Invasive Plant Management and Greater Sage-Grouse Conservation:

A Review and Status Report with Strategic Recommendations for Improvement

Western Association of Fish and Wildlife Agencies • Wildfire and Invasive Species Initiative – Working Group

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USFWS Conservation Objectives Team Report (2013): Objective:

"The long-term conservation of sage-grouse and healthy sagebrush shrub and native perennial grass and forb communities by maintaining viable, connected, and well-distributed populations and habitat across their range, through threat amelioration, conservation of key habitats, and restoration activities."

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Male Greater sage-grouse on lek

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EXECUTIVE SUMMARY

In 2013, the U.S. Fish and Wildlife Service (USFWS) Conservation Objectives Team (COT) identified wildfire and the associated conversion of low- to mid-elevation sagebrush *(Artemisia tridentata)* habitats to invasive annual grass-dominated vegetation communities as the two primary threats to the sustainability of Greater sage-grouse *(Centrocercus urophasianus,* hereafter GRSG) in the western portion of the species range (USFWS 2013). To facilitate the examination and evaluation of the role fire and invasive plants play in the conservation of GRSG, the USFWS solicited the assistance of the Western Association of Fish and Wildlife Agencies (WAFWA) to conduct a collaborative assessment of the conservation challenges associated with the fire and invasive threat. The results of this collaborative effort led by WAFWA can be found in a series of recent publications. With respect to the management of invasive plants within the range of the GRSG, WAFWA assessed conditions and activities within the geographic range of GRSG, including parts of 11 states in the western United States and two Canadian provinces represented by the northwestern Great Plains, Great Basin, Snake River Plain, Colorado Plateau, and Columbia Basin.

Marked Greater sage-grouse in sagebrush habitat

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Invasive Plant Threats to GRSG Habitat

Much public and scientific attention has been paid to wildfire and its effects on public safety, property and GRSG habitat and populations. However, the story of the effects of fire on GRSG conservation cannot be effectively told without recognizing and evaluating the critical role invasive annual grasses and invasive perennial forbs play, both in the wildfire cycle and the direct effect they have on the quality of GRSG habitat. The conversion of native sagebrush habitats to invasive annual grasslands has been identified as an issue for western rangelands for decades (Leopold 1949 p. 164-168, Young and Evans 1973, Mack 1981, Miller et al. 2011). Wildfire, while having a direct effect on GRSG habitat, has been shown to have a significant association with invasive non-native annual grasses such as cheatgrass *(Bromus tectorum)* and medusahead *(Taeniatherum caput-medusae)* (Miller and Eddleman 2001). The conversion of native perennial–dominated sagebrush ecosystems to exotic annual-dominated systems is well described by Chambers et al. (2014a). Many invasive plant species (both annual grasses and perennial forbs) have degraded GRSG habitat by outcompeting native species and by directly affecting the frequency and intensity of wildfires. Invasive annual grasses in particular fuel the wildfire threat and cause degradation of sagebrush communities, resulting in habitat loss and negative effects on GRSG populations, as well as other sagebrush-dependent wildlife species.

Cheatgrass (pictured) along with medusahead are considered the most problematic of the invasive annual grasses.

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While cheatgrass and medusahead are considered the most problematic of the invasive annual grasses, an array of other invasive plant species also exists in sagebrush ecosystems across the western U.S. (Miller et al. 2011). In many cases invasive plants can significantly transform ecosystems by altering their basic species composition, or habitats (ANSTF and NISC — Ad Hoc Working Group on Invasive Species and Climate Change 2014). Invasive forbs respond to changes in fire regimes and cause their own ecological impacts to GRSG habitat. Pre- and post-fire management of invasive forb infestations in GRSG habitats, particularly along riparian zones and critical GRSG brood-rearing areas, must also be taken into consideration. The effects of fire on invasive forbs often promote the persistence of these plants (Brooks et al. 2004). Many perennial invasive forbs are unharmed or may increase following fire due to such life-history traits as prolific seed production, persistent seed banks, and rooting characteristics including the ability to sprout from rhizomes, root crowns, or adventitious buds. Deep-rooted, creeping invasive perennials such as Russian knapweed *(Acroptilon repens),* squarrose knapweed *(Centaurea virgate* ssp. *squarrosa),* Dalmatian toadflax *(Linaria dalmatica),* and

Canada thistle *(Cirsium arvense)* are often some of the hardest invasive plants to manage, can dominate large areas, and are becoming increasingly important in terms of their effect on sagebrush habitat. Many invasive annual forbs (e.g., *Sisymbrium* spp., *Descuriania* spp, etc.) also increase after fires by taking advantage of improved resource availability caused by mortality of native sagebrush and/or reduced annual grass seedbanks (Chambers et al. 2014b).

Many invasive plant species (such as this medusahead) have degraded GRSG habitat by outcompeting native species.

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Distribution and Spread of Invasive Plants in GRSG Habitat

While fire is the most conspicuous disturbance factor, improper grazing, agriculture, development, and other anthropogenic activities play a significant role in the spread of invasive plant species on Western rangelands (Young et al 1972, 1978; Miller and Eddleman 2001; Benvenuti 2007). The average rates of spread of invasive plant populations are difficult to determine because very little accurate information has been available to describe the abundance of invasive plant distributions in the western U.S. However, it is widely accepted within the invasive species management community that the spread of invasive plants is exceeding treatment rates conducted by most weed management programs. Cheatgrass populations, for example, have expanded dramatically over time. An estimated 17 million acres in the Great Basin are currently dominated by cheatgrass and it has established itself as a component of the broader plant community in an additional 62 million acres (Diamond et al. 2012). This highly invasive annual grass is just one of at least 17 other priority invasive plant species increasing in extent and influence within the range of GRSG, causing irreversible ecosystem degradation on both federal and nonfederal lands. Invasive plant invasions are often tied to human activities that move or open dispersal pathways for movement, or modify ecosystems and site conditions that allow expansion, or both. Abundance and distribution data is critical for land managers to identify areas most vulnerable to invasion, prioritize sites and invasive plant species for control, and to plan effective management strategies (Higgins et al. 2000, Thuiller et al. 2005, Roura-Pascual et al. 2010). Unfortunately, updated, comprehensive landscape-scale maps of the distribution of priority invasive plants in the western U.S. do not currently exist, however they are being developed for some areas. Additionally, much of the invasive plant infestation data collected by land managers is incomplete and highly variable in quality, particularly spatial data. While it is evident that invasions of priority invasive plants pose a significant risk to sagebrush habitats across the range of the GRSG, resource managers are challenged to accurately define proactive measures to address the problem without accurate and updated information about plant distributions.

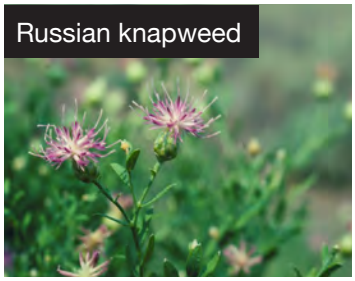
Prevention of invasive plant infestations, therefore, targets known pathways and high-risk vectors for establishment and spread, such as construction and other ground-disturbing activities, road maintenance, energy development and distribution projects, vehicles and equipment, recreation and other public-use activities, livestock grazing programs, mining operations, timber harvest, and many others. The impact of herbivory on invasive annual grass dominance in sagebrush ecosystems, particularly grazing by horses, sheep, and cattle, has been evaluated and discussed since before Leopold (1949) raised concerns about cheatgrass and land management practices in the mid-20th century. For example, Resiner et al. (2013) found inappropriate grazing can exacerbate cheatgrass dominance by reducing invasion resistance, and disturbing biological soil crusts (trampling by horses and cows), which facilitates the establishment and spread of invasive weeds into the system. Young and Clements (2007) pointed out that public land management professionals and rangeland management academicians often erroneously assumed that grazing regimes appropriate for lands dominated by native perennial grasses would automatically lead to a return of such grasses on sites almost exclusively occupied by cheatgrass, and documented that this erroneous assumption had influenced grazing management decisions regarding stocking numbers, timing of grazing relative to seed development, and evaluation of whether to rest an area from grazing pressures. There is a point in the relative abundance of native perennial grasses and cheatgrass where native perennial grasses cannot ascend successionally across the cheatgrass threshold. This threshold is especially important when considering the application of rest-rotation grazing because cheatgrass sometimes benefits from deferred grazing and complete rest from grazing (Young and Clements 2007). Range managers should be aware of this conundrum: defoliation that reduces cheatgrass may also reduce some native grass reproduction. The effectiveness of grazing techniques such as these requires a refined understanding of local site conditions and therefore should not be applied uniformly across sagebrush ecosystems. This is just one example of how improperly managed grazing may have detrimental effects on native plant community reestablishment and sagebrush restoration success following invasive plant suppression or fuels reduction (Reisner et al. 2013).

Governmental Responses to Invasive Plant Threats

Throughout the West, local, state, and federal government agencies are the principal entities responding to invasive plant threats, from both a regulatory and management perspective. However, in 1993 the Office of Technology Assessment noted that there was "no real national policy" on harmful introductions and that the system was "piecemeal, lacking adequate rigor and comprehensiveness." While numerous federal laws address invasive species, there is still no single federal law or combination of policies that provide clear authority or coordination among federal agencies to deal with the issue (Corn and Johnson 2013), especially in the terrestrial context. Overall, the current state of the law is fragmented and uncoordinated; direction for invasive species management comes from a collection of state and

federal rules and regulations which allocate responsibilities to many different agencies. The lack of a consistent, comprehensive policy has resulted in the creation of fundamentally different regulatory approaches among land management agencies and states. This has impeded the development of an effective regional or national program to ameliorate the threat of invasive plants across the range of the GRSG.

Executive Order 13112, signed in 1999 by President Clinton, requires federal agencies to establish, coordinate, and implement invasive species management programs across the U.S. The Executive Order also establishes a cabinet-level National Invasive Species Council (NISC), co-chaired by the Secretaries of Interior, Agriculture, and Commerce, and calls for the development of a National Management Plan to address invasive species in the U.S. Despite the existence of this Executive Order, and the development of two national management plans since 1999, federal invasive species research and management programs remain largely uncoordinated, and highly variable in structure, capacity, and functionality. The NISC has not met since 2008, and an update to the previous national management plan (which expired in 2012) has not yet been completed. Additionally, the Invasive Species Advisory Committee (ISAC), the Federal Advisory committee Act (FACA)-chartered advisors to the NISC, is another potentially excellent resource that has been underutilized since the passage of Executive Order 13112. While current ISAC activities have provided some value to federal government partners, their activities have not been well-guided by the three Department-level co-chairs of NISC. Thus, some ISAC's efforts and recommendations under FACA may be perceived as duplicative, underutilized, or low value to the federal agencies. In general, the three co-chair Departments of the NISC provide poor oversight and administration, of the activities, membership, and expertise of ISAC.


Russian knapweed

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Over 20 federal departments and agencies have responsibilities, authorities, and programs that deal with some facet of terrestrial invasive plant control, yet under the NISC no mechanism has been developed to provide unified support for increasing federal funding for research and management activities necessary to effectively counter the establishment and spread of invasive plant species, or for that matter any other invasive taxa. Although the scale and long-term impact of invasive plant invasions across the nation greatly exceeds that of wildfires, the perceived risk and threat of invasive plants has not reached the same level of priority funding status. Unlike fire prevention, invasive species prevention has not become a social norm in the 11 western states (nor anywhere else in the U.S. and Canada). While tens of millions of federal, state and local dollars are spent annually on wildfire prevention, suppression and habitat restoration, the amount of funding and resources spent on invasive plant invasions pales by comparison. Proposed federal legislation for invasive species prevention and control has recommended significantly increasing invasive species management capacity on federal lands to reach an annual goal of reducing inventoried infestations by a net 5% to reverse the invasion trends and begin to restore priority areas to proper function and composition (House Committee on Natural Resources, Subcommittee on Public Lands and Environmental Regulation 2014).

Invasive plant management activities conducted on federally administered lands in the West are often coordinated with state and local governments and may be largely performed by contractors (including county weed programs) under assistance agreements. Federal funding for these activities, however, is severely lacking throughout the 11-state GRSG range, and has resulted in the curtailment of many federal research and management programs or a significant reduction in their scope and scale. The lack of adequate federal infrastructure, funding, and management capacity severely hampers the ability to effectively deal with landscape-scale invasive species threats, including — and perhaps especially — infestations of invasive plants that degrade or eliminate native sagebrush ecosystems across the western U.S. Improving organizational capacity and regulatory mechanisms may lead to more effective invasive plant management and increase the ability of land managers to address the problems associated with the spread of invasive plants (particularly invasive annual grasses). A corresponding emphasis on advancing scientific research in invasive plant prevention and control techniques and development of new approaches for effective restoration of sagebrush ecosystems should also occur.

Across much of the western landscape, most of the regulatory and management activities designed to control invasive plants are led by state governments, primarily state agriculture departments, often with the cooperation of federal agencies. All of the 11 western states within the range of GRSG have invasive plant or noxious weed laws that follow the general principles developed on a federal level. State laws may also establish regulatory commissions, boards or councils, and require management plans, a statewide weed coordinator and county weed supervisors. Local weed management programs conduct much of the on-the-ground weed control work and public education throughout the range of the GRSG. These programs take a variety of forms, such as county weed programs, county weed districts, and Cooperative Weed Management Areas (CWMAs). Cooperative Weed Management Areas, as well as county weed programs and districts, play a valuable role in weed management across the West. CWMAs are local, multi-jurisdictional organizations. County weed programs generally receive some county or state funding (or both), and often have some form of regulatory authority. County programs also play a significant role in supporting federal and state agencies in the local area. Many federal and state agencies contract weed management efforts out to local county weed management programs, whereby the county employees will perform weed control on state and federal roads and other sites. These local activities are highly variable from year to year and may or may not be a high priority statewide, or provide added value to the conservation of sagebrush or GRSG. A key predictor of the success of weed management programs is the presence of enforceable weed regulations, well-established program budgets primarily dedicated to weed control, and institutional histories that allow for longer time frames to establish weed control efforts.

Challenges and Barriers

Despite the many local success stories across the West, as the scale increases to state-wide, region-wide and nationwide levels, so do a number of barriers which cause invasive species management programs to become more fragmented, inconsistent, and relatively ineffective at dealing with the significant problem of ecosystem degradation from invasive species. Chronically inadequate investment in invasive species management programs at all levels has undermined

the ability of managers to keep up with the rate of spread for most invasive species populations. From our review and analysis, WAFWA has identified several key challenges and barriers that will significantly affect the ability to effectively manage non-native plant invasions and conserve native sagebrush ecosystems and the wildlife that depend on those native plant communities for survival. These challenges and barriers fall into four major categories:

Information Management and Science Challenges

- Barrier: Lack of emphasis on surveys, inventories, and monitoring activities
- Barrier: Lack of scientific information to successfully re-establish desired perennial vegetation
- Barrier: Inadequate collection, retrieval, and sharing of invasive plant data
- Barrier: Lack of certainty for actions under a changing climate

Leadership, Coordination, and Communication Challenges

- Governmental Coordination and Emphasis for Invasive Species Management is Insufficient at Nearly All Levels (local, state, federal).
- Barrier: Very limited coordination and collaboration with non-traditional stakeholders
- Barrier: Lack of effective communication and engagement with the public.
- Barrier: Low level of public awareness and support for invasive species management

Policy and Regulatory Challenges

- Barrier: Lack of effective legal and regulatory framework for invasive species management
- Barrier: Insufficient evaluation, compliance monitoring, and enforcement

Operational Capacity and Program Management Challenges

- Barrier: Highly variable management prioritization of high risk invasive plants; Programs do not emphasize sagebrush conservation when targeting invasive plants across the range of the GRSG
- Barrier: Lack of internal structure and capacity for weed management programs at all levels
- Barrier: Lack of federal funding at the field level, which transfers risk to state and local governments
- Barrier: Inconsistent and fragmented prevention operations
- Barrier: Lack of an effective early detection and rapid response (EDRR) system across the landscape
- Barrier: Inadequate restoration strategies, implementation, and approaches

Strategic Recommendations for Improvement

Invasive plant invasions across the western U.S. represent a top threat to the conservation and restoration of native sagebrush ecosystems and wildlife, like GRSG, that depend on those systems for survival. These landscape-scale invasions continue to spread at an alarming rate, yet current invasive plant management program capacity has not sufficiently addressed this risk at any level. The lack of funding sufficient to meet the challenge is a chronic problem whose impacts are amplified over time. Recognizing the extreme risk that invasive plants pose to the habitat of the GRSG and other wildlife, and the necessity of building stronger capacity to address this risk at the local, regional, and national levels, WAFWA has analyzed the information gathered for this document and solicited input from professionals and experts in the weed management and research communities across the west. From this analysis and broad input, we have developed a set of strategic recommendations that may offer solutions to address many of the challenges and barriers listed above. WAFWA acknowledges the tremendous efforts and achievements of the weed management community at all levels and particularly commends their efforts in light of such limited capacity and public support. As a result, we have developed 11 recommendations that we believe will address the issues involved in identifying, describing, managing and resolving the significant problems associated with invasive plants and their effect on ecosystem health. Addressing these problems will lead to sustainable management of the sagebrush ecosystem in the West. By initiating immediate action on these recommendations, we believe that significant strides can be made to ameliorate the threat invasive plants have on the fire cycle, native sagebrush ecosystems, and the GRSG.

INTRODUCTION

The conversion of native sagebrush habitats to invasive annual grasslands has been identified as an issue for western rangelands for decades (Leopold 1949 p. 164-168, Young and Evans 1973, Mack 1981, Miller et al. 2011). In 2013, the U.S. Fish and Wildlife Service (USFWS) Conservation Objectives Team (COT) identified wildfire and the associated conversion of low to mid elevation (or low to mid resistance and resilience [R&R]) sagebrush habitats to invasive annual grass dominated vegetation communities as the two primary threats to the sustainability of Greater sage-grouse *(Centrocercus urophasianus,* hereafter GRSG) in the western portion of the species range (USFWS 2013). In the eastern portion of the bird's range, the wildfire and invasive plants cycle is not the major threat to GRSG, but expansion of invasive annuals are playing a growing role in the degradation of GRSG habitat and other sagebrush-dependent wildlife species. On January 6, 2015, the Secretary of Interior issued Executive Order 3336, which called for a comprehensive science-based strategy to address the more frequent and intense wildfires in the Great Basin region. The Order establishes enhanced policies and strategies for preventing and suppressing rangeland fires and for restoring sagebrush landscapes impacted by fire. This Secretarial Order also identifies invasive plants as an important issue that needs to be addressed.

Cheatgrass with sagebrush skeletons

© MIKE PELLANT

In 2013, the USFWS contracted with the Western Association of Fish and Wildlife Agencies (WAFWA) to conduct a collaborative assessment of management options for the conservation of sagebrush habitats across multiple ownerships in the west. The agreement calls for WAFWA to establish, in coordination with the USFWS, a cooperative initiative to discover, compile, integrate, synthesize and summarize information to assist the USFWS in their listing decision and also reduce the size, frequency and intensity of wildfire in sagebrush ecosystems (Havlina et al. 2015). This report is part of a series designed to accomplish that objective.

PURPOSE, SCOPE, AND STRUCTURE OF THE REPORT

The purpose of this report is to provide a high-level review of information related to the effects and management of invasive plants across an 11-state area that currently, or will potentially, provide habitat for the GRSG and other sagebrush obligate species. This report is divided into four sections. The background section provides a general overview of the threat of invasive species across the range of the GRSG and describes the relationships and impacts of invasive species on sagebrush habitats. The second section describes the current infrastructure and organization of invasive species management programs at the federal, state, local, and private-lands levels, including cooperative efforts and partnerships. The third section highlights the invasive species management program activities currently underway, and how well they are working across the range of the GRSG, including information on major challenges and barriers. The fourth section describes recommendations for improvement, and what will be necessary to better position resource managers and policy makers to successfully address the threats of invasive plants to the GRSG in the future.

This review and status report has been compiled from several sources, including discussions within the WAFWA Wildfire/Invasive Species working group; conversations with invasive plant management experts in government, non-government, and university programs; information gathered from the Western Weed Coordinating Committee, the North American Invasive Species Network, the Federal Interagency Committee for the Management of Noxious and Exotic Weeds, and the Invasive Species Advisory Committee; documents available from the National Invasive Species Council and the U.S. Government Accountability Office; and data compiled from an on-line assessment conducted by the Center for Invasive Species Management (CISM 2014; Montana State University, Bozeman, MT). The WAFWA Working Group, through the Great Basin Landscape Conservation Cooperative, contracted with CISM to develop and administer the on-line assessment, and to gather and analyze data on the specific characteristics and functions of invasive plant management programs within the current and historic range of the GRSG (see Miller et al. 2011). The on-line assessment provided information used to document the status and function of local, state and federal invasive plant management programs within a project area encompassing 11 western states, with additional information and data provided by western weed management experts to the Working Group for the report.

Medusahead

© STEVE DEWEY

Data collection methods of the 2014 on-line assessment were designed to include open-ended, multiple-choice, and yes/no questions, and used five-point Likert-type rating scales (CISM 2014). A total of 291 completed questionnaires were received from respondents associated with counties and weed management districts, wildlife management areas and other state lands, state agricultural and other state programs, local and regional Bureau of Land Management units, local and regional U.S. Forest Service units, local and regional U.S. Fish and Wildlife Service units, local National Park Service units (Table 1).

WHY INVASIVE PLANTS MATTER

Background and Description of Threat

An invasive species is defined as any species that is exotic (non-native) to the specific ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112 1999). While cheatgrass *(Bromus tectorum)* and medusahead *(Taeniatherum caput-medusae)* are considered the most problematic of the exotic annual grasses, an array of other invasive plant species also exists in sagebrush *(Artemisia* spp.) ecosystems across the western region of the United States (Miller et al. 2011). Invasive annual grasses fuel the wildfire threat and cause degradation of sagebrush communities, resulting in habitat loss and negative effects on GRSG populations, as well as other sagebrush-dependent wildlife species.

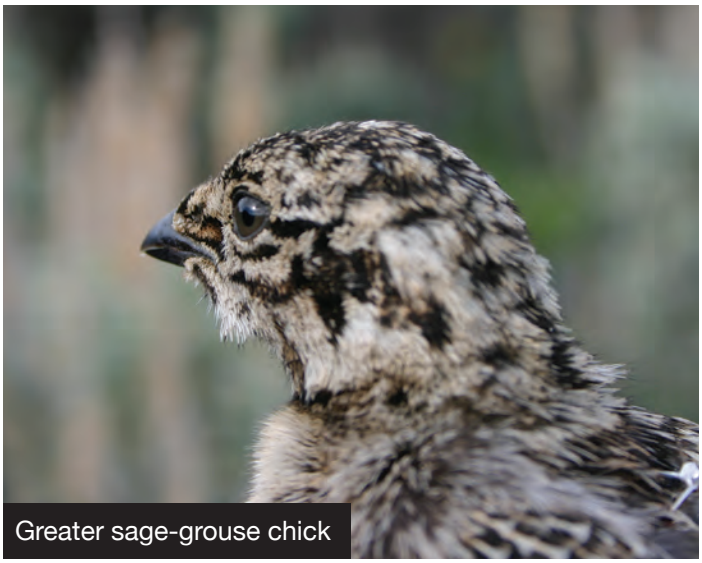
Despite the many local on-the-ground success stories across the West, as the scale increases to state-wide, region-wide and nationwide levels, a number of factors begin to cause invasive species management programs to become more fragmented, less consistent, and relatively less effective at dealing with the significant problem of ecosystem degradation. Inadequate investment into invasive species management programs, at all levels over the years, has undermined managers' ability to keep up with the rate of spread for most invasive species populations. The best example is cheatgrass, which has expanded significantly across the West over time. Cheatgrass currently dominates over 17 million acres in the Great Basin and occupies an additional 62 million acres as a component of the broader plant community (Diamond et al. 2012). This highly invasive annual grass is just one of at least 17 other priority invasive plant species (Table 2) increasing in extent and influence within the range of GRSG, causing irreversible ecosystem degradation on both federal and nonfederal lands. The average rates of spread of invasive plants in the western U.S. are difficult to determine because very little information is available to accurately describe invasive plant distributions. However, it is widely accepted that the spread of invasive plants is exceeding treatment rates conducted by most county, state, and federal weed management programs. The inadequate capacity for treatment of invasive plant populations is made worse by the lack of strong prevention, early detection, rapid response, and containment programs at each spatial scale. To be effective, the appropriate application of invasive plant treatments must involve a detailed understanding of the biology/ecology of the problem being treated, and a strategic approach to correcting identified concerns. Without this understanding and strategic approach, application of treatments is an exercise in treating symptoms; and while such exercises may record short-term successes, they are unlikely to be successful in correcting underlying conditions responsible for long-term proliferation of undesired species. Additionally, long-term control of invasive plants involves both a reduction in the invading species, as well as re-occupation of the now available niche by desired species. Thus, removing the immediate threat of undesired species is only the first step in securing the plant community and must be followed by re-establishment of desired species, an undertaking that has resulted in only limited success in many plant communities that display low resistance

and resilience (e.g., see Knutson et al. 2014). Invasions into native plant communities also may be sequential, as the initial invaders are replaced by a series of new exotics or by species adapting to new habitats within their range (Young and Longland 1996).

Major invasive species threats across the range of GRSG

The invasion and spread of invasive plants across the western landscape have resulted in significant ecosystem transformations. In the recent paper "Bioinvasions in a Changing World: A Resource on Invasive Species-Climate Change Interactions for Conservation and Natural Resource Management" (ANSTF and NISC - Ad Hoc Working Group on Invasive Species and Climate Change 2014) it was articulated that in many cases invasive species transform ecosystems by altering their basic species composition or habitats. In that paper, ANSTF and NISC offered examples of such transformations using cheatgrass in the western U.S (Mack 1986, Bradley et al. 2009), buffelgrass *(Pennisetum ciliare)* in the southwestern desert (Bovey et al. 1986) and Old World climbing fern *(Lygodium microphyllum)* in southern Florida, and noted how these invasive plants made habitats more prone to wildfires, which in turn accelerated changes in those ecosystems (Burgiel and Muir 2010). ANSTF and NISC noted that these new fire-prone systems then independently impact carbon sequestration and the release of greenhouse gases. Similarly, increased greenhouse gas emissions can affect both ecosystems and species with potential implications for invasive species. For example, increased CO2 concentrations may favor some invasive plants over their native competitors (Ad Hoc Working Group on Invasive Species and Climate Change — ANSTF and NISC 2014). These ecosystem-level changes create a trajectory of impact that will result in continued decreases in sagebrush habitat without active and successful management intervention.

One of the primary effects of invasive species on sagebrush ecosystems is amplifying the intensity and frequency of fire. Invasive annual grasses are well-established threats to sagebrush ecosystems and thus affect habitat for constituent wildlife species. Invasive annual grasses were cited by the USFWS as a primary threat to GRSG in the agency's 2010 "warranted but precluded" status determination. Annual grasses, such as cheatgrass and medusahead, can create heavy


Greater sage-grouse chick

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Inappropriate cattle grazing can exacerbate cheatgrass dominance by reducing invasion resistance.

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and continuous fine fuel loads that propagate frequent wildfires and result in the loss of sagebrush. The conversion of perennial-dominated sagebrush ecosystems to annual-dominated systems is well described by Chambers et al. (2014a). Invasive annual grasses not only have the potential to alter the fire regime and create additional risk of wildfire impacts to sagebrush, these harmful exotic plants can negatively affect the productivity and survival of native plant communities, and the associated native wildlife which depend on a healthy sagebrush ecosystem. As early as the 1940's, studies of the relationships between cheatgrass and native rangeland perennials found that cheatgrass dominance of native plant communities prevented recruitment of seedlings of perennial species (Robertson and Pearse 1945). Pyke, et al. (2014) found that if arid sagebrush ecosystems lack resilience to disturbances or resistance to annual invasives, then alternative successional states dominated by annual invasives, especially cheatgrass, are likely after fuel treatments. Loss of resilience and resistance to invasive annual grasses in sagebrush plant communities is typically associated with a decline in abundance of perennial bunchgrasses (Chambers et al. 2007, Davies 2008).

Invasive forbs both respond to changes in fire regimes and cause their own impacts. These attributes must be taken into consideration when implementing pre- and post-fire management of invasive forb infestations in GRSG habitats, particularly along riparian zones and critical GRSG brood-rearing areas. The effects of fire on invasive forbs often promote the persistence of these plants (Brooks et al. 2004). Many perennial invasive forbs are unharmed or may increase following fire, due to such life history traits as prolific seed production, persistent seed banks, and rooting characteristics including the ability to sprout from rhizomes, root crowns, or adventitious buds. Deep-rooted, creeping invasive perennials such as Russian knapweed *(Acroptilon repens),* squarrose knapweed *(Centaurea virgate* ssp. *squarrosa),* Dalmatian toadflax *(Linaria dalmatica),* and Canada thistle *(Cirsium arvense)* are often some of the hardest invasive plants to manage, can dominate large areas, and are becoming increasingly important in terms of their effects of sagebrush habitat (Table 2). Many annual invasive forbs (e.g., *Sisymbrium* spp., *Descuriania* spp., etc.) also increase after fires by taking advantage of resource availability caused by mortality of native sagebrush species or a reduction in annual grass seedbanks (Chambers et al. 2014b).

The impact of herbivory on invasive annual grass dominance in sagebrush ecosystems, particularly grazing by horses, sheep, and cattle, has been evaluated and discussed since before Leopold (1949) raised concerns about cheatgrass and land management practices in the mid-20th century. Resiner et al. (2013) found inappropriate grazing can exacerbate cheatgrass dominance by reducing invasion resistance, and disturbing biological soil crusts (trampling by horses and cows) that facilitates the establishment and spread of invasive weeds into the system. The specific impact of herbivory on plant community resistance and other plant community properties will vary in accordance with intensity, frequency, and season of use (e.g., see Crawford, et al. 2004, Davies, et al. 2011) and is further complicated by the interaction of grazing with abiotic site properties. For example, light levels of cattle grazing at the appropriate season can reduce herbaceous fuel abundance and increase herbaceous fuel moisture (Davies, et al. 2009 2010), both of which could help moderate the negative influence of fire on low-elevation sagebrush plant communities. However, Young and Clements (2007) pointed out that public land management professionals and rangeland management academicians often erroneously assumed that grazing regimes appropriate for lands dominated by native perennial grasses would automatically lead to a return of such grasses on sites almost exclusively occupied by cheatgrass, and documented that this erroneous assumption had influenced grazing management decisions regarding stocking numbers, timing of grazing relative to seed development, and evaluation of whether to rest an area from grazing pressures. There is a point in the relative abundance of native perennial grasses and cheatgrass where native perennial grasses cannot ascend successionally across the cheatgrass threshold. This threshold is especially important when considering the application of rest-rotation grazing because cheatgrass sometimes benefits from deferred grazing and complete rest from grazing (Young and Clements 2007). Range managers should be aware of this conundrum: defoliation that reduces cheatgrass may also reduce some native grass reproduction. The effectiveness of grazing techniques such as these requires a refined understanding of local site conditions and therefore should not be applied uniformly across sagebrush ecosystems. This is just one example of how improperly managed grazing may have detrimental effects on native plant community reestablishment and sagebrush restoration success following invasive plant suppression or fuels reduction (Reisner et al. 2013).

Distribution and Abundance of Invasive Plants and Their Risk to Sagebrush Habitats

The geographic range of GRSG includes parts of 11 states in the western United States and two Canadian provinces represented by the northwestern Great Plains, Great Basin, Snake River Plain, Colorado Plateau, and Columbia Basin (Figure 1). We focused on 30 invasive plant species known to threaten sagebrush communities of the western U.S. as described by Miller et al. 2011. This initial list of 30 species was reduced by first excluding the plants known to be ruderal weeds or associated only with highly degraded habitat, such as Russian thistle *(Salsola* spp.), and those listed as obligate or facultative wetland species, for instance perennial pepperweed *(Lepidium latifolium),* purple loosestrife *(Lythrum salicaria),* and poison hemlock *(Conium maculatum).* We also excluded plants rarely observed in sagebrush communities, for instance orange and meadow hawkweed *(Hieracium aurantiacum* and *H. caespitosum),* and plants with largely unknown invasiveness in sagebrush habitats, specifically oxeye daisy *(Leucanthemum vulgare)* and tansy ragwort *(Senecio jacobaea).*

From this reduced list and based on literature reviews, we prioritized invasive plants of sagebrush habitat according to a ranking system developed based on integrated ecological impacts, reproductive attributes, potential invasiveness, and management difficulty (Colautti and MacIsaac 2004, Skura Darin et al. 2011, Pyšek et al. 2012, Barney et al. 2013). The four categories and relative values of responses of our ranking system are presented in Appendix A-1. Ranking was used to distinguish species with major effects from those with lesser effects, or highly invasive from moderately invasive species, to guide data collection efforts. Species profiles of priority plants may assist in risk assessments and allow for comparison between species by the working group and other resource managers.

Abundance and distribution data helps land managers to identify areas most vulnerable to invasion, prioritize sites and invasive plant species for control, and plan effective management strategies (Higgins et al. 2000, Thuiller et al. 2005, Roura-Pascual et al. 2010). Unfortunately, comprehensive landscape-scale maps of the distribution of priority invasive plants in the western U.S. do not currently exist, and much of the invasive plant infestation data collected by land managers at the local, state and federal levels is incomplete and highly variable in quality. This may be due to the cost, ability, and effort required collecting field data on invasive plant invasions over large areas. Moreover, because collecting such data is a low priority for most agencies and that timely data collection on both public and private lands is challenging, these data are generally not available. Incomplete or spatially biased coverage is common, and may be partly attributable to a lack of coordination among multiple organizations collecting data across a wide range of landownerships. This contributes greatly to isolated and incomplete datasets. Unverified records and inventories that are outdated may further complicate the ability of weed managers to properly assess range conditions. Spatially biased coverage can also cause problems for land managers if they become reliant on surveys and mapping areas with a high likelihood of invasive plants (i.e., roadways, trails, and other disturbed areas).

Two agencies are conducting spatially unbiased surveys of plant communities that will provide this information at least for the most prominent invasive species. These are the USDA Natural Resources Conservation Service, Rangeland National Resources Inventory (NRI) on non-federal lands (Herrick, et al. 2010 and NRCS-NRI 2014), and the Bureau of Land Management Assessment, Inventory, and Monitoring (AIM) (Toevs et al. 2011). While it is evident that invasions of priority invasive plants pose a significant risk to sagebrush habitats across the range of the GRSG, we are challenged to accurately define proactive measures to address the problem.

WHAT'S BEING DONE

Infrastructure, Organizations, and Performance of Invasive Plant Management Programs

Federal Management Agencies

As early as 1993, the Office of Technology Assessment (1993) described federal regulatory authority on invasive species as "piecemeal." In contrast to such modern environmental policies as the Clean Water Act and Clean Air Act, which comprehensively regulate interstate water and air pollution, no single federal law or combination of

policies provides clear authority or coordination among federal agencies to address invasive species (Corn and Johnson 2013), especially in the terrestrial context. The lack of a comprehensive policy has brought about fundamentally different regulatory approaches between land management agencies, limiting the effectiveness of a regional or national response to the problem. Gaps in jurisdictional authorities, limited regulatory and enforcement capabilities, and declining public support for increased federal spending also limit the federal government's ability to protect the environment, the economy, and human health against invasive species. This lack of adequate federal infrastructure and capacity severely hampers effective management of a landscape-scale invasive species threat, including and perhaps especially infestations of invasive plants that degrade or eliminate native sagebrush ecosystems across the western U.S. It is also important to recognize that management of invasive plant populations, particularly annual grasses, is a complex problem (Boyd and Svejcar 2009) across spatial and temporal scales that defy the development of simple or consistent solutions. One potential strategy would be to increase regulatory authority, but unless the effect was to empower local management entities to adaptively manage invasive plant populations, such a strategy could be counterproductive. A successful approach would acknowledge that the ability of managers to effectively address threats requires sufficient flexibility to adapt management programs to the variable environments that characterize sagebrush ecosystems across the range of GRSG (Boyd et al. 2014).

Annual grasses, such as this medusahead, can create heavy and continuous fine fuel loads that propagate frequent wildfires and result in the loss of sagebrush.

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Federal agencies duties and responsibilities for addressing invasive species are currently directed under Executive Order 13112 signed in 1999 by President Clinton. This Executive Order, when coupled with a wide range of other federal authorities, laws, regulations, and policies, requires federal agencies to establish, coordinate, and implement better invasive species management programs across the U.S. Individual federal agency policies on invasive species management also vary widely, particularly across land management agencies and agencies that oversee trade, commerce, transportation and energy issues. In addition to broadly defining duties of federal agencies, the Executive Order established a National Invasive Species Council (NISC) to coordinate the federal response, a non-federal Invasive Species Advisory Committee operating under the Federal Advisory Committee Act, and the development of a National Invasive Species Management Plan (initially released in 2001 and updated in 2008) to guide federal agency activities. The NISC is composed of 13 federal departments and agencies and is co-chaired by the Secretary of the Interior, the Secretary of Agriculture, and the Secretary of Commerce. The principal goal of NISC is to provide national leadership, oversight, and coordination of federal agency activities. The NISC has not met since 2008, and an update to the previous national management plan (which expired in 2012) has not been completed, reviewed, or approved. As a result, management plans have not driven federal agency priorities nor have they provided a mechanism for increasing federal funding for invasive species research or management as contemplated.

Consequently, federal invasive species research and management programs remain largely uncoordinated, and highly variable in structure, capacity, and functionality. Federal funding for the management activities necessary to implement policy and effectively counter the establishment and spread of invasive species is severely lacking in most areas of the country, particularly the west, causing many federal research and management programs to be curtailed or significantly reduced in both scale and scope. In some cases, the budgetary discretion given to agencies allows the diversion of dedicated invasive species funds for other uses, often creating additional pressures on invasive plant management program capacity.

Over 20 federal departments and agencies have responsibilities, authorities, and programs that deal with some facet of terrestrial invasive plant control (Table 3). Management on federal lands is conducted by a number of land management agencies under a variety of rules and regulations, including national and state invasive species plans, national guidelines, and administrative plans and standards. The U.S. Forest Service (USFS) and Bureau of Land Management (BLM) manage invasive species on large tracts of federal land in the western U.S., and work with private landowners, county governments, state agencies, and Tribal governments on invasive species prevention and control activities. These agencies also provide varying levels of financial and technical assistance to state governments through cooperative agreements to support state invasive species management programs. In fact, several state invasive plant management programs have relied heavily on federal funding and grants to maintain annual operations. In addition, the USFWS manages invasive species within the National Wildlife Refuge System, and helps manage the spread of invasive species through conservation partnerships and financial assistance to non-federal landowners. The National Park Service (NPS) takes a slightly different approach to managing invasive species on lands it administers, by using Exotic Plant Management Teams modeled on rapid response teams used to fight wildfires. These specialized teams are generally mobile and provide support to multiple NPS units within a given geographic area. The Department of Defense (DOD) and the U.S. Army Corps of Engineers (USACE) manage invasive species according to individual plans governing each installation or base or the national USACE Invasive Species Policy, as appropriate. The Bureau of Indian Affairs (BIA) provides some support to control invasive species on Indian trust lands. The Bureau of Reclamation's (BOR) control and prevention programs primarily focus on lands adjacent to reservoirs, canals, pipelines, rivers, and riparian areas associated with federally managed dams. The Natural Resources Conservation Service (NRCS) also provides technical and financial assistance to non-federal landowners (state, tribal, and private) for invasive species management.

These federal agencies and programs address invasive species, albeit under an uncoordinated and complex federal legal framework. To craft a more comprehensive federal response, several interagency committees attempt to coordinate diverse activities and programs across federal agencies with responsibilities that deal with some aspect of the invasive species issue. Although NISC has the power to direct federal agencies, it has not significantly advanced invasive species management or research activities under the Executive Order, nor has NISC provided support for necessary infrastructure, authorities, or increased program funding. Any growth in program capacity within the federal agencies has been largely achieved as a result of their own initiative.

The Federal Interagency Committee for Management of Noxious and Exotic Weeds (FICMNEW) was established in 1994 by a consortium of 17 federal agencies, to coordinate federal agency activities against invasive plants and noxious weeds, share information and encourage cooperation; but FICMNEW has no legal authority, jurisdiction, or funding mechanism for increasing on-the-ground actions against invasive plants or noxious weeds. To improve interagency communication, FICMNEW member agencies meet at least monthly to discuss invasive plant related issues. Other interagency coordination groups for various aquatic and terrestrial invasive species taxa have been established, but have similar structural, jurisdictional, and funding limitations.

Major federal authorities to manage noxious weeds exist and include the Plant Protection Act of 2000 (PPA; 7 U.S.C. §§ 7781-7786 et seq.), Federal Seed Act of 1940 (7 U.S.C. §§1551 et seq.), Federal Noxious Weed Act of 1974 (7 U.S.C. §2814), the Noxious Weed Control and Eradication Act of 2004 (7 U.S.C. §§7781-7786), and the National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. §§4321 et seq.). The term noxious weed is defined in PPA as "any plant or plant product that can directly or indirectly injure or cause damage to crops (including nursery stock or plant products), livestock, poultry, or other interests of agriculture, irrigation, navigation, and the natural resources of the United States, the public health, or the environment."

The Federal Seed Act mandates accurate labeling of noxious weed seeds moving in interstate and foreign commerce. The Federal Noxious Weed Act of 1974 authorized the United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS) to place plants on the Federal Noxious Weed List, prohibit the import and entry of noxious weeds, and restrict their introduction and spread through port-of-entry and follow-up activities. Similar state-level noxious weed lists and laws regulate additional plants in respective states. The Noxious Weed Act also authorized the USDA to prohibit the movement of federal noxious weeds and cooperate with other federal, state, and local agencies and others to control and prevent the spread of such weeds. The federal government has primary authority and responsibility for managing invasive species on federal lands, including the prevention and control of federal- and state-listed noxious weeds. Management activities conducted on federally administered lands are often coordinated with state and local government, and may be largely performed by contractors (including county weed programs, described below) under assistance agreements. The oversight for all invasive species planning, treatments, surveys/inventories, and monitoring is usually provided by the designated invasive species management program coordinators of each federal unit (where such positions have been established).

From a regulatory standpoint, only invasive plant species listed on federal or state "noxious weed" lists are required to be managed. Although environmental risks and consequences of cheatgrass invasion are substantial, this plant is not listed as a federal noxious weed and is largely unregulated by the states, making it a low priority for management and funding allocations. Cheatgrass is listed as a "Class C" noxious weed in Colorado, meaning counties can prioritize management and enforce control if locally desired. As an example, cheatgrass is considered so widespread in Colorado that stricter regulation (listing as "Class B" or "Class A") would be far too much of a financial burden for the counties and state government combined to address in a systematic manner. In Montana, cheatgrass is a "regulated" plant, meaning it is not formally listed noxious and cannot be intentionally spread or sold other than as a contaminant in agricultural products. Where counties and states do regulate cheatgrass, it tends to be limited to those areas where cheatgrass is not well-established. However, a "Class C" listing of cheatgrass in some states should not be construed as inadequate, when in fact its listing as a state noxious weed of any classification does mean that it is "unlawful to intentionally introduce, cultivate, sell, offer for sale, or knowingly allow to grow" any noxious weed. In some cases, cheatgrass is not listed on state noxious weed seed registers because some state 'Seed Acts' intertwine listing a species as restricted with potential impractical burdens which may inadvertently be placed on certified seed growers in those states. This is a complicated issue, but implementing reasonable state restrictions of cheatgrass contamination may have far-reaching impacts on certified seed growers in some states, particularly where the species is prevalent.

Cheatgrass

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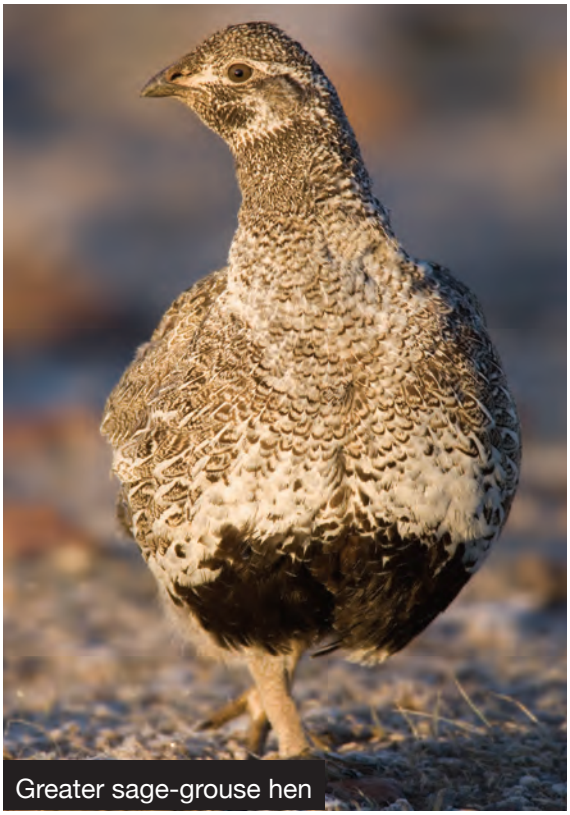
The Federal Noxious Weed Act (FNWA) of 1974 was superseded by the Plant Protection Act (PPA) of 2000, except for Section 2814 which was introduced in the 1990 Farm Bill to overcome policy implementation problems, mandating federal agencies to manage weeds in cooperation with state and local governments. The FNWA, as amended, requires each federal agency to (1) designate an office or person to develop and coordinate a weed program to control weeds on the agency's land, (2) establish and adequately fund the weed program through the agency's budget process, (3) implement cooperative agreements with the states regarding the control of weeds on agency land, and (4) establish systems to control weeds targeted under the cooperative agreements. Provisions of the 1990 amendment also require federal agencies, in the event of implementing weed control, to complete environmental documents required under NEPA within one year after the requirement for such documents have been established. The National Environmental Policy Act of 1970 requires federal agencies to consider the potential impact of their actions on the environment through an environmental assessment or environmental impact statement (environmental documents). For example, invasive plant control projects or programs, or actions that may spread or introduce invasive plants may be subject to NEPA.

The Plant Protection Act of 2000 is often cited as a key invasive plant control law. However, this statute was passed as part of the Agricultural Risk Protection Act and intended as an agricultural law to protect crops and consolidate major plant quarantine authorities, rather than as a tool to combat invasive species (Pidot 2005). More specifically, the PPA authorizes the Secretary of Agriculture to prohibit or restrict the importation, entry, exportation, or movement in foreign and interstate commerce of any plant, plant product, biological control organism, noxious weed, article, or means of conveyance, if the Secretary determines that prohibition is necessary to prevent the introduction or dissemination of a plant pest or noxious weed into or within the U.S. Despite the benefit of limited movement, the PPA lacks a provision providing for the management of noxious weeds that have already become established. The Noxious Weed Control and Eradication Act of 2004 amended the PPA, directing the USDA to establish a grant program for financial assistance to state and local agencies for control of established noxious weeds, but funds have yet to be allocated towards this purpose.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Greater sage-grouse hen

Overall, the current state of the law is fragmented and uncoordinated. Invasive species policy is a mixture of state and federal rules and regulations, found in many different places and allocating responsibilities to many different agencies. This hinders an effective federal response to the problem and our ability to ameliorate the threat of invasives across the range of the GRSG. Improving organizational capacity and regulatory mechanisms across the west may lead to better invasive plant management performance and increase the ability of land managers to address the problems associated with the spread of invasive plants (particularly invasive annual grasses). A corresponding emphasis on the need for scientific advancements in invasive plant prevention and control techniques, and new approaches for effective restoration of sagebrush ecosystems must also occur. Successful implementation of new management techniques, however, will require tackling socioeconomic challenges relating to policy, funding, and costs, as well as changing attitudes and human perceptions of invasions (Dombeck 2003, Pyšek and Richardson 2010, Simberloff et al. 2013).

State Management Agencies

The patchwork of federal laws regarding invasive plants (and noxious weeds) contributes to two different regulatory approaches (proactive and reactive approaches). Both approaches are based on the pathways concept, for instance, inspecting imported agricultural products, and the single-species approach of plants known to be highly invasive. These regulations focus on national borders rather than the domestic interior of the U.S. Much of the primary responsibility for invasive species management across the country is therefore delegated to state governments, often with the cooperation of federal agencies. All of the 11 western states within the range of GRSG have invasive plant/noxious weed laws that follow the general principles developed at the federal level.

In the western U.S invasive plants (including noxious weeds) are managed at the state level by the state agriculture departments. Invasive plant control activities can include a wide range of integrated pest management treatment techniques, including herbicide applications, mowing to prevent seed formation and dispersal, prescribed burning, biocontrol, and other measures that help to impede the establishment and spread of invasive plant populations. In general, invasive plant "control" activities at all levels (local, state, and federal) tend to be prioritized over "eradication" efforts, particularly for larger well-established populations, unless the project is part of an early detection and rapid response program for a targeted area or regulated/high risk invasive plant. State departments of agriculture enforce the Federal Noxious Weed Act and state noxious weed regulations, including maintaining noxious weed lists and implementing state weed laws. They have authority in most noxious weed management decisions affecting state and private lands. Most States in the range of GESR may have similar weed laws, but they all have different noxious weed lists. Many of the priority plants described in this report are regulated noxious weeds in the majority of project states (Table 4).

State weed laws typically discuss control steps, agency roles, provisions on the transport of listed weeds, and taxes as revenue to implement management. Most of the states in the project area, if not all, authorize the formation of weed control districts, weed control programs, and plans. Many western states allow counties to issue fines or penalties for noncompliance, or place liens on property when landowners fail to control weeds. Some western states authorize emergency orders and funding to control and eradicate weeds. Most states also authorize the use of quarantines. State law may also establish regulatory commissions, boards or councils, and require management plans, a statewide weed coordinator and county weed supervisors. State managers have noted that many state invasive plant management programs in the west are relatively well-structured (albeit limited in capacity), and managers stressed that funding additional program growth will be necessary to reach state-wide and region-wide goals and objectives necessary for GRSG conservation. Other state agencies involved in weed management and on-the-ground control of invasive species include state fish and game agencies, state parks, state natural resources offices, and state departments of transportation.

Some states have other mechanisms to help control weeds including invasive species or invasive plant councils. These interagency coun-

cils are intended to coordinate authorities and efforts from multiple sectors (public and private) and across agencies and levels (local and state). Most states in the project area use invasive species councils, which may be nonprofit associations, governmental entities, or authorized by statute, legislation, or executive order. The structure and operation of these councils varies and their operational effectiveness is not known, possibly due to inadequate funding, legal authorization, and permanent staffing (Porter et al. 2010).

State agencies involved in weed management and on-the-ground control of invasive species include fish and game, state parks and lands, and transportation agencies. State wildlife areas and state parks usually perform most of the weed control on their holdings using licensed staff. Weed control on state trust lands is commonly accomplished through lessees/permit holders with assistance from county weed programs. Transportation departments usually contract with county weed programs to manage weeds in the rights-of-way. Interstate and regional coordination of invasive plant management is complex and often difficult to accomplish due to the wide differences between state priorities, program capacities and jurisdictional authorities. However, several intergovernmental groups have been established to facilitate communication, collaboration, and coordination between state and county weed management programs (and Canadian provinces), including but not limited to the Western Weed Coordinating Committee, the North American Invasive Species Management Association (formerly known as the North American Weed Management Association), and the North American Exotic Pest Plant Council. Federal agencies participate in these organizations at the local, regional, and national levels when appropriate.

Local Weed Management Organizations

Local weed management programs conduct most of the on-the-ground weed control and public education throughout the range of the GRSG. These programs take a variety of forms, such as county weed programs, county weed districts, and cooperative weed management areas (Figure 2). County weed programs generally receive some county funding and have regulatory authority. These programs are bounded by county lines and tend to be found in states with a history of agriculture and institutionalized weed management (Hershdorfer et al. 2007). County weed districts employ taxation to fund weed control through state statute or voter-approved legislation. Weed districts are usually governed by volunteer weed control boards that administer the noxious weed control program according to state weed law. Weed boards also set county weed control priorities and adopt county noxious weed lists.

In most cases, county weed programs and districts are governed by a board of county commissioners. These weed boards have established legal and personnel infrastructure to support local weed control activities. County weed control programs usually elaborate on state authority and primarily function as local governmental entities to enforce noxious weed laws. The county board of commissioners usually provides the legal authority and oversight. County programs also play a role in supporting federal and state agencies in the local area. Many federal and state agencies contract weed management efforts out to local county weed management programs, whereby county employees will perform weed control on state and federal roads and other sites. This approach has been described as a very substantial and underlying flaw in western weed management. Counties often lack the staff and resources needed to coordinate activities across multi-jurisdictional lines in addition to performing their primary duties of weed control activities, educating the public, enforcing local or state weed laws. Some local weed management professionals point out that if federal and state land management agencies would hire their own staff or private contractors, the local weed management programs would have more time and resources to dedicate to these other needs. Contracts with state and federal agencies do not add to a county's capabilities – they distract from them. Feedback from several western counties have suggested that one of the ways to get ahead of the invasives curve would be to focus county programs on managing county-owned lands and assisting private landowners within county boundaries – not serving as contractors and chasing from one state park to another state wildlife area to a USFS ranger district to a BLM resource area, all because those state and federal agencies are not investing enough to effectively handle the invasive species problems on their ground with their own people.

Local governing entities in some states receive state and federal grant funding focused on high-priority regulated invasive plants (List A and List B noxious weeds), and some county programs depend on state and federal funding for their weed control infrastructure and personnel. Lacking these financial incentives to treat statewide priorities, it is likely that local programs would focus on locally prevalent species which may or may not be a high priority statewide, or provide added value to the conservation of sagebrush or GRSG. County programs also map and monitor weeds and use biological control techniques, such as exotic herbivorous insects and fungi. County programs frequently educate the public and sometimes provide cost-share programs for landowners. In some cases, private landowners conduct weed control with little communication between them and the county weed control office. Although locally enforceable weed regulations and ordinances exist, they may not be regularly enforced due to a lack of staff and funding or political will, or alternatively to encourage cooperation and compliance (Hershdorfer et al. 2007, Kokotovicha and Zeilinger 2011). In some states, county programs may help to coordinate weed management between agencies and neighboring landowners under certain situations. But in most states, management activities are often conducted through different federal and state agencies and by private landowners sometimes with no shared, central goals for management or measurable benchmarks to demonstrate progress. In response to this disconnect, authorities encourage the adoption of Cooperative Weed Management Areas (CWMAs). CWMAs, as well as county weed programs and districts, play a valuable role in weed management. For nearly two decades, federal agencies have provided cost-share funding for CWMA establishment and implementation through the National Fish and Wildlife Foundation's "Pulling Together Initiative", and through support from local federal and state agency offices. The Pulling Together Initiative has distributed over $21 million to CWMAs nationwide; a large portion of which has supported CWMAs in the West. CWMAs are cooperative partnerships between neighboring private and public land managers and others that develop and employ strategies to manage weeds collectively within a common area.

CWMAs are local, multi-jurisdictional organizations. These are often self-supporting entities, and usually bounded by natural rather than political boundaries. The forms and functions of CWMAs are similar to local cooperatives in that both involve a self-governing group

of individuals who voluntarily cooperate for their mutual benefit (Ostrom 1990). Because CWMAs and county programs employ a localized and largely stakeholder-driven approach to weeds, management may be successfully carried out within an adaptive framework, allowing groups flexibility to new information or changing conditions. Although the value of using such a cooperative approach across the landscape is well accepted, the sustainability and effectiveness of CWMAs is highly variable across the U.S. The success of a CWMA often depends on the strength of the partnership agreements, the individual capacities of the partners, the ability to maintain consistent funding from year to year, and the personalities of the people involved. Many CWMAs in the western U.S. have faltered or failed, usually because of a lack of funding and staff or volunteers leaving gaps in cooperative weed management coverage across relatively large geographic areas.

The operation and types of local programs vary dramatically in their composition and structure, coordination, communication, and cooperator involvement, which can also change from year to year. County weed supervisors are often directly involved in CWMAs, providing expertise and technical support to stakeholders. Steering committees may be appointed and written agreements to cooperate may be established. In some states, annual operating plans and integrated weed management plans are required for CWMAs to participate in legislatively-designated cost-share programs. For example Idaho has 44 county weed programs that are involved with one or more of the state's 33 formal CWMAs . To participate in the Idaho State Department of Agriculture (ISDA) cost-share program, a CWMA is required to have a steering committee, strategic plan, an annual operating plan, and written agreements to cooperate with all members of the CWMA, including agencies, tribal governments, private landowners, etc. The cost-share program is funded through state general fund and USFS cost- share dollars to assist agencies and promote public involvement in weed management. Not all CWMAs participate in the ISDA cost share program. In Montana and Wyoming, state government requires that each Board of County Commissioners establish a county weed district, employ a district supervisor or coordinator to carry out state weed law, and fund the program by tax levy, separate from the general, county, or city levies. In Nevada, the majority of control efforts and accomplishments can be attributed to the CWMA framework.

Trampling by horses and cattle disturbs biological soil crusts which facilitates the establishment and spread of invasive weeds into the system.

Cooperative Weed Management Areas, as well as county weed programs and districts, play an important role in weed management. Although the effectiveness of local programs is sometimes equivocal, their success is critical to long-term ecosystem management on habitats that vary dramatically in space and time within the range of GRSG. The different program attributes that contribute to invasive plant control efficacy include interagency coordination, enforcement, funding, and volunteer participation. In their study of local weed programs in the southwestern U.S., Hershdorfer et al. (2007) reported county weed management programs largely outperformed multiple-agency programs (e.g., CWMAs) in weed control. They attributed the success of county weed management programs to the presence of locally enforceable weed regulations, well-established program budgets primarily dedicated to weed control, and institutional histories that allow for longer time frames to establish weed control efforts. However, strong local regulations are only one element of a successful program to control invasive plant infestations.

The local, county, state, and federal program invasive plant management infrastructure described earlier in this report provides insight into the similarities and significant differences in how various operational levels are organized and function. Within and between each of these levels, there are wide variations in the way these programs address the key invasive species management program elements, specifically: prevention, early detection and rapid response, control, and restoration. This variation often reflects a range of variability in governance structures, policies, partnerships, available information, communication systems, and site-specific factors including environment, climate, and resources available for management. The situation on private lands is even more inconsistent and fragmented between landownerships and across the key program elements, especially at broader landscape scales.

CHALLENGES AND BARRIERS [1]

Every year, there are literally hundreds of thousands of invasive plant infestations that are treated across the West, targeting dozens of harmful exotic plant species in a wide variety of terrestrial, riparian, and aquatic ecosystems. Treatments tend to be relatively small (usually less than 450 acres each), with herbicide applications and biological control making up the majority of integrated pest management techniques used by land managers. As noted above, multi-landowner collaboration and partnerships, through the establishment of CWMAs, have helped to rally affected stakeholders against the threat of invasive plants across broader landscapes. In some areas, CWMAs provide a structure that allows for better prevention and control activi-

[1] The percentages and other information referenced in this section are based on the data analysis results from the invasive weed management program assessment conducted by the Center for Invasive Species Management in 2014, and information provided from county, state, and federal weed management programs during reviews.

ties across jurisdictional boundaries. Some CWMAs are highly effective. Additionally, new policy and regulations have helped encourage action against invasive species in some programs; and legislatively supported "weed-free" certification programs in some western states have addressed the demand for state-certified hay for livestock forage, and mulch for restoration needs. Improvements in weed science, weed inventory and treatment technology have also helped to advance programs by improving their effectiveness, offering land managers a broad array of tools and techniques to manage invasive plant populations. Advancements in restoration research have provided options to managers in some areas, yet techniques and approaches used in one location are not always viable in other locations or applicable across a broader landscape, and seasonal/climatic variations can significantly affect project effectiveness from year to year. Despite ongoing efforts to restore lands dominated by invasive plants into quality GRSG habitat, many restoration and rehabilitation techniques are considered mostly unproven and experimental (Pyke 2011).

Other complex challenges affect the ability to manage landscape-scale weed invasions across jurisdictional and regulatory lines. Coordination of prevention and control actions through CWMAs offers hope in some areas, yet the sustainability of CWMAs are inconsistent and undependable given many CWMAs are severely underfunded or lack participation by key stakeholders (NFWF Pulling Together Initiative Steering Committee, Pers. Comm.). In the West, most programs are government led or supported (either county government, state government, or federal government), whereas private and other non-government organization support in the West is limited or non-existent. Many private landowners struggle against invasive species on their lands, particularly when they have limited resources or expertise available to them. Across much of the West, invasive plant invasions exist within a patchwork of public and private landownerships, adding management complexity to the issue. Where landowners are unable, or unwilling to manage populations of invasive plants on their property because of associated management cost, the risk of establishment and spread can increase and hence threaten larger geographic areas. However, federal programs such as those administered through the NRCS and USFWS can be used to support private landowners by providing technical and financial assistance to help combat invasive plants and perform restoration efforts in some areas. In some states, funding and personnel for invasive species prevention and control are a severely limiting factor for all but the largest landowners. Thus, landowners often choose to prioritize other needs with their time and resources because the perceived invasive plant threat is not great enough or the economic cost of the current invasive plant is not perceived until a new invasive plant replaces it (e.g., Johnson et al. 2011).

The complexity of invasive plant management across the range of the GRSG was articulated through the responses provided during the assessment conducted by the Center for Invasive Species Management. Figure 3 provides the frequency at which managers reported select barriers to effective weed management in their unit by GRSG management zone (Stiver et al. 2006). Although there were many issues, challenges, and barriers identified from those responses and other feedback provided by local, state, and federal program managers, WAFWA has identified several key challenges and barriers which will significantly affect our ability to effectively manage non-native plant invasions and conserve native sagebrush ecosystems and the wildlife which depend on those native plant communities for survival.

INFORMATION MANAGEMENT AND SCIENCE CHALLENGES

Barrier: Lack of Emphasis on Surveys, Inventories, and Monitoring Activities

The lack of updated invasive plant inventory information, including spatial data on weed infestations, greatly impacts the ability for a unit to prioritize actions to prevent and control weed populations before they become established and spread. The assessment response data revealed that 60% of respondents indicated that less than 25% of their unit is surveyed (inventoried) for invasive plants each year; and about 23% of respondents indicated that less than 5% of their area was surveyed annually. Less than 5% of the units surveyed were responsible for more than 75% of the inventories in their area each year. Without an emphasis on the frequent collection of basic information about the extent, impact, and treatment of invasive species infestations, and monitoring for adaptive management, program efficiencies can easily plummet. More specifically, conducting systematic inventories and surveys for weeds, monitoring treatment effectiveness, collecting digital data using national standards and protocols, maintaining data in standardized databases, and sharing data with partners across jurisdictions are necessary elements for effective program operations. As all federal, state, and county programs are increasingly held to higher accountability standards, this basic information will be critical to ensure programs can maintain the strength necessary to effectively address the invasive species threat. The lack of emphasis on information management, surveys, inventories and monitoring has resulted in programs which are not designed for objective evaluation or adaptive management decision-making. Too often, information management and scientific design takes a back seat to the need to accelerate 'on-the-ground' treatment activities. Many invasive plant control programs are not designed with standardized sampling and inventory methods in mind or to collect data on treatment efficacy. Understanding treatment efficacy, and other strengths and weaknesses in a control program, are critical if progress is to be made from year to year. Records should be accurate, complete, and performance accountability systems should include meaningful targets which focus on long-term outcomes rather than short-term outputs.

Barrier: Failure to Re-establish Desired Perennial Vegetation

Maintenance of native perennial plant species is an effective and economical deterrent to plant community invasion by weeds (Davies et al. 2011, Chambers et al. 2014c). Thus, re-establishing native perennial vegetation following acute disturbance (e.g., fire) or chronic loss (e.g., mismanaged wildlife and livestock grazing) is of paramount importance to maintaining resistance of native plant communities to weed invasion. However, re-establishment of desired plant species in sagebrush-steppe communities frequently fails (Lysne and Pellant 2004, Epanchin-Neil et al. 2009, James et al. 2011, Knudson et al. 2014). Failure rates may approach 90% for native species in warmer and drier sagebrush ecosystems, but true failure rates are not well known due to underreporting of negative results in the literature (James and Svejcar 2010, Hardegree et al. 2011). A significant component of the problem is that most restoration practices are applied uniformly within a variable environment about which detailed knowledge of the ecological barriers to successful restoration is lacking. At low elevations, the ecology of many plant communities and landscapes has been dramatically altered by the loss of native perennial grasses and invasion of exotic annual grasses, and by associated increases in fire frequency. Overall, invasive species programs across the West are not geared for restoration and basic knowledge

gaps surrounding seedling ecology constrain the ability of managers to re-establish desired plant species.

Invasive weed management programs have found that suppressing or removing cheatgrass does not necessarily solve the restoration problem. Managers and researchers conducting experiments on cheatgrass control and seeding of native perennial grasses often find a host of other exotic species competing with their seedlings once cheatgrass is suppressed (Young and Clements 2007). This interaction of native and exotic plants, and the associated soil conditions, complicates native plant restoration efforts and lowers success rates. Research in the early 1930s found that cheatgrass was part of a succession of exotic annual invasive species that have become naturalized in degraded big sagebrush rangelands (Piemeisel 1951). In those years, there were fewer than 10 exotic plants considered high risk to rangeland managers, including both annual grasses and perennial forbs. Now the list of exotics that occur in "cheatgrass" communities includes more than 40 exotic, invasive species, including biennial and perennial species (Young and Clements 2007). Until restoration practitioners have ecologically sound strategies and tools that can be used to more reliably re-establish and maintain desired perennial plant species in variable environments, the expanding annual grass problem will continue in relatively warm and dry sagebrush ecosystems, regardless of other changes in programmatic structure, funding, implementation, outreach, or monitoring.

Barrier: Inadequate Collection, Retrieval, and Sharing of Invasive Plant Data

Inventory, monitoring, and assessment programs provide data on ecosystem stressors and the effects of management activities to implement project planning and adaptive management and increase understanding of how ecosystems operate, including knowledge on resilience and resistance. Invasive plant surveys, inventories, and mapping, regularly updated over time, are important for risk assessments at different spatial scales to target management based on the distribution of infestations in relation to priority sites. Monitoring treatment efficacy is critical for determining future management actions using adaptive management principles.

Cheatgrass among sagebrush

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Although weed managers reported they were satisfied with the overall performance of weed programs on many elements and procedures of digital spatial data gathering, storing, and sharing, there continues to be inconsistencies and a lack of coordination when it comes to information management at the county, state, and federal levels. More than half (59.3%) of local federal and county managers were not satisfied with weed program performance on storing and retrieving spatial and treatment data in a centralized database, rating the practice as well below average. The reason for this perceived underperformance may be that weed managers maintain their data in isolated datasets or proprietary databases and then share these data with their partners rather than storing and sharing data in a spatially explicit manner in a centralized clearinghouse or web-based database system, which may perhaps be accessible by the public.

Several web-based data management systems are available to store and retrieve distribution data in the western U.S. including, EDDMapS West (Early Detection and Distribution Mapping System West; http://www.eddmaps.org/west/), a web-based mapping system for invasive plant presence points; CalWeedMapper, an online decision-support tool and quad-level database of invasive plant distribution in California (http://calweedmapper.cal-ipc.org/); Oregon WeedMapper, an online database for storing and retrieving distribution data; and iMapInvasives (http://www.imapinvasives.org/), an on-line GIS based data management system for natural resource managers in Oregon. Unfortunately, private, county, state, tribal, or federal stakeholders for a variety of reasons do not use these consistently.

Feedback from invasive plant management programs across the 11 western state project area indicated that there continues to be a considerable amount of disconnect between invasive plant management researchers and invasive plant management practitioners, particularly as new techniques and tools are developed or proposed. There is a need to increase the interactions between these groups early in the process and encourage more information sharing. Managers often are not asking the right questions of researchers, and conversely, researchers often don't understand the problems or issues managers face and may develop tools which can't solve the managers' problems. By increasing collaboration early in the process, managers can be better informed about the options and potential solutions to their problems, and research can be guided by better informed management questions. This two-way communication process applies to any management issue, including but not limited to prevention, detection, control, monitoring, and restoration activities.

Barrier: Lack of certainty for actions under a changing climate

Greater certainty needs to be provided regarding the major drivers and likely effect of climate change on invasive plant management. The complexity and interpretation of climate forecasts and scenarios at the field unit level are often so daunting, and uncertainties so poorly understood at the field level, that climate adaption aspects of invasive plant management are left unaddressed. Additionally, few of the currently available invasive species management decision support tools have incorporated climate change. Public and private resource managers need to know that the actions they take today will be strategic, cost-effective, and result in positive outcomes many years into the future given a changing climate.

LEADERSHIP, COORDINATION, AND COMMUNICATION CHALLENGES

Barrier: Governmental Coordination and Emphasis for Invasive Species Management is Insufficient at Nearly All Levels (local, state, federal).

While various congressional committees and subcommittees and several states have called for a more aggressive approach to invasive species prevention and control by federal government agencies, the response has been weak. Although the 1999 Presidential Executive Order 13112 directs federal agencies to address invasive species

Greater sage-grouse in sagebrush habitat

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threats, the energy (political and otherwise) surrounding this Presidential mandate has waned significantly since it was signed over 15 years ago. Federal government leadership and support capacity for invasive species management has declined in many programs, and there continues to be a lack of departmental and agency coordination on budgets and policies. Consistent implementation of the provisions in Executive Order 13112 has been highly variable across the member departments and agencies within the NISC, which has been unable to provide the necessary cross-departmental oversight to allow for coordinated federal implementation and conflict resolution. Federal requirements and provisions within Executive Order 13112 are not being enforced nor met consistently across government agencies. Few federal and state agencies have comprehensive (all taxa) policies to direct their activities against invasive species. Additionally, where sound policies and directives exist, without adequate knowledge and resources for effective on-the-ground implementation, those policies become meaningless. The lack of a continental, national or regional framework to address invasives consistently across political boundaries hampers the ability to be effective against the invasive threats at broad landscape scales.

A national strategy for invasive species management does not exist for the U.S., yet both Canada (Government of Canada 2004) and Mexico (Mexico 2010) have national strategies upon which to set priorities, improve coordination, and build consistent programs for on-the-ground results. Similarly, no regional invasive plant management strategy has been built to address issues such as sagebrush restoration or GRSG habitat protection through invasive weed control. Theoretically, given the NISC co-chair roles held by the Departments of Interior, Agriculture, and Commerce, and given that the imperilment of GRSG in the western part of the range (USFWS 2010), has been driven by habitat loss due to invasive plant infestations, NISC is uniquely suited for, and could have directed the development of, such a regional strategy against invasive plants to restore GRSG habitat. However, NISC Departmental Principal Representatives have not met since 2008.

While NISC has been described by Congress as largely ineffective and lacking purpose (House Committee on Natural Resources, Subcommittee on Public Lands and Environmental Regulation 2014), it is an underutilized resource whose lack of direction is tied directly to the lack of engagement by the lead federal Departments.

In the absence of such Department-led coordination, important regional efforts have emerged. The WAFWA's efforts, including the associated Fire and Invasive Species Assessment Team activities (FIAT) and the resilience and resistance strategic approach (Chambers, et. al 2014a), offer another example of coordinated efforts to develop a regional invasive plant management strategy linked to sagebrush restoration and GRSG conservation. Such efforts could be more effective if they are linked through a fully-functioning, multi-Department coordinating entity, such as NISC.

Due to changes in capacity and funding, and lack of department-level leadership, the structure and function of the staff of the NISC has deteriorated since signing of Executive Order 13112 in 1999. This has forced NISC staff to formulate priorities based on needs they or their partners identify in attempts to continue to make a difference in invasive species management. This has resulted in quite a bit of information sharing, communications, and coordination at the staff level between some state and federal agencies and other stakeholders. However, without guidance from above, many of the efforts and activities of NISC staff may be outwardly perceived as lower-level/lower-priority projects, best suited to be addressed by agencies or interagency committees, states, or the non-government sector. Critical and high-level invasive species issues associated with federal government policy, interdepartmental collaboration, federal budgets, regulations, jurisdictional problems, or federal agency operational coordination, could be, but are not being well addressed. For example, senior officials in the various NISC member departments are most often absent from the regional, national and international dialog on invasive species research and management issues.

At the federal agency level, leadership and emphasis on invasive species management has also been inconsistent and highly tenuous for most programs. National and regional programs attempt to support field level operations with significantly limited resources using integrated approaches. National and regional programs in most agencies are largely understaffed and underfunded. Multiple priorities exist, making it difficult to focus resources to address new threats. As noted earlier, federal agencies tend to be uncoordinated and in some cases working against each other. Although there are examples of information-sharing, collaboration and cooperation, most federal agencies are trying to maintain their programs and address problems within their own jurisdictions irrespective of the activities in other agencies. This parochial condition is not unique to the invasive species issue, and spans a wide spectrum of organizations, topics, and programs.

Additionally, ISAC, the FACA-chartered advisor to the NISC, is another potentially excellent resource that has been underutilized since the passage of Executive Order 13112. While current ISAC activities have provided some value to federal government partners, their activities have not been guided by the three Department-level co-chairs of NISC. Thus, some ISAC's efforts and recommendations under FACA may be perceived as duplicative, underutilized, or low value to the federal agencies. In general, the three co-chair Departments of the NISC provide poor oversight and administration, of the activities, membership, and expertise of ISAC.

Recent proposed legislation by Congress (House Committee on Natural Resources, Subcommittee on Public Lands and Environmental Regulation 2014) to provide support to federal agencies for increasing on-the-ground management and prioritize invasive species prevention and control on federal lands, including providing National Environmental Policy Act (NEPA) categorical exclusion authorities, was met with some opposition, for various reasons, despite the broad support early on from the states, particularly in the west, and groups such as the Western Weed Coordinators Committee, Western Governors Association, North American Invasive Species Management Association, State Agriculture Directors, and other invasive species management groups. Federal and state legislation to increase on-the-ground action against invasive species across the broader landscape could help accelerate efforts to address invasive plant invasions threatening the survival of the GRSG across the 11 western states.

Conversations with state and county invasive species management programs indicate that state legislature and gubernatorial support has been highly variable over the years, and many states and counties continue to struggle to obtain the resources necessary to establish and/or maintain their programs. The lack of coordination and communication between state and local groups continues to plague local efforts to address invasive species problems at the community level. The frequent lack of coordination and communication between state fish and game agencies and state departments of agriculture, transportation, and other government organizations has contributed to lower program efficiencies and groups working at cross-purposes with each other in many cases.

The potential listing of the GRSG is an excellent example of this lack of coordination across landscapes and between government agencies. For instance, upon receipt of a petition for an initial status review for a native wildlife species, where invasive species are identified as a primary threat, the USFWS Directorate could have elevated this to the Interior principal co-chair of the NISC. The Interior co-chair, in turn, could initiate a meeting to discuss opportunities and strategies for collaboration with the other two Departmental co-chairs of NISC. Further, in collaboration with other partners, such as the Association of Fish and Wildlife Agencies or regional associations, a strategy to ameliorate the threat invasive plants pose to the petitioned species could have been be developed with actions subsequently initiated.

Although state and federal fish and game agencies, fire management agencies, researchers, and many non-government environmental groups are coordinating and communicating with each other on issues related to the loss of sagebrush and GRSG habitat, many key invasive species management players are absent from these discussions. Invasive plants have been clearly documented as the greatest threat to GRSG habitat within the western portion of the species' range, yet planning and management decisions related to invasive plant invasions are being made with little input from the invasive plant management programs at the county, state and federal levels. The invasive weed management community has not been included and is not serving in a leadership role on the issue, yet they are responsibility for invasive plant management within the range of GRSG. On January 10, 2015 the Western Weed Coordinators Alliance, representing 15 state invasive weed management agencies across the West, sent a letter to the Chairman of the Greater Sage-Grouse Executive Oversight Committee and the President of the Western Association of Fish and Wildlife Agencies calling for closer coordination and collaboration between the invasive plant management and the wildlife management communities on invasive plant issues affecting GRSG conservation. Strong, federal Department-level coordination, as well as coordination at the state level, could improve integration among these communities with shared goals. It is time for all levels of government to make a mutual and coordinated push to reduce the problem of invasive species across the landscape.

Barrier: Very Limited Coordination and Collaboration With Non-Traditional Stakeholders

Effective weed management often relies on coordination and cooperation between stakeholders to expand control and share resources. In the assessment, the majority of local, federal and county weed managers reported that the process of coordinating and engaging with non-traditional public and private stakeholders is below average, which means poorer than average performance in comparison to the scale mean score. Exactly what constitutes non-traditional stakeholders is not explicit and may only be determined in local contexts. Generally these stakeholders are outside of such traditional stakeholders as county weed managers and local weed or resource managers of federal lands and state holdings, as well as private landowners particularly ranchers in rural communities. From a GRSG conservation perspective, members of the wildfire community may be considered non-traditional stakeholders, in addition to local GRSG working groups. For example, more than two-thirds of local federal and county weed managers reported they are not active in GRSG conservation working groups or collaboratives. The vast array of public and private groups and affected stakeholders across the landscape offer managers many opportunities to develop relationships and partnerships to manage invasive species threats. Program managers frequently articulate the connection between invasive species, local economies, human health, and the environment, yet fall short of reaching out to

non-traditional partners for solutions. Local planning commissions, homeowners associations, local businesses, hunting and fishing clubs, economic development offices, religious and service organizations, recreation groups, water management districts, non-profit groups, and dozens of other organizations are potential partners in weed prevention and control, and can bring ideas and support to invasive plant management programs in many unique ways.

Cheatgrass

© USDA PLANTS DATABASE

Barrier: Lack of Effective Communication and Engagement With the Public

Similar to the barrier related to partnerships with non-traditional stakeholders, there is a need to improve communication with communities and use engagement to generate attitudes and behaviors so society can contribute to risk management and conservation practice. In terms of public awareness, more than half (61.9%) of the managers in our assessment reported that the delivery of weed awareness and prevention education to the public and visitors is below average performance. Over two-thirds (66.9%) of the managers reported that the engagement of the public in reporting weed sightings and serving as citizen scientists to conduct weed monitoring is also below average. Citizen science is a multi-disciplinary field involving volunteers that participate in environmental monitoring with the added educational benefit of awareness and local ownership toward the ecosystem and environmental concerns. In some cases, this barrier related to effective communication with the public may be the result of limited resources or experience in outreach, or a lack of interest or time and effort to manage volunteers or conduct outreach. However, feedback from invasive plant program managers across the West indicated that some program staff (at all levels) are simply not familiar with the demands of education and outreach, or communication. It was also noted that program managers often have difficulty communicating even within their own ranks, at all levels. With regard to GRSG conservation, much stronger and more frequent communication with all landowners and affected stakeholders will be required. In some places, these skills will need to be learned and in other places additional staff may be required to carry out these duties.

Barrier: Low Level of Public Awareness and Support for Increased Invasive Species Management

A nationally consistent public awareness or education campaign for the prevention and control of invasive species does not currently exist. Current awareness and education campaigns on invasive species are scattered at all levels, often duplicative, and have not been shown effective in influencing public behavior at large scales. Unlike other national issues such as disease awareness and safety, littering and pollution, water conservation, energy conservation, and seatbelt usage, the invasive species threat has for the most part not reached the hearts and minds of the public. Without public support, there is little political, legal, or financial support to gain resources necessary to effectively address the invasive species threats. Under the current economic conditions at the county, state, and federal levels, program managers struggle to maintain basic program functions without new investments to fill operational gaps.

POLICY AND REGULATORY CHALLENGES

Barrier: Lack of Effective Legal and Regulatory Framework for Invasive Species Management

The current legislative and regulatory framework on invasive species is fragmented, broad, and unfocused. Laws and regulations address a range of issues between multiple levels of government yet no explicit communication or coordination of action exists, particularly with respect to jurisdictional and interstate concerns. Many state and federal laws, and regulations are ineffective in protecting ecosystems against invasion and enforcing invasive species laws. Additionally, county-level capacity is not always able to meet statewide regulatory expectations for weed prevention and control. Program managers across the range of the GRSG have pointed out the need for a coordinated effort across landscapes, jurisdictions, and landowerships to improve effectiveness. At a regional scale, state laws and programs often vary between states, and may cause operational gaps across jurisdictions. Similarly management strategies, priorities, and plans are fragmented and inconsistent at all levels and across jurisdictions. This brings about fundamentally different regulatory and management approaches and encourages highly variable funding priorities between agencies and organizations, limiting an effective landscape-scale response. In an attempt to adopt a uniform approach to invasive plant management, more than half (60.7%) of BLM and USFS managers reported they rely on multi-jurisdictional Cooperative Weed Management Areas or county weed management programs for weed control, and for coordinating management and consolidating resources and workloads. Although improving the legal and regulatory framework to manage invasive plants across the West is important, feedback from some program managers at the county and state levels indicated that improving coordination and cooperation at the local (on-the-ground) level is even more vital.

A key purpose of a CWMA is to provide coordination and improve long-term management efficiency between landowners in a defined geographic area against invasive plants. Success, however, relies on consistent (even relatively small) contributions from all project partners to buffer the CWMA against different funding limitations that exist across partners. Federal managers reported CWMA gains on weed control have been lost recently due to funding declines that do not allow for follow-up treatment and monitoring in subsequent years, wasting past resources and impeding management benefit into the future. Other federal managers explained funding is sporadic and participation in CWMAs has been postponed because of uncertain funding scenarios. Managers also reported not receiving any funding in recent years for weed control, realizing the worst case where funding has been cut to the point at which management has been suspended. Partially or unfunded efforts result in population increases, costly invasive plant problems, unchecked dispersal, and contamination of neighboring lands. Progressive losses of resilience and resistance can result in the cross of abiotic and/or biotic thresholds (Beisner et al. 2003) and may lead to a catastrophic shift in community structure (Reisner et al. 2013).

There is a direct correlation between inadequate regulatory capacity and enforcement, low funding for effective management, and the ultimate degradation of ecosystems at very large scales from invasive species infestations. In other cases, federal agencies can be working at cross-purposes to each other and often take actions that are in direct conflict with the Executive Order 13112 on invasive species or agency policies. Federal deregulation of risk high-risk invasive species, including genetically modified exotic plants, is also becoming more common as aggressive exotics plant species are being targeted as commodities for production as biofuel energy alternatives. Therefore it is essential to improve legal and regulatory frameworks at all levels.

Barrier: Insufficient Evaluation, Compliance Monitoring, and Enforcement

Federal and state rules, procedures, and contract and permit clauses, as well as best management practices, are intended to ensure invasive weed prevention and control measures are being implemented during activities conducted by contractors, permittees, agency personnel, and public land users. Ensuring such requirements are in place, and effectively enforced, has been a challenge at both the federal and state levels. In our assessment, responses from invasive plant program managers indicated that although prevention and control requirements are often included in permits, contracts and agreements, their organizations usually fail to enforce these rules and best management practices to achieve the desired resource management objectives. Permittee and contractor compliance with weed prevention and control requirements on state lands, and requirements on the decontamination of state and local firefighting equipment are not always clear. Invasive plant program managers also indicated that ill-designed and insufficiently enforced laws and requirements often fail, leading to major control costs and reducing the reliability of the system by sending mixed messages to personnel and the public on importance and expectations (CISM 2014).

In some states, county ordinances require public and private landowners to manage invasive plants (particularly regulated species) on their property or suffer penalties for noncompliance. Compliance monitoring and enforcement are useful tools to control the spread of invasive plants, playing an important role in education, prevention, and management. In the recent assessment, nearly two-thirds (64%) of local federal and county managers reported that enforcement of weed regulations, compliance monitoring, and the regular identification of deficiencies in invasive plant management and their subsequent improvement in invasive plant management programs was below average performance.

The perceived underperformance of enforcement and compliance monitoring by managers was largely explained by insufficient funding and shortfalls in staff that help conduct compliance monitoring and enforce noxious weed rules and ordinances. Federal managers reported internal compliance with weed management policies and standards, including provisions under approved NEPA documents for federal land management activities, vary significantly within their respective field units. In fact the NEPA documents supporting invasive species prevention and control work on federally administered lands are highly variable, and in some cases non-existent. These variations may reflect many different influences, including:

- uncertainty by managers on best management practices,
- vague rules that involve interpretation of local standards,
- lack of strong program policy or too many flexible practices under policy,
- lack of administrative oversight and leadership

OPERATIONAL CAPACITY AND PROGRAM MANAGEMENT CHALLENGES

Barrier: Highly Variable Management Prioritization of High Risk Invasive Plants; Programs Do Not Emphasize Sagebrush Restoration When Targeting Invasive Plants Across the Range of the GRSG

Nearly 93% of invasive plant managers said their administrative unit carried out specific programs to manage high risk invasive plants, which is not surprising given the assessment demographics and the targeted geographic area. The most frequently reported invasive plants targeted in these programs were the knapweeds, *Centaurea* spp., (45.5%), thistles, *Cirsium* spp., (35.1%), and cheatgrass (34.4%). Forty-five percent of managers reported that their unit has a specific plan or strategy to protect or restore sagebrush habitats. Of the respondents that did not have a specific plan for sagebrush, over half (58.7%) said a broader sagebrush management plan is present that their unit could help implement. When participants were asked if their unit is an active participant in a local or regional sage-grouse conservation working group or collaborative, 40% said yes. In 32 of 289 cases (11.0%), respondents said invasive plant infestations are generally decreasing on their unit, approximately 34% said invasive plant infestations are stable, and 55.0% said invasive plant infestations are increasing.

In some cases, priority vegetation control activities in sagebrush communities target native plants rather than higher risk exotic species, such as invasive annual grasses. This is particularly the case in the fuels reduction projects where piñon pine *(Pinus monophylla)* and juniper *(Juniperus osteosperma* and *J. occidentalis)* tree species are targeted. Although invasive grasses do not have the same fuel loading risk as these heavier woody species, invasive annual grasses (such as cheatgrass) and other invasive plants pose a much greater threat to sagebrush and GRSG habitat across the West. Piñon and juniper trees occur in sagebrush ecosystems throughout most of the range of the GRSG, yet have not reached landscape population levels of the more aggressive and widespread invasive plants. Feedback from state and federal program managers indicated that despite the greater threat from invasive plants, wildfire management funding for fuels reduction (targeting native woody species) vastly surpassed funding provided by the fire programs for the prevention and control of highly flammable lighter fuels such as cheatgrass. Collectively and based on the scale and site conditions of the managers' administrative unit in our assessment, the relative risk and estimated abundances of 17 moderately and highly invasive weed species (Table 2) within the GRSG range are shown in Figures 4-11. Based on the assessment responses, the five highest ranked plants for risk to ecosystem health and GRSG habitats in the 11 western state region were cheatgrass, spotted knapweed, whitetop, leafy spurge, and Russian knapweed. Additionally, the five most abundant plants were cheatgrass, Canada thistle, whitetop, spotted knapweed, Russian knapweed, and musk thistle. Other species were likely to occur rarely or have small infestations across the 11-state region.

The overall accuracy of these estimates is unknown and will vary in each location across the 11 states. We can observe, however, that the relative risk and abundance measures are largely consistent with the multi-category state noxious weed lists in the western U.S., especially at the GRSG management zone scale. These tiered lists group noxious weeds and guide management according to invasion stage. The reliability of these estimates is also demonstrated by the overall level of experience, of respondents. Approximately 70% of the respondents were managers who reported 10 or more years of experience managing invasive plants in the western U.S. Due to their management experience and likely widespread concern about weed invasion in the region, these managers are familiar with rare or new invading species and the presence and abundance of invasive plants across habitats in their management units. Table 5 presents the five highest ranked plants for risk to sagebrush habitats and the mean ranks of estimated abundance and general distribution of these species by GRSG management zone. The relative risk and estimated abundances of the species across the GRSG management zones are shown in Figures 4-11.

In many western states, particularly the Rocky Mountain States within the range of the GRSG, there has been a long-time bias toward addressing invasive forbs instead of grasses. However, the spread of invasive annual grasses into the Rocky Mountain States, particularly GRSG management zones I, and II, is a significant cause for concern. In their responses, many program managers have noted that to address the expanding invasive annual grass threat effectively, and in a resource efficient manner, some states in the region and the broader invasive plant management community will need to consider shifting their management paradigm to addressing invasive annual grasses instead of the traditional invasive perennial forbs. Feedback from state program managers indicated that when setting priorities programs may not emphasize high risk species with GRSG conservation in mind. For example, where invasive annual grasses, such as cheatgrass, are not included on state regulatory lists, and where some state laws allow for county weed lists, it may be advantageous for counties to add those species to county weed lists and target prevention and control efforts to support priority habitat areas for GRSG conservation.

Barrier: Lack of Internal Structure and Capacity for Weed Management Programs At All Levels

There is a wide variation in management capacity across all local, state, and federal programs. It ranges from programs with little/no capacity/funding/personnel (more common), to a few relatively-strong programs which have better financial capacity and staffing. This lack of capacity affects the ability to maintain adequate pressures on invasive plant infestations across multiple landownerships or across a broader region. Many programs lack the necessary internal structure and capacity for effective invasive plant management on their unit, often relying on a third party for support; too often losing continuity and accountability in the process. Nearly 38% of the weed managers in the 11 states in GRSG range reported that external contractors or cooperators were accomplishing over half of the invasive plant management work on local, state, and federal units, and about 22% of the weed managers in the region said their unit accomplished more than 75% of their annual invasive plant management work through formal agreements (contracts) with an outside party. Some private landowners in the West, particularly the growing number of absentee landowners and seasonally occupied properties, have little capacity

Male Greater sage-grouse

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(funding, personnel, expertise, etc.) to deal with the invasive species problem alone. Although there are many private landowners aggressively managing invasive plants on their property, and capitalizing on the financial and technical support available from government programs, there continues to be an increase in the number of weed infestations establishing and spreading across private lands (Figure 12), (Herrick et al. 2010). Increasing development of road networks, and other infrastructure, to meet the needs of communities and population growth across the western landscape exacerbates the risk of invasive plant establishment and spread; yet invasive plant prevention and control programs have not kept up with this growth. In some cases, infestations from public lands invade neighboring private lands, often along major pathways, such as streams, roads, trails, electric energy transmission infrastructure, petroleum development and distribution infrastructure, and other invasion routes. Unfortunately, the reverse is also true. These common opportunities for weed spread, and other factors, cause problems for maintaining management pressure on invasive species populations across the landscape and across jurisdictional boundaries. This fragmented capacity creates different approaches between neighboring areas, which allows for increased establishment and spread. In some locales private landowners have few state or local protection mechanisms available to ensure invasive species are not established or spread to their lands during the development or maintenance of energy and transportation corridors, particularly when those activities pass through the private property. To address a portion of this risk of spreading invasive plants via these corridors, state and federal agencies are currently working closely with electric energy industry representatives and private power line rights-of-way maintenance organizations to ensure all operations and maintenance activities conducted on authorized rights-of-way address the prevention and control of invasive species during routine and emergency maintenance and operations activities within these easements (Interagency Memorandum of Understanding – Cooperative Vegetation Management on Electric Energy Rights-of-Way - Revised Draft. 2015).

Based on program manager responses, the most frequent issues that inhibited invasive weed management programs at the unit scale included insufficient staff time and resources (76.7%), lack of adequate or consistent funding (68.8%), and a lack of perceived importance to the public or demand to take action (29.9%). Most program managers responding to the assessment indicated they do not receive the funding or resources they need for effective weed management; 85.6% (225 of 298 cases) reported that a lack of adequate or consistent funding along with shortfalls in staffing constitutes the major deficiency in the effectiveness of weed programs. County weed programs are usually managed by a part- or full-time supervisor. In the West, county-level weed management programs generally receive funding for weed control from local dedicated taxes or levies and contracts with federal and state agencies. The strong message from program managers about the lack of funding does not necessarily mean that increased funding for programs will immediately overcome the ineffectiveness of weed management efforts in GRSG habitat. A comprehensive re-design of programs in some locales may be necessary. The existing system of weed management has proven ineffective at combating the most serious invasive species threats to GRSG habitat (i.e., invasive annual grasses); to the point that simply increasing funding in the absence of a strategic overhaul of program designs may actually increase the cost of failure.

In addition to funding limitations, the lack of full-time personnel focusing on invasive species greatly limits program effectiveness at all levels. Most federal invasive plant management programs in the 11 western states are being assigned to positions where the invasive plant management program is a collateral duty or the occupant serves in multi-purpose roles. This lack of focus and emphasis on invasive plant management weakens a program's ability to effectively address complicated and multi-scale invasive plant threats across the landscape. Most BLM and USFS weed programs are managed by resource program personnel as an ancillary or collateral duty rather than under a full-time position. Assessment responses indicated that well over half (61.6%) of BLM and USFS managers work in more than one resource area, and of these, over 67% of managers reported they work in either two or three resource areas. In these cases, management of the invasive plant program frequently becomes an ancillary duty of the botanist, biologist, or the rangeland or other resource specialist; often without significant expertise or training in invasion ecology, invasive species management, or restoration.

Funding structures for agency weed programs are frequently incidental to other programs in that weed control is based on project-specific responsibilities and tied to targets of benefitting resource programs such as fuels reduction, forestry, rangeland management, wildlife management, recreation, etc. In other words rather than being intentional in focus with a budget line at the national level, regional, and state levels, many invasive plant management programs cut across administrative and programmatic line-item boundaries. This budget structure promotes short-term management of invasive plants on a project-by-project basis rather than across entire ecosystems over time using a cost-effective and successful long-term outcome approach. Without dedicated and consistent funding, managers have difficulty with long-term strategic planning for program operations more than one year at a time.

Barrier: Lack of Federal Funding At the Field Level, Which Transfers Risk to State and Local Governments

Continued declines in federal funding for agency weed programs result in partial and fragmented efforts at the ground level, impeding adequate control and allowing for population increases and dispersal to un-infested sites. In the recent assessment nearly three-quarters (72.2%) of BLM and USFS managers perceived weeds are increasing on their units. Local state and county weed program managers reported federal lands remain a significant challenge. In these cases, severe infestations occur with unchecked invasion that continues to neighboring properties and over longer-distances. Many counties have a high percentage of federal lands and therefore must rely on the federal agencies to manage invasives. Partial or unfunded weed control resulting from federal agency budget cuts may have the effect of transferring risk and responsibility to the local level. For instance, attractive federal budget cuts for taxpayers often land at the field level, resulting in weed problems and the invasion of neighboring lands at the long-term expense of communities, county government, and local environmental quality. Federal responsibility and accountability is intended to fulfill agency commitments and offset and account for such consequences. Increasing spending cuts at the field-level by federal agencies illustrates the precise act of reducing responsibility and authority for managing invasive plants on federal lands. These cuts also translate into a shifting of the burden from the federal sector to the local and state sectors, and forces non-federal entities and neighboring landowners to carry responsibility for future consequences and impacts (External Review Communications, 2014).

Invasive annual grasses fuel the wildfire threat and cause degradation of sagebrush communities.

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Barrier: Inconsistent and Fragmented Prevention Operations

Invasive species prevention has not become a social norm in the 11 western states (nor anywhere else in the U.S. and Canada). There are literally dozens of human-caused invasion pathways and vectors for invasive species and no nationally consistent public awareness or education campaign for the prevention of invasive species akin to fire prevention. Invasive plant invasions are often tied to human activities that move or open dispersal pathways for movement, or modify ecosystems and site conditions that allow expansion, or both. Pre-

vention, therefore, targets pathways and vectors for establishment and spread (e.g., construction and other ground-disturbing activities, road maintenance, energy development and distribution projects, vehicles and equipment, recreation and other public use activities, livestock grazing programs, mining operations, timber harvest, and many other pathways and vectors).

Weed prevention requirements, however, continue to be fragmented and inconsistent across the landscape, especially associated with large-scale projects that promote the establishment and spread of invasive species across multiple landownerships. For example, transportation and energy corridors, and the associated impacts during construction and annual maintenance, are major pathways and vectors of weed spread across the U.S. Disturbances along roads, trails, power-lines, railroads, and gas and oil pipeline corridors allow invasive plants to more easily establish and spread into new areas across the landscape. Without a strong and consistent weed prevention and control aspect to these landscape-scale activities, local, state, and national weed management programs are unable to meet the demand alone. Without regulatory requirements and effective enforcement, the organizations operating these facilities and corridors tend to avoid their role for preventing invasive species and usually do not participate as part of a community-based approach or CWMA.

Although program managers reported weed control activities were being conducted on high-risk sites associated with public use facilities, transportation corridors, and construction sites, they perceived below average performance of programs on energy production sites and ancillary infrastructure. More specifically, over half (62.8%) of local federal and county managers were not satisfied with the effectiveness of weed control on energy development and transmission sites, rating the effectiveness of management at below average performance. Also, feedback from local weed managers indicated significant management inconsistencies between neighboring counties on these sites. The perceived underperformance of weed control on these sites, which may include power lines, flow lines, pipelines, compressor and pumping stations, electrical facilities, well pads, and roads, could be the result of inadequate weed management by energy companies responsible for weed control on those sites, or the lack of regulatory oversight by local, state, or federal officials. Additionally, since the operational orientation of many local, state, and federal weed management programs focuses on roadways and related transportation infrastructure, program managers may perceive larger gaps in prevention effectiveness in other areas.

Invasive plants have made habitats more prone to wildfires.

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Barrier: Lack of An Effective Early Detection and Rapid Response (EDRR) System Across The Landscape

The success of invasive species EDRR programs is largely contingent on pre-planning for quick response and resource allocations, and a strong network of monitoring, leadership, and cooperation. To be successful, EDRR programs need to include the financial and programmatic capacity for not only rapid detection and reporting, but also for identification and vouchering, rapid assessment, planning, and rapid response (FICMNEW 2003). Although the assessment responses from program managers indicated the presence of EDRR plans, sporadic partner support for EDRR activities, and coordination of EDRR activities under CWMAs, approximately two-thirds (65%) of local weed managers reported an overall underperformance of their programs on the core components of a strong EDRR system. More than half (64.1%) of the responses provided by local federal and county managers indicated weed programs were performing below average on assigning responsibilities for action and addressing jurisdictional concerns and command and control procedures in EDRR plans; indicating significant weaknesses in the ability to effectively implement EDRR across a broader landscape. A common perception from resource managers is that no one organization or agency wants to be responsible for EDRR across the landscape. From the financial capacity perspective, over 73% of local federal and county managers were not satisfied with the availability of 'emergency' or 'contingency' funding necessary for rapid response to new invasions within their programs, rating the performance of this factor well below average.

In over half (61.5%) of responses, program managers reported similar under performance of weed programs when EDRR plans include rapid response actions to new weeds following wildfire or other major disturbances. The perceived underperformance of programs on these factors may be largely explained by the absence of either a formal EDRR plan or rapid response guidelines that assign procedures and responsibilities. Additional comments from program managers included inherent limitations on emergency funding and support following large disturbances outside of post-wildfire Burned Area Emergency Response (BAER) funding. Federal program managers reported major deficiencies of the BAER program in providing funding for only one year when in reality several years of follow-up treatments are usually required (Mayer, et. al 2013). Federal managers also reported on the general absence of a "true" EDRR program owing to the lack of NEPA documents or decisions that allow for rapid herbicide treatments across the entire unit, or the prohibition of herbicide applications by unit administrators concerned about potential legal challenges.

Barrier: Inadequate Restoration Strategies, Implementation, and Approaches

Restoration strategies and approaches help to mitigate the impacts of invasive species and other disturbances on ecosystems. Restoration research is sometimes viewed as duplicative and lacking close coordination with the land manager's objectives; often providing generalized information in the literature without a strong element of ap-

plied-tech transfer to the customer. Most invasive plant management programs across the western states are structured around treatment activities, not surveys, inventories, monitoring, or restoration. This may be because invasive species management programs are generally not geared for restoration and many programs often lack the skills, resources, expertise, funding, or time to build integrated restoration programs. There are also few cross-jurisdictional or cross-boundary restoration efforts in the public and private sectors, which creates inconsistencies at landscape scales. Weed managers tend to rely on support from other programs and organizations to provide the skills and techniques needed to restore areas before or after weed control treatments. As mentioned above, over two-thirds (68.3%) of assessment responses by federal and county managers indicated below average performance of weed programs on the presence of restoration plans that (1) target all pre- and post-invasion activities; and (2) include monitoring and adaptive management strategies.

When asked about restoration activities on their units, over 74.2% of respondents said they prioritize restoration activities based primarily on the availability of resources (personnel, equipment, funding, etc.) and the potential for restoration success, possibly indicating that managers are attempting to be strategic about their restoration options, not just logistically convenient. Perhaps more importantly, this may point to a lack of available techniques that are reliably effective and a lack of resources to address the restoration problem. Essentially programs are both resource- and knowledge-limited. In addition, native plant restoration following weed treatments across broad landscapes has been relatively ineffective on relatively warm and dry sites, although there are a number of small-scale success stories. Also, managers indicated that the seeding methods, seed mixes, and equipment used for post-fire rehabilitation or habitat restoration have not been adequately updated to improve native plant (especially sagebrush) reestablishment, and land management programs have not widely implemented new tools and methodologies for post-fire rehabilitation or habitat restoration.

Nearly 39.0% of respondents during the recent assessment indicated that timing of restoration activities was a major factor in prioritizing restoration work, and the availability of native plant materials was ranked lowest in the criteria used to prioritize restoration work; with only about 20.0% of the respondents indicating the native plant materials factor as important.

STRATEGIC RECOMMENDATIONS FOR IMPROVEMENT

Invasive plant invasions across the western United States represent a primary threat to the conservation and restoration of native sagebrush ecosystems and the wildlife that depend on those systems for survival. These landscape-scale invasions continue to spread at an alarming rate, sometimes characterized as a wildfire in slow motion with a much greater risk. Yet, current invasive plant management program capacity at all levels has not sufficiently addressed this risk. This review and status report provides a brief description of the complex and difficult issues related to the management of invasive plants across the 11 western state range of the GRSG. Recognizing the extreme risk invasive plants pose to the habitat of the GRSG and other wildlife, and the necessity to build stronger capacity to address this risk at the local, regional, and national levels, the Working Group has used the information gathered for this document, along with input from professionals and experts in the weed management and research communities, to develop a set of strategic recommendations that may offer solutions to address many of the challenges and barriers listed above.

The following recommendations are therefore presented to serve as a starting point for further dialog about improving the management of invasive plants across the west for the conservation of GRSG. To help facilitate the appropriate linkage between the recommendations and the barriers and challenges identified in the report, we have grouped them in the four major topical areas as previously described. While, these recommendations are not listed globally in a priority order, they are listed in priority within the topic area. The Working Group believes it is essential to elevate the importance of invasive plant management in the public and private sectors, and to build stronger program capacity to prevent and control invasive plants and restore native plant communities across all landownerships. The Working Group further acknowledges the tremendous efforts and achievements of the weed management community at all levels, and particularly commends their efforts in light of such limited capacity and public support.

INFORMATION MANAGEMENT AND SCIENCE RECOMMENDATIONS

Recommendation 1.

The ISAC should establish a standing committee dedicated to promoting research and adaptive management to determine how we can a) prevent spread of existing weed infestations, and b) consistently re-establish desired perennial plants in invaded sites. This effort should be paired with a corollary initiative to develop scientific standards, protocols and methods for invasive species assessment and monitoring to be used for a) determining the most critical locations for prevention emphasis, and b) accurately tracking spatial dynamics of weed populations over time as well as the impact of weed treatments on those dynamics. These efforts need to be supported through a directive of the NISC departments and agencies, supported at the state level, and initially focused on invasive annual grass species.

LEADERSHIP, COORDINATION, AND COMMUNICATION RECOMMENDATIONS

Recommendation 1.

Convene a summit of federal Departments (i.e., DOI, USDA, DOC, etc.) and agencies, state government agencies, tribes, and key non-government organizations to review existing invasive species mandates (e.g., 1999 Presidential Executive Order 13112), overarching policies, and invasive species program budgets. The goal of the summit would be to develop a plan for consistent and appropriate implementation of the existing mandates, fill gaps in law and policy, and develop recommendations for securing adequate and consistent program funding at local, state and federal levels. In particular, develop federal departmental orders, and other direction for accelerating invasive plant management activities to meet the needs of GRSG conservation across the western U.S.

Recommendation 2.

Re-engage NISC at the Department level to establish a high-level

multi-federal agency working group and charge them with drafting a National Invasive Species Strategy in the U.S. Develop a template for the establishment of regional invasive plant management strategies that consist of assigned responsibilities, funding, invasive plant assessments and action plans. Link regional strategies to GRSG (and other imperiled wildlife) conservation priorities.

POLICY AND REGULATORY RECOMMENDATIONS

Recommendation 1.

Establish a subcommittee within ISAC to review the current legislative and regulatory framework (federal and state) on invasive species, including coordination with the Association of Fish and Wildlife Agencies and recommendations for NEPA categorical exclusion authority for rapid response against invasive plant infestations in priority areas. From this review, the subcommittee should provide a status report with recommendations for consolidation, elimination, and/or establishment of new laws, policies, and regulations that would facilitate and improve the assessment, control and management of invasive species.

Recommendation 2.

Establish a working group to review federal, state, and provincial rules, procedure's, work contract and permit clauses, and Best Management Practices (BMPs) designed to prevent the spread of invasive plants. The work group should make recommendations to establish a set of consistent, ubiquitous standards across the North America to better manage and prevent the spread of invasive plants across the range of the GRSG and other regions. If plausible, the approach developed could be similar in design and function as the interagency/intergovernmental fire model, but for invasive species, with standard procedures and reporting of actions and effectiveness.

PROGRAM MANAGEMENT AND OPERATIONAL CAPACITY RECOMMENDATIONS

Recommendation 1.

Conduct a comprehensive evaluation, including potential restructuring, of the funding and personnel model for invasive species management programs at all levels across federal, state, and county agencies and governments. Programs should consider instituting a holistic, site-based management approach to protect and restore critical areas from invasive plant invasions, and restore native plant communities in those areas to accomplish GRSG conservation goals. Rather than limiting activities to only a few, targeted high-risk invasive plants, design programs to build stronger capacity to address all invasive plant threats in priority areas to achieve long-term restoration success within GRSG habitats. Emphasis on the risk and threat to economies, human health, and the environment should be incorporated within program justifications for increasing operational capacity. Examine opportunities and examples within other invasive species management arenas (i.e., New Zealand, Australia, aquatic invasive species) for site-based approaches to help accelerate and emphasize invasive plant management capacity at local, regional, state, and national levels. Lead NISC Departments should consider assigning this task to ISAC for developing a first-cut draft, thereby leveraging the technical expertise provided by the ISAC membership.

Recommendation 2.

Develop funding mechanisms at state and federal levels to significantly increase program capacity to accelerate invasive plant prevention and control activities at all levels, with the goal of achieving a measurable net reduction of priority invasive plant populations each year and curtailing the exponential rate of spread of those priority populations, across the range of the GRSG. Financial support for pre- and post-treatment ecosystem restoration activities, including but not limited to native plant restoration should be included in the design of the program funding mechanisms.

Recommendation 3.

A new approach needs to be developed and funded to provide for early detection, rapid management response (EDRR) and restoration of areas to prevent invasive plant species from becoming established or spreading. A national system for invasive species EDRR should include consistent funding and a formal incident command structure (ICS) that can address invasive species threats at all levels and across all landownerships, particularly within the range of GRSG, in a timely and efficient manner. Again, this approach could mirror the relevant aspects of the national interagency/intergovernmental fire model, particularly with infrastructure and capacity to respond rapidly and share resources.

Recommendation 4.

Develop a nationally consistent public awareness and education program for the prevention and management of invasive species, similar to the successful national fire prevention program campaign, coordinated across public and private sectors. Such a program will require professional marketing and education expertise to design and implement an effective campaign to reach target audiences in a productive manner, with a goal of changing public behavior and elevating the priority of invasive species issues nationwide.

Recommendation 5.

As stated in the WAFWA Gap Report (Mayer et al., 2013), coordination between the public and private landowners to manage invasive plants across landscapes is essential and is occurring through the creation of Cooperative Weed Management Areas. Thus, the support and implementation of these CWMAs needs to be implemented across the range of GRSG. An assessment of the status and functional effectiveness of each CWMA should be conducted across the range of the GRSG. Using the assessment information, expand mechanisms to increase capacity building and support for CWMA operations to address GRSG conservation needs.

Recommendation 6.

Wherever feasible, maximize niche occupation with desired native species. Aggressive, fire-resistant, non-native perennial species, such as crested wheatgrass, may be necessary to stabilize and prevent further invasion of cheatgrass and medusahead. However, these species should be only used with the intent to stabilize the plant community and allow for long-term recovery of sagebrush and other native species.

MANAGEMENT AND POLICY IMPLICATIONS

Although our collective track record on controlling invasive plant infestations within the range of GRSG is poor, there is cause for optimism if state, federal, and local agencies embrace a paradigm shift and prioritize control efforts for sage-grouse conservation. Every year, there are literally thousands of invasive plant infestations that are successfully treated across the West, targeting dozens of harmful exotic plant species in a wide variety of terrestrial, riparian, and aquatic ecosystems. These successes tend to be relatively small scale, but they demonstrate that we have the knowledge and skills to be effective. Multi-landowner collaboration and partnerships, through the establishment of CWMAs, have helped to rally affected stakeholders against the threat of invasive plants across broader landscapes and create opportunities for larger scale success. Some CWMAs are highly effective, and can serve as models for areas without CWMAs or for improvement of less effective CWMAs. Additionally, new policy and regulations have helped encourage action against invasive species in some areas. Improvements in weed science, weed inventory and treatment technology have also helped to advance programs by improving their effectiveness, offering land managers a broad array of tools and techniques to manage invasive plant populations. Advancements in restoration research have also provided options to managers in some areas, and it remains a very active area of research.

The programmatic framework for success is in place, with an Executive Order, cabinet level invasive species council (NISC), a multi-agency science advisory group (ISAC), FICMNEW, AFWA Invasive Species Committee, state weed management programs and invasive species councils, the Western Weed Coordinating Committee, the North American Invasive Species Management Association, the North American Exotic Pest Plant Council, CWMAs, County weed management programs, etc. We need not create new entities, rather we must empower the existing structure by greatly expanding resources devoted to invasive plant control, ensure coordination of efforts across programs, and redefine success in terms of successful outcomes and not effort. We recommend utilizing the existing leadership elements to create four new working groups or coordinating committees, holding an invasive plant management summit, conducting reviews and evaluations to develop effective funding, outreach, and field-level coordination efforts, in order to redefine success in terms of successful outcomes and not effort. Sage-grouse conservation efforts have expanded ten-fold in recent years; there is no reason we can't see a comparable prioritization of invasive plant control efforts and achieve similar success in this arena as well.

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TABLES AND FIGURES

Table 1. Response rates of local federal and county weed programs in each GRSG management zone (Stiver et al. 2006). Sample size (n) is shown in parentheses. Respondents in the "other" category were included in the analysis and excluded from the response rates.

Management zone	Reporting units	Eligible Reporting	Response rate (%)	Distribution of sample (%)
MZ I – Great Plains (n = 44)				
County weed	16	43	37.2	36.4 (16 of 44)
Local BLM	3	10	30.0	
Local USFS	4	5	80.0	43.2 (19 of 44)
Local NPS	1	5	20.0	
Local FWS	11	16	68.8	
Total	35	79	44.3	
Other	9			20.5 (9 of 44)
MZ II – Wyoming Basin (n = 61)				
County weed	17	30	56.7	27.9 (17 of 61)
Local BLM	7	10	70.0	
Local USFS	10	12	83.3	47.5 (29 of 61)
Local NPS	2	5	40.0	
Local FWS	10	11	90.9	
Total	46	68	67.6	
Other	15			24.6 (15 of 61)
MZ III – Southern Great Basin (n = 41)				
County weed	9	31	29.0	22.0 (9 of 41)
Local BLM	9	19	47.4	
Local USFS	9	12	75.0	46.3 (19 of 41)
Local NPS	0	5	0.00	
Local FWS	1	5	20.0	
Total	28	72	38.9	
Other	13			31.7 (13 of 41)
MZ IV – Snake River Plain (n = 73)				
County weed	19	48	39.6	26.0 (19 of 73)
Local BLM	9	19	47.4	
Local USFS	17	20	85.0	49.3 (36 of 73)
Local NPS	5	6	83.3	
Local FWS	5	7	71.4	
Total	55	100	55.0	
Other	18			24.7 (18 of 73)
MZ V – Northern Great Basin (n = 18)				
County weed	0	10	0.00	0.0 (0 of 18)

Local BLM	7	10	70.0	94.4 (17 of 18)
Local USFS	6	14	42.9	
Local NPS	1	2	50.0	
Local FWS	3	10	30.0	
Total	17	46	37.0	
Other	1			5.60 (1 of 18)
MZ VI – Columbia Basin (n = 17)				
County weed	2	16	12.5	64.7 (11 of 17)
Local wildlife	9	12	75.0	
Local BLM	0	1	0.00	35.3 (6 of 17)
Local USFS	0	3	0.00	
Local NPS	0	0	0.00	
Local FWS	6	6	100	
Total	17	38	44.7	
MZ VII – Colorado Plateau (n = 37)				
County weed	11	27	40.7	29.7 (11 of 37)
Local BLM	1	8	12.5	24.3 (9 of 37)
Local USFS	8	9	88.9	
Local NPS	0	8	0.00	
Local FWS	0	3	0.00	
Total	20	55	36.4	
Other	17			45.9 (17 of 37)
Region response rate	218	458	47.6	
Other responses	73			
Region sample size	291			

Abbreviations: BLM, Bureau of Land Management; USFS, Forest Service; NPS, National Park Service; USFWS, Fish and Wildlife Service. The "Other" category includes responses from other local, state, and federal programs in the project area, including local Defense Department installations.

Table 2. Invasive plant species reported to invade sagebrush communities (from Miller et al. 2011) and their summary scores from the four categories comprising the Center for Invasive Species Management (CISM) invasive plant ranking system. Plants are ordered by management priority based on descending overall score. See Appendix (Table A-1) for details on the CISM invasive plant ranking system categories and relative values of responses.

Plant	Scientific name	Invasiveness	Aggressiveness	Ecological Impact	Management difficulty	Overall score (max. 36)
Highly invasive plant species						
1. Medusahead	Taeniatherum caput-medusae	9	9	9	9	36
2. Cheatgrass	Bromus tectorum	9	9	9	8	35
3. Spotted knapweed	Centaurea stoebe ssp. micranthos	9	9	9	8	35
4. Yellow starthistle	Centaurea solstitialis	9	9	9	8	35
5. Diffuse knapweed	Centaurea diffusa	8	7	8	9	32
6. Leafy spurge	Euphorbia esula	8	8	8	6	30
7. Rush skeletonweed	Chondrilla juncea	8	8	7	7	30
8. Dalmatian toadflax	Linaria dalmatica	7	7	5	9	28
9. Sulphur cinquefoil	Potentilla recta	6	7	7	8	28
10. Canada thistle	Cirsium arvense	7	5	7	8	27
11. Russian knapweed	Acroptilon repens	7	5	7	8	27
Moderately invasive plant species						
12. Squarrose knapweed	Centaurea virgata	4	5	8	8	25
13. Whitetop	Cardaria spp.	6	6	6	6	24
14. Yellow toadflax	Linaria vulgaris	4	5	5	8	22
15. Dyer's woad	Isatis tinctoria	4	5	6	6	21
16. Mediterranean sage	Salvia aethiopis	4	5	5	6	20
17. Scotch thistle	Onopordum acanthium	4	4	4	4	16
Weakly invasive plant species						
18. Halogeton	Halogeton glomeratus	4	4	3	4	15
19. Musk thistle	Carduus nutans	4	4	4	3	15
20. Common crupina	Crupina vulgaris	1	3	4	6	14
21. Perennial sowthistle	Sonchus arvensis	4	2	1	2	9

The ranks listed in Table 2 were estimated by CISM during the assessment project to determine the most threatening plants (from Miller et al. [2011]) and guide collection of GIS and distribution data and other information. Further evaluations are needed to better define the relative risk of invasive plants across the range of the GRSG, particularly with respect to direct and indirect impacts on GRSG conservation and sagebrush restoration. There is very little information describing the abundance of invasive plant distributions in the western U.S. and therefore assigning weights of spatial extent to the rankings was difficult.

Table 3. Federal agencies with authority and responsibility for some aspect of terrestrial invasive plant management (Corn and Johnston 2013, NISC 2001, FICMNEW 2014).

Agency	Major management activities
Department of Agriculture	
Animal and Plant Health Inspection Service (APHIS)	Protects agricultural productivity. Prevents certain invasive species from entering the U.S. and responds to such pests domestically under quarantine laws. Designates federal noxious weeds. Regulates certain biocontrol agents and foreign commerce in agricultural seeds and noxious weeds. Conducts research.
Agricultural Marketing Service	Regulates interstate commerce in noxious weeds and agricultural seeds pertaining to noxious weed seed content.
Agricultural Research Service	Provides research and expertise to states and other federal agencies. Disseminates findings through the Cooperative Extension Service. Conducts testing of biocontrol agents and area-wide pest control programs. Manages communication initiatives such as the National Invasive Species Information Center.
Economic Research Service	Provides economic research and informs private and public sectors on policy and economic issues related to agriculture and the environment. Supports invasive plant control through its research programs on pesticide use and pest management.
National Institute of Food and Agriculture	Delivers federal funding to land grant universities for Cooperative Extension programs, education and research on invasive plant control. Provides data and training to state university diagnostic labs.
Farm Service Agency	Administers the Conservation Reserve Program which provides for natural resource conservation including invasive plant control.
Foreign Agricultural Service	Works with APHIS to provide technical assistance to foreign countries to prevent the movement of pests to the U.S.
Forest Service	Conducts restoration and control on National Forest System lands. Partners with public and private landowners on control efforts. Provides cost-share and assistance to states and landowners for control on federal and nonfederal lands through its State and Private Forestry Program. Conducts research.
Natural Resources Conservation Service	Provides cost-share and natural resource conservation assistance programs to non-federal landowners, broadly providing for restoration and control. Develops and distributes plants and technology through its Plant Materials Centers. Provides native and invasive plant information through its PLANTS Database system.
Department of Defense (DOD)	
Armed Forces Pest Management Board	Coordinates the DOD pest management programs. Control and restoration is conducted based on the individual installation plans. Supports research and policy development in military quarantine.
U.S. Army Corps of Engineers (USACE)	Conducts control and restoration on managed lands and civil works projects pursuant to USACE Invasive Species Policy.
Department of Energy	Conducts control and restoration on managed lands.
Department of Homeland Security	
Customs and Border Protection	Conducts border protection inspections and actions at U.S. ports of entry. Works with APHIS to enforce laws prohibiting entry of invasive species. Partners with state, tribal and local authorities.
Federal Emergency Management Agency (FEMA)	FEMA's Emergency Support Function allows for the control of outbreaks of invasive species in partnership with state, tribal, and local authorities and other federal agencies.
Department of the Interior	

Bureau of Indian Affairs	Provides control assistance on Indian trust lands and education through its Noxious Weed Control Program.
Bureau of Land Management	Conducts control and restoration on public lands. Maintains cooperative research relationships with other federal agencies. Partners with public and private landowners on control efforts.
Bureau of Reclamation	Authority for control and restoration on managed lands. Partners with public and private landowners on control efforts.
Fish and Wildlife Service	Maintains programs on habitat conservation. Conducts control and restoration on National Refuge System lands. Partners with public and private landowners on control efforts.
Geological Survey	Supports efforts to record, distribute and integrate data on control and restoration and biological resources. Conducts research.
National Park Service	Authority for control and restoration on managed lands. Regional Exotic Plant Management Teams conduct rapid response. Partners with public and private landowners on control efforts.
Office of Surface Mining	Regulates the land reclamation of coal mining operations including revegetation and invasive plant control.
Department of State	Develops U.S. foreign policy on invasive species.
Department of Transportation	
Federal Highway Administration	Guides state departments of transportation on invasive plant issues through its Vegetation Management Program.
Federal Railroad Admin.	Supports invasive plant control on rail corridors.
Environmental Protection Agency	Oversees pesticide registration and distribution including herbicides to control invasive plants. Lead agency for the National Environmental Protection Act; directs federal agencies to regard potential impacts, including invasive species, of planned actions.

Table 4. State noxious weed listing status of highly and moderately invasive plants in decreasing order of relative invasiveness.

Plant	State listed noxious (from USDA NRCS 2014)
Highly invasive plant species	
Medusahead	CA, CO, NV, OR, UT
Cheatgrass	CO
Spotted knapweed	AZ, CA, CO, ID, MT, NV, NM, ND, OR, SD, UT, WA, WY
Yellow starthistle	AZ, CA, CO, ID, MT, NV, NM, ND, OR, SD, UT, WA, WY
Diffuse knapweed	AZ, CA, CO, ID, MT, NV, NM, ND, OR, SD, UT, WA, WY
Leafy spurge	AZ, CA, CO, ID, MT, NV, NM, ND, OR, SD, UT, WA, WY
Rush skeletonweed	AZ, CA, CO, ID, MT, NV, OR, SD, WA
Dalmatian toadflax	CO, ID, MT, NV, OR, SD, WY
Sulphur cinquefoil	CO, MT, NV, OR, WA
Canada thistle	AZ, CA, CO, ID, MT, NV, NM, ND, OR, SD, UT, WA, WY
Russian knapweed	AZ, CA, CO, ID, MT, NV, NM, ND, OR, SD, UT, WA, WY
Moderately invasive plant species	
Squarrose knapweed	CO, ID, OR
Whitetop	AZ, CA, CO, ID, MT, NV, NM, ND, OR, SD, UT, WA, WY
Yellow toadflax	CO, ID, MT, NV, NM, OR, SD, WA, WY
Dyer's woad	AZ, CA, CO, ID, MT, NV, NM, OR, UT, WA, WY
Mediterranean sage	CA, CO, ID, NV, OR, WA
Scotch thistle	AZ, CA, CO, ID, NV, NM, OR, UT, WA, WY

Table 5. Highest mean (± SE) ranks for relative invasion risk of priority plants and mean abundance estimates grouped by GRSG management zone (Stiver et al. 2006). Invasion risk values indicate these plants may continue to spread. Risk and abundance values were estimated by survey respondents based on the scale and site conditions of their management or administrative unit.

	Relative invasion risk		Abundance estimate	
Mgmt. zone/plant	Rank [a]	Risk category	Rank [b]	Abundance category
	Mean (SE)		Mean (SE)	
MZ I - Great Plains				
Leafy spurge	4.6 (0.12)	Mod high to high	6.3 (0.19)	Many small infestations
Canada thistle	4.2 (0.17)	Moderately high	6.5 (0.09)	Large infestations
Spotted knapweed	4.1 (0.20)	Moderately high	5.2 (0.26)	Few small infestations
Cheatgrass	3.9 (0.21)	Moderately high	6.1 (0.24)	Many small infestations
Russian knapweed	3.6 (0.19)	Mod to moderately high	4.9 (0.22)	Few small infestations
MZ II - Wyoming Basin				
Cheatgrass	4.4 (0.12)	Moderately high	6.4 (0.11)	Large infestations
Whitetop	3.8 (0.15)	Mod to moderately high	5.8 (0.16)	Many small infestations
Perennial pepperweed	3.8 (0.18)	Mod to moderately high	5.3 (0.24)	Few small infestations
Leafy spurge	3.8 (0.18)	Mod to moderately high	4.9 (0.24)	Few small infestations
Russian knapweed	3.7 (0.17)	Mod to moderately high	5.2 (0.23)	Few small infestations
MZ III - Southern Great Basin				
Cheatgrass	4.4 (0.17)	Moderately high	6.8 (0.07)	Large infestations
Whitetop	4.2 (0.15)	Moderately high	6.1 (0.17)	Many small infestations
Perennial pepperweed	4.0 (0.17)	Moderately high	5.5 (0.26)	Few to many small
Russian knapweed	4.0 (0.16)	Moderately high	5.6 (0.20)	Few to many small
Spotted knapweed	3.8 (0.18)	Mod to moderately high	5.0 (0.22)	Few small infestations
MZ IV - Snake River Plain				
Cheatgrass	4.2 (0.13)	Moderately high	6.3 (0.13)	Many small infestations
Spotted knapweed	4.1 (0.15)	Moderately high	5.6 (0.20)	Many small infestations
Rush skeletonweed	4.0 (0.19)	Moderately high	4.7 (0.29)	Few small infestations
Leafy spurge	3.8 (0.16)	Mod to moderately high	5.2 (0.21)	Few small infestations
Medusahead	3.6 (0.18)	Mod to moderately high	4.1 (0.30)	Rare and high concern
MZ V - Northern Great Basin				
Medusahead	4.5 (0.24)	Moderately high	6.1 (0.39)	Many small infestations
Cheatgrass	4.3 (0.29)	Moderately high	6.5 (0.34)	Few large infestations
Spotted knapweed	3.7 (0.36)	Mod to moderately high	4.6 (0.54)	Few small infestations
Perennial pepperweed	3.6 (0.34)	Mod to moderately high	5.4 (0.44)	Few small infestations
Whitetop	3.4 (0.30)	Moderate	5.3 (0.42)	Few small infestations
MZ VI - Columbia Basin				
Cheatgrass	4.2 (0.24)	Moderately high	6.3 (0.22)	Many small infestations
Whitetop	3.8 (0.26)	Mod to moderately high	5.3 (0.28)	Few small infestations
Rush skeletonweed	3.4 (0.47)	Moderate	4.0 (0.53)	Rare and high concern
Diffuse knapweed	3.3 (0.28)	Moderate	5.9 (0.14)	Many small infestations
Perennial pepperweed	3.2 (0.37)	Moderate	4.2 (0.37)	Rare and high concern
MZ VII - Colorado Plateau				
Cheatgrass	4.2 (0.19)	Moderately high	6.5 (0.12)	Few to many large
Yellow toadflax	4.0 (0.20)	Moderately high	5.9 (0.24)	Many small infestations

a Relative invasion risk ranks: 1, low risk; 2, moderately low risk; 3, moderate; 4, moderately high risk; 5, high risk.
b Abundance estimate ranks: 1, absent; 2, rare and low concern; 3, absent and high concern; 4, rare and high concern; 5, a few small infestations; 6, many small or few large infestations; 7, many large infestations.

Figure 1. Current and historical distribution of sage-grouse (image courtesy of the U.S. Fish and Wildlife Service).

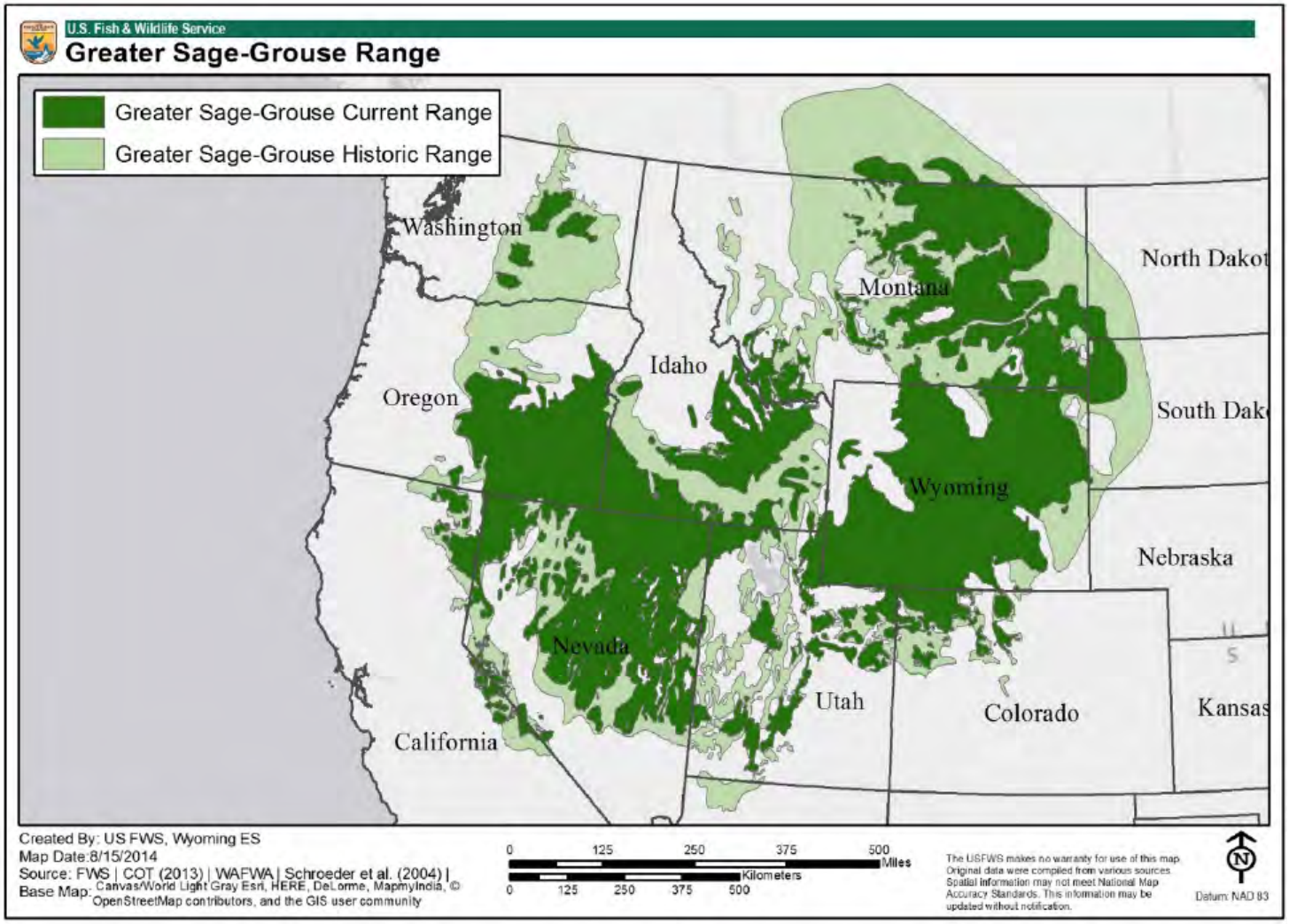

Figure 2. Invasive plant management network structure. Each node represents a different agency or stakeholder group (actors) and each arrow illustrates basic communication ties between the actors and the direction of the influence between actors. Different colors suggest distinct levels and direction of facilitation, collaboration, organization, and management.

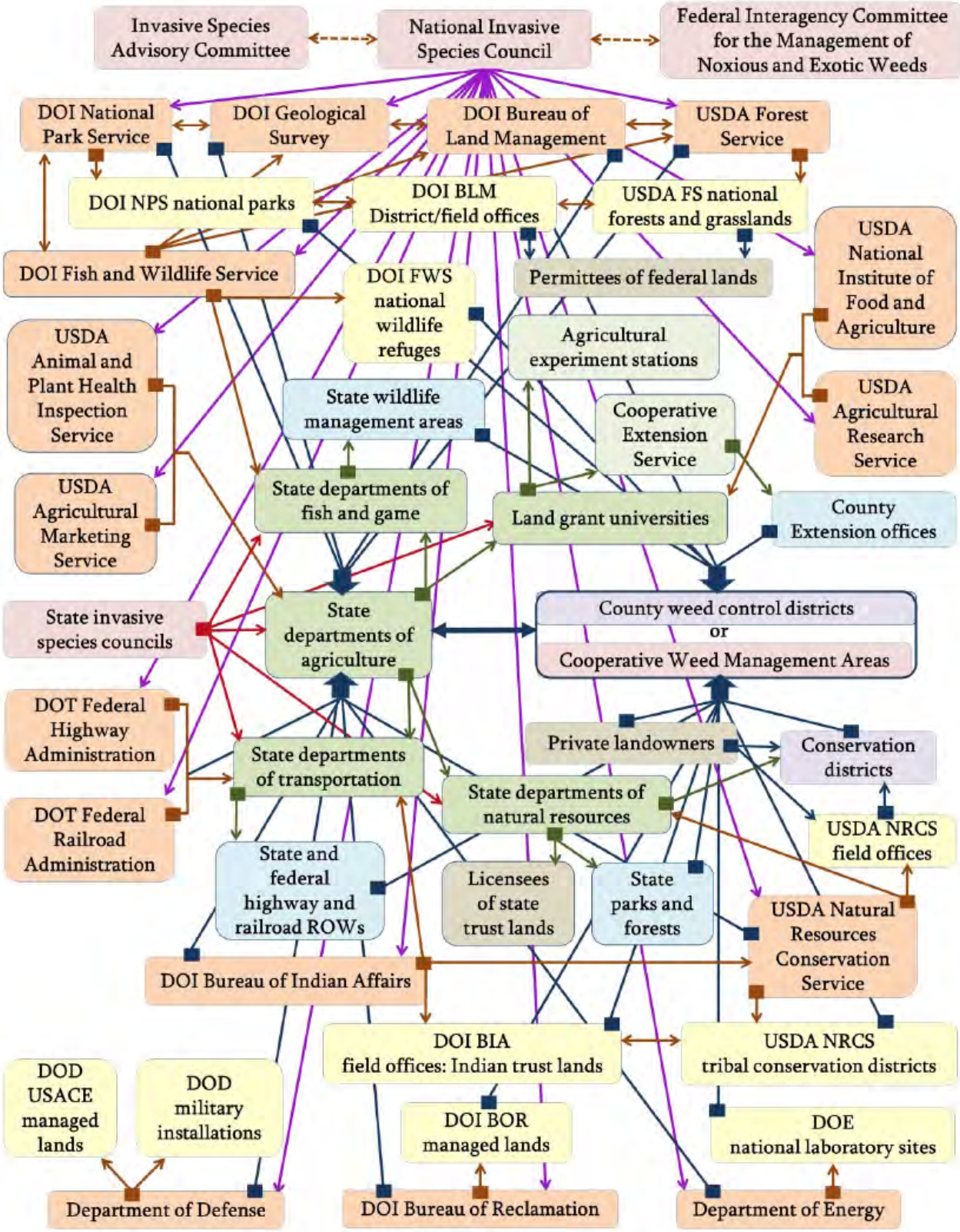

Figure 2 Description: (previous page) Invasive plant management may be generally viewed as a network with a set of nodes representing actors, for instance agencies and stakeholder groups, and ties or links between the nodes, shown as arrows in Figure 3 indicating the direction of the influence between the actors. At the heart of the diagram are the state departments of agriculture and the county weed control districts or CWMAs which are connected either directly or indirectly to each actor in the network. Radiating outward are state agencies, departments, and university systems (shown in green and light green), county-level offices and districts and state land holdings (shown in purple and blue), and private landowners, licensees, and permittees (shown in tan). Around the periphery are federal agencies (shown in orange) and local federal administrative or field units (shown in yellow). Coordinating entities, such as national and state-level committees and councils, and local CWMAs are shown in pink. Different arrow colors suggest distinct direction with other actors in the network. Purple or red arrows portray the direction of facilitation from the coordinating entities to lower level actors. Orange arrows indicate collaboration between federal agencies or the direction of policy implementation from federal agencies to lower level actors. Green arrows portray these responsibilities between state-level actors and from state-level actors to lower level groups. Blue arrows represent direct relational ties of collaboration or policy implementation to the heart of the network – county weed districts or CWMAs and state departments of agriculture. Additional network connections, not currently displayed in this figure, may exist between the various nodes and organizations.

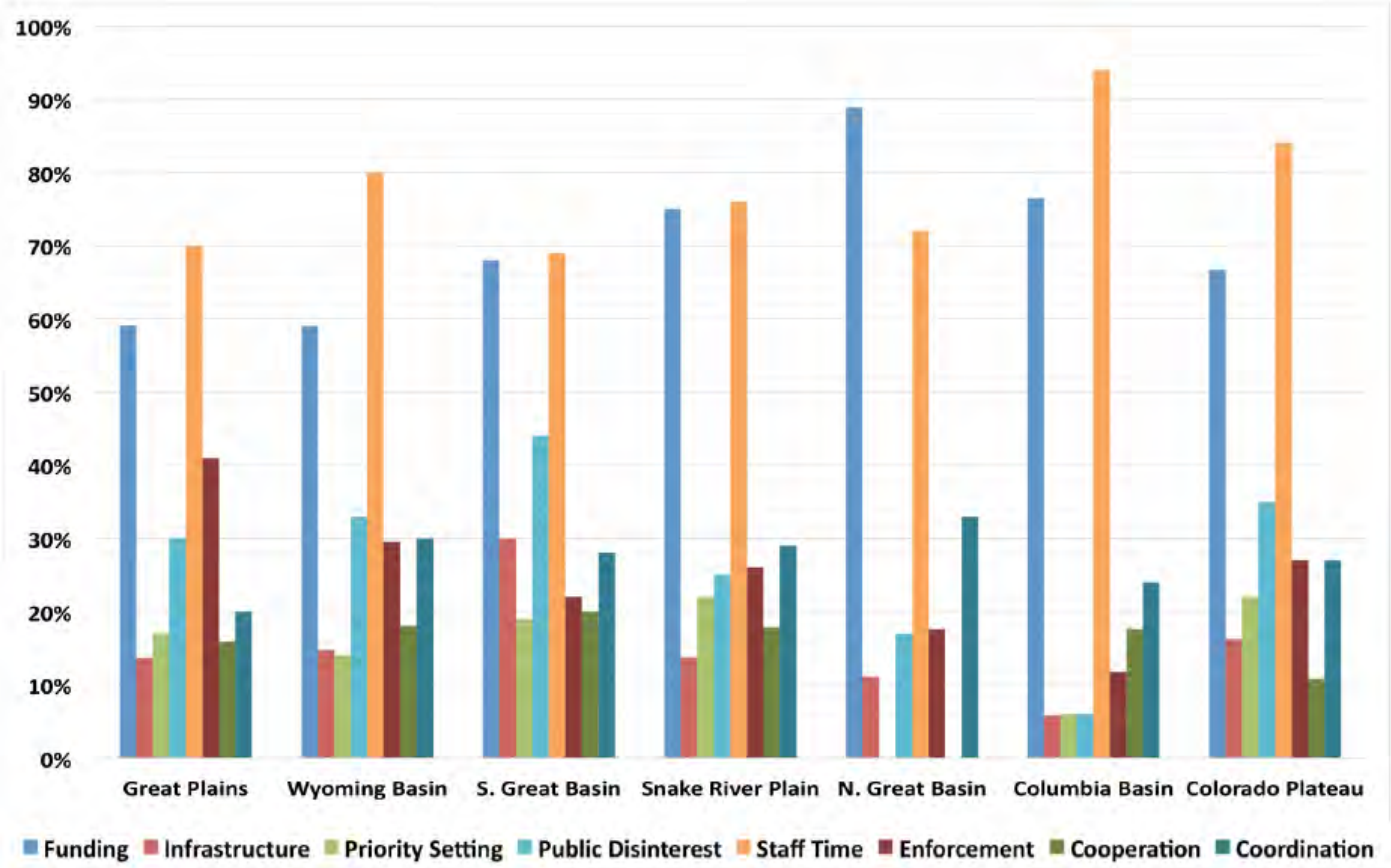

Figure 3. Frequency of managers that reported select factors as a barrier to effective weed management in their unit by GRSG management zone (Stiver et al. 2006). Responses are not independent as participants reported multiple factors.

Figure 4. Relative risk (dark blue bars; 1 = low risk to 5 = high risk) and estimated abundance (light blue bars; 1, absent; 2, rare and low concern; 3, absent and high concern; 4, rare and high concern; 5, a few small infestations; 6, many small or few large infestations; 7, many large infestations) of priority plants. Observations were estimated by responding managers based on the scale and site conditions of their management unit. Error bars are ± SD; n = 274 ± 16.4 (SD).

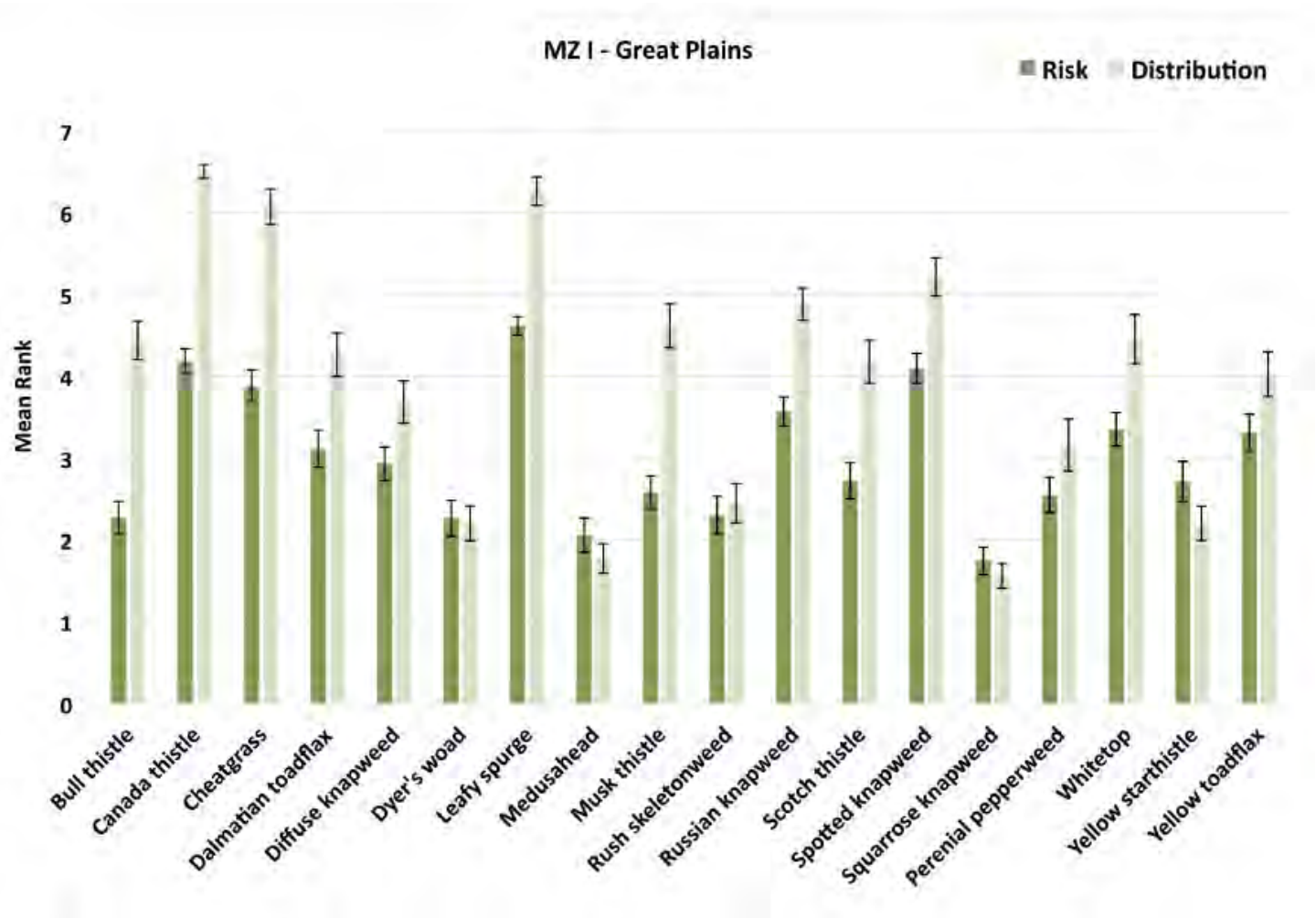

Figure 5. MZ I – Great Plains Management Zone. Relative risk (dark green bars) and estimated abundance (light green bars) of priority plants. Observations were estimated by respondents based on the scale and site conditions of their management unit. Error bars are ± SD; n = 40.5 ± 2.84 (SD). See Table 5 for details on risk and abundance ranks.

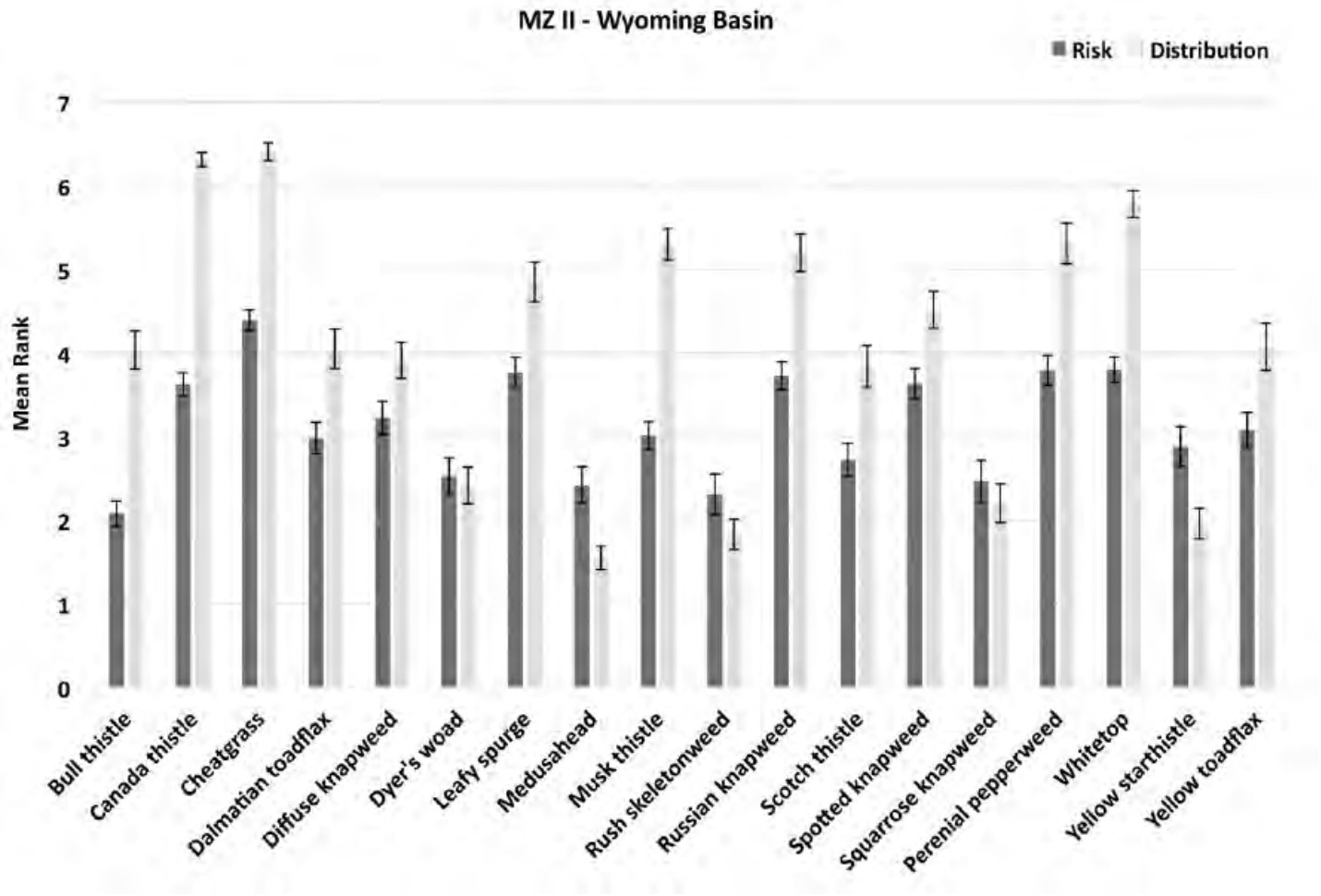

Figure 6. MZ II – Wyoming Basin Management Zone. Relative risk (black bars) and estimated abundance (gray bars) of priority plants. Observations were estimated by respondents based on the scale and site conditions of their management unit. Error bars are ± SD; n = 56 ± 5.4 (SD). See Table 5 for details on risk and abundance ranks.

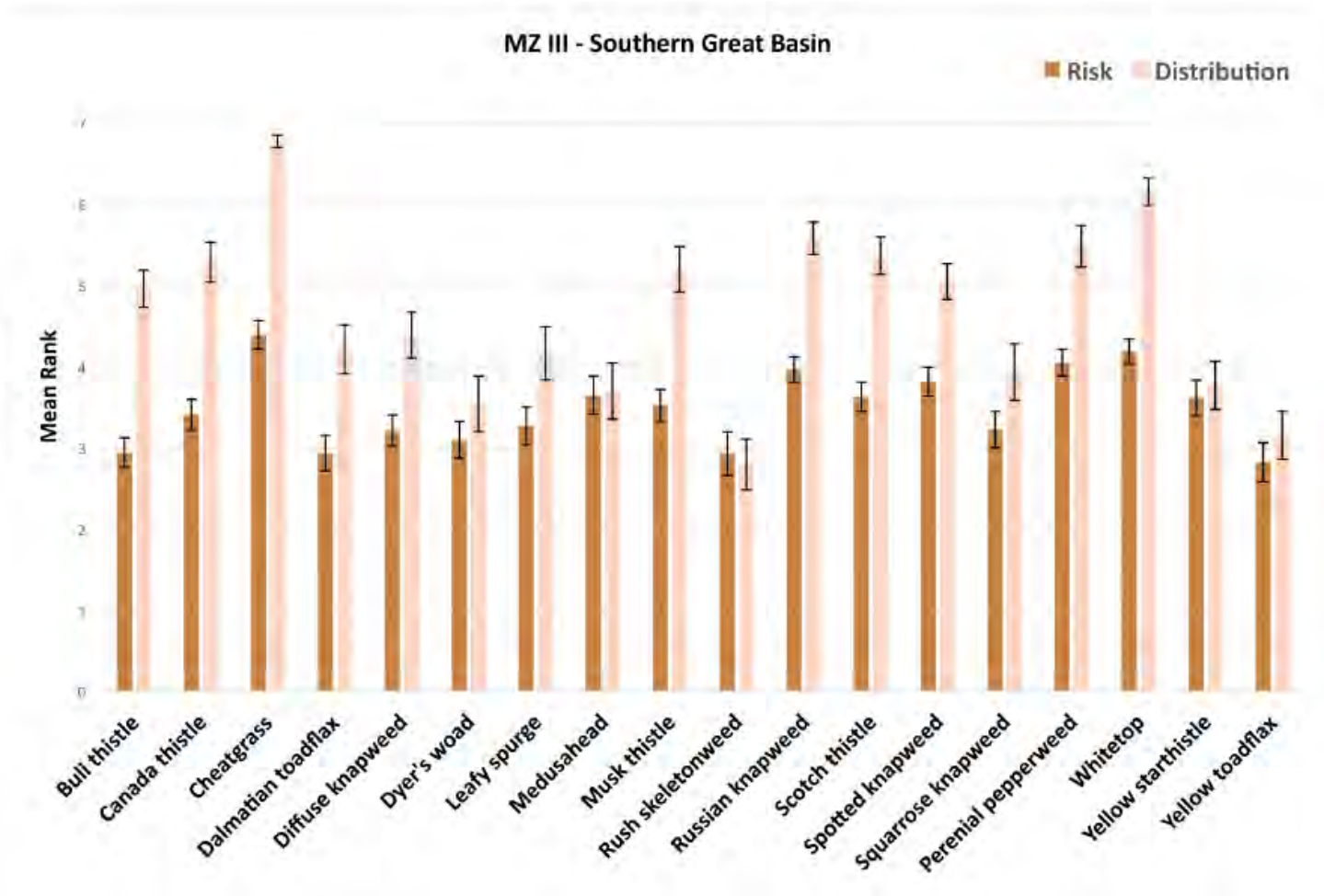

Figure 7. MZ III – Southern Great Basin Management Zone. Relative risk (orange bars) and estimated abundance (pink bars) of priority plants. Observations were estimated by respondents based on the scale and site conditions of their management unit. Error bars are ± SD; n = 45 ± 2.6 (SD). See Table 5 for details on risk and abundance ranks.

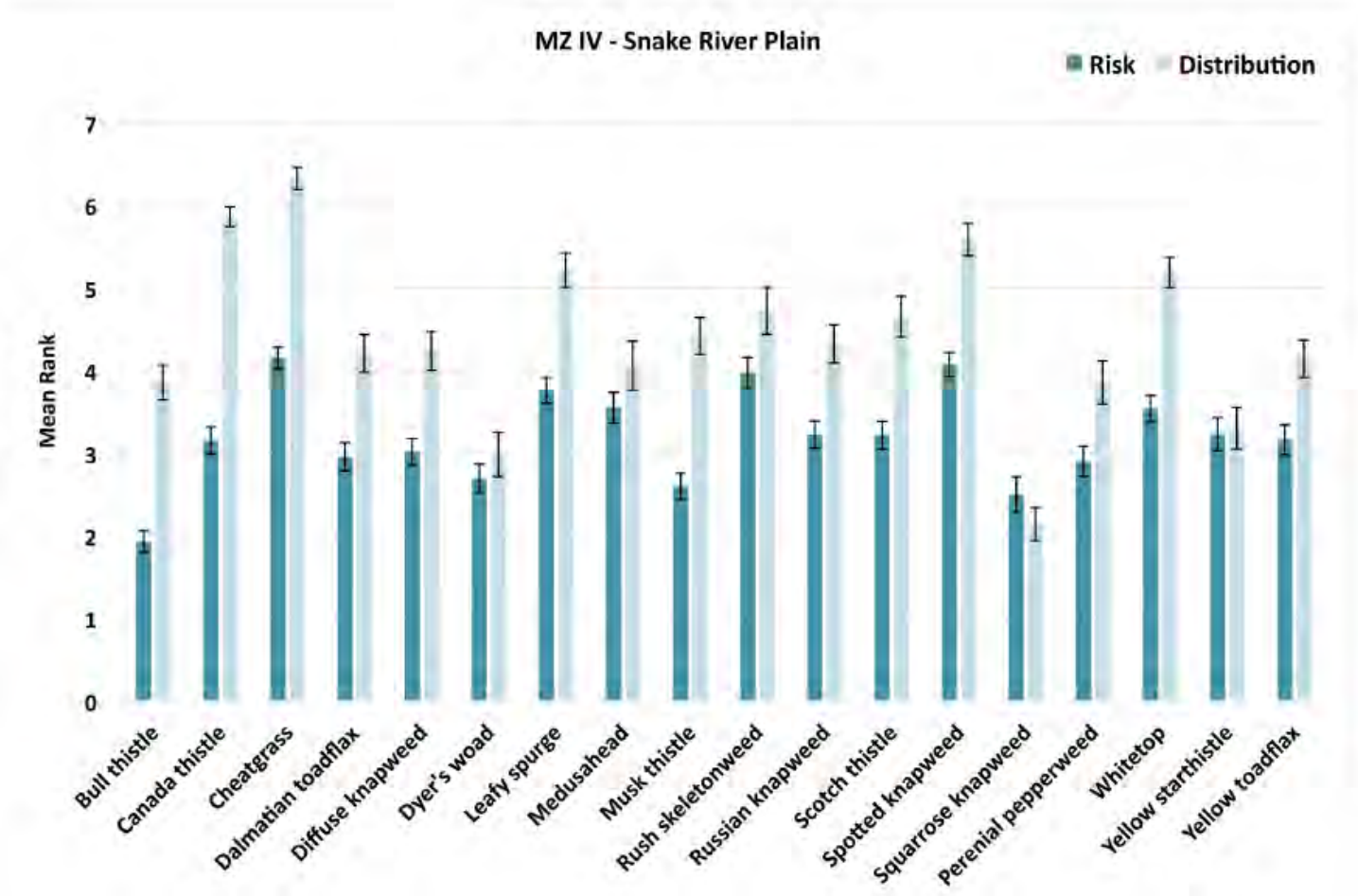

Figure 8. MZ IV – Snake River Plain Management Zone. Relative risk (dark blue bars) and estimated abundance (light blue bars) of priority plants. Observations were estimated by respondents based on the scale and site conditions of their management unit. Error bars are ± SD; n = 67 ± 4.1 (SD). See Table 5 for details on risk and abundance ranks.

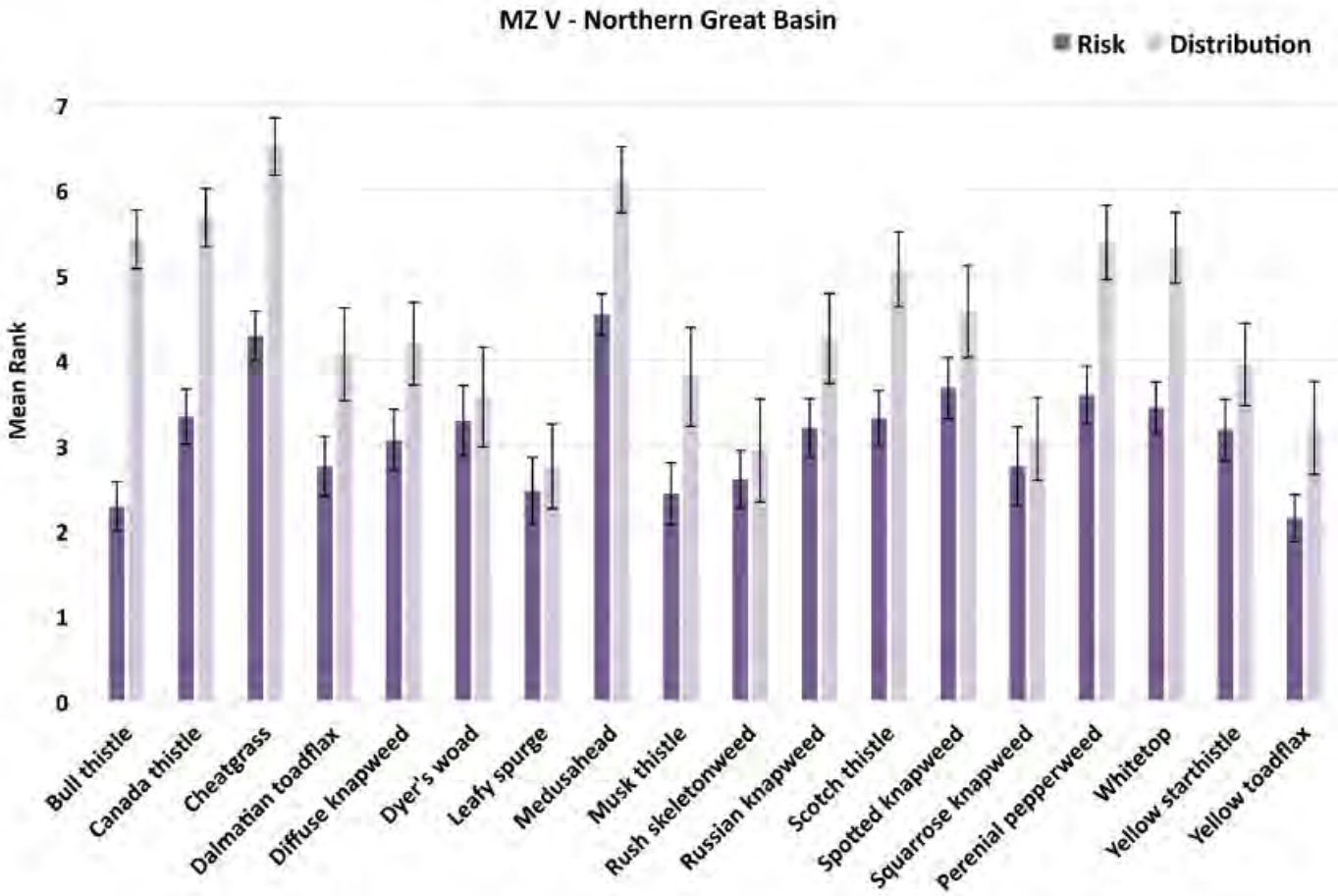

Figure 9. MZ V – Northern Great Basin Management Zone. Relative risk (dark purple bars) and estimated abundance (light purple bars) of priority plants. Observations were estimated by respondents based on the scale and site conditions of their management unit. Error bars are ± SD; n = 16 ± 1.4 (SD). See Table 5 for details on risk and abundance ranks.

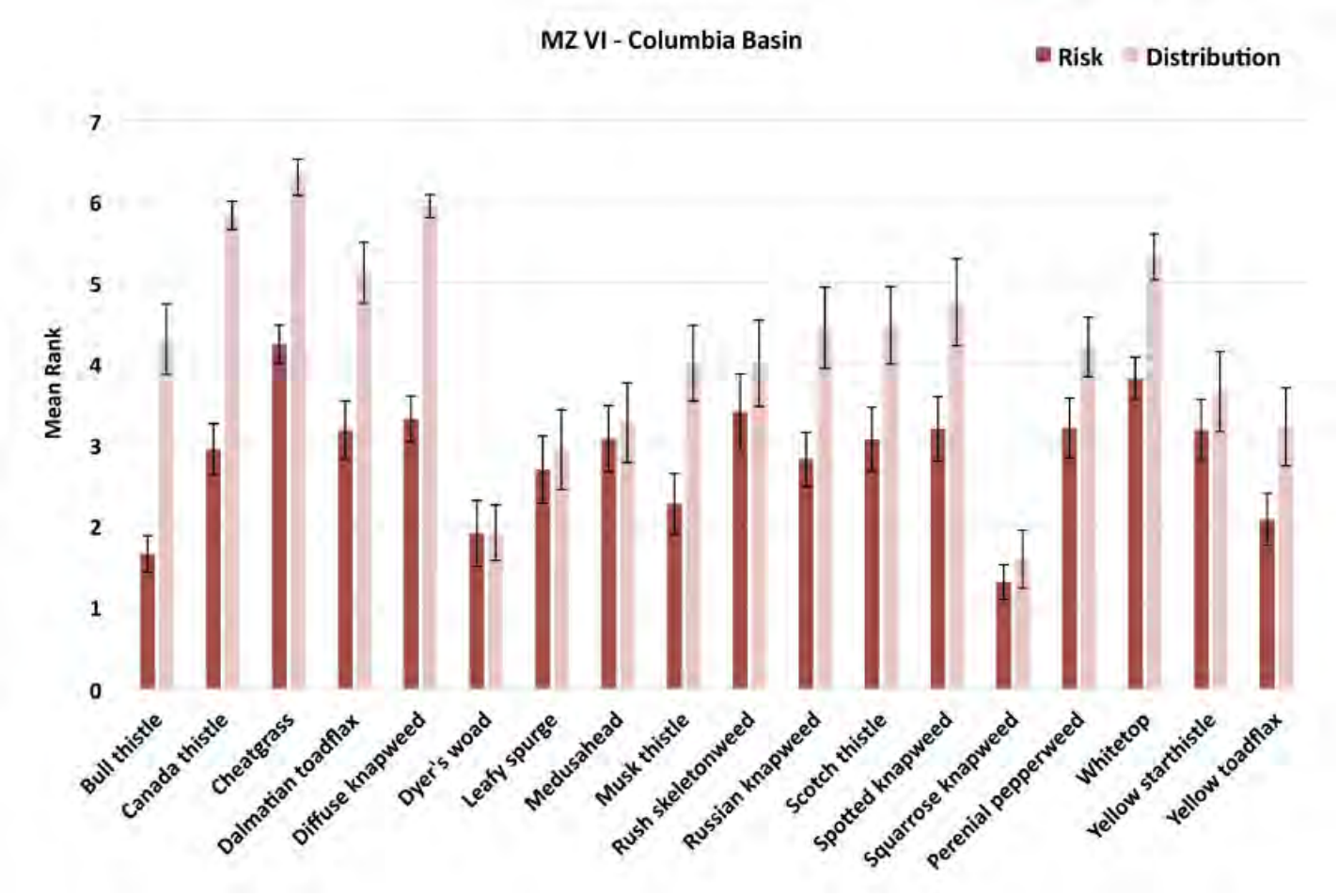

Figure 10. MZ VI – Columbia Basin Management Zone. Relative risk (dark red bars) and estimated abundance (pink bars) of priority plants. Observations were estimated by respondents based on the scale and site conditions of their management unit. Error bars are ± SD; n = 15 ± 1.9 (SD). See Table 5 for details on risk and abundance ranks.

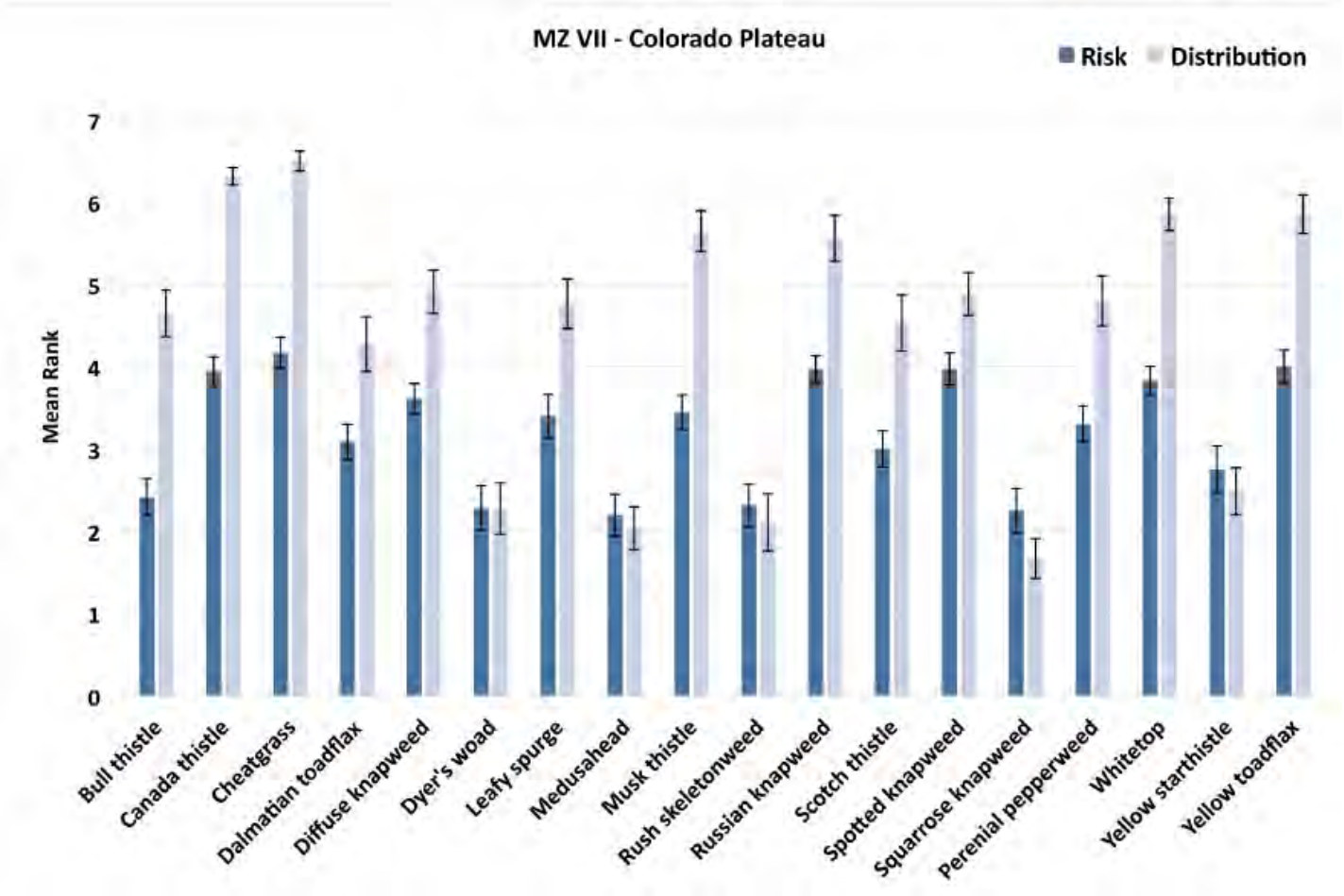

Figure 11. MZ VII – Colorado Plateau Management Zone. Relative risk (dark blue bars) and estimated abundance (light blue bars) of priority plants. Observations were estimated by respondents based on the scale and site conditions of their management unit. Error bars are ± SD; n = 34 ± 1.3 (SD). See Table 5 for details on risk and abundance ranks.

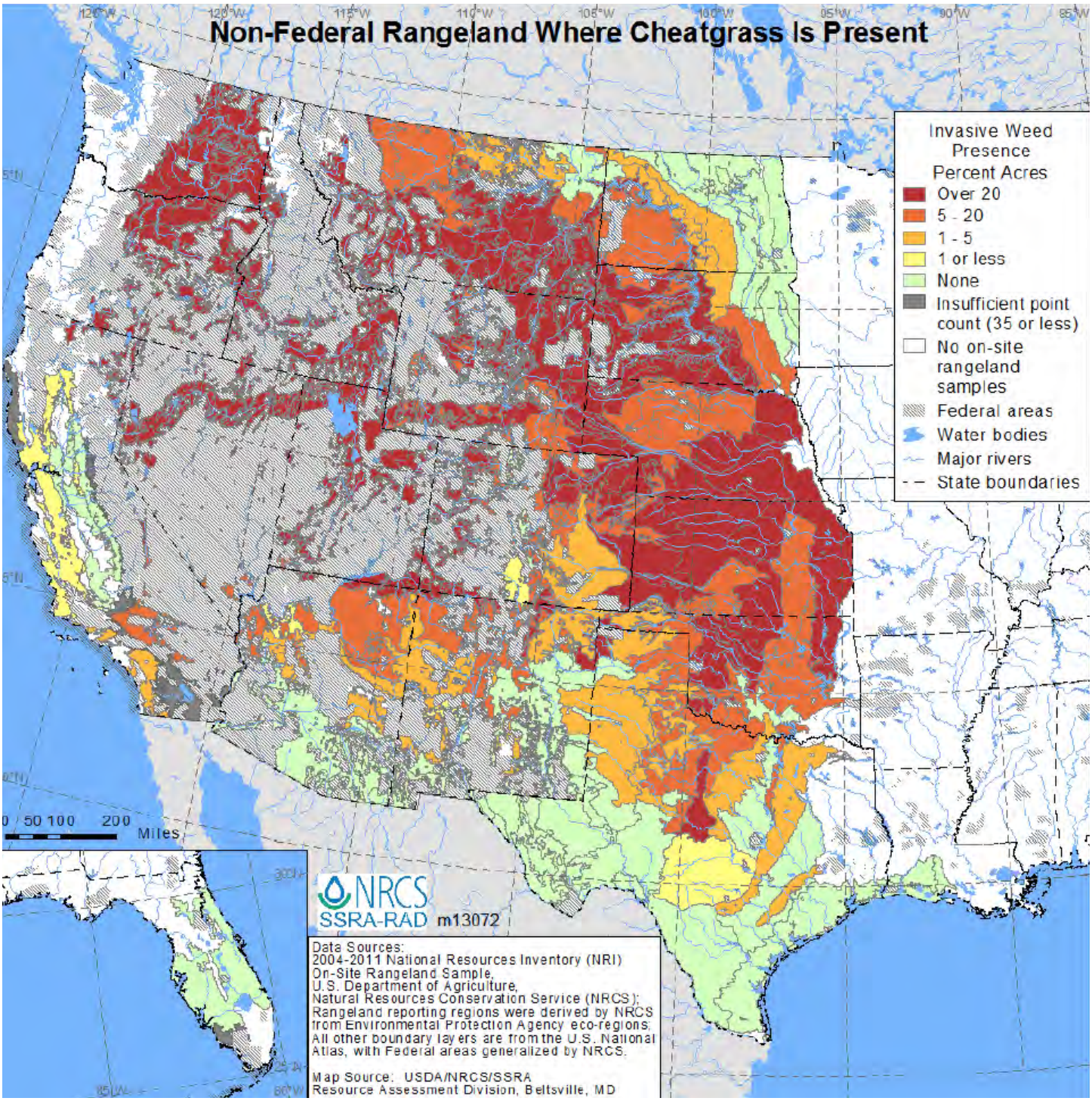

Figure 12. Non-federal rangeland where cheatgrass is present, 2004-2011. Data from the USDA Natural Resources Conservation Service – NRI.

Appendix

Table A-1. Excerpt of the Center for Invasive Species Management (CISM) invasive plant ranking system.	
Invasiveness: range size, abundance, and role of disturbance	Score
Highly invasive: widespread and dominant/common. Species occurs in a diversity of habitat types in introduced range. Regularly invades high-quality plant communities or those with naturally occurring disturbances.	7 - 9
Moderately invasive: localized and high density, rapid range expansion and low density, or widespread but infrequent. Species may be restricted in habitat type. Most infestations associated with human disturbances or degraded habitats.	4 - 6
Low invasiveness: localized and infrequent. Sagebrush habitat is not suitable.	1 – 3
Aggressiveness: growth, mode of reproduction, and seed banking	Score
Highly aggressive: grows rapidly to maturity and may reproduce both vegetatively and by seed. Long flowering period, high seed production and perhaps viability and longevity of seed, or deep rooting system and perhaps ability to re-sprout from roots.	7 - 9
Moderately aggressive: exhibits or more weakly exhibits some reproductive characteristics (above) that may be considered aggressive.	4 - 6
Mildly aggressive: sometimes exhibits or very weakly exhibits one or two characteristics (above) that may be considered aggressive.	1 - 3
Ecological Impacts: species, community composition, and ecosystem processes	Score
High impacts: causes major alterations of structure or composition, e.g., eradicates most or all layers, endangers one or several native species or populations, or significantly reduces nesting or foraging sites. Considerable, possibly irreversible, alteration or disruption of ecosystem processes, e.g., changes in fire frequency.	7 - 9
Moderate impacts: Alters community structure by creating or eliminating a layer, or changes community composition, e.g., reduces population size of one or more species. Alters ecosystem processes by changing mineral or water content in soil, for example.	4 - 6
Minor impacts: Influences community structure or composition, e.g., reduces density of one layer. Affects ecosystem processes to a minor degree, e.g., mild influences on litter depth.	1 - 3
Management Difficulty: general difficulty, level of effort, and accessibility	Score
High difficulty: control of well-established stands usually requires a major, long-term investment of resources. Plants are difficult to prevent from spreading. Effective management tools are limited. Many invaded areas may not be accessible for treatment. Low detectability of plants and patches.	7 - 9
Moderate difficulty: control of established stands requires a major, short-term investment or moderate long-term investment of resources. Effective management tools are sometimes available. Some problems with accessibility.	4 - 6
Low difficulty: control is relatively easy and inexpensive. Effective management tools are available. Sites are accessible.	1 - 3