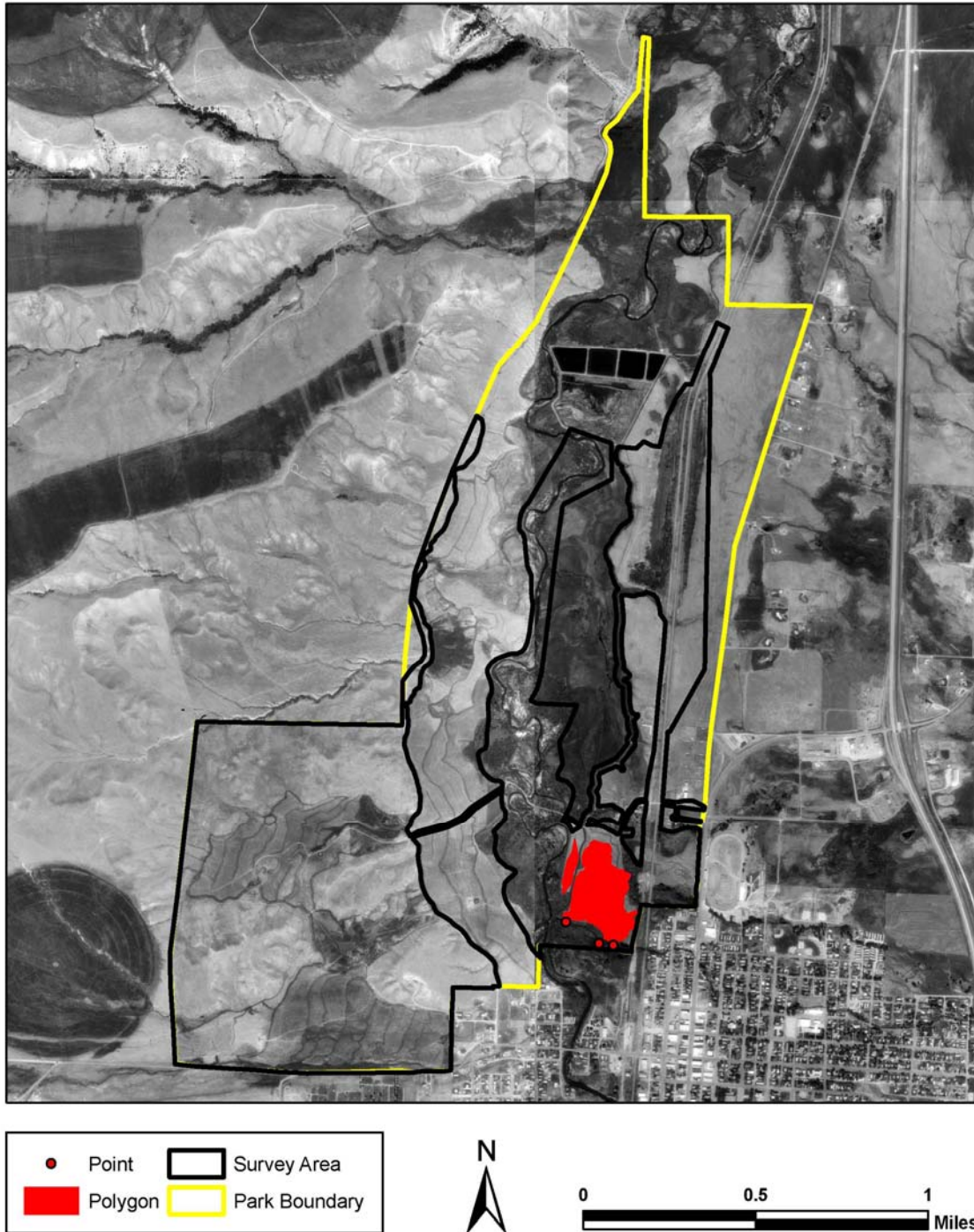


Figure 16. Map of tall buttercup distribution in GRKO.

Common tansy (*Tanacetum vulgare*)

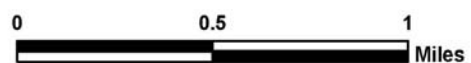
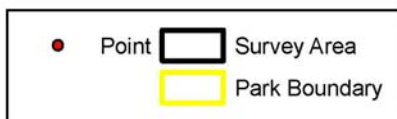
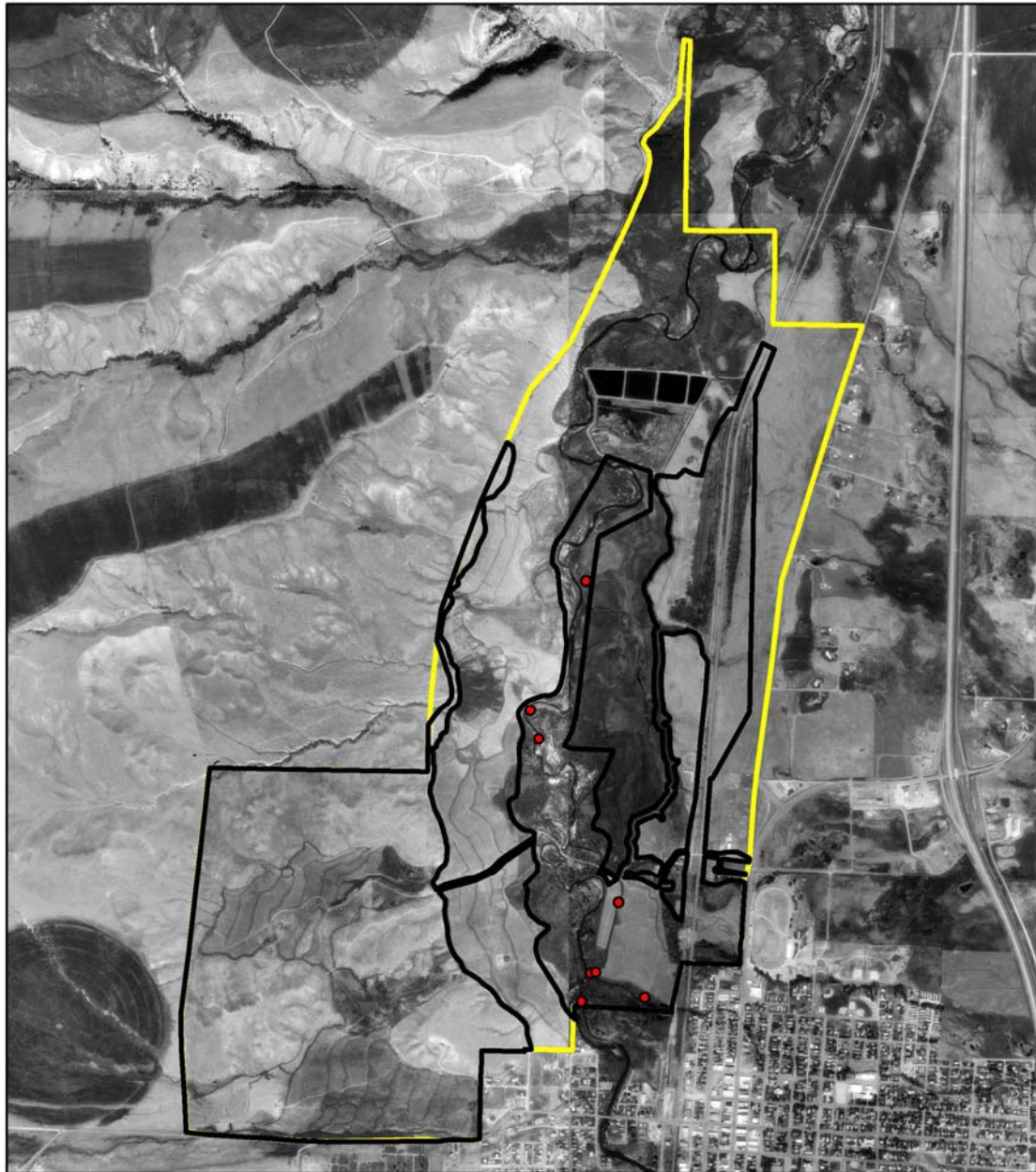


Figure 17. Map of tall buttercup distribution in GRKO.

Conclusion

The 2003 non-native plant survey provides managers at GRKO and the IMR with a snapshot of non-native plant distributions in portions of Grant-Kohrs Ranch. This spatial data should supplement the Grant-Kohrs Ranch Weed Management and Restoration Plan by providing estimates of location and abundance of non-native plants of concern.

Total infested area is simply the estimated area within the survey area that is occupied by any non-native plant, whether it is one or many species. Total infested area is important because while it indicates the proportion of land within the survey area that is infested it also provides insight into the proportion of land that is potentially weed-free. This allows managers to prioritize management within the infested areas as well as to promote weed resistant plant communities in areas that are not invaded. From our survey, we estimated that 65% - 70% of the survey area was infested with one to several of the targeted non-native plants. This percentage is high because of the ubiquitous nature of several of the species mapped, including Canada thistle, spotted knapweed, and field bindweed.

We recommend that periodic surveys continue to search for these and other invasive plants. There were extensive infestations of Canada thistle and spotted knapweed throughout most of the areas of the ranch we surveyed. Field bindweed was pervasive throughout pastures and other mesic areas we surveyed. The weed management plan addresses different strategies for these plants based on the management unit where they are located.

The Clark Fork riparian area will undoubtedly prove to be the most challenging habitat for weed management and restoration efforts. There are significantly large infestations of leafy spurge, yellow toadflax, perennial pepperweed, and Canada thistle. However, there are small infestations of Russian knapweed and common tansy that have the potential to be successfully eradicated here. Outside the riparian area, there are scattered infestations of leafy spurge, Russian knapweed, and houndstongue. Because of their small size, these patches also hold the potential to be successfully eradicated.

The 2003 survey did locate one new invader, tall buttercup, which was previously unrecorded at Grant-Kohrs Ranch. We did not locate sulphur cinquefoil (*Potentilla recta*), a species previously recorded in the riparian area. Our survey could easily have missed this plant. Again, we stress the importance of continued mapping and monitoring. We recommend that managers use these data as a baseline for designing long-term monitoring of the invasiveness of non-native plants, of impacts of non-native plants on the ecosystem, and of the impacts of management on both non-native plants and the ecosystem. Following we provide guidelines on how this might be achieved.

Recommendations

Monitoring of non-native plant populations

As stated in the introduction, there are three phases of non-native plant species management, inventory/survey, monitoring and control. Once we have completed an inventory/survey, as we

have for GRKO, the next phase is monitoring. There are different aspects of the monitoring phase:

- to monitor for new populations of non-native plants in close proximity to current populations,
- to evaluate if non-native plant populations are growing at a rate fast enough and consistent enough to be considered invasive (increasing in spatial extent),
- to determine if non-native plant populations are having a significant impact on an ecosystem, under the management objectives for that ecosystem,
- to determine if invasive species management is having a significant impact on the non-native plants, and on the ecosystem under the management (i.e. cost benefit analysis) objectives for that ecosystem,
- and to monitor for species not currently found in the area.

Here we will provide information on the first steps of monitoring, which is to determine which species, under which environmental conditions are changing most rapidly. By determining which species and populations in which environments are most invasive, they can be ranked. The problem list can then be systematically worked down as time and money allows. To achieve the ranking we need to select a number of patches and set up permanent markers to determine how much the patches are changing over time in situations where no management practices are being used and areas where they are. In this way, we could also evaluate which management practices are reducing the density or size of the patch as we intend, and if they are changing the occurrence and density of the native species. We may also want to evaluate different management practices and see how they compare.

Different monitoring objectives may require different methods to accomplish them. There is no set of well-tested conventional methods for monitoring. We have been experimenting with some methods in the field and with simulation models. Thus, the concepts for monitoring methods presented here are general, preliminary, and are suggested based on theory and experience, but are not well tested. Examining these different types of monitoring will be addressed in a forthcoming publication by Maxwell and Rew at MSU, however if any detailed information is desired before then please feel free to contact Lisa Rew by email at lrew@montana.edu, or visit the following website, which is frequently updated:
<http://weedeco.msu.montana.edu/class/LRES443/lres443.htm>.

Finding new colonies

Identifying new colonies of the non-native plant 7 ft to 328 ft (2 m to 100 m) around an existing population (patch) can be accomplished efficiently using adaptive sampling (Thompson and Seber 1996). This method first must determine the maximum distance that one can detect a new colony (a few plants). This will be called the identification distance. Once the distance is determined, three random patch edge points are identified by standing in the middle of the patch, selecting random values between 1 and 360, and using the random number as an azimuth to travel along to the patch edge. From the random starting point, one travels the identification distance plus 7 ft (2 m) and turns so that s/he is traveling parallel to the patch edge maintaining the 7 ft (2 m) plus identification distance from the patch (Figure 18). If no new colonies or plants are identified and the patch is fully circled, then continue moving away from the patch another

increment of the identification distance and circle the patch again parallel to the edge. Continue this sampling path until the sampler is 328 ft (100 m) from the edge of the original patch. If a new colony is encountered, then start the process again using the new patch like the original patch, but keeping track not to exceed 328 ft (100 m) from the edge of the original patch and not resampling any already located colonies. When a new colony is located, create a GPS location point in the center of the new colony and estimate its area. Estimates of area can be obtained by using the methods described below. If one collects information along the sampling path about points where the invasive species do not occur and where the vegetative communities change, as well as the new colony occurrence, the data can be used to estimate the probability of occurrence using the methods described by Rew et al. (in press).

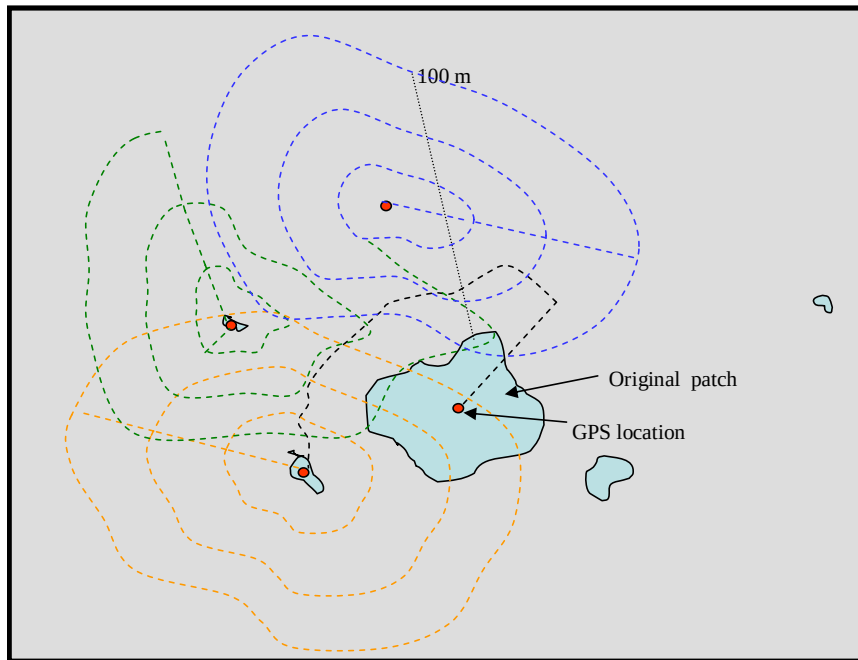


Figure 18. Hypothetical map showing non-native plant patch boundaries (solid lines) and adaptive sampling walking paths (dashed lines) for finding new colonies of the same species.

Monitoring for invasiveness

Monitoring for invasiveness is determining if representative populations of a non-native plant (from across the environments where the species was found with the survey or inventory) are consistently increasing in spatial extent. It is important to select populations from across a range of the habitats where the species was found in the survey, to ensure identifying which populations are truly invasive. Plants tend to increase in spatial extent (spread) in two different ways:

- as a moving front where patches enlarge with expanding radius, and
- by establishing new colonies away from a source population, forming groups of patches (metapopulation) that can coalesce to form larger patches (Cousens and Mortimer 1995).

In order to rapidly determine if a population is increasing in spatial extent, we need to use a technique that will allow us to accurately quantify the area occupied so that the change in area

can be detected from one generation (year) to the next. However, with the standard GPS used by most government agencies, consultants and county weed supervisors, the mean horizontal accuracy is rarely less than 3.3 ft (1.0 m) error. Therefore, at the rate that most populations (patches) spread, it would take a minimum of 4 to 5 years to be certain that the area of a patch was actually increasing, even at a consistent maximum spread per year. Our data indicates that one could not conclude invasiveness of any of the non-native plant populations measured with GPS over 2 years. If the GPS method is employed, there is certainly no reason to return to a patch to determine change in area for at least 4 years.

A more accurate and consistent approach would be to establish permanent points on the ground and measure the distance to patch borders with a tape measure. This is a “low tech” approach but will enable accurate detection of only small changes in patch borders, which is necessary to assess invasiveness in only a few years. It also does not take long to do. It is quite possible that populations will show increases in area occupied in one year, but not other years. If patches are mapped each year, the number of times the patch increases, decreases, or stays the same can be calculated and used to determine the degree of invasiveness. The degree of invasiveness that will trigger management or monitoring for ecosystem impacts is the decision of the manager.

A more complete description of the tape measure method is provided on the following website: <http://weedeco.msu.montana.edu/class/LRES443/lres443.htm>

If monitoring shows that the species is invasive, (all replicate patches are expanding) then it should be monitored for impact and/or management could be initiated. If some patches are found to be consistently expanding and others not, then monitoring should continue and the patches that are expanding should be considered for management. Many may think that most non-native plant populations are expanding rapidly and that measuring that expansion is of academic interest and it would only delay proactive management to incorporate tedious measurements. In fact, where non-native plant patches/populations have been measured (data not published), there was high variability in area occupied from year-to-year and it was often difficult to make accurate measures and conclude that the population was consistently growing or declining.

Monitoring for non-native plant impacts

Monitoring populations found to be invasive for impacts on ecosystem function, species assemblage, and/or productivity can be complicated. There is a well-developed theory for quantifying the economic impacts of a weed on a crop in agroecosystems. A good review of the theory and methods for quantifying weed impacts in crops is available in Cousens and Mortimer (1995). There is a rich body of theory applicable to assessing impacts of invasive species on ecosystem function and species assemblage (Shea and Chesson 2002; Davis et al. 2000; Rejmánek et al. 2000; Mack et al. 2000; Levine 2000; Lonsdale 1999), but there are far less empirical studies that allow comparison of methods (Levine 2000). Quantifying impacts will typically require small spatial scale observations over longer periods to draw conclusions with confidence. In order to offer some methodology that will comply with typical land management goals, that is, protecting ecosystems, one might establish permanent monitoring plots on the edge or on a tangent to the invasion, and observe the invasion and any coincidental change in the desirable plant community. If desirable species are consistently displaced, one might consider the

invasive species to have a significant impact. Upon measuring a significant impact, it would be logical to commence management.

Methodology to quantify species displacement by invasive species requires careful consideration to ensure random selection of invasive populations and placement of sample plots. Random selection of populations or patches of an invasive plant should follow the same logic as selection for determining species invasiveness. That is, the selection of populations from across the environmental conditions where the species is found, within the specific management area. The best approach for selecting sample plots may be to create maps of the edge of several randomly chosen invasive plant patches, then randomly select edge points on the map that can be relocated in the field for repeated sampling (using GPS and field markers). Sample plots (quadrats) should be between 0.25 m² and 5 m² depending on the size of the plants. Larger plants require larger plots, and nesting of quadrat sizes would provide more information (Stohlgren et al. 2003).

Clearly, desirable species displacement does not necessarily result in disruption of ecosystem function, nor does the lack of species displacement mean that the ecosystem could not be significantly disrupted through influence on critical cycles or indirect effects. There is no conventional set of measures to detect these effects, so it will require a keen ability to observe changes, assess their significance and adapt the sampling methodology to quantify such changes. In turn, there must be careful weighing of significance of impacts of the invasive species against the potential disruption of the ecosystem from the management.

Monitoring for impact of non-native plant management

This phase of monitoring occurs after the invasiveness and negative impact of the non-native plant has been quantified, and involves monitoring for the impacts of weed management practices on ecosystem function, species assemblage, and/or productivity. Management would be initiated preferably only on part of a patch, or on one patch and not an adjacent patch of the same species. In this way, the impact of the management could be measured by continuing the same measurements, in the same plots, as established to quantify impacts of the invasive species. In addition, the same metrics of community response to the invasion should be good measures of community impact by management.

Appendix 1.

List of non-native plants that were targeted in the 2003 IMR weed survey.

Species	Common Name	Mapped in 2003	State Noxious Weed List
<i>Acroptilon repens</i>	Russian knapweed	X	MT, WY
<i>Cardaria draba</i>	Whitetop, hoary cress	X	MT, WY
<i>Centaurea biebersteinii</i>	Spotted knapweed	X	MT, WY
<i>Cirsium arvense</i>	Canada thistle	X	MT, WY
<i>Convolvulus arvensis</i>	Field bindweed	X	MT, WY
<i>Cynoglossum officinale</i>	Houndstongue	X	MT, WY
<i>Euphorbia esula</i>	Leafy spurge	X	MT, WY
<i>Gypsophila paniculata</i>	Babysbreath	X	
<i>Lepidium latifolium</i>	Perennial pepperweed	X	WY
<i>Linaria vulgaris</i>	Yellow toadflax	X	MT
<i>Potentilla recta</i>	Sulphur cinquefoil		MT
<i>Tanacetum vulgare</i>	Common tansy	X	MT

Note: *Ranunculus acris* (tall buttercup) was not on the list, but was mapped in 2003. Tall buttercup is on the Montana state noxious weed list.

Appendix 2.

List of dominant species used in the 2003 IMR weed survey, adapted from GRKO vascular plant inventory (Rice and Hardin 2002b).

SPECIES	COMMON NAME
<i>Agropyron cristatum</i>	Crested wheatgrass
<i>Artemisia frigida</i>	Fringed sage
<i>Artemisia cana</i>	Silver sage
<i>Artemisia tridentata</i>	Big sage
<i>Bromus inermis</i>	Smooth brome
<i>Cardaria draba</i>	Whitetop, hoarycress
<i>Carex sp</i>	Sedge
<i>Centaurea biebersteinii</i>	Spotted knapweed
<i>Cirsium arvense</i>	Canada thistle
<i>Convolvulus arvensis</i>	Field bindweed
<i>Cynoglossum officinale</i>	Houndstongue
<i>Deschampsia caespitosa</i>	Tufted hairgrass
<i>Elymus repens</i>	Quackgrass
<i>Ericameria nauseosa</i>	Rubber rabbitbrush
<i>Equisetum laevigatum</i>	Smooth scouring-rush
<i>Euphorbia esula</i>	Leafy spurge
<i>Festuca campestris</i>	Rough fescue
<i>Glycyrrhiza lepidota</i>	Wild licorice
<i>Gypsophila paniculata</i>	Baby's breath
<i>Hesperostipa comata</i>	Needleandthread
<i>Juncus balticus</i>	Baltic rush
<i>Lepidium latifolium</i>	Perennial pepperweed
<i>Linaria vulgaris</i>	Yellow toadflax
<i>Melilotus officinalis</i>	Yellow sweetclover
<i>Pascopyrum smithii</i>	Western wheatgrass
<i>Phleum pretense</i>	Timothy
<i>Phlox hoodii sp. muscoides</i>	moss phlox
<i>Poa secunda</i>	Sandberg's bluegrass
<i>Polygonum amphibium var. emersum</i>	Water smartweed
<i>Populus balsamifera ssp. trichocarpa</i>	Black cottonwood
<i>Potentilla anserina</i>	
<i>Potentilla recta</i>	Sulphur cinquefoil
<i>Pseudoroegneria spicata</i>	Bluebunch wheatgrass
<i>Ribes oxycanthoides</i>	Canadian gooseberry
<i>Rosa woodsii</i>	Wood's rose
<i>Rumex crispus</i>	Curly dock
<i>Salix sp</i>	Willow
<i>Salix bebbiana</i>	Bebb willow
<i>Salix boothii</i>	Booth's willow
<i>Salix exigua</i>	Sandbar willow, coyote willow
<i>Salix geyeriana</i>	Geyer willow
<i>Sonchus arvensis</i>	Annual sowthistle
<i>Symphoricarpos occidentalis</i>	Western snowberry
<i>Tanacetum vulgare</i>	Common tansy
<i>Trifolium pratense</i>	Red clover
<i>Trifolium repens</i>	White clover

<i>Typha latifolia</i>	Cattail
<i>Urtica dioica</i>	Stinging nettle
<i>Vicia americana</i>	American vetch
Unknown	

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