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National Park Service
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Natural Resource Stewardship and Science

A Framework for Ecologically-based Invasive Plant Management

John Day Fossil Beds National Monument

Natural Resource Report NPS/UCBN/NRR—2015/911

ON THIS PAGE
Logos of the agencies that collaborated in the development of this Plan

ON THE COVER
Photograph looking south up the John Day River valley from a high point in the Clarno Unit of the John Day Fossil Beds National Monument. National Park Service photo.

A Framework for Ecologically-based Invasive Plant Management

John Day Fossil Beds National Monument

Natural Resource Report NPS/UCBN/NRR—2015/911

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Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Acknowledgments

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Introduction

Sagebrush steppe is one of the most threatened ecosystems in the Intermountain West. Prior to Euro-American settlement, sagebrush steppe ecosystems in the upper Columbia Basin extended across the eastern half of Washington and Oregon, and the northern Great Basin of southern Idaho. Substantial portions of the region have been converted to agriculture and heavily grazed rangeland. Much of the remaining sagebrush steppe has been degraded through altered fire regimes and invasion of introduced plants. Historic and current land use practices continue to fragment and alter steppe ecosystems and predicted climate change scenarios for the region could exacerbate these changes.

Oregon vegetation is heavily influenced by the interactions of climate and topography and it is likely that future climate change will affect plant species by shifting vegetation types (OCCRI 2010). Increased fire activity and expansion of invasive species will also influence the response of native systems to climate change. Ecologically-based invasive plant management may help in fostering ecological resiliency, the capacity of an ecosystem to absorb disturbances such as climate change or wildfire without shifting to a drastically different state that is undesirable. Therefore, fostering resilience is a fundamental goal for ensuring that the negative effects of climate change are minimized or otherwise slowed. The NPS will apply adaptation actions to support resilience in a scientifically rigorous manner by protecting remaining intact plant communities and restoring damaged landscapes through the control of noxious weeds and restoration of native plant species (NPS 2010).

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's (NPS) ability to manage park resources in a manner that preserves them unimpaired. Consequently, the NPS’s Upper Columbia Basin Network Inventory and Monitoring Program (UCBN) was established to monitor important park vital signs, including sagebrush steppe vegetation, in parks across the region. Monitoring establishes a baseline against which future change will be measured. The results from the first few years of study, have revealed that cheatgrass (*Bromus tectorum*) dominates much of the sagebrush steppe landscape within the park. Medusahead (*Elymus caput-medusae*), another invasive grass, is patchily abundant but spreading rapidly, with worrisome trends increasing in all three subunits of the park. The cover of big sagebrush (*Artemisia tridentata*) is low and many areas that once supported sagebrush have burned. The cover of important native bunchgrasses such as bluebunch wheatgrass (*Pseudoroegneria spicata*) and Thurber’s needlegrass (*Stipa thurberiana*), which are iconic to the Monument’s steppe character, is low to moderate.

In order to operationalize these findings for guiding park management, we developed predictive models and corresponding maps of native bluebunch wheatgrass and non-native cheatgrass abundance and distribution from monitoring data. The maps were used to prioritize areas for implementation of a science-based management tool known as Ecologically-based Invasive Plant Management (EBIPM) developed by the U. S. Department of Agriculture’s Agriculture Research Service. EBIPM is a step-wise decision-making process that allows land managers to systematically develop restoration and invasive plant management plans. The process of modeling and application to landscape prioritization for implementation of EBIPM was described in a scientific paper published in the journal *Ecopshere* in 2014.

This document provides additional guidance for implementing EBIPM in the Monument that provides strategies for invasive plant management in areas that are prioritized into one of three hierarchies based on abundance of native bunchgrass species and exotic annual grass species and proximity to roads and trails. Prevention strategies to reduce invasion by non-native plants are identified for the areas that are in good condition that contain a high percentage of native bunchgrasses. Because prevention and protection of remnant intact areas is recognized as being the most ecologically-effective, these areas are referred to as Priority 1 areas. On partially weed invaded sites (Priority 2), goals are to reduce the abundance of non-native species in order to eliminate competition to native plants so they can recover, possibly without further restoration efforts. For heavily degraded areas that have become monocultures of non-native species (Priority 3), complete revegetation of native species is required to fully restore native plant communities. Due to the high costs and low success probabilities associated with restoring such degraded sites, these areas are considered lowest priority except in small, highly-visible parcels such as fallow agricultural fields along roads where potential for restoration is high.

We conclude with a review of the principles of adaptive management, in which feedback from monitoring and experience is incorporated into an evolving strategy of restoration and landscape management. Adaptive management promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and ever changing environmental conditions become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust treatments as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental goals and increases scientific knowledge.

This document provides the Monument a framework for action that recommends a substantial amount of work even for the Priority 1 areas. The National Park Service's 2006 Management Policies states that all exotic plant species will be managed up to and including eradication if control is prudent and feasible and the exotic species interfere with natural processes (NPS 2006). High priority will be given to managing exotic species that have, or potentially could have a substantial impact on park resources, and that can reasonably be expected to be successfully controlled. Where exotic species cannot be successfully eliminated, managers will seek to contain the exotic species to prevent further spread or resource damage. This plan will only be effective if the correct amount of time, effort and funding will be devoted to monitor and control invasive weeds annually.

Goals and Objectives

Overall Vegetation Management Goal

John Day Fossil Beds National Monument is managed from an ecosystem perspective, striving to retain its ecological integrity using the best available scientific information and technology and adaptive management strategies (NPS 2009). Natural processes, ecosystem dynamics, and population fluctuations occur with as little human intervention as possible. However, potential threats are identified early and proactively addressed. The condition of vegetative communities will be reminiscent of the period before Europeans began altering the Monument. Areas external to the Monument where ecological processes and/or human use affect Monument vegetation are identified and managed cooperatively to resolve issues and concerns.

Specific Objectives

- Monument vegetation will be inventoried and monitored over the long-term to quantify, locate, and document plant populations to assess their current status and trends over time. Collected data will be used as a baseline against which to regularly monitor the distribution and condition of selected species, including indicators of ecosystem condition and diversity, rare or protected species, and invasive exotics.

- The Monument's bunchgrass/sagebrush steppe environment is restored as nearly as possible to the condition it would be in today had natural ecological processes not been altered using native genetic materials (when available) from the local region to regain maximum habitat value.

- Previous or new disturbed areas will be restored using native genetic material.

- Native species populations that have been severely reduced in or extirpated from the Monument are reintroduced where feasible.

- NPS staff will participate in regional ecosystem efforts to restore native species.

Photo 1. Native bunchgrass hillside

Invasive Plant Management Goal

The presence of invasive nonnative species in the Monument is minimized and controlled to the degree possible to reduce the economic, ecological, and human health impacts that these species cause (NPS 2009).

Specific Objectives:

- Invasive nonnative plant species will be inventoried and monitored over the long-term to quantify, locate, and document plant populations to assess their current status and trends over time.
- Integrated pest management procedures will be used to control nonnative plants.
- Active restoration efforts will focus on management of nonnative species.

The management of populations of nonnative plant species, up to and including eradication, will be undertaken. High priority is given to managing exotic species that have the potential to rapidly spread and dominate native plant communities and can be controlled successfully.

Photo 2. Dalmation Toadflax

Land Use History

Contemporary upland vegetation in the Monument is dominated by bunchgrass steppe and western juniper (*Juniperus occidentalis*) woodlands. However, many plant communities have also been altered by historic settlement and post-settlement land use activities and altered disturbance regimes. As a result, much of the Monument uplands have been converted to annual grasslands dominated by cheatgrass (*Bromus tectorum*), medusahead (*Elymus caput-medusae*), and other exotic invasive species generally of Eurasian origin. Effective management of upland vegetation in the Monument must be informed by an understanding of the settlement patterns and land use activities because this has been an overwhelming driver of ecological change in the region. If the Monument cannot use pre-settlement vegetation as a target for restoration and management, it can at least serve as a reference point to enhance our understanding of the magnitude and rate of historic vegetation change, and to guide our discussion of the goals and objectives of Monument vegetation management. Because of the National Park Service's mission to preserve and protect natural resources in parks, the connection to pre-settlement conditions is perhaps more relevant here than in other rangelands which are managed for other purposes such as forage production.

Pre-historically the John Day area was comprised of a heterogeneous distribution of plant associations. Grasslands were interspersed with sagebrush-steppe and woodlands. The distribution of these communities was largely influenced by natural disturbance in the era prior to Euro-American settlement. Dominant grasses at this time consisted of varying distributions of bluebunch wheatgrass (*Pseudorongeneria spicata*), Idaho fescue (*Festuca idahoensis*) at higher elevations, Sandberg bluegrass (*Poa secunda*), and Great Basin wild rye (*Leymus cinereus*). Dominant shrubs included sagebrush (*Artemisia* spp.), antelope bitterbrush (*Purshia tridentata*), and rabbitbrush (*Chrysothamnus* spp. and *Ericameria* spp.). Juniper woodlands were typically restricted to rocky outcroppings and low production sites (Miller and Rose 1999) and consisted primarily of western juniper.

The John Day region has seen dramatic shifts in landscape composition and species diversity. The rate of current juniper expansion is comparable to similar expansions of large woody species in the southwestern U.S., Africa, Australia, and South America (Miller and Rose 1999). Juniper seedlings are very susceptible to fire induced mortality and this is considered to be one of the main factors limiting pre-historic rates of juniper expansion (Burkhardt and Tisdale 1976, Miller and Rose 1999, Johnson and Miller 2008). It is generally believed that juniper distribution in the region was restricted to rocky outcrops or low sagebrush (*Artemisia arbuscula*) sites with similarly rocky substrates where low amounts of fine fuels limited the spread of fire (Miller and Rose 1999, Johnson and Miller 2008). In wetter mountain big sagebrush (*Artemisia tridentata vaseyana*) communities, mean fire intervals historically ranged from 12 to 15 years which would ensure the restriction of woody encroachment into shrub-steppe systems (Miller and Rose 1999). However, in low-elevation Wyoming (*A. t. wyomingensis*) and basin big sagebrush (*A. t. tridentata*) communities typical of the Monument, average annual production tends to be even lower than mountain big sagebrush sites and fine fuels accumulate at a much slower rate. Mean fire intervals of 100 years or more are believed to have contributed to stand development which was typified by widely distributed individuals (Miller and Rose 1999).

Johnson and Miller (2008) looked at spatial distribution and density of pre-settlement juniper in southwest Idaho and southeast Oregon and they determined that prior to 1860, the size of high density, wooded stands tended to be relatively small (< 0.5ha). The typical stand structure observed consisted of widely spaced individuals (1 to 26 trees per hectare) which they believe increased the potential for greater species diversity within the understory. Due to the distribution of trees observed in their study, Johnson and Miller (2008) believe that grasslands as well as shrub-steppe type vegetation dominated the landscape at this time.

Prior to the arrival of Euro-American settlers, these landscapes were actively managed by Native American tribes living in the area (Hessburg and Agee 2003). Historical reports suggest that the observed frequency of low intensity fires, believed to have influenced the vegetative structure of the landscape, may have been anthropogenic in origin. The introduction of Spanish horses into native cultures may have led to intensified burning regimes in an effort to increase production of herbaceous species (Hessburg and Agee 2003). Fur trapping expeditions, which had been active since the 1770s, exposed native peoples to a wide range of new diseases. As a result, between 1770 and 1870 populations were severely impacted, reducing occupancy in some areas by greater than 80%; this reduction in population may have influenced the observed change in fire intervals during this time period (Hessburg and Agee 2003). Because of reduced hunting pressure, native populations of deer and elk increased dramatically during this time, intensifying grazing pressure until Euro-American hide markets once again intensified hunting pressure (Hessburg and Agee 2003).

Fur trappers in the northwest nearly decimated the native population of beaver, creating far reaching environmental alteration and degradation (Hessburg and Agee 2003). Beavers are considered to be ecosystem engineers because of their active management of selected sites to improve their habitat. This has a cascade of effects on the surrounding area. The dams they construct reduce stream flow and lead to the formation of wetlands (Hessburg and Agee 2003). These wetlands have a number of ecological benefits including sediment capture, habitat establishment, increases in water infiltration, and enhancement of species diversity (Hessburg and Agee 2003). The decline in beaver populations would have had systemic effects throughout the John Day Basin including wetland losses and associated changes in hydrologic cycles.

In 1862, gold was discovered in the basin, accelerating settlement. As the gold mining industry developed in the region, efforts were made to relocate the remaining populations of native tribes in order to increase land access (Hessburg and Agee 2003). Pan mining of gold placers was soon replaced by dredging operations (Wissmar et al. 1994, Hessburg and Agee 2003). Riparian systems were clear cut or burned in an effort to increase access to profitable mining sites. These operations severely degraded watershed structure and functionality leading to the alteration of hydrologic cycles within the basin, extensive erosion and pollution of waterways by mining leachates (Wissmar et al. 1994, Hessburg and Agee 2003). In the North and Middle forks of the John Day River evidence of past mining activities persist today in the form of dredge deposits and toxic metal settling ponds (Wissmar et al. 1994).

Photo 3. Gold dredging operation near John Day, Oregon

Increased clearing of upland forests spurred the establishment of the first saw mill in the region in 1862 (Wissmar et al. 1994). The establishment of railroad systems as well as active road development during this period created greater opportunities for nation-wide trade of commodities. The clearing of forests and establishment of a railroad coincided with the introduction of large numbers of domestic grazing animals (Wissmar et al. 1994, Hessburg and Agee 2003). Land grant proposals aimed at expanding the road and rail systems initiated a process of landscape subdivision (Hessburg and Agee 2003) where alternative land management strategies produced a fragmented landscape. The boom of the mining industry in the John Day Basin stimulated the import of cattle to feed growing numbers of settlers. Hessburg and Agee (2003) reported over 200,000 cattle present in the region by 1860. Due to a relatively large demand for water, cattle are often attracted to gazing sites near, or in, wetlands and riparian zones (Hessburg and Agee 2003). Cattle grazing in these areas compounded the degradation which had previously occurred as a result of mining and logging operations (Hessburg and Agee 2003).

Migrating from the Willamette Valley in 1861, Eli Casey Officer and his brother became the first family to begin grazing operations in Butler Basin, an area within the Sheep Rock Unit of the Monument. The Officer family introduced many of the first sheep into the region. Vast herds of sheep were subsequently introduced and the region was a global leader in wool exports during the late 19th century and early 20th century (Wissmar et al. 1994, Hessburg and Agee 2003). Because sheep and cattle have different foraging strategies and preferences, their combined presence on the landscape severely degraded the remaining native upland vegetation. In 1890, one of Eli's sons, Floyd Officer, and Floyd's wife Sylvia, established a homestead in Butler Basin. Floyd assisted in the early explorations of Thomas Condon, a minister and scientist who was responsible for identifying the paleontological significance of the area. In 1910, Floyd Officer moved his family to the Dayville area and sold their ranch to the Cant family, recent immigrants from Scotland. The Cant family grazed sheep, and eventually cattle, for the next six decades, becoming one of the largest, longest lasting ranching operations in the area. Their ranch home serves as the Monument headquarters. The Clarno family, after whom the northernmost unit of the Monument was named, also settled in the region in the 1860's. Like the Officers and Cants, the Clarno family established a successful and well known cattle ranching operation. Carroll Rim, in the Painted Hills Unit of the Monument, was named for the Carroll family, another early-settlement ranching family. The Carroll family grew subsistence crops and grazed sheep in the surrounding hills until about 1900, selling the ranch shortly after the Second World War.

Photo 4. Cant Ranch – present day Monument headquarters

The introduction of domestic livestock to the region during the mid-19th century coincides with the introduction of cheatgrass and other exotic plant species (Hessburg and Agee 2003). As bunchgrass communities failed under the combined pressures of juniper establishment and overgrazing, ranchers began to seed exotic forage species such as crested wheatgrass (*Agropyron cristatum*) in order to increase productivity on the range (Hessburg and Agee 2003). The import of large amounts of non-native seeds rapidly accelerated rangeland degradation (Hessburg and Agee 2003). Invasive annual grasses such as cheatgrass and medusahead have played a major role in reshaping the Monument's bunchgrass steppe ecosystem.

The introduction of large numbers of grazing animals is believed to be one of the major drivers of change to historic fire intervals (Burkhardt and Tisdale 1976, Wissmar et al. 1994, Miller and Rose 1999, Johnson and Miller 2008) and exposed the area to invasion by exotic plant species. Reduction of fine fuels at this point in time coincides with increased fire return intervals as well as an increase in the rate of western juniper establishment (Burkhardt and Tisdale 1976, Miller and Rose 1999, Johnson and Miller 2008). Western juniper has an extensive root system and has the ability to transpire large amounts of ground water. In the absence of fire, juniper continued to out-compete understory vegetation in resource acquisition. The establishment of a stand of juniper can dramatically alter the site hydrologic processes, affecting the ability of shallow rooted species to persist (Angell and Miller 1994).

Photo 5. Sheep grazing in the John Day Basin

Following the westward expansion of Euro-Americans, fire return intervals were significantly altered as a result of three factors, fine fuels reduction induced by heavy grazing pressure, displacement of native peoples and subsequent reduction in anthropogenic ignitions, and the increase in active fire suppression (Miller and Rose 1999). Altered fire return intervals and climactic conditions are believed to have contributed to the expansion of juniper woodlands (Gedney et al. 1999; Miller and Rose 1999) and exotic annual grasses (UCBN fire effects data) in the Intermountain West. Fire affects not only vegetation composition and diversity, but also has a profound influence on primary ecosystem processes such as nutrient, energy, and hydrologic cycles (Kauffman et al 1997). The removal of sagebrush from the landscape can impact on-site nutrient cycling as sagebrush and other deep rooted, persistent shrubs are believed to aid in the cycling of nutrients located deep within the soil profile toward the surface layer, making them accessible to the herbaceous community. Kauffman et al (1997) noted that levels of nitrogen within the upper soil profile increase significantly following burn treatments. The high level of soil N was reported to persist for 14 months after the burn. This pulse of nutrients can facilitate the rapid expansion of early-season growing exotic annual grass species such as cheatgrass and medusahead which take advantage of additional resources prior to perennial bunchgrass green-up. The flush of fine fuels provided from these annual grass infestations in turn causes a rapid acceleration in the frequency of fires, a positive feedback loop now known as the fire-cheatgrass cycle. The Clarno Unit of the Monument has burned repeatedly in recent decades as a result of lightning strikes, apparently expressing this fire-cheatgrass feedback loop.

Prescribed fires have been used in some portions of the Monument in an effort to recover native vegetation. In the fall and spring of 1987-88, small-scale prescribed fires were ignited in the Picture Gorge section of the Sheep Rock Unit of the Monument. These ignitions were part of a study intended to produce additional information concerning the effects of fire on the landscape, and to assess the efficacy of fire as a restoration tool (Kauffman et al. 1997) within the Monument.

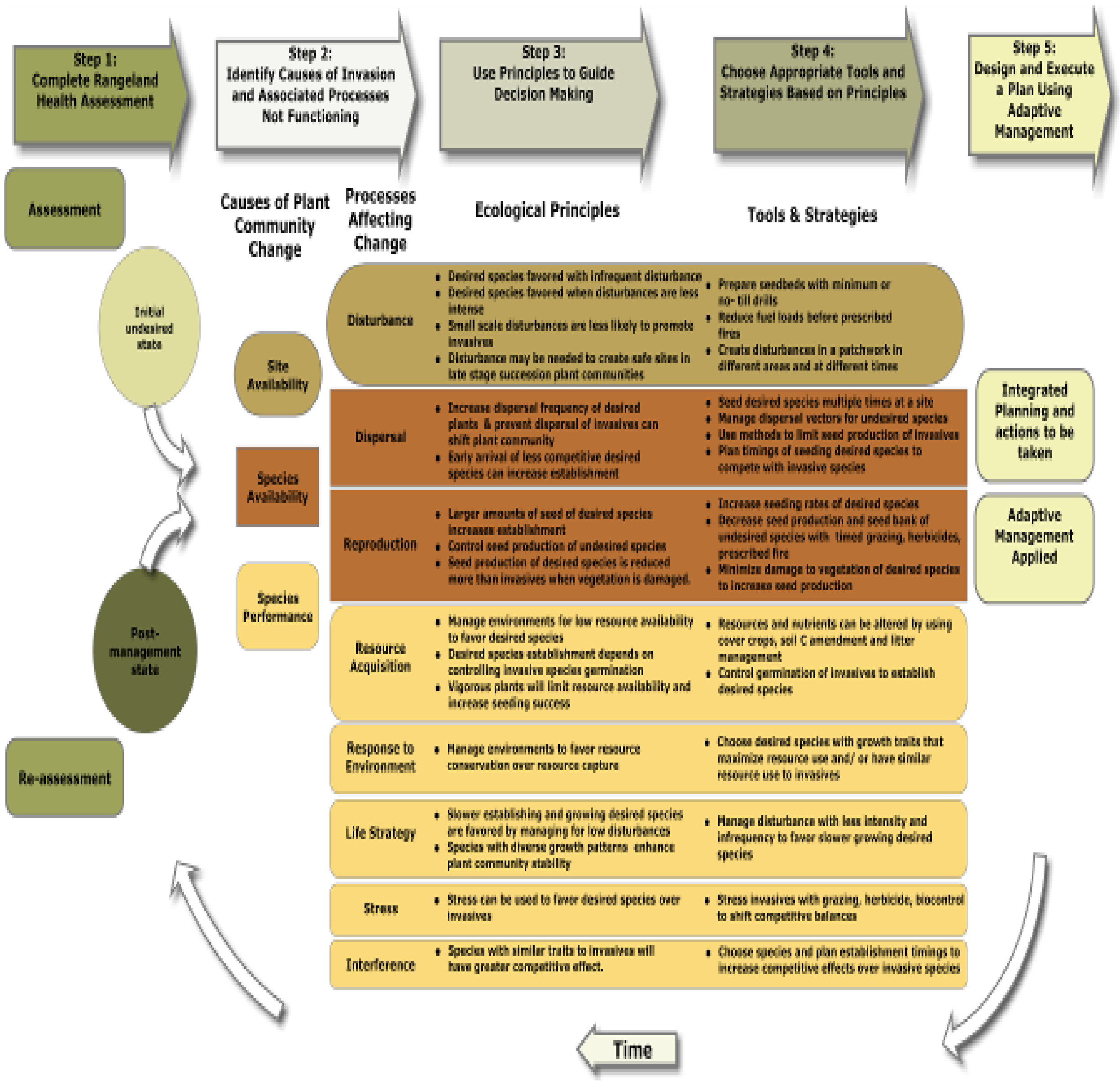
Subsequent fire effects monitoring were initiated by NPS in the Sheep Rock Unit during the 2000s when a series of unit-wide landscape-scale prescribed fires were ignited. Although the earlier research conducted in the highest and coolest portions of Sheep Rock suggested favorable response by native, desirable vegetation, results from NPS fire effects monitoring suggests that in many places cheatgrass increased dramatically following these fires. The NPS Inventory and Monitoring Program began surveying the entire Monument for upland vegetation change. This program has documented widespread cheatgrass and medusahead infestation, particularly in the Clarno Unit and in many portions of the other units as well (Yeo and Rodhouse 2012). Medusahead expansion within the Monument is a significant concern of the resource management staff and has been a motivation for introducing EBIPM into park planning and resource management.

Photo 6. Prescribed fire on Sheep Rock

EBIPM Planning and Prioritization Process

Ecologically-based invasive plant management (EBIPM) is the framework from which this management guidance document for the Monument was developed. The following section contains a brief description of the EBIPM steps and how the framework was developed.

Figure 1. EBIPM step-wise decision-making flowchart



Managing or restoring arid land ecosystems threatened by or dominated with invasive plants is highly complex, and success based on traditional cropping system techniques has been limited (Boyd and Svejcar 2010, Epanchin-Niell et al. 2009). Historically useful models and frameworks for making management decisions have proven much less valuable in complex restoration planning, especially in situations where invasive plants are a major problem (Dyksterhuis 1949, Westoby et al. 1989).

A major constraint in restoration ecology and invasive plant management has been the lack of a useful decision-making process with an ecological basis that allows prediction of vegetation dynamics in response to management (Halle and Fattorini 2004). A decision-framework that includes a method for assessing and manipulating ecological processes and mechanism causing degradation is essential to sustainable management of complex land management systems (Sheley et al 1996, Whisenant 1999).

EBIPM is a step-wise decision-making process that allows land managers to systematically develop restoration and invasive plant management plans (Sheley et al. 2010). EBIPM is based on the successional management model developed by Pickett et al. (1987), which includes three general causes of succession (site availability, species availability, and species performance). Managers can manipulate ecological processes to cause desired changes in species abundances.

The five steps of this holistic EBIPM process include: 1) conducting a Rangeland Health Assessment, 2) identifying causes of invasion and associated ecological processes in need of repair, 3) using ecological principles to guide decision-making, 4) choosing appropriate practices based on principles, and 5) designing and executing an EBIPM plan using adaptive management (Sheley et al. 2010). Managers systematically consider each step in EBIPM and apply the concepts to their specific situation. Using this decision-framework has improved restoration and invasive plant management success by 66% over that of traditionally designed programs (Sheley et al. 2006).

Each step in the EBIPM process emphasizes a series of concepts that provide an ecological basis for consideration in planning and is then applied to specific situations based on local knowledge. Each step has a well-developed description, often with worksheets, providing EBIPM practitioners detailed descriptions of thought processes, concepts, and ideas central to making wise decisions with respect to each step. A general guide for applying EBIPM has been developed by Sheley et al. (2010).

Rangeland Health Assessment has been linked to successional management and provides qualitative information on ecosystem attributes that can be used to determine the causes and ecological processes in need of repair during management (Step 1 and Step 2; Sheley et al. 2011). A set of principles, synthesized from the literature, provide ecological targets to direct favorable successional dynamics based on the Rangeland Health Assessment (Step 3; James et al. 2011).

The most critical component of the stepwise decision-framework is a description of how ecological principles are clearly linked to the choice of tools, management strategies and integrated programs that have the highest probability for success (Step 4). Lastly, Reever-Morghan et al. (2006) provided a method for testing current practices, comparing management strategies to develop locallyapplicable “best management practices” while encouraging continued improvements over time (Step 5).

Success in an EBIPM context is a program that stimulates vegetation dynamics toward native species. Primarily we are interested in increasing diversity by native species over time. EBIPM is based on the linkage between ecological processes that direct vegetation dynamics, ecological principles which are the synthesized knowledge about how these ecological processes need to be repaired to positively affect vegetation change, and the practices managers employ to stimulate changes in ecological processes to create desired vegetation trajectories. The core of this decision-framework rests on managers’ ability to manipulate ecological processes to cause desired changes in species.

James et al. (2011) provided a literature review of ecological processes as a way to provide principles for EBIPM that provide an ecological target to be achieved to create desired vegetation change (see tables on the following pages). He defined principles specific to EBIPM as fundamental causes of vegetation dynamics that link ecological processes to the relative abundance of native and invasive species.

Photo 7. Increasing plant diversity, moving vegetation in a positive trajectory and toward a dynamic of native species is considered success in an EBIPM context because it can lead to a system that is healthy and more resistant to invasion.

Table 1. Causes of Succession

Causes of Succession	Processes	Principles
Site Availability	Disturbance	– Native species will be favored when disturbances are less frequent – Native species will be favored when disturbances are less intense – Smaller-scale disturbances over time are less likely to promote growth of invasive plants – Disturbance is usually needed to create safe sites in plant communities in late-stage succession
Species Availability	Propagule Dispersal	– Increasing dispersal frequency of native species and limiting dispersal frequency of invasive species can shift to a more desirable plant community – Early arrival of less-competitive desired species can increase their competitiveness
	Propagule Pressure	– Increasing amount of seeds of native species and decreasing seed production of non-native species can improve the plant community – Controlling seed production of invasive species is required to establish native seedlings – Seed production of native species is reduced more than invasive species when vegetation is damaged
Species Performance	Resource Acquisition	– Manage environments for low resource availability to favor native species Successful establishment of native species depends on controlling germination of invasive species – Vigorous plants producing high amounts of biomass will limit resource availability and choose native species with variability in growth traits to maximize resource use – Species with similar resource use increase success in establishing native species
	Response to Environment	– Manage environments for resource conservation to favor native species – Inhibit performance of invasive species in low-nutrient environments by using appropriately-timed stresses

Table 1 (continued). Causes of Succession

Causes of Succession	Processes	Principles
	Life Strategy	– Use infrequent and less-intense disturbances to favor slower-establishing and growing native species – Establish species with diverse growth patterns to enhance stability of plant communities
	Stress	– Use moderate, prolonged stress to favor native species over short duration, intense stress, which favors invasive plants – Choose species with plant tissue characteristics that resist stress
	Interference	– Native species that take up resources similar to invasive species will increase competitive ability

The EBIPM process guides users through the fundamental steps of managing invasive annual grasses and other undesired invasive plant species and is the basis for this plan. Each step has been simplified to fit this format and guidelines are available to assist in assessing the land, creating a prevention plan and prioritizing prevention, mapping, control methods, adaptive management, containment methods, augmentative restoration, and other suggestions provided. Guidelines are available at www.ebipm.org.

The first step is to assess and group the land into one of three categories:

Priority 1: no/light infestation

Photo 8. Land with no/light infestation should focus on preventing the invasion of non-native species and protecting the healthy ecosystem

Priority 2: moderate infestation with some desired plants

Photo 9. The focus in a moderate infestation of non-native plants and some native species should prevent weeds from spreading further

Priority 3: high infestation without desired species

Photo 10. Areas of high infestation without native species have the lowest likelihood, and highest cost, of successful restoration

It is also important to consider and identify conditions on any neighboring land and Bureau of Land Management allotments. Invasive species have developed effective methods for spreading across a landscape so failure to consider neighboring land could result in rapid re-infestation.

Once land is grouped, follow the arrows through the steps downward in Figure 2 on the following page and then back up to the top using the “assess and improve” boxes. If treatments are successful and lead to an improved condition of the land, follow the “success” arrows to the left and continue.

Also note the box at the bottom that displays the priority level and likelihood of success and the red text displaying cost. Restoration can cost up to 17 times more than prevention. In other words, every dollar spent on prevention potentially saves 17 dollars that would later be spent on restoration.

Photo 11. Dalmation toadflax infestation

Photo 12. Cheatgrass and medusahead infestation

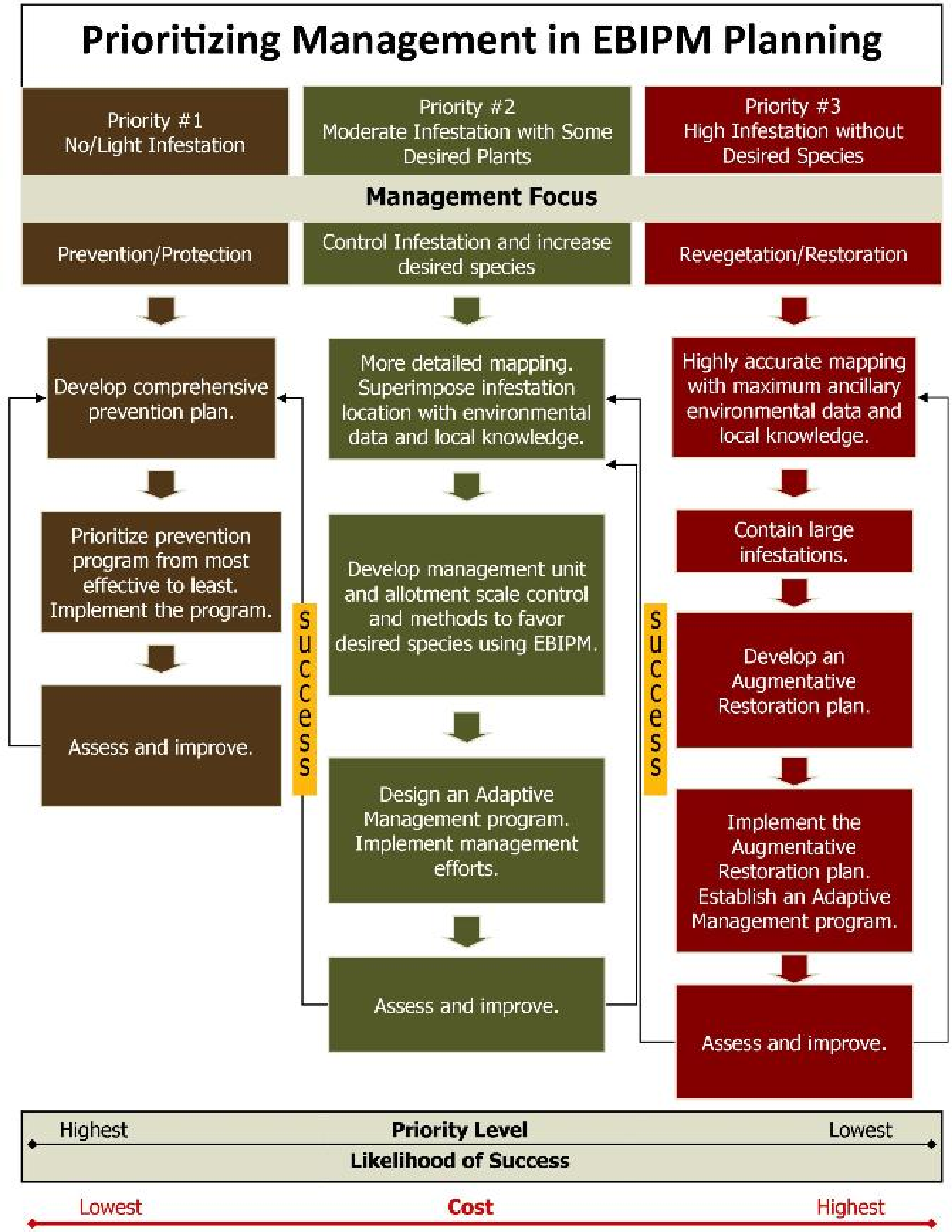


Figure 2. Conceptual diagram describing the prioritization scheme

Priority 1: Prevention Plan

This portion of the plan is for areas in the Monument that are in good condition with high percentage of native plants. There are three sections to the prevention plan: *Develop an education and awareness program, develop an early detection and eradication program and develop a program to interrupt the movement (dispersal of seeds)*.

Vision: No new weed infestations.

Goal: Stop/slow the spread of invasive species to currently un-infested areas.

Specific objectives**:**

- Stop any new invasive weeds from becoming established in the Monument.
- Eradicate yellow starthistle, knapweeds, kochia, Dalmation toadflax, whitetop and ventenata from the Monument.
- Slow cheatgrass and medusahead from advancing to new areas.
- Enhance protection of ecologically-intact plant communities

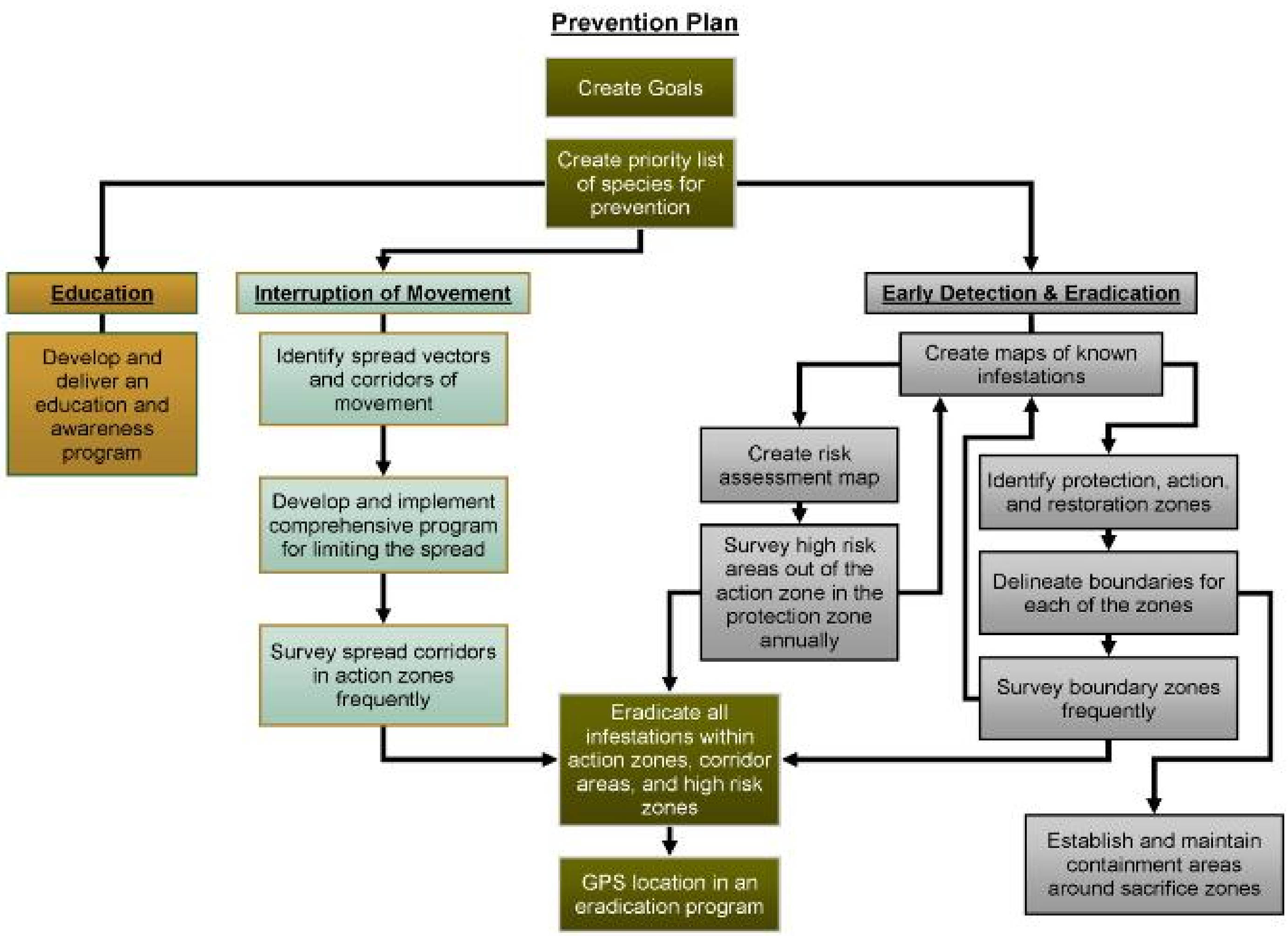


Figure 3. Prevention Plan schematic diagram.

Education and Awareness Plan

The essence of an effective prevention program is a thoughtful and comprehensive education and awareness plan that focuses on teaching Monument employees and visitors about the threat invasive weeds present to the Monument lands, how to identify high priority species in new areas, and what to do about them if they are found. It will also be important to educate employees and Monument visitors on how invasive plants are spread throughout the Monument and how they can minimize their spread. A secondary goal would be to educate visitors about species composition, function, and structure of intact native grassland systems. This plan is aimed at achieving these education and awareness goals.

Print Media

- Develop site bulletin on native species/invasive species, modern methods of ecosystem management and how visitors can reduce dispersal.
- Develop articles for the John Day Blue Mountain Eagle newspaper.

Online/Social Media

- Revise the Monument's web page about natural resources to include the EBIPM plan and other invasive weed information.
- Include invasive weed information on Facebook such as invasive weed control and restoration progress with links to the Monument's website.

Exhibits

- Create a temporary exhibit in the Thomas Condon Paleontology Center or the Cant Ranch on native plant communities.
- Create a traveling display on invasive weeds for conferences, fairs, other facilities, etc.

Outreach

- Explore the possibility for an invasive weed curriculum program with local school groups.

Photo 13. EBIPM field tour.

Additional ideas:

- Add the prioritized weed list (Appendix A) and weed identification to the website.
- Set up a drop box for visitors to report sightings of invasive weeds.
- Install boot cleaning stations at trailheads.
- Strategically place signage at trailheads about invasive plants of concern in the area.
- Develop maps to inform Monument visitors where areas of weed infestations are located.
- Develop weed alert fact sheets for employee and visitor education.
- Install weed-free zones signage.
- Host a weed awareness day and tour for visitors.
- Set up a “weed bounty” program for visitors spotting new infestations.
- Produce a Monument weed identification guide.

<u>Early Detection and Eradication Program</u>
In this section the prevention planning focuses on identifying protection, action, and restoration zones and drawing “do not cross” lines for movement of invasive species.

Protection zones are areas free of weeds of concern but are at risk of future infestations.

Action zones are areas identified on maps as bordering existing infestations and are “active” treatment zones.

Restoration zones are areas with larger well-established infestations of invasive plants and are areas where infestations are not to spread from.

Survey Strategies for Early Detection

- Repeated systematic surveys along action zone boundaries. Action zone boundaries should be a minimum of 100 feet in grassland areas, and even lower 50-75 feet in diverse vegetation areas.
- Surveys will be performed during peak flower periods for target plants. Areas where a high likelihood of weeds might occur are targeted because the objective is to locate new infestations.
- Survey high risk areas (maybe moderate risk areas).
- Surveying resources should be concentrated in the action zone areas.
- A comprehensive program will be developed in action zones. A systematic survey is a suitable method to employ in the action zones when searching for invasive species not yet known to be

growing in the action zone. This survey method is used when the likelihood of occurrence of a target species may be anywhere within the action zone.

- Reporting information should document the known locations that were visited, date of visit, phenology of the target species and distribution if the target species are found.

Strategies for Establishing and Maintaining Containment around Restoration Zones

In these zones the goal is to never allow invasive plants to produce seed. A comprehensive eradication program will include primarily herbicide applications to keep invasive species from producing seed. Spot applications of 2, 4-D, if species are found before flowering, will often provide adequate control of priority list species.

Photo 14. Creating containment zones to prevent the further spread of invasive species is an essential part of a comprehensive eradication program

<u>Program to Interrupt Movement (dispersal of seeds)</u>

In this part of the prevention plan, programs to interrupt dispersal of seeds of invasive plants are the focus. Being able to identify the vectors that species of concern are moving is the first step.

Identify Spread Vectors and Corridors of Movement

- People and pets on hiking trails, fishing access, and other developed sites.
- Wildlife through known areas of movement including watering areas of herd animals.
- Motorized vehicle traffic on highways, parking areas, and service roads.
- Rivers and creeks - natural corridors for movement of weed species.

Photo 15. Riparian vegetation along the John Day River.

Comprehensive Program for Limiting the Spread

- Routinely clean weed seeds from off-road vehicles
- Encourage visitors and employees to clean weed seeds from hiking boots.
- Survey vectors and eradicate weed species.

Priority 2: Using EBIPM to Develop Control Programs

In this section an integrated plan has been developed to control invasive plants to eliminate competition to native plants so they can recover in an area, possibly without further restoration efforts.

<u>Principles and Practices to Guide Management of Site Availability</u>
During the invasion process, the abundance of annual grasses increases and native perennial bunchgrasses deceases over time. On partially intact sagebrush steppe ecosystems, enough native species generally exist to facilitate restoration once the abundance of invasive annual grasses is reduced. These partially-invaded systems are considered moderate priority for management because restoration of fully-invaded ecosystems is nearly impossible.

The EBIPM model indicates that successional dynamics are not limited by species availability because native species can provide propagules for their reestablishment. Therefore, *the two primary causes of succession central to reversing the invasion by weedy species are site availability and species performance.*

The primary ecological process that can be managed to influence site availability is disturbance. Disturbance can be used to create niches for native species and remove niches for invasive species. Disturbance is defined as a relatively discrete ecological process disrupting ecosystems, community, or population structure and changes the resources, substrate availability, or physical environment (White and Pickett 1985). Natural disturbances occur periodically and can have positive and/or negative impacts on vegetation dynamics. Similarly, we can use disturbances to create safe sites for species to increase the abundance of native species.

<u>Principles</u>**:**

- Lower disturbance frequencies favor establishment of native species compared to higher disturbance frequencies.
- Lower disturbance intensity will favor establishment of native species compared with higher disturbance intensity.
- Smaller-scale disturbances spread through time will be less likely to promote growth of invasive plant populations than simultaneous, large-scale disturbances.

<u>Practices</u>**:**

- *Increase Fire Intervals and Reduce Intensity*

Fires are a natural and common disturbance occurring on rangelands throughout most of the world. In the western U.S., the occurrence of fires has increased dramatically with the invasion of annual grasses. The frequency and intensity of fires can be managed by managing fuels needed for carrying the flames. In sagebrush steppe ecosystems and juniper woodlands, controlled fires, mowing, herbicides, and grazing have been used to manage fuels (Bourne and Bunting 2011, Hunter et al. 2007, Belsky and Blumenthal 1997). Each treatment can be used to gain a variety of fuel levels and even alter the phenology of plants so combustibility of fuels can be altered to reduce the risk of fire.

The frequency and intensity of fires can also be lowered by establishing species that continue growing late into the growing season. In the native sagebrush steppe ecosystems of the western U.S., fire intervals were between 30 and 90 years, but occur every 5 to 7 after cheatgrass dominates. Native vegetation provided a diversity of vegetation with differing phenologies. Species with the ability to grow later than cheatgrass provides a fire suppressive effect because they remain green and much less combustible. Planting fire-suppressive species to manage the frequency and intensity of fires is possible where restoration can be accomplished.

- *Limit Frequency, Intensity, and Scale of Management*

Disturbance is a central component of most management systems and managed disturbance is central to maintaining ecosystem health (Fuhlendorf and Smeins 1999, Miller and Rose 1999). Disturbance is central to invasive plant management because their removal is often an important step in allowing native species to occupy the newly opened niches (Sheley et al. 2008). Where invasive weeds dominate, managing for low disturbance frequency can be achieved by planning activities that will ensure newly-opened niches are immediately filled with native species (Carpinelli 2001). The intensity of any practice can be moderated by choosing tools that create limited disturbances yet still fill the need for the creation of safe sites for native species. Using selective herbicides, low intensity prescribed fires, and shallow versus deep tillage are useful practices to minimize disturbance intensity. In addition, the scale of disturbance can be limited by only disturbing specific areas where seeds of native species are carefully placed, such as no-till drilling.

Photo 16. 2011 wildfire sweeps through the Clarno Unit.

- *Manage Small-scale Disturbances*

Small-scale disturbances are common and troublesome events in areas where invasive species can potentially invade because they create open niches to invasion (Petroff and Sheley 1999). Natural and human-caused small-scale disturbances can be created by various activities. In any case, a small disturbance should be contained by immediately seeding the disturbed soils with seeds of native species.

<u>Principles and Practices to Guide Management of Species Performance</u>
Species performance is the ability of a plant (species) to grow and reproduce to its maximum capacity in different environmental conditions. Managers can impose techniques to alter the relative species performance to alter successional dynamics in favor of native species. The Monument will focus on two primary ecological processes: interference and stress.

<u>Principle:</u> Removing interference from invasive plants.

Competition occurs when acquisition of a common, limited resource by one plant preempts acquisition by another plant (Craine 2009; p.93). Plants can also interfere with the nutrient uptake of neighboring plants by their effects on resource cycling (Suding et al. 2004). Competition between invasive and desirable species is considered a primary biotic filter to the assembly of plant communities (Hobbs and Norton 2004; p. 77). For this reason, managers will work to minimize the ability of invasive species to control these processes by reducing their proportional dominance in the plant community and by establishing native plant species assemblages that are capable of exerting biotic resistance to invasive species effects. Biotic interventions are thus needed to speed up or alter the course of ecosystem recovery (Hobbs and Cramer 2008).

Practice: Reduce the competitive ability and seedbank of invasive plants by controlling invasive plants for at least two years.

Low soil Nitrogen environments do not directly provide native species with an initial growth advantage over invasive species (James et al. 2011). Seedlings of invasive plants often can maintain greater growth rates than native species in low N environments. Over time, however, slow-growing native species can begin to accumulate more N than invasive species because they often have a greater ability to store and recycle N and lose less N to abiotic and biotic processes compared to invasive species (Berendse 1994). As a consequence, over time, native species can capture and retain more N than invasive species. In nutrient poor soils, this increased retention can eventually give slower-growing native species a competitive edge (Berendse 1994; Berendse et al. 2007).

These principles suggest it will likely be necessary to manage the invasive plant seedbank for at least two years to allow native species the opportunity to establish and build sufficient nutrient reserves that will provide them a competitive advantage in nutrient-poor soils. This may be done by using pre-emergent herbicides (Appendix B) for several years to deplete the seedbank of invasive species prior to seeding native species. Various herbicides, such as imazapic and glyphosate, are applied, usually at rates ranging from 6 to 12 ounces per acre. (Monaco et al. 2005, Morris et al. 2009, Kyser et al. 2007, Kyser et al. 2012). Applications control invasive annual grasses with minimal negative effects on perennial grasses because they are dormant. Repeated applications are often required for long-term control of annual grasses, and over time native perennial grasses increase.

Photo 17. Limiting an invasive plant's ability to produce seed will greatly reduce its capacity to compete with native species.

Principle: Apply stress to undesirable species.

Plants are frequently exposed to a variety of external conditions able to affect their growth, development and productivity. Their ability to adapt and live in a changing environment relies on tolerance or resistance to adverse growing seasons. In many cases, plants can be stressed to reduce their dominance in a plant community (James et al. 2011). The metabolism of plants undergoes deep modifications in order to minimize energy losses, the most important changes concern photosynthesis. In general the addition of stress is aimed at reducing growth and reproduction of non-native species.

Practice: Increase invasive species to stress them.

Repeated interruption of a plant's capacity to store energy is the basis for using mowing as a tool for weed control such as spotted knapweed (*Centaurea maculosa*). Each weed species must be researched to select the best time to be mowed to stress the plant and prevent seed set and not spread seeds and increase the size of the infestation.

Photo 18. Management of weed invasion in heavily-degraded sites is expensive and often unsuccessful.

Principle: Moderate prolonged stress favors native species over invasive species compared to short-duration, intense stress.

Practice: Use biocontrol.

Bicontrol stresses invasive species as a result of the action of parasites, predators and pathogens. Plant populations are maintained at a lower density than would occur in their absence. If natural enemies are available for specific plant species, they can best be used in areas that are relatively stable and are not regularly disturbed and are in areas that have low levels of management. It is expected that natural enemies will establish and self-perpetuate, locating and reproducing on target plants and negatively impacting target species. Natural enemies will not eradicate the target plants. Candidate noxious weed species for biocontrol are listed in Appendix C.

Priority 3: Revegetation Plan

In this section, additional plans to restore areas with native plant species have been developed. Restoration efforts can be expensive and the likelihood of success is limited unless restoration efforts can be accomplished with the Monument's farm equipment in areas with easy and level access such as fallow agricultural fields.

During the invasion process, the abundance of annual grasses increases and native perennial bunchgrasses deceases over time. After sustained periods, plant communities become monocultures of invasive species. In these cases, too few native species generally exist to facilitate restoration even when the abundance of invasive annual grasses is reduced.

The EBIPM model indicates that successional dynamics are limited by species availability, as well as site availability and species performance because there are not enough propagules to facilitate their reestablishment. To fully restore plant communities and ecosystems, all three causes of succession require management. This section enhances the information in Priority 2: using EBIPM to develop control programs by providing direction for managing species availability. It must be clear that restoration will require managers to address all three general causes of succession. The major processes are associated with the availability of seeds and propagules of native species. Some attention is also given to reducing the availability of invasive plant seeds.

In some cases, natural disturbance does not create enough safe sites to facilitate establishment of native species during seeding. However, broad scale wildfires are common and reoccurring in annual grass dominated rangeland. Other areas in the park to focus on restoration are areas that had been farmed and heavily grazed. However, wildfire areas must be reseeded prior to fall of the year it burns.

The availability of native species is a critical determinant of successional dynamics and must be considered during restoration of fully degraded park lands. Managing species availability involves principles and practices that increase the availability of seeds or propagules of native species and removes those of invasive plants. These principles and practices are aimed at influencing species availability.

<u>Propagule Dispersal</u>

Dispersal is the movement of propagules (seeds or other vegetative structures like rhizomes) away from a parent plant or population through time and space (Harper 1977) and commonly occurs through wind, animals, water, and gravity. Managers can influence dispersal to ensure that native species have a higher likelihood than invasive species of reaching safe sites created through disturbance.

<u>Principles:</u>

- Increasing the frequency of dispersal of native species and decreasing frequency of dispersal of non-native species can allow plant communities to change in a favorable direction.

- Less competitive native species can “win” a safe site from more competitive invasive species by arriving at the safe site first.

Practices:

- *Seed Native Species Multiple Times at a Site*

Successful establishment of native species depends largely on environmental conditions, for example precipitation timing and amount, temperature, and solar radiation that occur the year or season of seeding (Wirth and Pyke 2003). By increasing the frequency of seeding at a site, the chances of environmental conditions and other random elements being conducive to establishment are improved. Instead of applying a seeding treatment as a fall dormant seeding all at one time, a portion of the seeds could be planted in fall of year one, spring of year two, and fall of year two, for example.

Seeding multiple times at a site can also allow managers to transition plant communities from one successional stage to the next. For example, initially fast-growing, short-lived species could be seeded to provide immediate and direct competition with invasive species regenerating from the seedbank (Vasquez et al., 2008; Perry et al., 2009). These species may be seeded as an individual phase or as a mix with mid-seral species that are intermediate in their growth rate, nutrient use, and longevity. Late-seral species that meet longer-term management objectives would be seeded lastly (Mangold 2012).

Photo 19. Tilling old fields in preparation for native reseeding.

- *Reduce Propagule Production of Invasive Species*

Many invasive species are prolific propagule producers (Baker 1974). Non-native species that produce large amounts of propagules have a higher likelihood of colonizing safe sites than native species that are generally not as prolific (James et al. 2010). In order to tip the balance in favor of native species, it is necessary to reduce propagule production of invasive species in addition to increasing dispersal frequency of native species. Reducing propagule production of invasive species can be achieved with herbicides, biological control, and mowing, as well as other activities like handpulling and tillage. Control efforts should be timed so that seed production is greatly reduced or eliminated. Efforts to reduce propagule production will need to be extended for multiple years so that the seedbank is depleted, and native species are allowed to fully re-occupy safe sites (Wilson et al. 2004).

- *Manage Dispersal Vectors of Invasive Species*

Propagules can disperse in a variety of ways (Plummer and Keever 1963). Invasive plant management must limit the number of propagules dispersing to non-infested areas and/or areas currently being restored through active management. Davies and Sheley (2007) proposed a framework for preventing dispersal of invasive species. This framework identifies major potential dispersal vectors associated with numerous seed adaptations and then suggests management strategies designed to limit dispersal by those vectors. Weed-free zones can be maintained along trails and roads through herbicide applications. If propagules of invasive species are buoyant and dispersed through water, then screens could be placed along waterways to trap seeds and prevent them from moving into non-infested areas (Figure 2, Davies and Sheley 2007). These are just two examples of how vectors can be managed to prevent propagule dispersal of invasive species.

- *Plan Timing of Seeding of Native Species to Arrive at Safe Sites Earlier than Non-native Species*

The order at which species arrive at safe sites can influence which species establish and persist in the plant community (Korner et al. 2008). The species that arrives first has an advantage over a later arriving species, even if the later arriving species is considered more competitive (Stevens and Fehmi 2011). This occurs because the earlier arriving species has had an opportunity to grow larger and can therefore remove a disproportionate amount of resources. Managers could modify the standard timing of revegetation practices to ensure that native species considered less competitive than invasive species receive a sufficient head start (i.e. two to four weeks). This initial size difference would favor native seeded species. Another way to promote an initial size difference would be planting transplants or plugs of native species in high priority critical areas in dire need of restoration.

Photo 20. Yellow starthistle infestation.

Propagule Pressure

Propagule pressure is another phrase for seed production or an increase in plants by vegetative plant parts (James et al. 2010). Invasive plant management often involves applying tools that limit seed production by invasive species, including herbicides, mowing, cultivation, and flower and seed-feeding biocontrol agents. Managers typically focus to a lesser extent on propagule pressure of native species, but low seed production of native species may leave an area more prone to invasion by non-native species. To be most effective, management should address propagule pressure of both native and non-native species.

Principles:

- Increasing propagule pressure of native species and decreasing propagule pressure of invasive species can allow plant communities to change in a favorable direction;
- Control of seed production by invasive plants is required to realize benefits of seeding native species;
- Damage to vegetative material may have a larger negative effect on seed production by native plants than by invasive plants.

Practices:

- *Increase Seeding Rates of Native Species*

Seeding rates should be high to increase the frequency of propagules of native species reaching safe sites relative to propagules of invasive species. When reseeding sites infested with non-native species, recommended seeding rates are two to three times higher than for seeding in weed-free areas (Sheley et al. 2008). One study suggested that seedling establishment could be further improved by increasing seeding rates to five and 25 times the recommended rate when revegetating grasslands infested by invasive forbs like spotted knapweed (*Centaurea stoebe* L.) (Velagala et al.1999). Ideally, there should be adequate propagules of native species to fill all available safe sites that are naturally occurring and/or created through designed disturbance (Satterthwaite 2007).

- *Decrease Seed Production and Seed Bank of Invasive Species*

As discussed above under reducing propagule production of non-native species, many invasive species are prolific propagule producers (Baker 1974). Over time this results in large numbers of propagules in the soil seed bank. In order for seeding of native species to be effective, it is necessary to reduce seed production of invasive species in combination with reducing the number of seeds in the seed bank. This requires efforts to prevent existing weeds from producing seed and may include herbicide applications, and mechanical control (e.g. mowing). The release of flower and seed-feeding biocontrol agents can also reduce seed production, but may take more time because insect populations must obtain levels where they have impact on plant populations. Augmentative release of biocontrol agents, which involves releasing a large number of insects with the goal of inundating the weed population with natural enemies, can speed up the process (Collier and VanSteenwyk 2004). In this way, biological control can act more similar to an herbicide application, or mowing (Collier and VanSteenwyk 2004).

Critically important in conjunction with preventing seed production from existing weeds, is managing invasive species re-emerging from the seed bank. As seed production and seed longevity of an invasive species increases, so will the time it takes to deplete it from the seed bank. Because plant community composition is somewhat predictable based on seed bank composition (Van der Valk and Pederson 1989), seed bank sampling can provide insight into whether invasive species are likely to remain dominant for some time (D'Antonio and Meyerson 2002). If the proportion of non-native species propagules to native species propagules is very high, then multiple years of control may be necessary prior to seeding native species (Fansler and Mangold 2011). For example, cultivation could be used to stimulate germination and emergence of invasive species followed by herbicide application, or repeated cultivation.

- *Minimize Damage to Native Species to Maximize Seed Production*

Because even a moderate difference in seed production by non-native species compared to native species can decrease establishment of native species (DiVittorio et al. 2007), care should be taken to minimize damage to native species and maximize their seed production capacity. Many native species remain in a juvenile stage longer than invasive species, are less prolific seed producers, and only produce seed in episodic events (Rejmanek and Richardson 1996). All these traits suggest that seed production of native species can be impacted from stress more than that of invasive species and support the practice of minimizing damage to native species while in the process of controlling invasive species. Timing control treatments to coincide with the most vulnerable growth stages of non-native species can help to achieve maximum results. For example, with cheatgrass, herbicide applications can occur in the fall or very early in the spring when cheatgrass is actively growing but native perennial grasses are dormant.

Photo 21. Diffuse Knapweed infestation.

Landscape Prioritization

Prioritization of the Monument landscape followed the scheme outlined in Figure 2 as described:

Priority 1: Areas to prevent weed infestations. Typically land without weed infestation and intact ecologically. Mapped as areas predicted to have bluebunch wheatgrass >25% cover.

Priority 2: Areas of weed control or containment, with some native bunchgrass. Mapped as areas predicted to have bluebunch wheatgrass >5% cover.

Priority 3: Areas of extensive degradation that require revegetation efforts. Mapped as areas predicted to have no bluebunch wheatgrass cover.

We use vegetation monitoring data and predictive models to prioritize the Monument's upland landscapes for implementation of EBIPM as described in Figure 1 and by Rodhouse et al. 2014. Areas in which bluebunch wheatgrass occurred in sufficient abundance so as to prevent or slow medusahead and cheatgrass invasion were considered as high-value areas that reflected both the historic conditions as well as ecological conditions desired by park management. The abundance of bluebunch wheatgrass correlates strongly with resilience to fire and resistance to invasion in the Wyoming and basin big sagebrush/bunchgrass steppe systems found in the Monument (Chambers et al. 2007, Brooks and Chambers 2011, Davies et al. 2011, Reisner et al. 2013). In general, the uptake of soil nitrogen and water by big sagebrush and by bunchgrasses has been shown through removal experiments to reduce community invasibility (Chambers et al. 2007, Prevey et al. 2010a, 2010b). Additionally, the severity of infestations of cheatgrass and medusahead are inversely correlated with the abundances of pre-existing native perennial bunchgrasses (Davies 2008, Reisner et al. 2013). Tall tussock-type bunchgrasses like bluebunch wheatgrass seem to effectively reduce dispersal of medusahead seeds, and therefore robust stands of these bunchgrasses may contain incipient infestations (Davies 2008).

We also considered abundance patterns of Thurber's needlegrass (Achnatherum thurberianum) and Sandberg bluegrass (Poa secunda) in models (Rodhouse et al. 2014). The Natural Resource Conservation Service site descriptions for the upland ecological site types that occur in the Monument show bluebunch wheatgrass, or in a few xeric site types, Thurber's needlegrass, yielding more than twice the amount of biomass than any other associated species, including big sagebrush (NRCS 2013). Sandberg bluegrass is a consistently present but much smaller and less productive species in all ecological site types, but it is known to be highly resilient to drought, grazing, and trampling. Other important bunchgrass species common in the region, including Idaho fescue (Festuca idahoensis) and bottlebrush squirreltail (Elymus elymoides) associated with cooler and wetter mountain big sagebrush (A. t. vaseyana) habitats, and indian ricegrass (Achnatherum hymenoides) and sand dropseed (Sporobolus cryptandrus) associated with hotter and drier habitats, are relatively rare in the Monument (Yeo and Rodhouse 2012) and not useful for landscape-scale modeling and prioritization.

We developed predictive models using an ordinal regression statistical technique (Irvine and Rodhouse 2010, Rodhouse et al. 2014), drawing on the extensive monitoring dataset available for the Monument (Yeo and Rodhouse 2012). We predicted the abundances of bluebunch wheatgrass, Thurber's needlegrass, and Sandberg bluegrass as a function of topography, exposure to past fire, distance to roads and Monument boundary, and also as a function of the abundances of cheatgrass and medusahead, these species having been modeled in a separate, previous step (Rodhouse et al. 2014). Because monitoring data are collected in cover classes, we used bluebunch wheatgrass cover ≥ 25% as a prioritization threshold, corresponding to a monitoring cover class category and also a biologically meaningful approximation of landscape invasion resistance. Additional details are provided by Rodhouse et al. 2014.

Figures 4 and 5 illustrate the outcome of this model process. Our models suggested that that remnant stands of abundant wheatgrass and bluegrass were associated with steep north-facing slopes in higher and more remote portions of the landscape outside of recently burned areas where invasive annual grasses were less abundant. These areas represented only 25% of the landscape and were prioritized for protection efforts (Figure 4). Notably, even less than this 25% area actually had high probabilities of wheatgrass abundances ≥25% (Figure 5). Needlegrass was associated with south-facing slopes, but in low abundance and in association with cheatgrass (Rodhouse et al. 2014). Because of this, predictions for this species were not explicitly incorporated into prioritization. Abundances of all three native bunchgrass species were strongly negatively correlated with medusahead. The role of fire in influencing these patterns was clear: both cheatgrass and medusahead occur in greater abundance in burned areas of the Monument. While bluebunch wheatgrass may be relatively resilient to fire (Miller et al. 2013), cheatgrass and medusahead exploit post-fire conditions and rapidly infest into previously intact areas, particularly if bluebunch wheatgrass fire-induced mortality is high (Mata-Gonzalez et al. 2008, Davies et al. 2009).

The rarity of priority bunchgrass stands across the landscape underscored the extent of degradation and the need for prioritization. We found no evidence that protected-area insularity (distance to boundary) reduced invasibility; annual grass invasion represents a continuing, serious threat to the remnant high-quality bunchgrass communities in the Monument. The Monument is entirely within the Wyoming/basin big sagebrush ecological zone, which is understood to have inherently low resilience to disturbance and resistance to weed invasion (Chambers et al. 2013). However, our models revealed important variation in resilience and resistance along the topographic-soil moisture gradient within this ecological zone that provides an important foothold for strategic management decision-making and implementation of EBIPM. The Monument study area is very rugged and the erosion of intact bunchgrass stands from fire, weeds, and historic grazing appears to be strongly buffered by topography (Appendix D). This pattern provides an important foothold for management, with the many steep north-facing slopes and canyons and draws still supporting relatively intact bunchgrass stands. Protecting the largest of these presents both an opportunity and a challenge, but it is likely the best long-term strategy for success at the landscape scale.

To provide greater resolution and specificity for targeted protection and EBIPM implementation, we identified 10 locations (Figure 4) as being of particularly high priority for specific actions. These areas were identified because of their proximity to areas of abundant bunchgrass stands that are highly visible to visitors and vulnerable to invasion because of their proximity to trails and sources of weeds. In some cases, we also included areas already being restored. The following section describes these locations and management concerns for each.

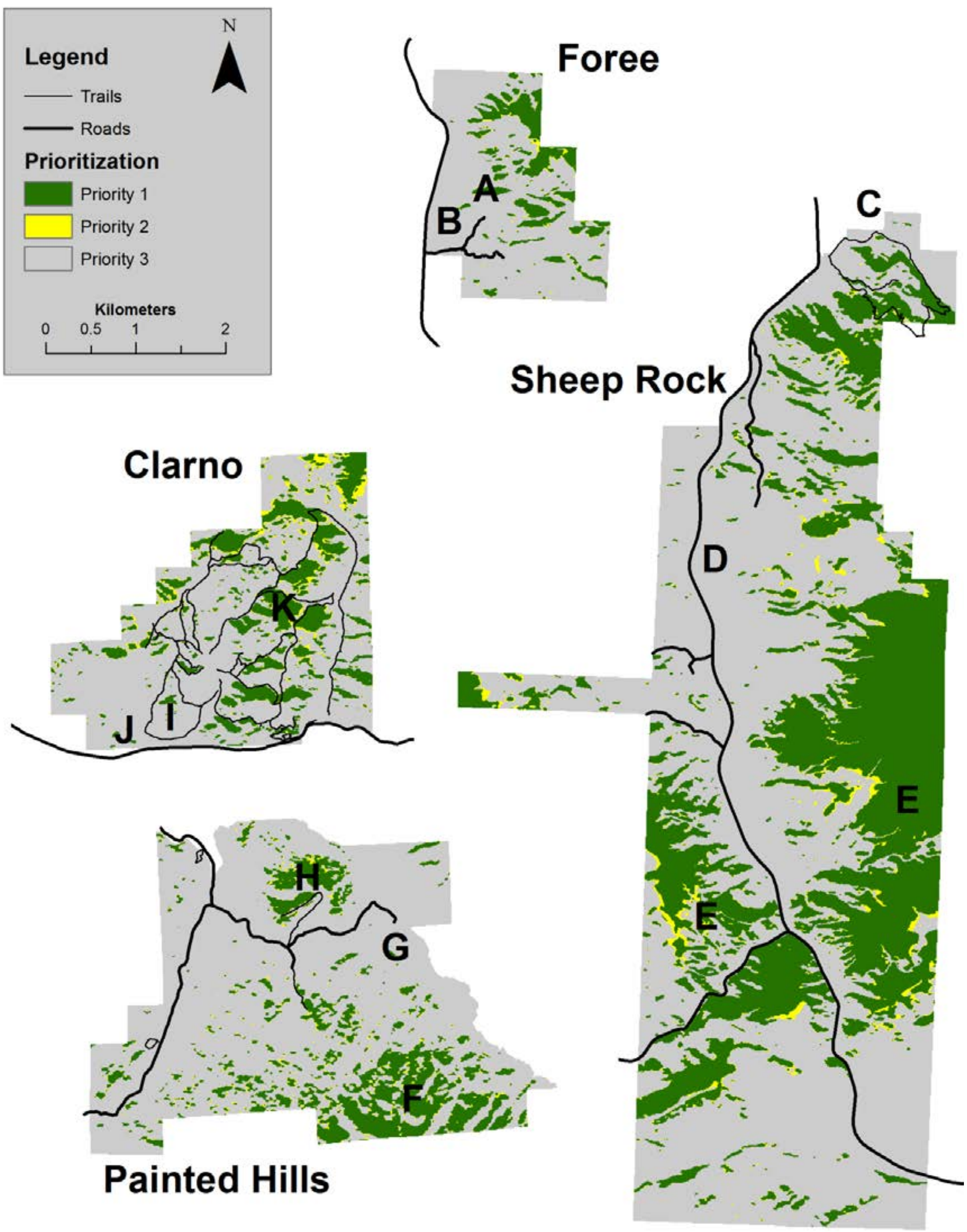


Figure 4. Intact stands of steppe vegetation dominated by bluebunch wheatgrass are of particular interest for protection efforts and are indicated by letters A-K. Adapted from Rodhouse et al. (2014).

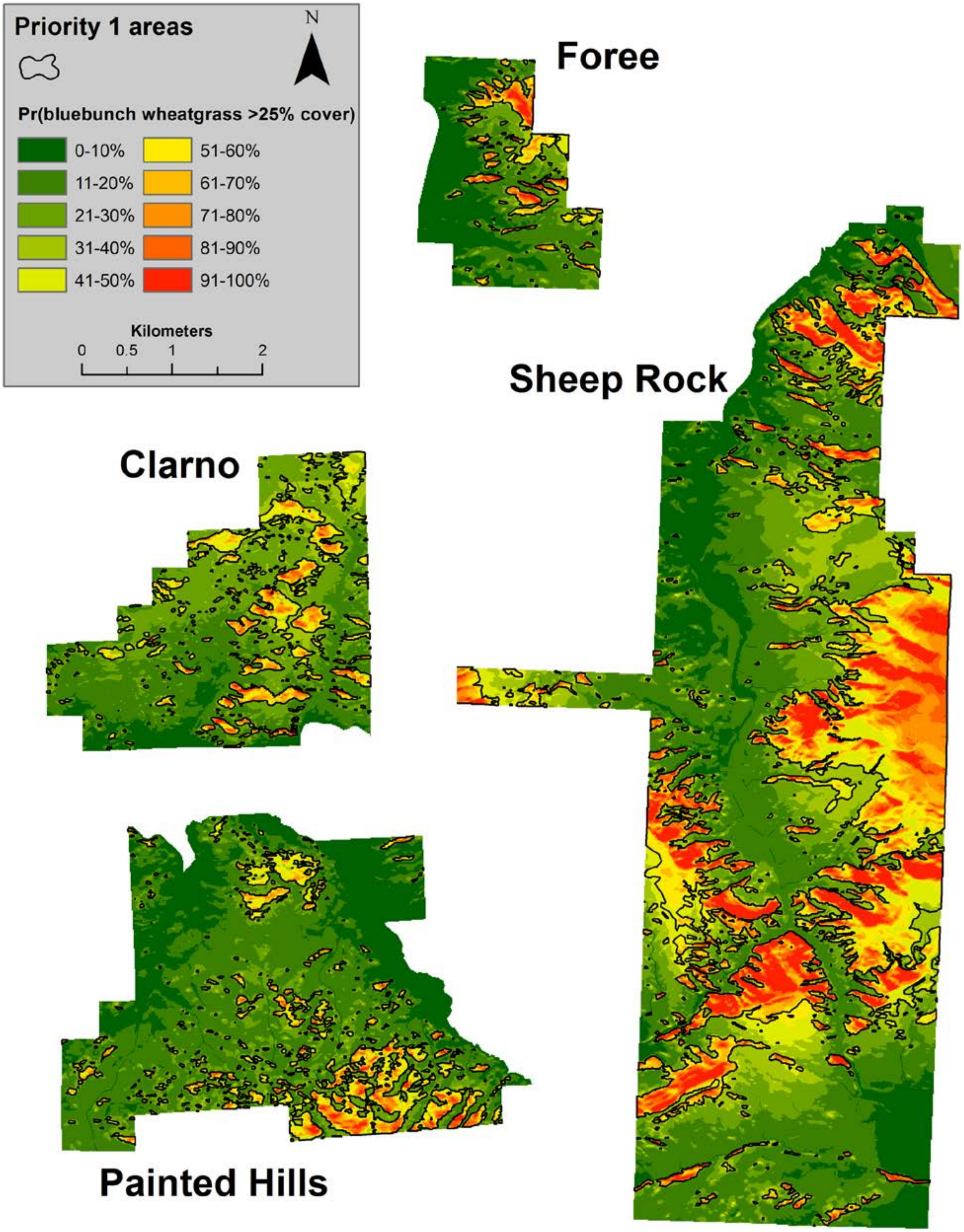


Figure 5. Predicted probabilities for bluebunch wheatgrass occurring in abundance >25% foliar cover with boundaries of Priority 1 areas also shown. Reproduced from Rodhouse et al. (2014).

Selected Priority 1 Areas

Ideally, all Priority 1 areas should be surveyed annually. Areas threatened by encroaching invasive weeds may also require additional surveys during the year. However, it is impossible to survey all areas annually due to small staff levels, budget constraints, and time. Other limiting factors are terrain, logistics, and safety. Most of the Priority 1 areas are located in higher elevations and the park's few roads do not provide access directly to these areas. The only access is by foot across the steep rugged terrain. Because communications are poor (no cell phone coverage exists and park radio transmissions are easily blocked by high elevations), two employees should be required to conduct each survey to ensure their safety. Consequently, a few Priority 1 areas have been selected in each unit (Figure 4) and described in the following section, to be surveyed, monitored, and treated, if necessary to stop new weed encroachment from becoming established.

<u>1. Foree Sub-unit</u>

Location A: Behind the Restrooms - The area west of the restroom and between the Flood of Fire and Story in Stone trails was not burned during either of the two prescribed fires and consists of a mix of bluebunch wheatgrass, Wyoming sagebrush, and native forbs.

Location B: Two other possible areas where bluebunch wheatgrass is returning after the 2007 prescribed fire are just off the entrance road to the west and just off the Fire of Flood trail to the west after crossing the drainage. All of these areas are threatened by Dalmation toadflax (*Linaria dalmatica*), diffuse knapweed (*Centaurea diffusa*), common mullein (*Verbascum thapsus*), and cheat grass.

<u>2. Sheep Rock Unit</u>

Location C: Middle Mountain/Blue Basin - The north slopes of Middle Mountain near Blue Basin contain several areas with high percentages of native bunchgrasses. The 3-mile loop trail at Blue Basin provides access to some of these areas, which are threatened by Dalmation toadflax and common mullein.

Location D: West side of Hwy 19 - There are also a few Priority 1 areas on the north-facing slopes of the foothills just west of State Highway 19 from the visitor center south to Picture Gorge. Access to these areas is by foot from the highway, which are threatened by Dalmation toadflax, Scotch thistle (*Onopordum acanthium*), cheat grass and medusahead.

Location E: Research Natural Area - RNAs are high quality examples of representative natural communities that are protected ensuring the value of these plant communities and provide excellent opportunities for ecological research. The RNA is divided into two separate sections, one on the east side of the John Day River centered above Waterspout Gulch and the other on the west side of the river spanning Rock Creek and U.S. Highway 26. Because of the steep rugged topography, very little grazing has occurred on either section. Consequently, the communities are in a fairly pristine condition, offering good examples of climax vegetation. Access to both sections is extremely difficult because it involves hiking up into the higher elevations through steep, rugged and rocky drainages.

Photo 22. Sheep Rock.

3. Painted Hills Unit

Location F: South Boundary – The largest area of bluebunch wheatgrass is located along the south boundary of the unit. The problem with inspecting this area is access. The only access is by foot from the county road or the primitive path along the irrigation ditch south of the employee residence. This area is also steep and rugged and is threatened by whitetop (*Cardaria draba*), Russian knapweed (*Acroptilon repens*), medusahead, and cheat grass.

Location G: Bridge Creek floodplain - Another potential location is south of the picnic area restrooms within the Bridge Creek floodplain. This greasewood community includes a nice stand of bluebunch wheatgrass and basin wildrye but is threatened by Russian knapweed, whitetop, and kochia (*Kochia scoparia*).

Location H: Carroll Rim - The north-facing slope of Carroll Rim exhibits a high percentage of native bunchgrasses. This area is accessible from the Carroll Rim Trail. Medusahead grass is located along the beginning of the trail and could easily be transported to the north slope by foot traffic.

Photo 23. Painted Hills.

4. Clarno Unit

Location I: Right Equisetum Trail, Mimulus Trail - Both of these trails provides access to Priority 1 areas that are located on north-facing slopes on higher elevations above the road into Hancock Field Station. Both areas are threatened by medusahead, cheat grass, Russian knapweed, Dalmation toadflax and common mullein.

Location K: Pictograph Trail – The north-facing slopes adjacent to the Pictograph Trail are covered with bluebunch wheatgrass. Access is by foot starting from the picnic area then proceeding north up Indian Canyon. This area is threatened by medusahead, cheat grass, Dalmation toadflax and common mullein.

Photo 24. Clarno.

Critical Considerations

1. Threatened/Candidate/Rare Plants

A rich diversity of nearly 250 plant species occurs on ridge, slope, alluvial fan, floodplain, and badland landforms (Erixson et al. 2011). Plant communities range from Western juniper woodlands and Wyoming sagebrush shrub steppe associations to Idaho fescue and bluebunch wheatgrass grasslands. Some of these vegetation types are recognized as critically endangered due to the proliferation of non-native invasive plant species as well as habitat reductions in biodiversity associated with agricultural conversion, livestock grazing and the associated alteration of natural fire regimes.

No federally-listed threatened, endangered, or candidate plant species occur in the Monument. However, the presence of several rare endemic plant species occurs in all three park units. Oregon lists arrow-leaf thelypody (*Thelypodium eucosmum*) and South John Day milkvetch (*Astragalus diaphanous var. diurnus*) as threatened and Henderson ricegrass (*Achnatherum hendersonii*) and Jungermann's monkeyflower (*Mimulus jungermannioides*) as candidate plant species.

The Oregon Biodiversity Information Center (ORBIC) participates in an international system for ranking rare, threatened and endangered species throughout the world. The system was developed by The Nature Conservancy and is now maintained by NatureServe in cooperation with Heritage Programs and Conservation Data Centers in all fifty states. ORBIC lists hotrock penstemon (*Penstemon deustus* var. *variabilis*) and pauper milkvetch (*Astragalus misellus*) as two plant species that need more abundance information before their status can be determined, but which may be threatened or endangered. John Day chaenactis (*Chaenactis nevii*) and snowball cactus (*Pediocactus nigrispinus*) are listed as common rare plants with conservation concerns, but are not currently threatened or endangered.

Photo 25. Snowball Cactus.

Photo 26. John Day chaenactis.

Plant inventories have been conducted in the park in 1976 (Youtie and Winward 1977), 1991 (Wright 1992), 2004-06 (Ordway 2004, 2005, 2006), 2007 in the Painted Hills Unit (Buechling 2008), and 2008-10 (Erixson et al. 2011). These inventories documented the occurrences of six of the eight species listed by Oregon as threatened, candidate, or rare species. The six species are South John Day milkvetch, Henderson ricegrass, John Day chaenactis, snowball cactus, hotrock penstemon, and pauper milkvetch.

Before any EBIPM treatments are executed, all proposed treatment areas will be surveyed to identify and locate state-listed threatened/candidate/rare plants. If any of these plants are located, all treatments must avoid negatively impacting them.

2. Archeological Resources

The park preserves a substantial archaeological record of its more recent prehistoric and historic human past. Archaeological surveys conducted throughout the park in 1993-94 and 2005-06 provide valuable insight into long-term human use of the park and the broader central Oregon-Blue Mountain Region (Burtchard 1998).

Prehistoric sites are dominated by lithic scatters of varying density and complexity. Lithic analysis suggests that past uses included residential base camps, short-term hunting camps, lithic procurement, and hunting and observation activities. Other prehistoric site types have stacked rock features and rock art pictographs.

For the most part, historic period artifacts and features are associated with early 1900s farming, ranching and mining activities. Sites include remains of an abortive Clarno area oil exploration venture, irrigation features, boundary cairns, and widely dispersed early 1900s bottle and can scatters.

Before any ground-disturbing EBIPM treatments are executed, all proposed treatment areas will be surveyed to identify and locate prehistoric and/or historic sites. If any sites are located, all ground-disturbing treatments must avoid them.

3. Paleontological Resources

The Monument was established because of its world-class fossil beds. The Monument lies within the John Day River Basin, an area where thousands of feet of sediment were deposited from approximately 50 million years ago to about 6 million years ago. These sediments make up four major groups with fossil-bearing geologic formations, spanning almost 50 million years of the Tertiary Period: the Clarno Formation (formed 54 to 37 million years ago), John Day Formation (39 to 18 million years ago), Mascall Formation (15 to 12 million years ago), and Rattlesnake Formation (8 to 6 million years ago). Exposures of layers of these formations throughout the basin and the Monument reveal one of the finest fossil records of Tertiary Period plants and vertebrates in the world.

Paleosols are defined as a soil that formed on a landscape in the past with distinctive morphological features resulting from a soil-forming environment that no longer exists. Almost all of the Monument's mammalian fossils are found directly in paleosols. The paleosols are identified by their brilliant red, orange, blue and gray colors.

Fossils can be damaged or destroyed from people walking over fossil-bearing rocks and paleosols and unintentionally crushing or dislodging the fossils on or just beneath the surface. All EBIPM treatments will be planned so that no foot or vehicle traffic will cross fossil-bearing paleosol and geologic formations.

Photo 27. Blue Basin.

Adaptive Management

Using adaptive management to implement and assess management treatments is a way for resource managers at the Monument to manage in the face of uncertainty. Adaptive management can be practiced in a number of ways, but the process ultimately involves formulating questions, selecting alternative techniques to test the questions and testing the techniques on the landscape (Reever-Morghan et al., 2006). At this stage of the management plan a number of adaptive management steps have been covered. This section will present the steps of adaptive management to consider when a treatment is ready to be implemented.

Choosing Site Locations

Sites should represent the area of interest and should be as uniform as possible. At a good study location, different treatments are applied across an area that is as unvarying as possible. The more natural the variability of the landscape is minimized, the easier it will be to make valid comparisons from the treatments applied. The area should be uniform and similar in densities of invasive grasses, native plants, soil types and aspects. The goal is to factor out landscape variation and make sound comparisons of treatment differences, which at times can be subtle.

Plot Size

Once site locations have been decided, 'plots' need to be determined. A plot is an area of predetermined size that has a treatment applied to it. The size of the plots depends on the size of the site, the number of treatments, and how many times treatments will be replicated (see below) at a specific site. While it is desirable to have plots of the same size, it is not crucial. Nor do plots have to be in straight lines. They can follow land contours as boundaries are established.

Replication

Using the adaptive management approach will assist Monument managers' in knowing if treatment responses are more than a one-time event. Year-to-year variation in precipitation and site-to-site variation in important characteristics (e.g. soil type) can make it difficult to make this determination. Replicated plots will make it possible to determine if a positive response occurs because of a management treatment and that if applied again a similar response can be expected again.

Replication is repeating an experiment in different places (sites) and in different years to reduce the chance of drawing incorrect conclusions. To gain confidence in management, replicate treatments in as many areas as reasonable.

Control Plots

In order to test the effectiveness of competing management alternatives, control plots will be necessary. Without a control, it will be difficult to determine whether changes are occurring due to management or the changes are just happening naturally or are weather-related. Effective adaptive management allows for a comparison of the management alternatives implemented against control areas.

Randomization of Treatments

Once the number of alternatives and replications are determined and the sites, locations, and plots are chosen, management treatments and controls should be randomized. Randomization removes the potential for bias in an experiment and is important when data is collected. Randomized treatments are necessary to use some basic statistics to help draw conclusions from the treatments.

Collecting Data and Monitoring

Data collection is ideally conducted at the end of each growing season, though in some situations the treatments may be run for a couple of years before collecting data. Yearly data collection will create a better understanding of how the treatment will work in different years, while longer periods between data collection give an average (over time) response of the site to the treatment. Data collection may be added as a part of a monitoring plan developed for the Monument.

The type of data to collect, such as plant biomass or density, should be amenable to answering the question of whether the management strategy is driving the plant community in a desired direction. If the objectives stated at the beginning of the process have measurable outcomes, then sampling will provide the statistical picture whether progress is being made toward achieving the objectives outlined in this plan.

As part of the adaptive management plan for the Monument, data will be statistically analyzed to assess how well the best treatment compares to the predetermined land management objectives. Treatments can be compared with one another statistically using a simple T-Test. If a comparison of more than two different treatments is part of the plan, a T-Test is not adequate for analyzing the data. Statisticians may be consulted for more complex comparisons.

Benefits of implementing adaptive management at John Day Fossil Beds National Monument

- Increases documentation and support management decisions to ensure they have the highest chance for protecting and conserving natural resource base.
- Empowers managers to proceed with management, instead of waiting for solutions to be developed.
- Gains information on specific areas being managed and knowing if strategies will 'work' for your site.
- Continually builds on the knowledge about how to manage specific sites for invasive plants.
- Management techniques are supported with credible data that could be valuable if management choices are challenged in court.
- Promotes the most efficient use of funds.

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Appendix A. Priority List of Noxious Weed Species for Prevention

Common Name	Scientific Name
Medusahead	*Taeniatherum caput-medusae*
Cheatgrass	*Bromus tectorum*
Ventenata	*Ventenata dubia*
Yellow star thistle	*Centaurea solstitialis*
Knapweed species (spotted, diffuse, Russian)	*Centaurea maculosa, Centaurea diffusa, and Acroptilon repens*
Dalmation toadflax	*Linaria dalmatica*
Canada thistle	*Cirsium arvense*
Scotch thistle	*Onopordum acanthium*
Perennial pepperweed	*Lepidium latifolium*
Whitetop	*Cardaria draba*
Mustard (Tumble and Black)	*Sisymbrium altissimum, Brassica nigra*
Russian thistle	*Salsola iberica*
Prickly lettuce	*Lactuca serriola*
Common mullein	*Verbascum thapsus*
Kochia	*Kochia scoparia*

Appendix B. Herbicide Application Chart

Species	Herbicides	Rate	Timing
Medusahead	Imazapic Glyphosate	6 oz/acre 16 oz/acre	Late fall, seedling Spring, before bloom
Cheatgrass	Imazapic Glyphosate	6 oz/acre 16 oz/acre	Late fall, seedling Spring, before bloom
Ventenata	Imazapic	6 oz/acre	
Yellow star thistle	Aminopyralid Clopyralid (less soil residual)	.75-1.75 oz ai/acre 2-3 oz ai/acre	Late fall - seedling stage
Knapweed species (spotted, diffuse) Russian Knapweed	Clopyralid +2,4-D Clopyralid +2,4-D	.59 lbs ai/acre 1.19 lbs ai/acre 1.8 lbs ai/acre	Fall regrowth, Bolt stage Late bud/early bloom
Dalmation toadflax	Imazapic Metsulfuron	12 oz/acre 1.5 oz/acre	Late Fall Fall or spring
Canada thistle	Clopyralid +2,4-D	12 oz/acre 1.5 oz/acre	
Scotch thistle	Clopyralid +2,4-D	12 oz/acre 1.5 oz/acre	
Perennial pepperweed	Imazapic Metsulfuron	8-12 oz/acre 1 oz/acre	After full bloom Before full bloom
Hoary cress	Imazapic Metsulfuron	8-12 oz/acre 1 oz/acre	After full bloom
Mustard (Tumble and Black)	2, 4-D	.5-1 pt/acre 1-4 pt/acre	Actively growing Older plants
Russian thistle	Dicamba	.25-1 pt/acre 1 pt/acre	Actively growing Established plants
Prickly lettuce	Fluroxsypyr Chlopyralid	12 oz/acre .25-.33 pt/acre	Actively growing Actively growing
Common mullein	Aminopyralid	4-7 oz/acre	Basal rosettes
Kochia	Fluroxypyr	6-12 oz/acre 13-17 oz/acre	Small plants Large plants

Appendix C. Candidate Noxious Weed Species for Biocontrol

For Dalmation Toadflax:

Stem-boring Weevil (*Mecinus janthinus*) - This 4.5mm-long weevil severely damages the flowering and reproduction of Dalmation toadflax. Adult weevils feed externally on the foliage and the larvae feed within the plant. Larval feeding damages the weed's vascular tissues, reduces or eliminates flowering and causes conspicuous wilting of attacked shoots.

Seed Capsule Weevil (*Gymnetron antirrhinni*) - These hardy weevils feed on the developing seed capsules of Dalmation toadflax and further reduce the number of new seeds produced each year.

For Yellow Starthistle:

Hairy Weevil (*Eustenopus villosus*) - Adult weevils feed externally on young flowers and larvae feed within mature flowers, dramatically reducing seed production.

For Canada thistle:

Thistle Stem Weevil (*Ceutorhynchus litura*) - This weevil attacks young Canada thistle plants as they sprout from the soil in early spring. The developing larvae internally mine the stem of the thistle plant as the shoot elongates during the summer. Fully developed larvae will exit the plant at the root crown causing multiple exit holes. Larvae will pupate in the soil and emerge as adults later in the summer. Adults over winter in the soil.

Thistle Stem Gall Fly (*Urophora cardui*) - The gall fly attacks the primary and lateral stems of Canada thistle. Adults will lay their eggs on the thistle plant in the early summer when plants are bolting. The developing larvae stimulate the plant to form a hard, woody, stem gall. Galling directs nutrients away from the plant's normal metabolic and reproductive functions. Abnormally developed flower heads frequently occur above the gall, often reducing seed production.

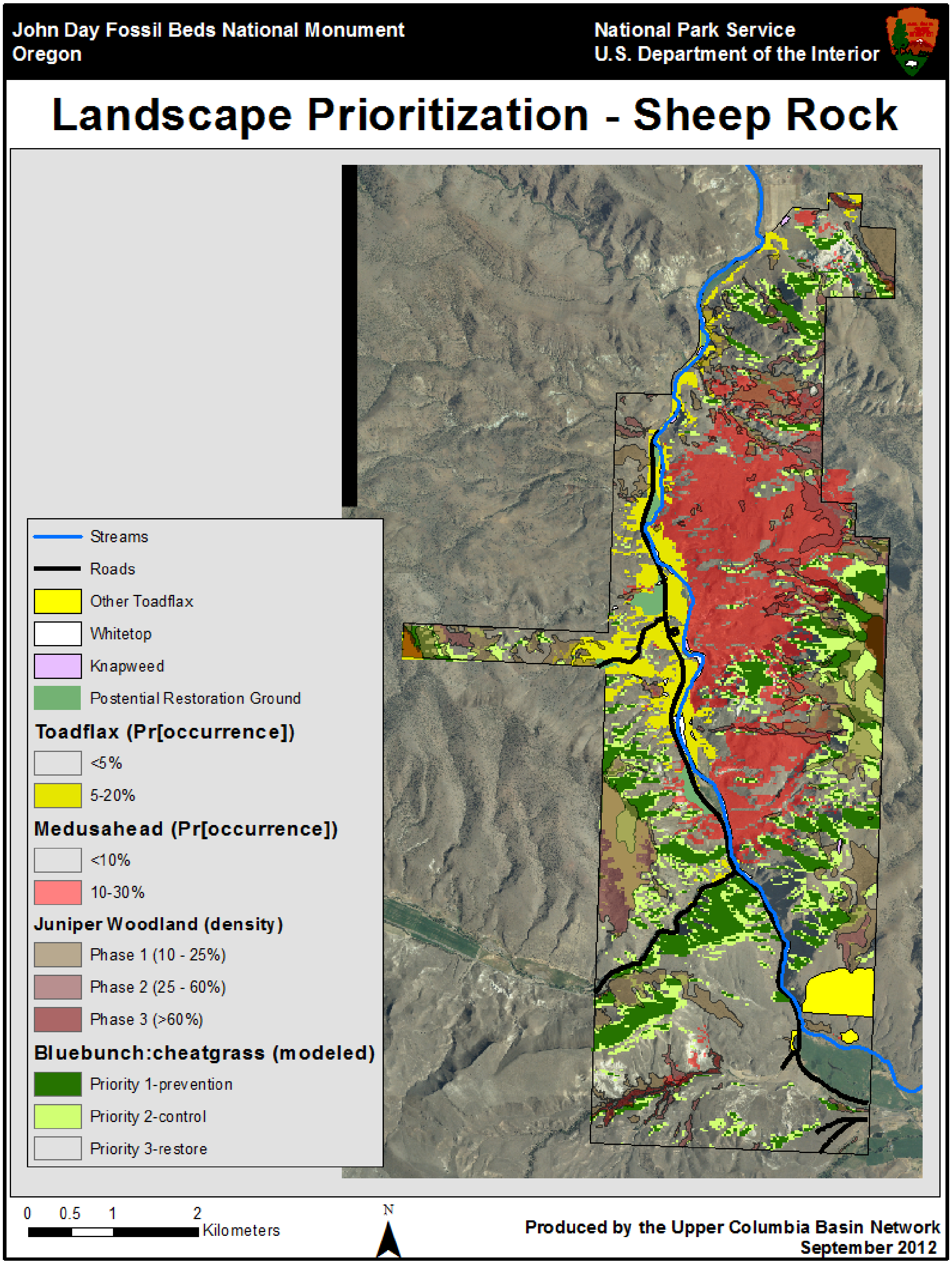
For Spotted and Diffuse Knapweed:

Blunt Knapweed Flower Weevil (*Lirinus obtusus*) - This cold-hardy weevil lays its eggs throughout the summer on the flowers of spotted and diffuse knapweed reducing the production of new knapweed seed.

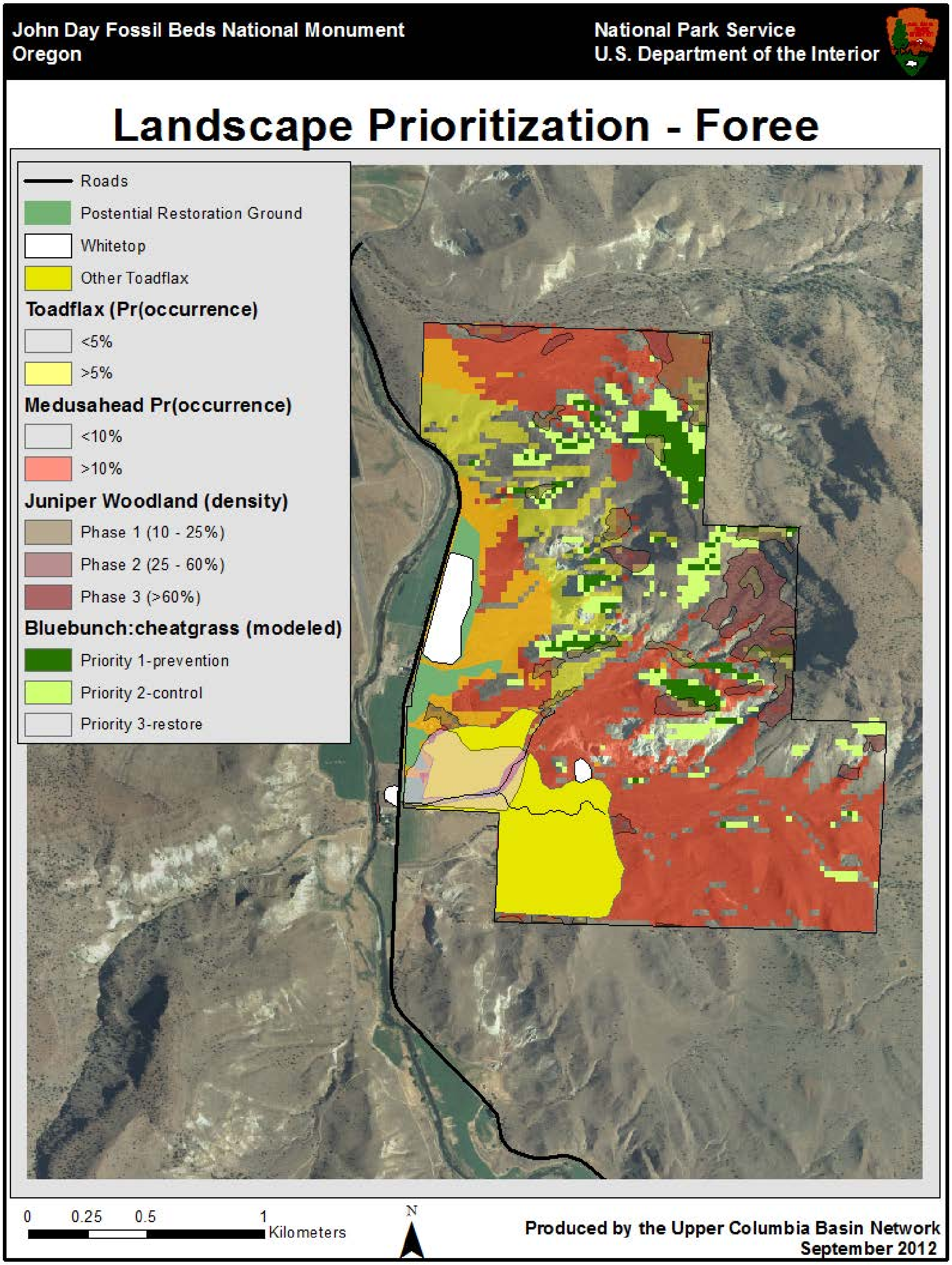
Knapweed Root Weevil (*Cyphocleonus achates*) - This large weevil lays approximately 100 eggs at the base of spotted and diffuse knapweed plants. The developing larvae mine the central taproot, damaging the weed's vascular tissue and causing rootgall formation.

Lesser Knapweed Flower Weevil (*Larinus minutus*) - In drier areas, this weevil lays its eggs throughout the summer on the flowers of diffuse and spotted knapweeds. This specie contributes to reducing the production of new seed. This weevil is winter cold hardy yet thrives in hot, dry summer environments.

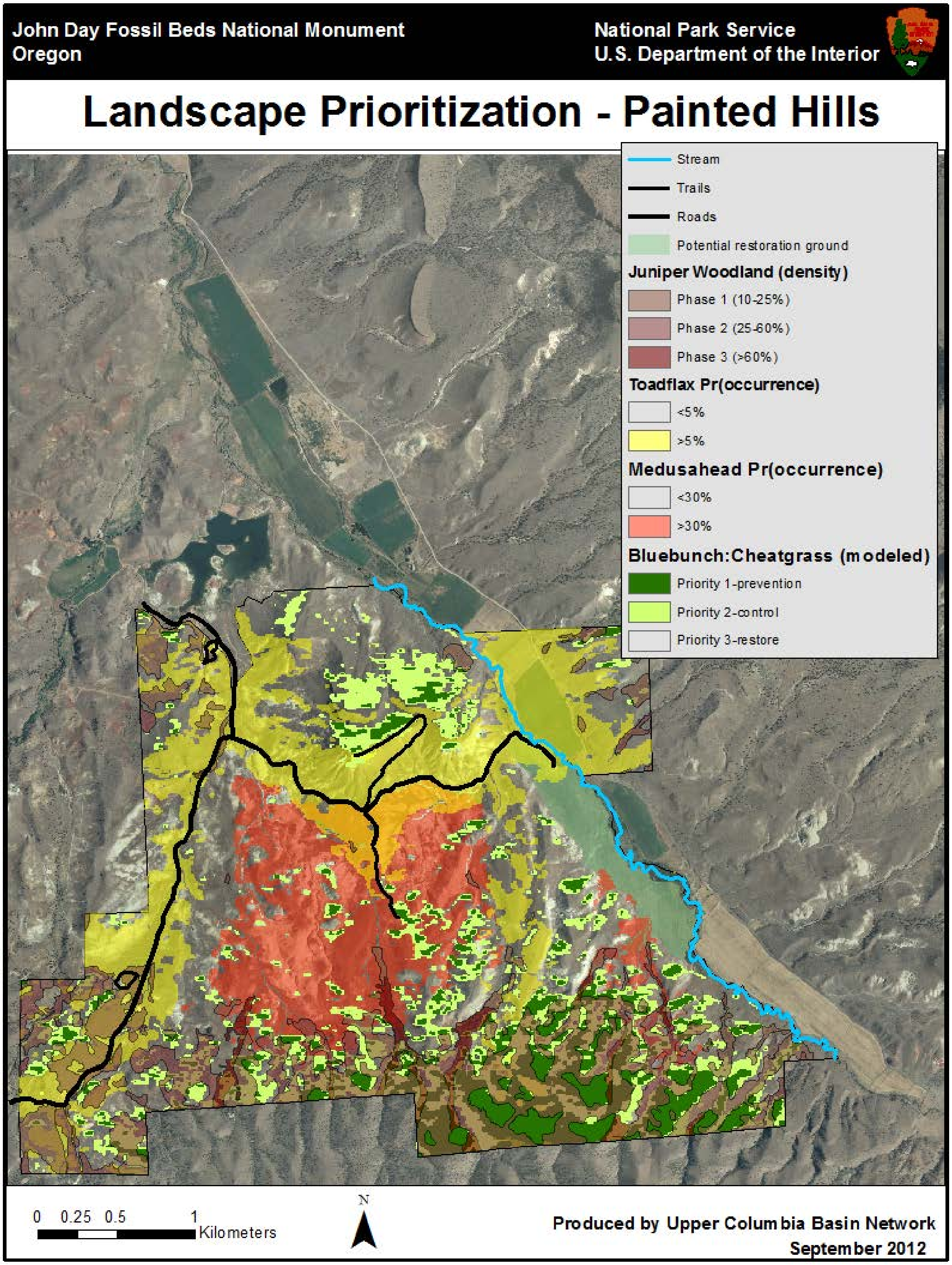
Appendix D. Landscape Prioritization Maps



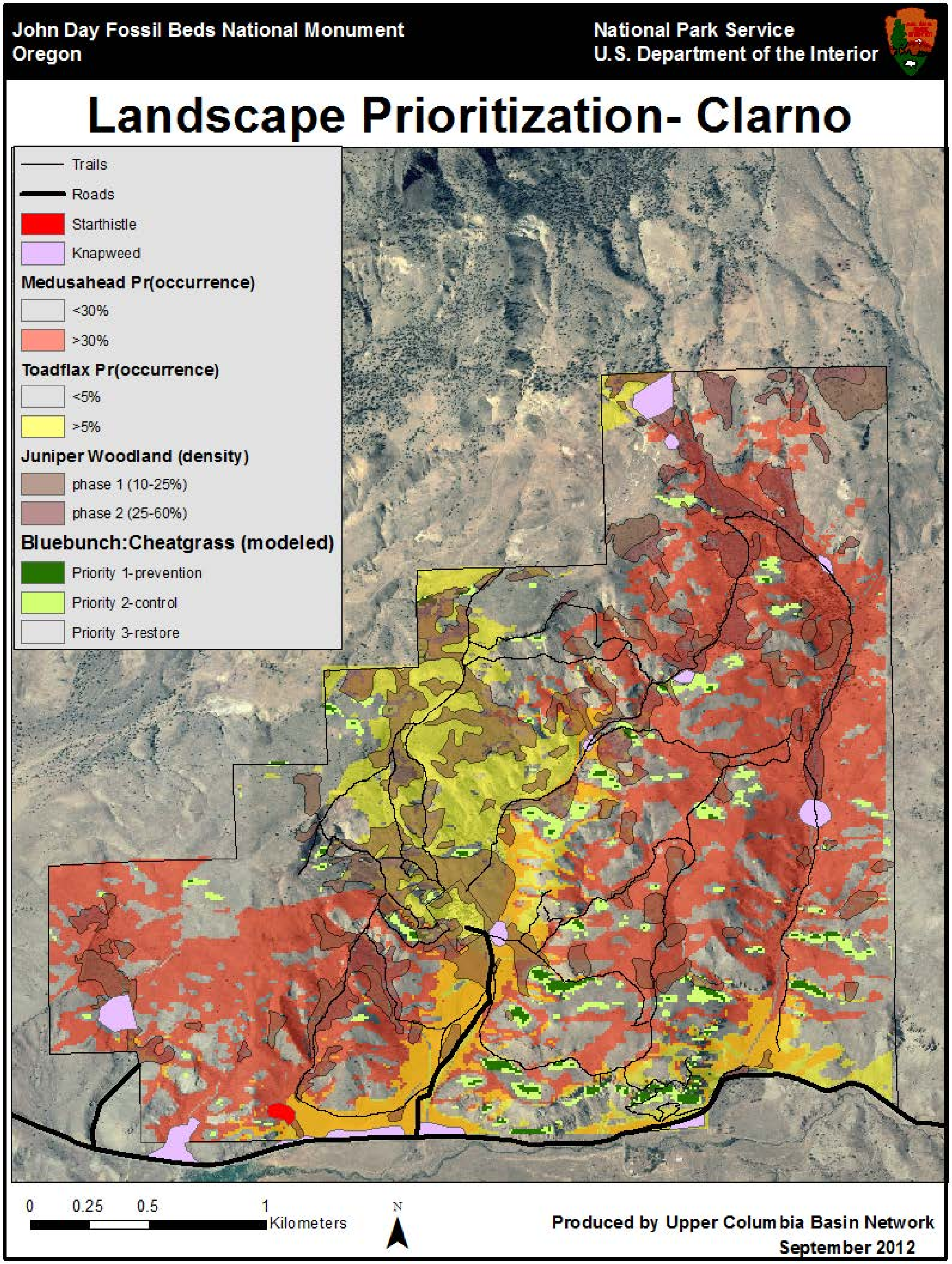
Appendix D (continued). Landscape Prioritization Maps



Appendix D (continued). Landscape Prioritization Maps



Appendix D (continued). Landscape Prioritization Maps



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