Date: June 28, 2017

To: Invited Reviewers

Re: Science Framework Part 2 Review

The Science Framework Editorial Team (Karen Prentice and Michele Crist, Bureau of Land Management; Jeanne Chambers, U.S.D.A Forest Service; Sue Phillips, U.S. Geological Survey; and Lief Wiechman, U.S. Fish and Wildlife Service) invites you to provide review and comment on the attached DRAFT of Part 2 of the Science Framework for the Conservation and Restoration (C & R) Strategy, Integrated Rangeland Fire Management Strategy**. You have been invited specifically because of your expertise and experience. You are welcome to comment on any section(s) that may be of interest to you.**

This DRAFT of Part 2 is related to another document, Part 1, that was released earlier this year. Part 1 of the Science Framework focused on the *science basis and applications* for the C & R Strategy. Part 1 provided scientific information and decision-support tools to: 1) facilitate prioritization of areas for conservation and restoration management actions; 2) inform budget prioritization of management actions; and 3) inform management strategies across scales and ownerships. Part 2 of the Science Framework focuses on *management considerations* and is intended to facilitate application of the scientific information and decision-support tools provided in Part 1. Part 2 is meant to enable managers to: 1) implement resource management priorities at large, landscape scales; and 2) apply management strategies that increase ecosystem resilience to disturbance and resistance to invasive plant species at local, project scales. Part 1 of the Science Framework is referenced below, as is a webinar that explains Part 1 and its intended applications.

The Editorial Team is *specifically looking for feedback on: (1) the usefulness of the information provided, especially the management considerations, and how the information could be improved; (2) the organization and clarity of the information provided; and (3) the level of detail (too much/too little/just right)*. Please provide full citations of important peer-reviewed literature the authors might have overlooked. Please note that stylistic edits are not needed, as a professional editor will perform a final review before publication.

The review comments will be assembled by EnviroIssues staff, who are providing administrative support for this effort. The Editorial Team and individual section authors will use your comments to improve Part 2 of the Science Framework. The comments, along with additional discussion among the larger C & R Team, will also be used to develop a final section that integrates the information in the individual sections and discusses management tradeoffs. The intent is to have a final document that is "in press" by the end of 2017.

Please provide your comments on Part 2 of the Science Framework by July 31, 2017. Please send your comments to facilitators@enviroissues.com.

HOW TO PROVIDE COMMENTS

Please use the attached reviewers' spreadsheet to capture your comments. *Due to the number of people involved, we cannot track comments that are not in the reviewer spreadsheet format, and cannot address comments embedded in the report*. The following table describes the intent for each column in the spreadsheet:

Column name	Information
Name	Who provides which comment
Section (dropdown)	Specific section for each comment
Page	Number of the page for each comment
Line number	Line(s) number for each comment
Comments on (1) content, and (2) major editorial concerns	Provide specific comments on the content of the sections. Examples: "Consider this management strategy…" "Rewrite to say…" Also, provide major editorial comments. Example: "Reorganize this section so that management strategies come first."

Thank you in advance for your review and comments. If you have any questions about the review process, how to provide comments, or need any assistance, please contact us at facilitators@enviroissues.com.

For Reference:

General Technical Report: Chambers, J.C.; Beck, J.L.; Bradford, J.B.; Bybee, J.; Campbell, S.; Carlson, J.; Christiansen, T.J.; Clause, K.J.; Collins, G., Crist, M.R.; Dinkins, J.B.; Doherty, K.E.; Edwards, F.; Espinosa, S.; Griffin, K.A.; Griffin, P.; Haas, J.R.; Hanser, S.E.; Havlina, D.W.; Henke, K.F.; Hennig, J.D.; Joyce, L.A.; Kilkenny, F.M.; Kulpa, S.M.; Kurth, L.L.; Maestas, J.D.; Manning, M.; Mayer, K.E.; Mealor, B.A.; McCarthy, C.; Pellant, M.; Perea, M.A.; Prentice, K.L.; Pyke, D.A.; Wiechman, L.A.; Wuenschel, A. 2017. Science Framework for Conservation and Restoration of the Sagebrush Biome: Linking the Department of the Interior's Integrated Rangeland Fire Management Strategy to Long-Term Strategic Conservation Actions. RMRS-GTR-360. Fort Collins, CO: U.S Department of Agriculture, Forest Service, Rocky Mountain Research Station. https://www.treesearch.fs.fed.us/pubs/53983

Webinar: A science framework for assessing threats to sagebrush ecosystems and greater sage-grouse and prioritizing conservation and restoration actions. Sep 26, 2016. Jeanne Chambers and Steve Hanser. http://greatnorthernlcc.org/event/867

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Science Framework for Conservation and Restoration of the Sagebrush Biome: Linking the Department of the Interior's Integrated Rangeland Fire Management Strategy to Long-Term Strategic Conservation Actions

Part 2. Management Applications

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Contents

Navigate to a particular section by pressing the 'Ctrl' key while clicking on the section title.

1. OVERVIEW OF PART 2 OF THE SCIENCE FRAMEWORK

Introduction

In May 2015 the Department of the Interior released "An Integrated Rangeland Fire Management Strategy: Final Report to the Secretary of the Interior," (IRFMS; USDI 2015) that outlined longer-term actions to implement policies and strategies for preventing and suppressing rangeland fire and restoring rangeland landscapes affected by fire in the Western United States. The strategy emphasizes the use of collaboration and integration with partners to prioritize resources, budgets, and capacity; and to promote efficiency and expediency in managing sagebrush (*Artemisia* spp.) rangelands. The IRFMS placed priority on protecting, conserving, and restoring Great Basin sagebrush ecosystems and, in particular, Greater sage-grouse (*Centrocercus urophasianus*; hereafter, GRSG) habitat. The IRFMS identified multiple actions including developing a multi-scale Conservation and Restoration Strategy (C and R Strategy) for sagebrush ecosystems.

Part 1 of the "Science Framework for Conservation and Restoration of the Sagebrush Biome: Linking the Department of the Interior's Integrated Rangeland Fire Management Strategy to Long-Term Strategic Conservation Actions" (Science Framework) focuses on the *science basis and applications* for the C and R Strategy (Chambers et al. 2017). Scientific information and decision-support tools are provided that are intended to: 1) facilitate prioritization of areas for conservation and restoration management actions, 2) inform budget prioritization of management actions, and 3) inform management strategies across scales and ownerships.

Part 2 of the Science Framework focuses on *management considerations* for the C and R Strategy. Information is provided to facilitate application of the scientific information and decision-support tools provided in Part 1 in order to: 1) implement resource management priorities at large, landscape scales, and 2) use management strategies that increase ecosystem resilience to disturbance and resistance to invasive species. Part 2 of the Science Framework is intended to target field managers and resource specialists, while providing a broader context for regional or national level managers. The concepts and approaches that form the basis for Parts 1 and 2 of Science Framework are briefly reviewed in Section 1. The applications of these concepts and approaches to key resource management areas are described in subsequent sections:

Section 2. Adaptive management and monitoring, Section 3. Climate adaptation, Section 4. Wildfire and vegetation management, Section 5. Nonnative invasive plant species management, Section 6. Application of National Seed Strategy concepts, Section 7. Livestock grazing management, and Section 8. Wild horse and burro considerations. The last section, Section 9, is being developed and will discuss integration of the management strategies discussed for the different focal areas, and the trade-offs involved in managing for diverse resources over large landscapes.

Concepts and Approaches Used in the Science Framework

The Science Framework focuses on the sagebrush biome and GRSG, but provides information and tools to allow managers to address other resource values and at-risk species as geospatial data for those values and species become available. A cross-walk is provided between Environmental Protection Agency ecoregions (EPA 2016) and sage-grouse Management Zones (Stiver et al. 2006) (fig. 1.1). This approach aligns with the Sage-grouse Habitat Assessment Framework (Johnson 1980; Stiver et al. 2015). Three scales are included to inform different aspects of the planning process: 1) the sagebrush biome scale where consistent, data across the range of sagebrush and GRSG can inform budget prioritization, 2) the mid-scale (individual or multiple ecoregions and Management Zones) where assessments are typically conducted to inform budget prioritization and develop priority planning areas, and 3) the local scale where local data and expertise are used to select project sites and determine appropriate management strategies and treatments within priority planning areas (table 1.1).

The threats addressed in the Science Framework were identified in the Sage-Grouse Conservation Objectives Team Final Report (COT Report; USFWS 2013) and reflect the threats to sagebrush ecosystems in general. These threats are consistent with those included in the Greater Sage-Grouse Monitoring Framework developed by the Interagency Greater Sage-Grouse Disturbance and Monitoring Subteam (IGSDMS 2014) and the State Wildlife Action Plans, which were prepared for the purpose of maintaining the health and diversity of wildlife within the state and reducing the need for future listings under the Endangered Species Act. In addition to these previously identified threats, climate change is addressed in the Science Framework and climate adaptation strategies are provided.

The Science Framework uses an approach for prioritizing areas for management and determining effective management strategies that is based on ecosystem resilience to disturbance and resistance to invasive species. Resilient ecosystems have the capacity to ***reorganize and regain*** their basic characteristics when altered by stressors such as invasive plant species and disturbances such as improper livestock grazing and altered fire regimes (Holling 1973). Ecosystems that are resistant to invasion by nonnative plants have attributes that limit the establishment and expansion of the invader (D'Antonio and Thomsen 2004**)**. Definitions of the terms used in this document are in Appendix 1. Management focused on ecosystem resilience and resistance can help sustain local communities by ensuring that ecosystem services, such as water for culinary and agricultural use, forage for livestock, and recreational opportunities are maintained or improved over time. The resilience of socio-economic systems, threats to those systems, and current capacities to implement management actions to address those threats is a separate aspect of developing an approach for conservation and restoration of the sagebrush biome that will be addressed elsewhere.

The approach used in the Science Framework is intended to help prioritize areas for management and determine the most appropriate management strategies. The Science Framework is based on: 1) the likely response of an area to disturbance or stress due to threats and/or management actions (i.e., resilience to disturbance and resistance to invasion by nonnative plants), 2) the capacity of an area to support target species and/or resources, and 3) the predominant threats. It uses a mid-scale approach and has six steps.

- Identify focal species or resources and key habitat indicators for the assessment area, and then delineate their distribution or area using the best information available. For GRSG, this currently includes the recently modeled breeding habitat probabilities and the population index (Doherty et al. 2016). Information and tools are provided to allow managers to address other resource values and at-risk species as geospatial data for those values and species become available.
- Develop an understanding of ecosystem resilience and resistance for the assessment area. At landscape scales, the resilience and resistance of sagebrush ecological types are closely linked to soil temperature and moisture regimes (Chambers et al. 2014a, b; Chambers et al. 2017), and soil temperature and moisture regimes are used to quantify and map resilience and resistance (Appendix 2; Maestas et al. 2016a). More detailed

information on soil characteristics and ecological site descriptions assist managers to step-down generalized vegetation dynamics, including resilience and resistance concepts, to local scales.

- Integrate ecosystem resilience and resistance with species or resource habitat requirements and develop a decision matrix that can be used to spatially link ecosystem resilience and resistance, habitat requirements, and management strategies (fig. 1.2).
- Assess the key threats in the assessment area using geospatial data and maps.
- Prioritize areas for management in the assessment area using geospatial data and maps of species or resource habitat requirements, such as the breeding habitat probabilities for GRSG, resilience and resistance, and the key threats.
- Determine the most appropriate management strategies for areas prioritized for management based on its habitat characteristics, relative resilience and resistance, and predominant threats. The management strategies are developed in collaboration with stakeholders and are reconciled with socio-economic and budgetary considerations.

These six steps help identify priority areas for management and overarching management strategies for the assessment area. Key aspects of the approach are sage-grouse habitat resilience and resistance matrix (table 1.2) and the linked management strategies for addressing threats to sagebrush ecosystems (table 1.3). To step down ecoregion/Management Zone priorities to the local scale, managers and stakeholders are engaged to: 1) refine priorities and management strategies based on higher resolution geospatial products, additional species information, and local knowledge (including traditional ecological knowledge), 2) select specific project areas, and 3) identify opportunities to leverage partner resources.

Part 1 of the Science Framework provides methods and decision tools for determining the suitability of an area for management actions as well as the most appropriate management strategies. Part 2 provides the necessary detail to effectively implement the management strategies for key resource management areas.

Application of the Science Framework

The Science Framework, both Part 1, science basis and applications, and Part 2, management considerations, are intended to be adaptive and will be updated to highlight potential management considerations as new science and information on resources and focal species become available. The Western Association of Fish and Wildlife Agencies and U.S. Fish and Wildlife Service (FWS) have developed the Sagebrush Science Initiative, which has identified and prioritized science needs for conservation of sagebrush dependent species and allocated funding to address them. As information and data are compiled for these species, they will be used to inform the Science Framework. Future updates to the Science Framework can be further informed by the outcomes of the research conducted as part of implementation of the Actionable Science Plan (IRFMSASPT 2016). The State Wildlife Action Plans provide a resource for more detailed information for the Science Framework at the state level, while the Science Framework provides a resource for the state plan revisions.

The Sagebrush Science Initiative, with additional support from the Department of Interior and the Bureau of Land Management (BLM), is developing a collaborative strategy to conserve sagebrush, sagebrush dependent species, and human uses of the sagebrush system that adopts the use of resistance and resilience concepts, threat assessments, and habitat prioritization methods described in the Science Framework. This strategy will identify sagebrush dependent species and associated habitat and vegetation types for the sagebrush biome as a whole.

To support use of the Science Framework, geospatial data, maps, and models are provided through the U.S. Geological Survey (USGS) ScienceBase (https://www.sciencebase.gov/catalog/item/576bf69ce4b07657d1a26ea2) and BLM Landscape Approach Data Portal (http://www.blm.gov/wo/st/en/prog/more/Landscape_Approach/dataportal.html).

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Table 1.1—Scales and areas included in the strategic approach for managing threats to sagebrush ecosystems, sage-grouse, and other sagebrush obligate species and the data, tools, models, and processes considered at each scale or area. (table 2 in Part 1 of the Science Framework; Chambers et al. 2017).

Area	Geographic scale	Map extent	Data, Tools, Models	Process
Sagebrush biome and multiple Management Zones	Broad	West-wide	Habitat Soils Population data and models Priority resource data Fire and other threat data Climate change projections	Budget Prioritization within DOI for Rangewide Consistency
Sage-grouse Management Zones and ecoregions	Mid	State or National Forest	Above, plus Assessments and planning docs Regional data and models Regional tools	Assessments at Ecoregion/MZ Scales for Prioritization of Management Actions
Local planning areas	Local	District, Field Office, or Project Area	Above, plus Local data and information	Selection of Treatment Types within Prioritized Project Areas

Table 1.2—Sage-grouse habitat resilience and resistance matrix based on resilience and resistance concepts from Chambers et al. (2014a, b), and GRSG breeding habitat probabilities from Doherty et al. (2016). Rows show the ecosystem's relative resilience to disturbance and resistance to invasive annual grasses (1 = high resilience and resistance; 2 = moderate resilience and resistance; 3 = low resilience and resistance). Resilience and resistance categories were derived from soil temperature and moisture regimes (see Appendix 2; Maestas et al. 2016) and relate to the sagebrush ecological types in table 6 in Part 1. Columns show the landscape-scale sage-grouse breeding habitat probability based on table 7 in Part 1 (A = 0.25 to < 0.5 probability; B = 0.5 to < 0.75 probability; C = ≥ 0.75 probability). Use of the matrix is explained in text. Potential management strategies for persistent ecosystem threats, anthropogenic threats, and climate change are in table 1.2 (table 8 in Part 1 of the Science Framework; Chambers et al. 2017).

Landscape-Scale Sage-Grouse Breeding Habitat Probability

Ecosystem Resilience to Disturbance and Resistance to Invasion	Low (0.25 to < 0.5 probability)	Moderate (0.5 to < 0.75 probability)	High (≥ 0.75 probability)
	Landscape context is likely limiting habitat suitability. If limiting factors are within management control, significant restoration may be needed. These landscapes may still be important for other seasonal habitat needs or connectivity.	Landscape context may be affecting habitat suitability and could be aided by restoration. These landscapes may be at higher risk of becoming unsuitable with additional disturbances that degrade habitat.	Landscape context is highly suitable to support breeding habitat. Management strategies to maintain and enhance these landscapes have a high likelihood of benefiting sage-grouse.
High	1A	1B	1C
Moderate	2A	2B	2C
Low	3A	3B	3C

1A, 1B, 1C (High):

Potential for favorable perennial herbaceous species recovery after disturbance without seeding is typically high.

Risk of invasive annual grasses becoming dominant is relatively low. EDRR can be used to address problematic invasive plants.

Tree removal can increase habitat availability and connectivity in expansion areas.

Seeding/transplanting success is typically high.

Recovery following inappropriate livestock use is often possible given changes in management.

2A, 2B, 2C (Moderate):

Potential for favorable perennial herbaceous species recovery after disturbance without seeding is usually moderately high, especially on cooler and moister sites

Risk of invasive annual grasses becoming dominant is moderate, especially on warmer sites. EDRR can be used to address problematic invasive plants in many areas.

Tree removal can increase habitat availability and connectivity in expansion areas.

Seeding-transplanting success depends on site characteristics, and more than one intervention may be required especially on warmer and drier sites.

Recovery following inappropriate livestock use depends on site characteristics and management.

3A, 3B, 3C (Low):

Potential for favorable perennial herbaceous species recovery after disturbance without seeding is usually low.

Risk of invasive annual grasses becoming dominant is high. EDRR can be used to address problematic invasive plants in relatively intact areas.

Seeding/transplanting success depends on site characteristics, extent of annual invasive plants, and post-treatment precipitation, but is often low. More than one intervention likely will be required.

Recovery following inappropriate livestock use is unlikely without active restoration.

Table 1.3—Management strategies for persistent ecosystem threats, climate change, and land use and development threats. Recommendations are provided for prioritizing and targeting strategies based on cells in the sage-grouse habitat resilience and resistance matrix (table 1.1). Threats and strategies are cross-cutting and affect multiple program areas. While many of these fall under the broad umbrella of vegetation management, a coordinated and integrated approach will likely be used in addressing threats. For example, it is expected that multiple agency program areas such as nonnative invasive plant management, fuels management, range management, wildlife, and others will contribute to strategies that use vegetation manipulation to address persistent ecosystem and anthropogenic threats (table 9 in Part 1 of the Science Framework; Chambers et al. 2017).

Threat--Nonnative Plant Invasive Species

Management strategies

- Apply integrated vegetation management practices to manage nonnative invasive plant species, using an interdisciplinary and coordinated approach in designing and implementing projects and treatments.
  - Prioritize areas where management resources are likely available to ensure successful management in the long-term.
- Use resilience and resistance categories and knowledge of invasive plant distributions to select appropriate management approaches.
  - Protect high quality (relatively weed-free) sagebrush communities with moderate-to-high sage-grouse habitat probabilities (cells 1B, 1C, 2B, 2C, 3B, 3C):
    - Focus on preventing introduction and establishment of invasive plant species, especially in low resistance areas with high susceptibility to annual grass invasion (in and adjacent to cells 3B, 3C);
    - Avoid seeding introduced forage species (crested wheatgrass, smooth brome, etc.) in post-fire rehabilitation or restoration in moderate to high resilience and resistance areas because these species can dominate sagebrush communities; and
    - Practice Early Detection-Rapid Response (EDRR) approaches for emerging invasive species of concern (in and adjacent to cells 1B, 1C, 2B, 2C, 3B, 3C).
  - Where weed populations already exist, seek opportunities to maximize treatment effectiveness by prioritizing restoration within relatively intact sagebrush communities (cells 1B, 1C, 2B, 2C, 3B, 3C). Restoration will likely be easier at locations in cooler and moister ecological types with higher resilience and resistance.
    - Prioritize sites with sufficient native perennial herbaceous species to respond to release from invasive plant competition;
    - Manage grazing to reduce invasive species and promote native perennial grasses. In the West-Central Semiarid Prairies and other cool and moist areas, manage grazing to reduce crested wheatgrass, Kentucky bluegrass, smooth brome, and other introduced forage species and to promote native cool season perennial grasses (see grazing strategies).
  - Restrict spread of large weed infestations located in lower breeding habitat probability areas (cells 1A, 2A, 3A) to prevent compromising adjacent higher quality habitats (cells 1B, 1C, 2B, 2C, 3B, 3C).

Threat—Conifer Expansion

Management strategies

- Addressing localized conifer expansion requires an interdisciplinary approach and necessarily involves multiple program areas.
    - Apply integrated vegetation management practices to treat conifer expansion, using an interdisciplinary approach in designing projects and treatments.
    - Focus tree removal on early to mid-phase (e.g., Phases I, II) conifer expansion into sagebrush ecological sites to maintain shrub/herbaceous cover.
    - Use prescribed burning cautiously and selectively in moderate to high resilience/resistance (cells 1A, 1B, 2A, 2B) to control conifer expansion.
    - Prioritize for treatment:
        - Areas with habitat characteristics that can support sage-grouse with moderate to high resilience and resistance (cells 1B, 1C, 2B, 2C), especially near leks. (Note: cells 3B and 3C are generally too warm and dry to support conifers.)
        - Areas where conifer removal will provide connectivity between sagebrush habitats.

Areas where sufficient native perennial grasses and forbs exist to promote recovery and limit increases in invasive plant species.

Threat--Wildfire

Management strategies

The wildfire threat is generally addressed through fire operations, fuels management (mechanical treatments, prescribed burning, chemical and seeding treatments), and post-fire rehabilitation.

Fire Operations: Protection of areas supporting sagebrush is important for maintaining sagebrush habitat. The types and locations of GRSG habitats have been incorporated into decision support, dispatch, and initial attack procedures, and represent key considerations for fire managers.

If resources become limiting, consider the following prioritization:

- Fire suppression - typically shifts from low to moderate priority when resilience and resistance categories shift from high to moderate, but varies with large fire risk and landscape condition (cells 1B, 1C, 2B, 2C). In low resilience and resistance areas, the priority shifts from moderate to high as sage-grouse habitat probability increases (cell 3B, 3C). Scenarios requiring high priority may include:
    - Areas of sagebrush that bridge large, contiguous expanses of sagebrush and that are important for providing habitat connectivity;
    - Areas where sagebrush communities have been successfully reestablished through seedings or other rehabilitation investments; and
    - All areas during critical fire weather conditions, where fire growth may move into valued sagebrush communities. These conditions may be identified by a number of products including, but not limited to: Predictive Services National 7-Day

Significant Fire Potential products; National Weather Service Fire Weather Watches and Red Flag Warnings; and fire behavior analyses and local fire environment observations.

Fuels Management: Fuels management is a subset of vegetation management. Fuels management activities include treatments that mitigate wildfire risk, modify fire behavior, improve resilience to disturbance and resistance to invasive annual grasses, and protect and restore habitat. Mechanical treatments are typically applied to reduce fuel loading, modify fire behavior, augment fire suppression efforts, or alter species composition consistent with land use plan objectives. Roadside fuel breaks are applied most commonly in MZ III, IV, and V. Prescribed burning is one form of fuels management that may be used to improve habitat conditions or create fuel conditions that limit future fire spread in areas with moderate to high resilience and resistance, but should be considered only after consultation with local biologists and land managers. Chemical and seeding treatments are conducted to reduce invasive plants and change species composition to native and/or more fire resistant species where native perennial grasses and forbs are depleted. When setting priorities for fuels management, consider the following.

<u>Mechanical Treatments – Conifer Removal</u>

- Conifer removal conducted to decrease woody fuels and reduce the loss of large, contiguous sagebrush stands are high priority in areas with high GRSG breeding habitat probabilities and moderate to high resilience and resistance (cells 1B, 1C, 2B, 2C), and shift to low in areas with low breeding habitat probabilities (cells 1A and 2A). In these areas, the focus is primarily on conifer expansion areas with sufficient native perennial understory species for recovery.
- Management activities may include:
    - Tree removal in early to mid-phase (Phases I, II) post-settlement conifer stands to maintain shrub/herbaceous cover and reduce fuel loads; and
    - Herbicide and/or seeding associated with mechanical treatments to reduce invasive species and restore native perennial herbaceous species where native perennial species are depleted.

<u>Mechanical Treatments - Fuel Breaks</u>

Fuel breaks are strategically placed treatments where vegetation is modified in order to change fire behavior, making fire control efforts safer or more effective. Common types of fuel breaks include road maintenance/roadside disking (brown strips), mowed fuel breaks, and vegetative fuel breaks (greenstrips).

- In areas of low resilience and resistance, fuel breaks may increase in priority as sage-grouse habitat probability increases (cells 3B, 3C). Repeated treatments may be necessary to maintain functional fuel breaks.
- Key management considerations for the design and placement of fuel breaks are:
    - Implemented where fire managers believe they will benefit suppression efforts;
    - Designed at large landscape scales, providing multiple options for fire managers;
    - Designed collaboratively with interdisciplinary specialists, private landowners, fire response partners, and other agencies;
    - Include plans for long-term monitoring and maintenance;

    - Designed to minimize habitat impacts, including nonnative invasive species introduction and spread, while maximizing potential fire management benefits.
- Key ecological considerations for the design and placement of fuel breaks:
    - Design fuel breaks in an interdisciplinary setting which addresses the need, cumulative effects, alternative treatments, and possible undesired results;
    - Consider ecosystem resilience and resistance and place fuel breaks to minimize catastrophic ecological state changes;
    - Includes conservation buffers around sagebrush leks, habitat fragmentation thresholds and minimum habitat patch sizes;
    - Includes the influence on habitat connectivity between seasonal sage-grouse habitats;
    - Follow technical guidance related to recommended design features (see Maestas et al. 2016b).

<u>Prescribed Fire</u>

Prescribed fire to address the threat of wildfire includes burning to reduce woody biomass resulting from treatments, to control conifer expansion, to reduce hazardous fuels, and to create fuel breaks which augment fire suppression efforts. When setting priorities for prescribed fire, consider the following:

- Consider alternatives to prescribed burning where other treatment alternatives may meet management objectives.
- In low resilience and resistance areas, consider prescribed fire only after consultation with local biologists and land managers and when:
    - Site information, such as state-and-transition models, affirm that the post-burn trajectory will lead to functioning sagebrush communities. Most low resilience and resistance areas that receive < 12 in/yr (30.5 cm/yr) of precipitation do not respond favorably to burning (See Miller et al. 2014.)
    - Burning is part of multi-stage restoration projects where burning is required to remove biomass following chemical treatments for site preparation or for improved chemical applications.
    - Monitoring data validates that the pre-burn composition will lead to successful, native plant dominance post-burn
- Use prescribed fire cautiously and selectively in moderate to high resilience and resistance areas, after consultation with local biologists and land managers and assessing site recovery potential and other management options based on the following:
    - Pre-burn community composition;
    - Probability of invasive species establishment or spread;
    - Historic fire regime, and patch size/pattern to be created by burning;
    - Wildfire risk and desired fuel loading to protect intact sagebrush; and
    - Alternative treatments that may meet objectives.

<u>Chemical Treatment of Nonnative Invasive Plant Species and Seeding</u>

Chemical treatments and seedings are used to decrease invasive species composition and increase native species dominance in areas where native perennial grasses and forbs are insufficient for site recovery. Chemical and seeding treatments may be selectively applied in conjunction with prescribed fire or mechanical treatments. Typically, these treatments are in response to clear evidence of a nonnative invasive species threat. Areas of higher priority for chemical and seeding treatments:

- Lower resistance and resilience cells (2A, 2B, 3A, 3B) lacking the ability for natural recovery;
- Recently disturbed areas where recovery will not occur without chemical or seeding treatments;
- Areas where investments have been made and objectives cannot be attained without chemical or seeding treatments.

Post-Fire Rehabilitation: General considerations for prioritization of post-fire rehabilitation efforts are:

- Priority generally increases as resilience and resistance decrease and habitat probability for sage-grouse increases. High priorities include areas of low to moderate resilience and resistance that (1) lack sufficient native perennial grasses and forbs to recover on their own and (2) have nearby areas still supporting sage-grouse habitat (cells 2B, 2C, 3B, 3C). Areas of low habitat probability for sage-grouse (cells 2A, 3A) are generally lower priority but may become higher priority in areas that support other resource values or that increase connectivity for GRSG populations.
- Areas of higher priority across all cells include:
    - Areas where pre-fire perennial herbaceous cover, density, and species composition is inadequate for recovery (see Miller et al. 2015);
    - Areas where seeding or transplanting sagebrush is needed to maintain habitat connectivity for sage-grouse;
    - Areas threatened by nonnative invasive plants; and
    - Steep slopes and soils with erosion potential.

Threat—Sagebrush Reduction

Management strategies

- Avoid intentional sagebrush removal (either prescribed fire or mechanical removal) across all areas in the West-Central Semiarid Prairies due to relatively limited sagebrush availability and extended periods of recovery in the region. Many areas are characterized by moderate to moderately low resilience and resistance, and many sagebrush species lack the capacity to resprout.
- Use caution when attempting to increase herbaceous perennials by reducing sagebrush dominance through mechanical or chemical treatments in general.
    - Lower resistance and resilience areas are prone to annual grass increases and potential dominance if invasive annual grasses exist in the area before treatment.
    - Pretreatment densities of 2 to 3 native perennial bunch grasses per square meter are often necessary for successful increases in perennial herbaceous plants and for suppression of invasive annual grasses after treatment in lower resistance and resilience areas (Miller et al. 2014, 2015).

Threat—Climate Change

Management strategies

- Continue to use best management practices where effects of climate change and its interactions with stressors are expected to be relatively small and knowledge and management capacity are high.
- Consider proactive management actions to help ecosystems transition to new climatic regimes where climate change and stressor interactions are expected to be severe.
- Practice drought adaptation measures such as reduced grazing during droughts, conservation actions to facilitate species persistence, and seeding and transplanting techniques more likely to work during drought. Consider developing formal drought management plans for livestock grazing.
- Anticipate and respond to species declines such as may occur on the southern or warmer edges of their geographic range.
- Favor genotypes for seeding and out-planting that are better adapted to future conditions because of pest resistance, broad tolerances, or other characteristics.
- Increase diversity of plant materials for restoration activities to provide those species or genotypes likely to succeed.
- Protect future-adapted regeneration from inappropriate livestock grazing.
- Monitor transition zones between climatic regimes (the edges) to provide advanced warning of range shifts. Plant community shifts that affect management decisions often occur between Major Land Resource Areas or Level III Ecoregions.

Threat—Cropland Conversion

Management strategies

- Secure Conservation Easements to maintain existing sagebrush grasslands and sage-grouse habitat and prevent conversion to tillage agriculture. Prioritize all areas supporting moderate-to-high sage-grouse habitat probability (cells 1B, 1C, 2B, 2C, 3B, 3C) in locations where tillage risk is elevated (see Sage Grouse Initiative, Cultivation Risk layer).
- Secure term leases (e.g., 30 years) to maintain existing sagebrush grasslands and sage-grouse habitat and prevent conversion to tillage agriculture as a secondary strategy to Conservation Easements. Prioritize all areas supporting moderate-to-high sage-grouse habitat probability (cells 1B, 1C, 2B, 2C, 3B, 3C) especially in locations where tillage risk is elevated (see SGI Cultivation Risk layer).
- Offer alternatives to farming on expired USDA Conservation Reserve Program (CRP) lands through federal and state programs. Prioritize lands in and around intact habitats (cells 1B, 1C, 2B, 2C, 3B, 3C).

  Encourage enrollment in the USDA CRP or similar programs to return tilled lands to perennial plant communities supporting mixtures of grasses, forbs, and sagebrush where there are benefits to sage-grouse. Prioritize lands in and around intact habitats (cells 1B, 1C, 2B, 2C, 3B, 3C).

Threat—Energy Development

Management strategies

- Avoid development, if feasible, in areas with high breeding habitat probability for sage-grouse and high sagebrush cover (cells 1C, 2C, 3C) and steer development in non-habitat areas (1A, 2A, 3A).
- Minimize habitat fragmentation in areas with moderate and high breeding habitat probabilities for sage-grouse (cells 1B, 2B, 3B, 1C, 2C, 3C).
- For disturbances that remove vegetation and cause soil disturbance, minimize and mitigate impacts (top soil banking, certified weed-free [including annual bromes] seed mixes, appropriate seeding technologies, and monitoring). Plan for multiple restoration interventions in areas with low resilience and resistance (cells 3B, 3C).
- Minimize or co-locate energy transport corridors (e.g., roads, pipelines, transmission lines) and limit vehicle access, where feasible.
- Maintain resilience and resistance of existing patches of sagebrush habitat by aggressively managing weeds that may require the following management practices (especially important in low resilience and resistant areas - cells 3A, 3B, 3C):
    - A weed management plan that addresses management actions specific to a project area;
    - Use certified weed-free (including annual bromes) gravel and fill material;
    - Assess and treat weed populations, if necessary, prior to surface disturbing activities;
    - Remove mud, dirt, and plant parts from construction equipment;
    - Address weed risk and spread factors in travel management plans;
    - Ensure timely establishment of desired native plant species on reclamation sites;
    - Use locally adapted native seed, whenever possible;
    - Intensively monitor reclamation sites to ensure seeding success, determine presence of weeds, and implement corrective actions as necessary;
    - Use mulch, soil amendments, or other practices to expedite reclamation success when necessary; and
    - Ensure weeds are controlled on stockpiled topsoil.

Threat—Urban and Exurban Development

Management Strategies

- Secure conservation easements to maintain existing sagebrush stands and sage-grouse habitat. Prioritize areas with high habitat probability for sage-grouse and high sagebrush cover (cells 1C, 2C, 3C).
- Encourage the protection of existing sage grouse habitat through appropriate land use planning and federal land sale policies. Steer development towards non-habitat (cells 1A, 2A, 3A) where habitat is unlikely to become suitable through management

Threat—Livestock Grazing

Management strategies

- Manage livestock grazing to maintain a balance of native perennial grasses (warm and/or cool season species as described in Ecological Site Descriptions for that area), forbs, and biological soil crusts to allow natural regeneration and to maintain resilience and resistance to invasive plants. Ensure strategies prevent degradation and loss of native cool-season grasses in particular. Areas with low to moderate resilience and resistance may be particularly vulnerable (cells 2A, 2B, 2C, 3A, 3B, 3C).

- Implement grazing strategies that incorporate periodic deferment from use during the critical growth period, especially for cool season grasses, to ensure maintenance of a mixture of native perennial grasses. This strategy is important across all sites, but particularly essential on areas with low to moderate resilience and resistance supporting sage-grouse habitat (cells 2B, 2C, 3B, 3C).
- Ensure grazing strategies are designed to promote native plant communities and decrease nonnative invasive plants. In ephemeral drainages and higher precipitation areas in the West-Central Semiarid Prairies that receive more summer moisture and have populations of nonnative invasive plant species, too much rest may inadvertently favor species such as field brome, Kentucky bluegrass, and smooth brome. Adjustments in timing, duration, and intensity of grazing may be needed to reduce these species.

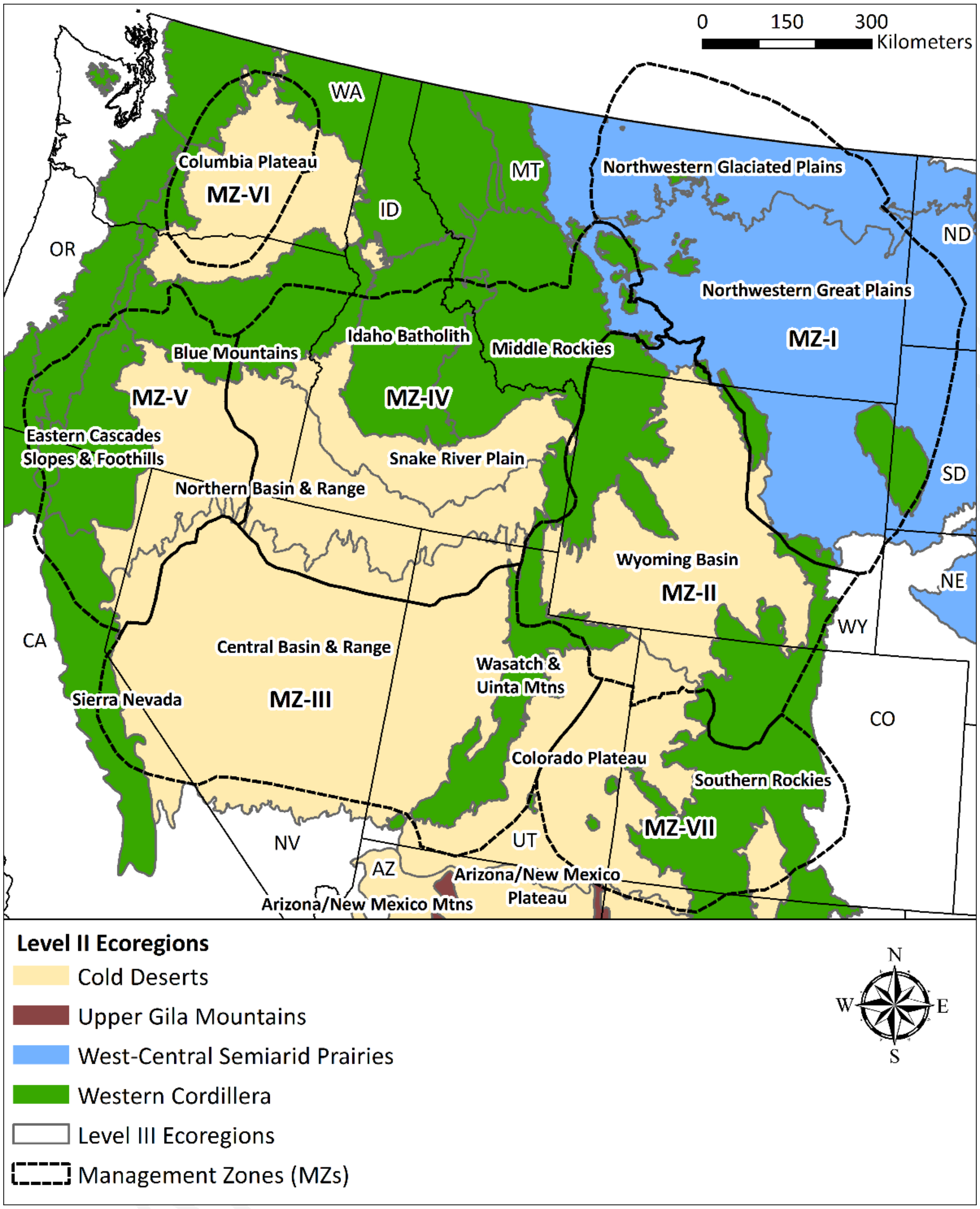

Figure 1.1—A cross-walk between Level II and Level III Ecoregions (EPA 2016) and sage-grouse Management Zones (MZs; Stiver et al. 2006) (fig. 1 in Part 1 of the Science Framework; Chambers et al. 2017).

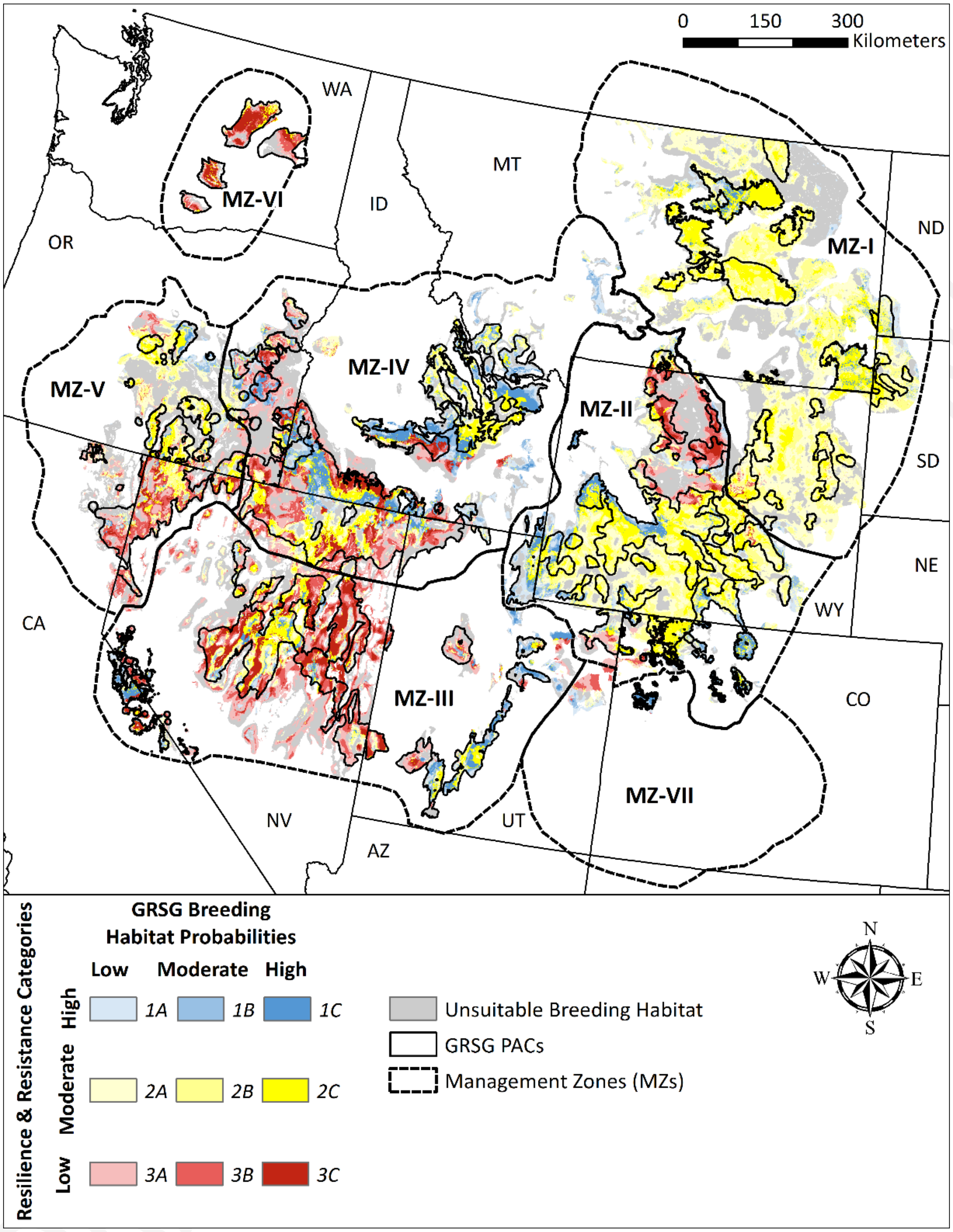

Figure 1.2—Greater sage-grouse (GRSG) breeding habitat probabilities based on 2010–2014 lek data (Doherty et al. 2016) intersected with resilience and resistance categories developed from soil temperature and moisture regimes (Chambers et al. 2017). This map provides a spatial depiction of the sage-grouse habitat resilience and resistance matrix (fig. 38 in Part 1 of the Science Framework; Chambers et al. 2017).

2. ADAPTIVE MANAGEMENT AND MONITORING

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Introduction

Monitoring programs designed to track ecosystem changes in response to both stressors and disturbances can use repeated observations of ecosystem attributes. Such programs can increase our understanding of how interactions among resilience to disturbance, resistance to invasive species, and a suite of 'change agents' (e.g., disturbance, management actions, and climate), influence resource conditions and trends and subsequent outcomes of conservation and restoration actions. This type of monitoring information provides the basis for adaptive management. The overarching goals of an integrated monitoring and adaptive management program are to reduce the uncertainty of management actions over time by modifying management objectives and strategies to increase the effectiveness of those actions.

An integrated monitoring and adaptive management program includes a series of steps that are repeated over time and are designed to facilitate "learning by doing" (fig. 2.1). Using a structured decision making process is necessary for developing meaningful objectives, and when used in the assessment and design, these steps can aid land managers and stakeholders in examining the context, options, and probable outcomes of decisions through an explicit and repeatable process (Allen et al. 2011; Marcot et al. 2012; Thomson et al 2013). The first step, assessment, involves defining the problem, identifying objectives, and determining evaluation criteria. In the second step, design, the alternatives are defined, the consequences and key uncertainties identified, and tradeoffs evaluated. Next, the preferred alternative is identified, and the decision is made to implement the preferred alternative and management action.

Monitoring is a key step in adaptive management. The information from a well-designed monitoring program is used to evaluate ecological status and trends and whether or not management objectives are being met. A well-designed monitoring program has multiple components (table 2.1). Elzinga et al. (1998) describe how to establish a monitoring program for plant populations, and Hayward and Suring (2013) describe this process for wildlife habitat monitoring. Both sources provide the necessary information for developing monitoring programs for other types of resources.

Monitoring is most effective for adaptive management when the objectives are clearly defined and are consistent with the broader management objectives for the resource (table 2.1). To determine if the objectives are being met, specific indicators are identified that can be measured and can account for changes in the resource within a realistic timeframe given the site potential of the area being managed. To provide a clear path for management options/alternatives under adaptive management, monitoring triggers (levels of change to maintain management or to cause adjustments/alternatives in future management actions) and management responses to the triggers are specified before actions are implemented (Goldstein et al. 2013).

A rigorous monitoring design is needed to estimate the proportion of an area that is or is not meeting certain objectives or standards (table 2.1). An unbiased estimate of resource conditions and changes can be gained by incorporating randomization into sampling designs for ecosystems, species, and populations. Describing the likely data analysis techniques can help ensure that the sampling design will produce meaningful results.

Once the monitoring program is implemented, monitoring of the indicators is repeated over sufficient, pre-determined time intervals to detect changes and trends in land status at the spatial scale of management interest. After each measurement cycle is complete, the data are entered into standardized databases, verified, and backed-up. The monitoring data are then analyzed to assess if the management objective has been achieved or if any triggers (soft or hard) have been tripped. Management is either continued or changed at the scale necessary to achieve the desired response or condition (Section 1. Overview, table 1.1). Natural resource decisions are often complex, and made with uncertainty, yet managers and biologists are expected to effectively justify and communicate their decisions. In the context of the Science Framework Part 1 (Chambers et al. 2017), monitoring results can be used to adjust priority areas for programs of work and budget allocation, to inform Land Use Plan and State Wildlife Action Plan revisions, to assess the effectiveness of management strategies and treatment methods, and guide improvements.

Overview of the Types of Monitoring

Monitoring can be subdivided into two main categories. The first category describes the ecological status and trends of management areas, while the second category evaluates how well management objectives are being met in project areas. For the purposes of this document, we define “treatments” as site-specific management actions that directly influence one or more of the four ecosystem attributes that are defined below (e.g., biotic integrity can be influenced by conifer removals, fuel treatments, or greater sage-grouse (GRSG) population size). “Projects” can encompass multiple treatments and may relate to broader-scale landscape objectives. “Management action” is a general term that includes active treatments, but may also include passive actions such as changing management of livestock grazing, recreational uses, etc.

Regardless of the type of monitoring, four ecosystem attributes (described below) are important to monitor when determining ecosystem status of an individual management unit (local scale), an ecoregion or Management Zone (mid scale), or the sagebrush biome (broad scale). Because these attributes are difficult to measure directly, they are tracked through multiple indicators (see Herrick et al. 2010, 2015).

Soil Stability and Health – Soil is the basic foundation of terrestrial ecosystems and thus the attributes of soil stability and soil health (quality) are critical elements for sustaining plant, animal, fungal, and microbial functions.

Hydrologic Function – Hydrologic function of terrestrial systems is closely linked to soil stability and quality. All land types (upland, wetland, and riparian ecosystems) are important for maintaining the capture, storage, and release of water.

Water Flow and Quality – Lentic (still water) and lotic (moving water) ecosystems have unique functions as basic resources for biotic integrity, but their capacity to function properly (e.g., recharge and discharge of water to or from the soil) may be linked to other attributes such as soil stability (e.g., sedimentation) or hydrologic function.

Biotic Integrity – Biotic integrity of the plant, animal, fungal, and microbial components of the ecosystem, whether on land or in water, is closely linked to resilience to disturbance and resistance to invasion.

Monitoring Ecological Status and Trends (Condition and Change)

Status and trend monitoring aims to understand the current condition of natural resources (status) as well as changes in resource condition over time (trends). This type of monitoring informs adaptive management decision-making by revealing whether thresholds/triggers in soil stability and health, hydrologic function, water flow and quality, and biotic integrity have been reached and if subsequent management actions are necessary. Status and trends monitoring in sagebrush ecosystems can address questions about the quality and quantity of habitat, the spatial distribution of observed changes, and when possible, *why* resource conditions are changing over time. Such monitoring is often a subset of a larger program or inventory aimed at a broad set of resources within a particular land ownership/jurisdiction. Ideally, standardized protocols across land ownership/jurisdictional boundaries can be aggregated to understand changes at multiple scales (Rowland and Vojta 2013). Monitoring may be intensified in areas where more information is needed such as in high-priority GRSG habitat or areas with low resilience and resistance (table 1.2; cells 3B and 3C). Determining causal associations between resource conditions and drivers of change, such as land management decisions or climate change, can be accomplished using information from status and trends monitoring along with spatial information about those drivers (text box 1).

> **Text Box 1 – Climate Change Effects**
>
> Results from long-term monitoring plots can document co-occurring landscape-level changes and climate changes. Combining ground-based monitoring with remote sensing can help scale-up to assess which species, communities, and habitats may be vulnerable to climate change. Monitoring along environmental gradients is most likely to help detect early change. Monitoring in areas projected to exhibit rapid change (rapid warming events, loss of snowpack, extreme drought) will verify management strategies to help ecosystems transition to the new climatic conditions (See Part 2, Section 3).

An unbiased estimate of resource conditions and changes can be gained by incorporating randomization into sampling designs across an area and resource of interest. A rigorous monitoring design can also be used to estimate the proportion of an area that is or is not meeting certain objectives or standards, which is often of interest in heterogeneous landscapes. Finally, this type of monitoring can provide information at multiple scales of interest. Several monitoring programs have been developed to address status and trend of resources including: the BLM's Assessment Inventory and Monitoring (AIM) and NRCS's National Resources Inventory (NRI;

both of which use common indicators and protocols), the USFS Forest Inventory and Analysis (FIA) program, and the national Landscape Monitoring Framework that is part of the BLM's AIM strategy. Although FIA and NRI/AIM use different measurement techniques, their sample designs allow for analyses that cross administrative boundaries provided appropriate analytical methods are implemented (Patterson et al. 2014). Regional and smaller scale monitoring efforts are also implemented through BLM AIM, the National Park Service Inventory and Monitoring Program, National Inventory and Monitoring Initiative (I&M) managed by the National Wildlife Refuge System, and other efforts. In general, monitoring is the recommended means of understanding status and trends of GRSG habitat (e.g., Stiver et al. 2015; USDOI 2014).

Monitoring to Evaluate Management Objectives

To evaluate whether management objectives are being met, measurements can be conducted at multiple scales, e.g., at the management unit (local-scale); Management Zones (MZ) or ecoregions (mid-scale); and sagebrush biome (broad-scale). There are three types of monitoring typically used to monitor management objectives defined below: *Implementation*, *Effectiveness*, and *Validation* monitoring.

Implementation monitoring

Implementation monitoring determines whether planned management decisions, actions, and treatments have been implemented, and if standards outlined within planning documents were followed or modified. The BLM and USFS report on the actions implemented that are described in their Land Use Plans and that relate to decisions aimed at conserving, improving, or restoring sagebrush habitats (USDOI 2014). Initially, this type of monitoring is conducted by planning unit; however given the consistencies across planning unit boundaries, this level of monitoring can be scaled up to the Management Zone/ecoregion scale.

Effectiveness monitoring

Effectiveness monitoring assesses the condition of a management action's outcome. Success is typically achieved by meeting pre-determined treatment objectives which can be measured against baseline or reference conditions determined by status and trends monitoring, or another desired condition stipulated in the treatment objectives (table 2.1). An example of this kind of monitoring at the project scale is conducted through the removal of expanding conifers or nonnative plants in order to restore GRSG habitat. Monitoring indicators such as landscape cover of conifers or nonnative invasive plants relative to perennial native grasses and forbs post-treatment would be compared against pre-treatment levels (baseline). Depending on understory quality, subsequent use by an adjacent population of GRSG could support the efficacy of the treatment. At the Management Zone/ecoregion scale, the effectiveness of multiple projects can help inform the effectiveness of the management objectives contained within a Land Use Plan or other guiding management strategy. If project objectives are tied to landscape level indicators, then there may be an opportunity to assess the effectiveness of efforts in achieving conservation goals at the biome level. This type of monitoring also lends itself to evaluating the effectiveness of, and potential benefit achieved from mitigation efforts.

Validation monitoring

Validation monitoring uses an experimental approach to determine if the observed outcome is due to the management action. This requires leaving some areas untreated to serve as a “control” for the treated areas. The untreated areas are compared to the treated areas to determine if they differ in meeting the stated objectives. For example, after a wildfire in a Wyoming big sagebrush ecosystem at low to mid elevations with low to moderate resilience and resistance, restoration efforts might focus on seeding Wyoming big sagebrush and native perennial bunchgrasses in a randomly selected sample of potential treatment sites. After X years (‘X’ is equal to the time stated in the objectives statement) of monitoring, cover of native perennial bunchgrasses and stem density of sagebrush are measured to determine if they are trending towards desired management objective. Such validation monitoring would discern whether this outcome is a product of the management/treatment actions, if it represents natural regeneration after fire in elevations with moderate precipitation and an absence of invasives and conifer expansion, or if the outcome is influenced by the resilience and resistance of the site. Due to its relatively high costs and complexity, validation monitoring is most likely to occur at the project scale rather than at MZ/ecoregion or biome scales and it forms the basis of research and management projects like the Sagebrush Treatment Evaluation Project (SageSTEP.org).

A combination of these monitoring approaches can ensure that management objectives are achieved at multiple spatial scales and that the observed outcome is due to the treatment. These types of monitoring provide important feedbacks for adaptive management. Archiving data collected through implementation, effectiveness, and validation monitoring in tools, such as the Land Treatment Digital Library for the BLM (Pilliod and Welty 2015), can allow managers to learn from past treatments and decide appropriate management treatments in the future. Text boxes 2 and 3 provide examples of techniques that be used for ecological status and trends monitoring.

Text Box 2 − Early Detection of Invasive Species

Early Detection and Rapid Response (EDRR) provides an opportunity to control the spread of invasive species (USDI 2016). This type of monitoring requires:

(1) Covering a broad area of landscape;

(2) Including invasive plant species presence and abundance as a monitoring indicators as in BLM AIM and NRCS NRI monitoring programs;

(3) Coordinating monitoring across land management agencies and prioritizing likely invasion pathways to identify areas where invasive species are starting to establish, e.g., recreation sites, trails, roadsides, and within areas of treatments, recent fires, energy development, and other disturbance types.

(4) Developing management triggers designed to address early invasions. Monitoring plans can be greatly improved when an invasive species list or georeferenced abundance data are available (Brooks and Klinger 2009).

Standardization of Indicators and Protocols

Adoption of a standardized set of indicators and protocols for collecting those indicators will allow a wide range of users (i.e., managers, land owners, interested public, and researchers) to compare data collected in different areas and for different objectives. The NRCS and BLM currently use common protocols for national and regional monitoring of many rangeland vegetation and soil indicators (Toevs et al. 2011; Herrick et al. 2010, 2015). The USFS recently released protocols for standardized wildlife habitat monitoring (Rowland and Vojta 2013), which rely primarily on existing, commonly used sampling methods and data sets. The Integrated Rangeland Fire Management Strategy (IRFMS 2015) aims to work out some of the differences among protocols and indicators to reduce conflicts.

Measuring standardized indicators with consistent protocols allows ground-based data to be scaled-up from the site level to larger scales (e.g., Management Zones/ecoregions) through ground-truthing and validation with remotely sensed data. Provided data are collected using a sampling design with a known stratification method, data collected from each location or landscape can be weighted in a statistically sound manner and combined with similar data in other areas to obtain cross-site or cross-landscape comparisons with spatial relevance and known levels of error (Patterson et al. 2014).

Rule sets for making data collection decisions are necessary to ensure precise measurement among different field crews (Rowland and Vojta 2013). Herrick et al. (2005) provide illustrations of how rule sets are stipulated. BLM AIM and NRCS NRI both use rule sets to standardize measurement decisions. No one rule set is perfect, but rule sets provide a means for collecting consistent data among different observers.

Text Box 3−Fuels Assessment Based on the Ratio of Woody to Herbaceous Plants

Monitoring survey plots (NRI, AIM, and FIA) as well as remote sensing can show the ratio of woody to herbaceous plant abundance, and transitions that may occur between dominance of woody plants to herbaceous species (especially highly flammable invasive annual grasses). The calculated ratios between woody and herbaceous abundance can be linked to fire potential, fire behavior, and fire severity. These fuels monitoring attributes may be useful in developing treatments that address build-up of fuels, as well as preparing for certain hazardous fire behavior.

Linking Resilience and Resistance Concepts and Monitoring

Monitoring landscape heterogeneity over time can provide a clear understanding of how sagebrush dominated landscapes are changing in response to natural ecosystem processes, anthropogenic disturbances, and management actions. Relative resilience to disturbance and resistance to invasive species influence the responses of sagebrush ecosystems to threats like wildfire and invasive annual grasses, land uses and development. Information on resilience and resistance can provide an additional data layer in monitoring programs that can be used to help understand the changes in ecosystem status and trends and the effectiveness of management treatments at broad, mid, and local scales. Resilience and resistance information can be used to inform monitoring designs, to help develop triggers for changes in management, and to determine appropriate changes in management strategies and treatments.

By stratifying monitoring across resilience and resistance categories, the range of potential responses to management actions can be captured. If a monitoring program is already in place, including resilience and resistance as a factor in the analyses may still provide useful information on the effects of resilience and resistance given adequate sample sizes in the different categories.

The relationships among resilience and resistance as indicated by soil temperature and moisture regimes, the predominant sagebrush ecological types, and the responses of these types provide information that can help develop triggers for adjusting management (see Section 6; Chambers et al. 2017). Generalized state-and-transition models developed for the dominant ecological types in both the western and eastern parts of the sagebrush biome and greater GRSG range, provide information on the alternative states for these types, the effects of ecosystems threats and management actions on these states, and the potential restoration pathways (see Appendices A.5 and A.6; Chambers et al. 2017). Examples of how to apply resilience and resistance concepts are provided for areas with different ecological types and threats (See Section 9.2, Chambers et al. 2017).

Using the Science Framework Approach to Inform Monitoring

The Science Framework Part 1 (Chambers et al. 2017) provides an approach for prioritizing areas for management and determining effective management strategies based on: 1) the likely response of an area to disturbance or stress due to threats and/or management actions (i.e., resilience to disturbance and resistance to invasion by nonnative plants), 2) the capacity of an area to support target species and/or resources, and 3) the predominant threats. The geospatial data layers and analyses used in the approach are described in sections 8.1 and 8.2 in Chambers et al. (2017) and can be used to help design monitoring programs and interpret monitoring results. Analyses are conducted at the ecoregional or Management Zone scale because of similarities in ecoregional climate, soil properties, resilience to disturbance and resistance to invasive species. Key data layers include resilience and resistance as indicated by soil temperature and moisture regimes, GRSG breeding habitat probabilities, and densities or other sagebrush obligate habitats, and the primary threats for the ecoregions or Management Zones (fig. 6.2; Chambers et al. 2017). Interpretations of these analyses for monitoring programs, based on the Science Framework approach for GRSG, follow (see table 1.2 and table 1.3) a similar approach and can be used for other species at-risk as well as priority resources.

Monitoring areas of high GRSG breeding habitat probability (table 1.2; cells 1C, 2C, 3C) provides information on whether these areas are retaining their composition, structure and function as GRSG habitat. Protective management is used to retain resilience and resistance in these areas, and monitoring for status and trends and Early Detections and Rapid Response (EDRR; USDI 2016) of invasive plant species can be used to ensure that invasive species do not increase and thereby degrade these high-value sites. Monitoring areas of low resilience and resistance with high breeding habitat probabilities is especially important because these areas are at high risk of habitat loss due to fire and invasive annual grasses (table 1.2; cell 3C). Regardless of an area's resilience and resistance, implementation and effectiveness monitoring are used to assess treatment effectiveness and determine if follow-up management is needed.

Areas with moderate breeding habitat probabilities are a focus for habitat improvements (table 1.2; cells 1B, 2B, 3B). Treated areas within GRSG habitat are often intermediate to high priority for monitoring because habitat improvements resulting from treatments could translate into increased use and/or improved demographic indices (e.g., population trends, survival) for GRSG. Treated areas typically undergo EDRR, implementation, and effectiveness monitoring to ensure that the treatments were implemented as planned, objectives of the management action(s) are met, and an understanding of the effectiveness of the outcome is gained (Noss and Cooperrider 1994, Mulder et al. 1999).

Monitoring areas with low GRSG breeding habitat probabilities and low resistance and resilience can provide information on continued changes in composition, structure, and function, but is generally lower priority unless other at-risk species or management concerns are identified in these areas (cells 1C, 2C, 3C (table 1.2). Areas of low resilience and resistance and low breeding habitat probabilities that are currently dominated by invasive annual grasses may be given the lowest priority for monitoring (table 1.2; cell 3A).

Monitoring Change in Landscape Status and Trend

Landscape monitoring is an important aspect of land management that provides a way to examine the big picture – it gives information on ecosystem processes, habitat characteristics, and species distributions and movements that operate beyond the scope of management unit and land ownership boundaries. It can also provide information on the landscape characteristics of areas with different resilience and resistance and the response of these areas to ecosystems threats and management actions. There are a wide variety of metrics (e.g., indicators developed for categorical map patterns) that can be used to monitor landscapes (Cushman et al. 2013a) including: 1) quantifying environmental conditions, 2) change of status over time, 3) cumulative effects of management activities, and 4) establishing or identifying thresholds of change. These metrics may be used to measure physical characteristics on the ground and connect them to ecological processes. They may also act as surrogates for conditions that cannot be measured directly. Typically, these types of metrics are calculated for data classed within a specified landscape at a defined extent (e.g., ecoregion, Management Zone, jurisdictional boundary, etc). Landscape components at the broad, mid, and local scales will differ, thus it is important to measure the appropriate metrics at all scales of importance to provide comprehensive, integrated monitoring.

Landscape Metrics

Some metrics are useful for monitoring and quantifying landscape heterogeneity and change at multiple scales. The following metrics could easily be monitored on a landscape with a mosaic of land cover classes: **mean patch size, patch size coefficient of variation, mean nearest neighbor distance, patch richness, and edge contrast or density** (Cushman et al. 2008; Cushman et al. 2013a,b, Goldstein et al. 2013). These metrics measure separate aspects of landscape structure, but when analyzed together can offer a comprehensive evaluation of changes in key indicators of connectivity such as landscape pattern, land cover class conversion, and fragmentation. For example, an aggregate of local-scale monitoring data and/or remote sensing data (e.g., LANDFIRE) can be examined to quantify sagebrush landscape pattern, heterogeneity, and change over time by simply using **mean sagebrush patch size** independently or relative to other landscape class mean patch sizes. This metric, quantified annually, provides a measure of how sagebrush patches have expanded or contracted in response to natural ecosystem processes, anthropogenic disturbances, and management over time. **Mean nearest neighbor distance** can help provide information on fragmentation and patch juxtaposition – an increase in the value of this metric over time typically indicates an increase in fragmentation of the land cover class; whereas a decrease in this value over time may indicate successful restoration and a decrease in fragmentation (decrease in distance among patches) across the landscape. This information can inform land management decision processes for that particular landscape. Goldstein et al. (2013) provide an example monitoring plan for GRSG habitat monitoring at multiple scales, with sagebrush patch size, sagebrush canopy cover, and habitat connectivity selected as landscape-level habitat monitoring indicators.

Landscape Monitoring of Habitats

Habitats are spatially structured forming patterns at multiple scales. These patterns may influence wildlife species use and behavior and influence population dynamics and community structure (Johnson et al. 1992). For all species, habitat must have sufficient size and proximity of resource patches to: 1) support reproduction, 2) facilitate dispersal, and 3) maintain metapopulation structure (if that is a characteristic of the species; Cushman et al. 2013b). To monitor landscape level changes within the sagebrush ecosystem with a focus on wildlife-specific species' indicator data, landscape metrics can be used to quantify how habitat changes over time in response to management decisions and natural ecosystem processes. For example, much information is available on landscape indicators for GRSG such as: habitat intactness (Aldridge et al. 2008; Wisdom et al. 2011), breeding habitat probability (Doherty et al. 2016), landscape genetics (Row et al. 2015, Cushman et al. 2013a), habitat patch size, habitat connectivity and networks, ecological minimums (thresholds) (Meinke et al. 2009; Knick and Hanser 2011; Crist et al. 2015), edge effects (Coates et al. 2014b; Howe et al. 2014), and distance to water (Donnelly et al. 2016). Using land cover classes developed through remote sensing (e.g., LANDFIRE ecological systems) along with monitoring data collected on the ground, these indicators can be analyzed with landscape metrics to quantify the amount of habitat area and connectivity lost or gained due to habitat conversion or natural succession (Goldstein et al. 2013).

Disturbance, Reclamation, Restoration

Tracking and measuring the influence of discrete and diffuse persistent ecosystem and anthropogenic threats independently at the landscape scale in sagebrush ecosystems can provide useful information on whether or not management objectives are met. Overlaying resilience and resistance information can aid in the interpretation of management outcomes. For example, monitoring the time it takes to achieve successful reclamation and subsequent restoration in the context of ecosystem resilience and resistance can help inform where to prioritize management and conservation actions, what to expect under certain measured conditions, and what are the best indicators of overall management effectiveness. Classifying habitat restoration, vegetation treatments for fuel management, and other types of vegetation treatments separately from land cover classifications used in vegetation mapping (e.g. LANDFIRE) can allow these treatments to be monitored and evaluated over time at the landscape scale. This can provide the basis for determining if an area has recovered or if adaptive management actions are needed. This can provide the basis for determining if an area has recovered, if thresholds at the landscape level (ecosystem or species-specific) have been exceeded, and if adaptive management actions are needed. For example, thresholds, such as percent land cover of conifer (Baruch-Mordo et al. 2013) and distance to and density of oil and gas development (Lyon and Anderson 2003; Holloran et al. 2005; Walker et al. 2007; Doherty et al. 2008; Naugle et al. 2011), have guided science-based land use/management decisions in recently amended BLM and USFS Land Use Plans (LUPs). Similarly, resilience and resistance information has provided the basis for developing appropriate management strategies based on the likely response of ecosystems to both disturbance and management actions. Monitoring ecosystem threats and land use and development threats at the same time will aide in determining the effectiveness of on-the-ground conservation actions, understanding the reasons for changes in the landscape, and designing more effective management strategies.

Linking Efforts to Identify GRSG Habitat Thresholds

Certain individual and population response thresholds have been defined for managing GRSG habitat within state and federal plans, and in the scientific literature (Knick et al 2013, Manier et al. 2014b; Chambers et al. 2016, 2017). Disturbance data collected at the project-scale can be aggregated across a landscape to ‘scale up’ and inform whether adaptive management thresholds/triggers (such as disturbance caps and density disturbance limitations specified in the Federal LUPs) have been met or exceeded and prompt actions/decisions by the appropriate agencies or groups of individuals. Based on the GRSG Monitoring Framework (BLM/FS 2014) and the Sage-Grouse Habitat Assessment Framework (Stiver et al. 2015), disturbance and sagebrush land cover data are used to inform adaptive management triggers tied to ‘GRSG habitat’ in the form of large-scale assessment (defined as a cluster of leks or a population) to determine if over 70% of the landscape is supporting 15% sagebrush canopy cover. For GRSG, estimations of range-wide habitat thresholds are available in terms of their individual and population responses to road densities, oil and gas densities, etc. (Knick and Hanser 2011; Knick et al 2013; Manier et al. 2014b) and can also be assessed in this context, to gain a better understanding of where habitat and GRSG are relative to these specified thresholds as well as to provide more of the landscape-level perspective.

In conclusion, establishing a robust monitoring program or strategy that informs clearly defined management objective is paramount to a meaning adaptive management process. By monitoring the outcomes, land managers and resource specialist will be better suited to site their efforts in areas more likely to be effective and improve resilience and resistance. Understanding the methods as well as the environmental characteristics can increase the return on conservation investments.

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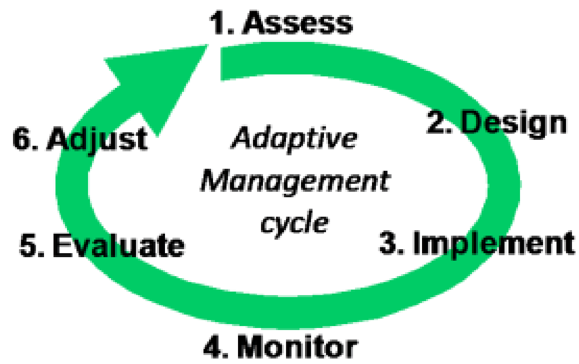

Figure 2.1–The primary components of the adaptive management cycle.

Table 2.1–Components of a monitoring program based on Elzinga et al. (1998) and Goldstein et al. (2013).

A. Complete Background Tasks

1. Compile and review existing information on the ecosystems, species, and/or populations. Ecological models of the relationships among ecosystem/habitat characteristics, species abundance, and management effects can help in developing monitoring objectives and improve interpretation and application of the data.
2. Review existing planning documents describing management objectives and planned management actions.
3. Prioritize the ecosystems, species, and/or populations to be monitored based on existing assessments. These priorities may require periodic reassessment due to changes in threats, management, conflicts, and the interests of outside parties.
4. Access the resources available for monitoring, including management support, priorities, and people and equipment available.
5. Determine the scale of interest for the monitoring effort, e.g., the sagebrush biome, the range of a species, certain ecotypes or habitats, populations in certain types of management units.
6. Determine the type and intensity of monitoring based on the management objectives.
7. Ensure adequate review of the proposed monitoring program by higher level management and by individuals working in relevant disciplines. For larger programs or highly controversial ecosystems, species and populations, a team may need to be assembled.

B. Develop Monitoring Objectives

1. Develop monitoring objectives that are consistent with the management objectives.
2. Select indicators that can be used to identify the status and trends of a resource or the effectiveness of a management action.
3. Identify the attributes that are most sensitive for measuring status and trends or change towards the management goal.
4. Specify the amount and direction of change that is desired or that can be tolerated. This science-based value may include a percentage change, absolute value, or a target or threshold value.
5. Specify a biologically meaningful time frame for monitoring to measure ecosystem and species responses following a management action.
6. Specify the management responses needed if monitoring indicates that the management objectives have or have not been met.

C. Design the Monitoring Methodology

1. Develop the sampling objectives.
2. Determine and map the area to be monitored.
3. Define the sampling unit for each attribute that will be measured.

4. Determine the method of sampling unit placement within the monitoring area. An unbiased estimate of resource conditions and changes can be gained by incorporating randomization into sampling designs.

5. Determine biologically meaningful monitoring durations, intervals, and frequencies.

6. Design the data sheets for the attributes to be measured.

7. Describe the likely data analyses techniques for the different attributes.

8. Identify the necessary resources required to implement the monitoring plan.

9. Write a monitoring plan that has sufficient details for the monitoring to be repeated over time.

F. Implement Monitoring

1. Collect the data at specified intervals using trained personnel.

2. Analyze the data that are collected after each measurement cycle.

3. Evaluate monitoring methods, costs, sample sizes, and relevancy after each measurement cycle. Conducting a trial run or pilot study can expose problems and allow adjustments in the methodology to increase monitoring effectiveness.

G. Manage, Store, and Report Data

1. Ensure that the data for each measurement cycle are complete, entered into standardized databases, verified, and backed-up.

2. Analyze all data collected over the reporting period.

3. Review the results for potential issues with either the data collection protocols or the amount and direction of change occurring in the indicator variables.

4. Compile the data and analyses into reports. For data collected over longer-time periods, reports should be developed at regular intervals.

H. Apply Results of Monitoring in an Adaptive Management Context

1. Use monitoring results to adjust priority areas for programs of work and resource allocation.

2. Use monitoring results to inform revisions of Land Use Plans and Amendments.

3. Use monitoring results to access the effectiveness of management strategies and treatment methods and guide revisions in management strategies and treatment methods.

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3. CLIMATE ADAPTATION

Jeanne C. Chambers, Louisa Evers, and Linda Joyce

Introduction

Management actions that enable adaptation to climate change and promote resilience to disturbance are becoming increasingly important in the sagebrush biome. In recent decades temperatures have increased, growing seasons have lengthened, and in many areas the timing and amount of precipitation has changed (see Part 1, Section 1.4; Kunkel et al. 2013a,b,c). Future changes in temperature and precipitation are projected from global climate change models based on likely carbon dioxide (CO_2) and other trace gases emissions (relative concentration pathway or RCP) and information on the earth's surfaces and oceans. Although the magnitude and rate of change differs based on the RCP used, these models project continued temperature increases and additional changes in precipitation throughout the remainder of the century (Section 1.4; Kunkel et al. 2013a,b,c).

Continued changes in climate are likely to influence the distributions of native species (Bradley 2010; Schlaepfer et al. 2012a; Homer et al. 2015; Still and Richardson 2015), invasive annual grasses (Bradley et al. 2016), fire regimes (Littell et al. 2009; Abatzoglou and Kolden 2013; Westerling et al. 2014), and insects and disease (Bentz et al. 2016). Snowpacks are declining in many areas (Mote and Sharp 2016), droughts are becoming more severe (Cook et al. 2015; Prein et al. 2016), and the length of the fire season and duration of extreme fire weather is increasing (Littell et al. 2009; Abatzoglou and Kolden 2013; Westerling et al. 2014; but see also McKenzie and Littell 2017). Reducing the vulnerability of ecosystems and the services they provide to changes in climate will require scientific guidance and agency direction to enable climate adaptation planning and implementation across scales.

Adaptation and mitigation are important components of management strategies in the face of climate change. Adaptation is the process of adjusting to actual or expected changes in climate; adaptation seeks to moderate or avoid harm or to exploit beneficial opportunities (IPCC 2014). Adaptation can be *incremental* where the objective is to maintain the integrity of a system or process at a given scale. Climate scientists anticipate that climate will continue to change throughout the 21st century due to ongoing changes in the concentration of greenhouse gases. Consequently, future climate may not be suitable for many of the current ecosystems on the landscape. Thus, adaptation can also be *transformational* where actions focus on changing the fundamental attributes of a system in response to climate and its effects (IPCC 2014). Mitigation of climate change is an intervention that seeks to reduce the sources or enhance the storage of greenhouse gases (IPCC 2014). This section discusses incremental and transformational adaptation actions as well as mitigation actions that enhance the resilience of natural systems.

Climate Adaptation and Resilience Management

Concepts

Managing natural resources within the context of climate adaptation is consistent with the approach described in Part 1 of the Science Framework, but requires the necessary flexibility to modify management actions as environmental conditions change. A conceptual approach for addressing adaptation in use by USFWS (USFWS 2010) and USFS (USFS 2011) focuses on resistance, resilience, and response strategies. These include: (1) building resistance to climate-related stressors such as drought, wildfire, insects, and disease; (2) increasing ecosystem resilience by minimizing the severity of climate change impacts, reducing the vulnerability and/or increasing the adaptive capacity of ecosystem elements; and (3) facilitating large-scale ecological transitions in response to changing environmental conditions.

These concepts of climate resistance, resilience, and response apply to many management and land ownership contexts and can be used to help determine appropriate management strategies. Using these concepts to manage for changes in climate involves examining whether current assumptions about weather/climate effects on environmental responses and underlying assumptions about the expected result of management actions are still viable in a changing environment. Examples are ecological site descriptions and state-and-transition models in which the reference state often serves as the management target (fig. 3.1; Briske et al. 2005; Bestelmeyer et al. 2009; Caudle et al. 2013). While managers can use historical data to help understand ecosystem response to environmental changes (e.g., Swetnam et al. 1999), it is important to recognize that the relationship between climate and ecosystem response will shift over time with continued warming. Consequently, managing for historical conditions may not maintain ecological sustainability (goods and services, values, biological diversity) into the future (Millar et al. 2007; Hobbs et al. 2009).

Climate Adaptation Strategies

Due to uncertainty about exactly what the future will look like, planning for multiple possibilities and using adaptive management principles is essential. Adaptive management uses the best available information for enhancing ecosystem resilience and resistance, and helping plant and animal species within ecosystems to adapt to inevitable changes in climate (Millar et al. 2007). Table 3.1 lists climate adaptation strategies for the sagebrush biome based on Millar et al. (2007, 2012) and Butler et al. (2012). The specific approaches for sagebrush ecosystems build on the sage-grouse resilience and resistance habitat matrix (table 1.1) and the sagebrush ecosystem management strategies (table 1.2).

Climate adaptation strategies incorporate multiple scales and focus on preventing the loss of ecosystem services by maintaining and enhancing ecosystem processes, functional attributes, and feedbacks (table 3.1). For example, the extent and connectivity of intact sagebrush ecosystems are critical elements for maintaining the dispersal and reproductive processes of most plant and animal species; they enable these ecosystems and species to absorb the increasing footprint of human development and land use and to adapt/migrate in response to climate change (e.g., Millar et al. 2007; Knick et al. 2011, 2013). Maintaining intact and connected sagebrush ecosystems is based on developing public land use plans and policies that reduce the impact of existing ecological, land use, and development stressors on these ecosystems at biome to mid scales. It also involves strategic placement of conservation easements to prevent conversion to tillage agriculture and anthropogenic developments and to maintain existing connectivity at mid to local scales.

Many climate adaptation strategies work together to accrue multiple ecosystem benefits. Maintaining or enhancing key plant structural and functional groups is central to most climate adaptation strategies. Certain plant structural and functional groups are critical for stabilizing hydrologic and geomorphic processes, promoting desired successional processes, and lowering risk of conversion to invasive annual grasses following disturbances that remove native vegetation (Pyke et al. 2011). Post-fire rehabilitation and restoration activities can increase ecosystem capacity to absorb change by using functionally diverse species mixtures and including plant materials from across a greater geographic range that considers current climate and near-future climate (next 20 to 30 years) (table 3.1; Butler et al. 2012; Finch et al. 2016). Favoring existing genotypes that are better adapted to future conditions because of pest resistance, broad tolerances, or other characteristics can also increase adaptive capacity and, where necessary, facilitate community adjustments through assisted migration (table 3.1; Butler et al. 2012; Finch et al. 2016). Implementing these strategies requires developing the necessary research and management capacity to forecast changes in ecological conditions and species distributions and to better understand ecosystem response to changes in climate at ecoregional (mid) to project level (local) scales.

Management and research studies coupled with landscape monitoring can provide the basis for developing cost-effective and feasible management strategies for adapting to climate change. Carefully designed management and research studies implemented in the near future may increase our understanding of viable approaches for adaptation measures such as appropriate grazing regimes for drought conditions, conservation actions to facilitate species persistence during climate warming, seeding and transplanting techniques during drought, and species and ecotypes for assisted migration. Monitoring to detect the rates and magnitudes of change occurring across the landscape can identify both populations and habitats that are declining (Field et al. 2004; Carwardine et al. 2011), as well as new or novel combinations of species that constitute a functioning ecosystem under climate change. Increased understanding of both the changes occurring and viable strategies for addressing those changes may reduce uncertainty and provide direction for proactive management strategies (Hobbs et al. 2009).

Prioritizing Management Actions and Determining Appropriate Management Strategies

Assessing ongoing and projected climate change using the best available data is integral to evaluating priority areas for management at ecoregional and management zone scales and to determining appropriate management treatments at local scales. In the context of the Science Framework, the effects of changes in climate on species and ecosystems can be addressed similarly to other persistent ecosystem threats such as wildfire and invasive annual grasses (see Part 1, section 8 and table 3.1). For species at risk like Greater sage-grouse (GRSG) the process involves overlaying key data layers in a geospatial analysis to both visualize and quantify: (1) species locations and abundances, (2) the probability that an area has suitable habitat, (3) the likely response to disturbance or management treatments, and (4) the dominant threats including climate change projections.

Geospatial analyses with overlays of key data layers can (1) help evaluate the level of risk to vegetation types and species to climate change, (2) target areas for adaptive management, and (3) determine the most appropriate types of management actions. Key data layers include projected changes in climate variables (see Part 1, section 8). Additional websites and resources are in Appendix 2. Land managers can use these layers to assess the rate and magnitude of change projected for the assessment area. Other important layers are projections for changes in individual plant species (e.g., Homer et al. 2015; Still and Richardson 2015; Bradley et al. 2016) or vegetation types under different climate change scenarios (e.g., Rehfeldt et al. 2012; Schlaepfer et al. 2012a). These can be used to evaluate the degree to which incremental or transformational adaptation strategies are needed.

Climate change projections can be factored into prioritizing areas for management within assessment areas (Part 1, section 8) by considering the following factors.

- Continued changes in climate (i.e., increases in temperature and shifts in precipitation patterns) and the associated effects are expected to be relatively small within the next decade or two. Areas can be prioritized for management that provide suitable habitat and support species populations at ecoregional and management zone scales, and management practices can be adapted to build resilience to changes in climate into sagebrush ecosystems at local scales (table 3.1). Monitoring can provide critical information on changes in species and ecosystems resulting from climate changes that allows managers to take advantage of opportunities to facilitate transitions to systems that will be better adapted in the long-term.
- Changes in climate and the interactions of these changes with other threats are already documented and are expected to be large (rapid warming events, uncertainty of snowpack, extreme drought) in the next few decades (table 3.1). The impacts of changes in climate on plant community composition and vegetation types are most likely to manifest following a major disturbance, such as a wildfire, that occurs at an ecotone between different vegetation types or on warmer, drier sites. In this case more proactive adaptation strategies may be necessary to facilitate community adjustments and species persistence. These may include favoring or restoring native species that are expected to be better adapted to the future range of climatic and site conditions. It may also involve assisted migration, the purposeful movement of individuals or propagules of a species to

facilitate or mimic natural range expansion or long distance gene flow within the current range.

Key Topics in Climate Adaptation and Mitigation

Fire Regimes

Wildland fire is a disturbance of primary concern in the sagebrush biome, especially in the western part of the range. Climate is a top-down driver of fire regimes, operating at the ecoregional or multiple ecoregional level to influence fire frequency (Littell et al. 2009; Abatzoglou and Kolden 2013; McKenzie and Littell 2017), while the interaction among topography, soils, and vegetation are bottom-up drivers that primarily affect the variation in fire size and severity (Dillon et al. 2011; Pausas and Keeley 2014). Under drought conditions, weather and climate can result in mixed severity and stand-replacing events across a variety of fuels complexes and terrains, potentially triggering shifts in fire regimes (Abatzoglou and Kolden 2013).

Fire resistant and resilient landscapes in semi-arid ecosystems tend to have fuelbeds with high temporal variability (Littell et al. 2009; Abatzoglou and Kolden 2013) and spatial variability (Kay 1995; McAdoo et al. 2016). Sagebrush communities that maintain higher live fuel moisture during drought as a result of different phenologies and water use patterns may be more resistant and resilient to fire (Schlaepfer et al. 2012b; Palmquist et al. 2016a, 2016b). Also, sagebrush communities that have patchy sagebrush, variability in gap sizes (the distances between shrubs and grasses), differences in the relative proportions of herbaceous vegetation to shrubs, as well as the cure rate of grasses and forbs may be more resilient to fire (Kay 1995; McAdoo et al. 2013).

It may be possible to decrease drought stress and maintain higher live fuel moisture by reducing biomass and, in turn, competition for resources through removal of conifers in expansion woodlands, thinning of sagebrush, and grazing of herbaceous biomass. However, not all treatment methods are suitable in all locations or situations. For example, grazing to manage herbaceous fuel loadings is generally ineffective where woody plants dominate and when burning conditions become extreme (Strand et al. 2014). Also, mowing degraded Wyoming big sagebrush communities does not promote native herbaceous vegetation and may result in conversion to invasive annual grasses (Davies et al. 2012). Regardless of method, treatment success depends on having a low risk of invasive species and sufficient perennial herbaceous species to promote recovery (Chambers et al. 2014a,b; Chambers et al. 2016).

Patch burning to increase vegetation heterogeneity is increasingly used in the U.S. Great Plains, southern Africa, and Australia (e.g., Brockett et al. 2001; Bird et al. 2013; Voleti et al. 2014; Ricketts and Sandercock 2016). It may be possible to create fuelbed heterogeneity by using a patch-scale approach to removing conifers and shrubs, such as conducting small-scale burns in early spring. Fuelbed continuity and packing ratio could be decreased by enhancing native plant species with growth forms and structures (e.g., size of stems, distance between stems) that are not conducive to carrying fire, even when cured, such as many native forbs and some rhizomatous grasses like western wheatgrass (*Pascopyrum smithii*). Use of traditional phenological knowledge to determine the appropriate timing of treatments, including use of prescribed fire for thinning purposes, shows promise for achieving such desired despite ongoing changes in climate (Huffman 2013; Armatas et al. 2016).

Drought

From a meteorological perspective drought is defined as the accumulated imbalance between the supply of water and the demand for water by plants, animals, the atmosphere, the soil column, and humans (Kunkel et al. 2013a, b). Drought can also be defined from other perspectives including hydrologic (e.g., streamflow), agricultural (e.g., ecosystem productivity), or socioeconomic (Luce et al. 2016). Determining if a drought is in process can take a relatively longer time for areas where the effects of drought may accumulate slowly such as forests and sagebrush ecosystems. Ecological indicators of drought exist for rangelands and can be listed sequentially - water shortages stress plants and animals, vegetation production is reduced, plant mortality increases, plant cover is reduced, amount of bare ground increases, soil erosion become more prevalent, habitat and food resources for wildlife are reduced, wildlife mortality increases, rangeland fires may increase, some insect pests and invasive weeds may increase, forage value and livestock carrying capacity decreases, and then, economic depression in the agricultural sector sets in (Finch et al. 2016).

Drought adaptation measures with short-term and longer-term horizons have been identified for rangelands and forests across the western United States (see Joyce et al. 2013; Briske et al. 2015; Finch et al. 2016). Planning for a drought involves developing a drought management plan (UNL-NDMC 2012; examples available at http://drought.unl.edu/ranchplan/WriteaPlan.aspx). Management actions vary regionally and reflect the resources available to cope with drought. In general, the goal is to minimize the risk of environmental degradation and the loss of ecosystem function. Across all land ownerships, careful planning of adaptation actions will be most successful if management plans consider the next drought as well as the current drought and its aftermath (Finch et al. 2016).

Current management actions may need to be re-examined with the onset of drought. For example, adaptation actions with respect to livestock management during the drought include: reducing stocking rate to allow plant recovery; using fencing and other developments to manage livestock distribution; using drought-resistant feed crops; using drought-adapted stock; adjusting season of use; implementing a deferred grazing system; developing, restoring, or reclaiming water sources; providing shade structures for livestock; reducing the time livestock graze a specific grazing unit; increasing the time or rest between periods of grazing; and testing new techniques for responding to drought. With respect to restoration, management may require delaying planting and shifting the focus to less desirable species. For example, implementing measures to control crested wheatgrass during dry years and seeding native grass in wetter years may result in more effective restoration in the West-Central Semiarid Prairies (Bakker et al. 2003). Strategies and techniques for planting in a drought year are available and may increase plant establishment and species persistence (see review in Finch et al. 2016). To mitigate the impact of drought or other abiotic stress, plant material selection can benefit from considering adaptive capacity among species and genetic variation within species (Richardson et al. 2012). Assisted migration, the purposeful movement of individuals or propagules of a species to facilitate or mimic natural range expansion or long distance gene flow within the current range, can be considered for areas with high rates of climate change (table 3.1). These decisions will be critical given the potential for increased frequency and duration of drought in the future.

Snowpack and Dust

Total snowfall has been declining precipitously in the West since the 1920s (Kunkel et al. 2009). Maximum seasonal snow depth has been declining over the period of winter 1960/1961–winter 2014/2015 across North America; other studies show declines in snow cover as well (Kunkel et al. 2016). A recent analysis of April snowpack data, which is used extensively for spring streamflow forecasting, indicated declines at more than 90 percent of the sites when measured from 1955 to 2016 (Mote and Sharp 2016). The average change across all sites amounts to about a 23-percent decline in snow water equivalent. These decreases have been observed throughout the western United States, with the most prominent declines in Washington, Oregon, and the northern Rockies (Mote and Sharp 2016).

Decreases in snowpack may not affect overall patterns of soil water availability if precipitation that arrives during the cold season simply switches from snow to rain (Schlaepfer et al. 2012c). However, associated increases in soil temperature and decreases in soil water availability due to longer growing seasons and higher evapotransporation may influence plant species establishment and survival and thus community composition (Palmquist et al. 2016a, b).

Drought, wildfire, and agricultural activities in the western United States contribute to dust in the atmosphere which settles on snow-covered areas in the winter. Over the last decade, the number of dust-on-snow events have increased in intensity in the Colorado Rocky Mountains (Toepfer et al. 2006; Painter et al. 2007). Dust on snow events reduce duration of snow cover (Painter et al. 2007), increase rate of snowmelt associated with more extreme dust deposition, and produce earlier peak stream flows of 1–3 weeks (Steltzer et al. 2009; Painter et al. 2012; Livneh et al. 2015). As a result of these dust-on-snow events, snow chemistry increases in pH, calcium content, and acid neutralizing capacity with more pronounced effects at upper elevations than lower elevation forested sites (Rhoades et al. 2010).

Effects of decreasing snowpack on sagebrush ecosystems will be widespread, but will likely be most significant in areas with measurable changes in the amount and duration of snowpack. The most vulnerable areas will likely be those that previously retained snow cover over all or most of the winter, or where winter snowpack was critical to recharge deep soil water. Adaptation strategies specific to these areas have not been developed (but see David 2013). However, identifying these areas and managing them to sustain ecological functions and reduce the impact of existing ecological, land use, and development stressors can facilitate adaptation (table 3.1). Monitoring these areas for changes in soil moisture and temperature and in species composition can provide information on (1) establishment and spread of nonnative invasive plant species and the need for intervention and (2) the need for community adjustments through species transitions.

Insects and Disease

Major insect pests and diseases affecting the sagebrush biome and sagebrush obligate wildlife species are poorly identified and studied. For example, Aroga moth (*Aroga websteri*), or sagebrush defoliator, is a native moth that experiences periodic large-scale outbreaks affecting sagebrush and sage-grouse habitat quality and quantity. West Nile virus is a recently established disease in the western hemisphere with potential to greatly reduce many avian species populations such as greater sage-grouse.

Outbreaks of the native aroga moth can damage and kill sagebrush over local, landscape, ecoregional and multi-ecoregional scales, although the only documented outbreaks to date have been in the Cold Deserts in the western part of the sagebrush biome. Anecdotal evidence from the northern Great Basin indicates that aroga moth outbreaks can be associated with years that have much larger than average fires (Svejcar 2012, personal communication). Outbreaks are associated with warm conditions from mid-May through mid-June, during the first and second instar development, followed by high precipitation in June and July, during fourth and fifth instar development (Bolshakova 2013; Bolshakova and Evans 2016). Since peak larval abundance occurs around 239 degree-days (accumulated since January 1 using a base temperature of 5°C), managers can track degree-days and monitor larval populations to determine when an outbreak is possible (Bolshakova and Evans 2016). How changes in climate may alter the likelihood of such outbreaks is unclear. Outbreaks may occur at the same frequency but earlier in the year as conditions warm or the frequency may decline due to the combination of warming temperatures and changes in precipitation timing.

Higher moth survival and abundance is also associated with north aspects at mid-elevation, suggesting that sagebrush canopy cover may play an as-yet poorly understood role in outbreaks (Bolshakova and Evans 2014). These sites typically experience lower daily and annual temperature fluctuation, greater snow accumulation, and slower snowmelt, thereby creating more favorable conditions for moth larva and adults (Bolshakova and Evans 2014). More homogeneous stands of sagebrush may serve as epicenters for outbreaks (Bolshakova 2013; Bolshakova and Evans 2014), suggesting that enhancing heterogeneity of sagebrush cover may serve to limit the size and impact of future outbreaks.

Sage-grouse mortality from West Nile virus typically occurs between mid-May and mid-September with peak mortality in July and August (Walker and Naugle 2011), which are also the warmest and driest months. Sage-grouse frequently use ponds, springs, and other standing water sources during hot weather, which are the same sites used by *Culex tarsalis*, the primary mosquito species that transmits West Nile virus to birds (Shrag et al. 2010; Walker and Naugle 2011). Increasing storm intensity that results in more run-off than infiltration, and the potential need to develop additional water sources for domestic and wild ungulates or for irrigation could result in creating new or enhancing existing breeding sites for *C. tarsalis* mosquitos. Where West Nile virus is present, fencing or other modifications to watering sites to limit trampling by livestock, free-roaming equids, and wild ungulates can reduce the number of potential *Culex* mosquito breeding sites (NTT 2011, p. 61).

Changes in Species Distributions and Community Composition

The changes in precipitation and temperature regimes occurring as a result of climate warming are projected to have large consequences for species distributions, and because individual species differ in their climatic requirements, for community composition. The distribution of species like big sagebrush is projected to move to the north and upward in elevation (Bradley 2010; Schlaepfer et al. 2012a; Homer et al. 2015; Still and Richardson 2015). Cheatgrass will likely spread upwards in elevation while red brome (*B. rubens*) moves northward and/or increases its abundance in the Cold Deserts and Colorado Plateau (Bradley et al. 2016). Decreases in average summer precipitation or prolonged summer droughts could enable cheatgrass invasion into sagebrush ecosystems that are currently more resistant to invasion and resilient to fire disturbance (Mealor et al. 2013; Bradley et al. 2016), like the northern mixed-grass prairie, allowing it to more successfully colonize what is currently considered a largely invasion-resistant grassland (Blumenthal et al. 2016).

Climate adaptation strategies for the sagebrush biome are designed to facilitate adaptation of species and communities to a warming climate, and to reduce the risk of nonnative invasive plant species introduction, establishment, and spread. An understanding of the rates and magnitude of projected change (Part 1, Appendix 3) can help managers to prioritize areas for different types of management actions (table 3.1). Areas that are likely to support big sagebrush ecosystems in the future may be good candidates for proactive weed and fire management. Areas that may become more suitable for big sagebrush over time may be candidates for assistant migration during restoration activities. Areas that are unlikely to support big sagebrush ecosystems in the future require careful evaluation to determine the types of ecosystems they are likely to support and if they merit investment in conservation and restoration resources.

Successful adaptation will include monitoring along climate transition zones to detect changes in both soil temperature and moisture regimes and species composition. Consideration of scale will ensure that planning at broader scales promotes strategies such as landscape connectivity, ecosystem redundancy, and refugia, and that planning at more local scales promotes strategies such as maintaining or enhancing key structural and functional groups, increasing genetic diversity, facilitating community adjustments through species transitions, and planning for and responding to disturbance.

Greenhouse gas emissions and carbon storage

Mitigation of climate change is an intervention that seeks to reduce the sources or enhance the storage of greenhouse gases (IPCC 2014). Federal policy for addressing climate change includes reducing greenhouse gas emissions from federal land management activities and increasing carbon storage on federal lands. Also, many state climate change plans include increasing carbon storage in forests as a mitigation measure for greenhouse gas emissions. However, individual states and agencies have differing policies for addressing carbon storage and greenhouse gas emissions at the land use plan and project scales. Several impact estimation tools provide estimates of carbon storage, but most of these have relatively low resolution (see Appendix 2).

Actions taken to maintain or enhance the resilience and resistance of sagebrush ecosystems have implications for greenhouse gas emissions and carbon storage. Semiarid ecosystems strongly influence the trend and interannual variability in the global carbon balance, in part due to widespread woody species expansion and high interannual variability in temperature and precipitation (Ahlström et al. 2015). In wetter years, semiarid systems are typically carbon sinks, while in drier years they tend to be carbon sources because respiration exceeds photosynthesis. In more-or-less average years, semiarid systems tend to be more carbon neutral with uptake by photosynthesis roughly equal to release by respiration (Svejcar et al. 2008; Ahlström et al. 2015).

Conversion of native sagebrush ecosystems to annual grassland converts a greenhouse gas sink into a greenhouse gas source with reductions in both aboveground and belowground carbon storage (Bradley et al. 2006; Rau et al. 2011a; Germino et al. 2016). Actions intended to avoid or halt the spread of invasive annual grasses by increasing resilience to disturbance and resistance to invasion and to restore invaded sites to sagebrush communities would enhance carbon storage and reduce potential greenhouse gas emissions at all scales, which is consistent with national and many state-level climate change goals.

Conifer expansion into sagebrush ecosystems increases aboveground carbon storage many-fold due to the large increase in biomass, but the impacts belowground are not well understood (Rau et al. 2011b, 2012). Once aboveground tree cover equals 50 percent, resilience to disturbance and resistance to invasive annual grasses drops, and the site may become susceptible to invasive annual grasses after fire (Rau et al. 2012) or other stand-replacing disturbances. The tree cover at which this reduction occurs may be lower on less productive sites. Further, conifer expansion reduces total soil N, which has long-term adverse implications for carbon storage in deep soil where the carbon pool is very stable (Rau et al. 2012). Conifer expansion tends to lengthen fire return intervals but greatly increase the biomass consumed during fire in comparison to sagebrush dominated ecosystems. Consequently, the science is unclear as to the long-term trade-offs in potential greenhouse gas emissions. Even though the increase in biomass from tree cover would seem more consistent with national and state climate change goals, over the longer-term it may be less sustainable than maintaining or restoring sites to sagebrush ecosystems. Short-term greenhouse gas emissions and reductions in carbon storage from projects intended or designed to reduce conifer expansion and restore sage-grouse habitat are acceptable trade-offs (CEQ 2016, p. 18). Federal climate change policies do not require that goals to increase carbon storage come at the expense of habitat or key ecosystem functions.

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Table 3.1--Climate change adaptation strategies for the sagebrush biome. General strategies are based on Millar et al. (2007, 2012) and Butler et al. (2012). Specific approaches for sagebrush ecosystems build on the sage-grouse resilience and resistance habitat matrix (table 1.1) and the sagebrush ecosystem management strategies (Part 1, table 1.2). Resistance = R1; Resilience = R2; Response = R3.

Sustain fundamental ecological conditions (R1, R2, R3)

- Maintain or restore soil quality and nutrient cycling by re-evaluating the timing and intensity of land use practices such as livestock grazing
- Maintain or restore hydrologic and geomorphic processes following stress and disturbance

Reduce the impact of existing ecological, land use, and development stressors (R1, R2, R3)

- Develop appropriate policies and project and land use plans to protect sagebrush habitat and prevent fragmentation
- Secure conservation easements to prevent conversion to tillage agriculture, housing developments, and other land conversions, and maintain existing connectivity

Promote landscape connectivity (R2, R3)

- Reduce conifer expansion to maintain connectivity among sage-grouse and sagebrush obligate species populations and facilitate seasonal movements

- Suppress fires that occur under more severe burning conditions in targeted areas where altered fuelbeds facilitate fire sizes and severities increase landscape fragmentation and impede dispersal, establishment, and persistence of native plants and animals
- Manage landscapes to create or enhance permeability and increase the ability of sagebrush obligate species to move between individual Priority Areas for Conservation/Biologically Significant Units

Maintain or create refugia (R1)

- Identify and maintain ecosystems that: (1) are on sites that may be better buffered against climate change and short-term disturbances, and (2) contain communities and species that are at risk across the greater landscape
- Prioritize and protect existing populations on unique sites
- Prioritize and protect sensitive or at-risk species or communities
- Establish artificial reserves for at-risk and displaced species

Reduce the risk of wildfires that result in abrupt transitions to novel states (R1, R2)

- Reduce fuel loads and fuel continuity to (1) decrease fire size, alter burn patterns, decrease perennial grass mortality, and maintain landscape connectivity, (2) decrease competitive suppression of native perennial grasses and forbs by woody species, and thus (3) lower the longer-term risk of dominance by invasive annual grasses and other invaders
- Use prescribed fire in areas with moderate resilience and little or no presence of invasive annual grasses and with high resilience to create fuel mosaics and promote successional processes
- Suppress wildfires in moderate and especially low resilience and resistance sagebrush-dominated areas to prevent conversion to invasive annual grass states and thus maintain ecosystem connectivity, ecological processes, and ecosystem services
- Suppress wildfires adjacent to or within recently restored ecosystems to promote recovery and increase capacity to absorb future change
- Use fuel breaks in carefully targeted locations along existing roads where they can aid fire suppression efforts and have minimal effects on ecosystem processes (Maestas et al. 2016b)

Reduce the risk of nonnative invasive plant species introduction, establishment, and spread (R1, R2, R3)

- Limit anthropogenic activities that facilitate invasion processes including surface disturbances, altered nutrient dynamics, and invasion corridors
- Use Early Detection and Rapid Response (USDI 2016) for emerging invasive species of concern to prevent invasion and spread
- Manage livestock grazing to promote native perennial grasses and forbs that compete effectively with invasive plants
- Actively manage invasive plant infestations using integrated management approaches such as chemical treatment of invasives and seeding of native perennials from climatically appropriate seed sources.

Maintain or enhance key structural and functional groups (R1, R2, R3)

- Manage grazing to maintain soil and hydrologic functioning and capacity of native perennial herbaceous species, especially perennial grasses, to effectively compete with invasive plant species

- Manage grazing and free-roaming equid populations to maintain riparian-wetland functioning, streambank and floodplain stability, and vegetation sufficient to dissipate flood energy, promote infiltration, minimize erosion, and compete with invasive plant species.
- Reduce conifer expansion to prevent high severity fires and maintain native perennial herbaceous species that can stabilize geomorphic and hydrologic processes and minimize invasions
- Restore disturbed areas with functionally diverse mixtures of native perennial herbaceous species and shrubs from climatically appropriate seed sources and with capacity to persist and stabilize ecosystem processes under altered disturbance regimes and in a warming environment

Enhance genetic diversity (R2, R3)

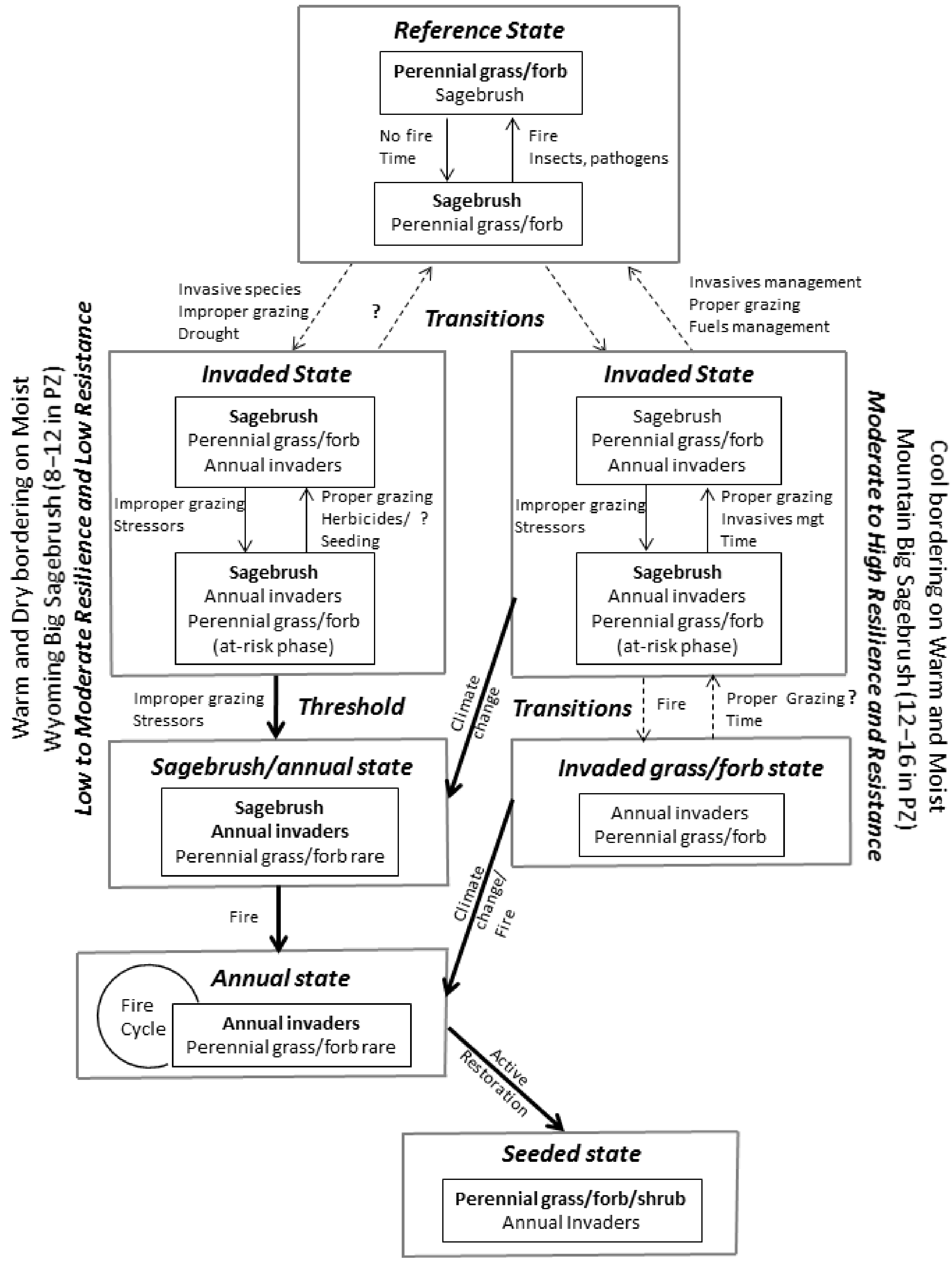
- Use seeds, germplasm, and other genetic material from across a greater geographic range that considers current climate and near-future climate (next ~20-30 years)
- Favor existing genotypes that are better adapted to future conditions because of pest resistance, broad tolerances, or other characteristics
- Increase diversity of nursery stock to provide those species or genotypes likely to succeed

Facilitate community adjustments through species transitions (R3)

- Monitor both native and invasive species at range margins to provide advanced warning of range shifts
- Implement assisted migration - *purposeful movement of individuals or propagules of a species to facilitate or mimic natural range expansion or long distance gene flow within the current range* – in areas with high rates of climate change

Plan for and respond to disturbance (R3)

- Practice drought adaptation measures such as altered grazing seasons or reduced grazing during droughts, conservation actions to facilitate species persistence
- Identify current and potential future areas where snowpack cover and duration are declining in order to manage to reduce other current stressors
- Anticipate and respond to species declines such as may occur on the southern or warmer edges of their geographic range by including plant materials from neighboring climate types in seed and planting mixes
- Favor or restore native species that are expected to be better adapted to the future range of climatic and site conditions
- Protect future-adapted regeneration from inappropriate livestock grazing and wild horse and burro grazing
- Avoid seeding introduced forage species that out-compete natives (Lesica and Deluca 1996; Davies et al. 2013)



Reference State
Perennial grass/forb
Sagebrush
No fire
Time
Fire
Insects, pathogens
Sagebrush
Perennial grass/forb
Invasive species
Improper grazing
Drought
?
Transitions
Invasives management
Proper grazing
Fuels management
Warm and Dry bordering on Moist
Wyoming Big Sagebrush (8–12 in PZ)
Low to Moderate Resilience and Low Resistance
Invaded State
Sagebrush
Perennial grass/forb
Annual invaders
Improper grazing
Stressors
Proper grazing
Herbicides/ ?
Seeding
Sagebrush
Annual invaders
Perennial grass/forb
(at-risk phase)
Invaded State
Sagebrush
Perennial grass/forb
Annual invaders
Improper grazing
Stressors
Proper grazing
Invasives mgt
Time
Sagebrush
Annual invaders
Perennial grass/forb
(at-risk phase)
Cool bordering on Warm and Moist
Mountain Big Sagebrush (12–16 in PZ)
Moderate to High Resilience and Resistance
Improper grazing
Stressors
Threshold
Climate change
Transitions
Fire
Proper Grazing ?
Time
Sagebrush/annual state
Sagebrush
Annual invaders
Perennial grass/forb rare
Invaded grass/forb state
Annual invaders
Perennial grass/forb
Fire
Climate change/ Fire
Annual state
Fire Cycle
Annual invaders
Perennial grass/forb rare
Active Restoration
Seeded state
Perennial grass/forb/shrub
Annual Invaders

2122

2123

Figure 3.1. Generalized conceptual model showing the states, transitions and thresholds for relatively warm and dry Wyoming big sagebrush ecosystems with low to moderate resilience and low resistance to cheatgrass and cool and moist mountain big sagebrush ecosystems with moderate resilience and resistance in the Cold Deserts (see Part 1, Appendix 6, Chambers et al. 2017). **Reference state:** Vegetation dynamics are similar for both types. Perennial grass/forb increases due to disturbances that decrease sagebrush and sagebrush increases with time after disturbance**. Invaded state:** An invasive seed source, improper grazing, and/or stressors such as drought trigger a transition to an invaded state. Perennial grass/forb decreases and both sagebrush and invaders increase with improper grazing and stressors resulting in an at-risk phase in both types. Proper grazing, invasive species management, and fuels treatments may restore perennial grass and decrease invaders in relatively cool and moist Wyoming big sage and in mountain big sage types with adequate grass/forb, but return to the reference state is likely only for mountain big sage types. **Sagebrush/annual state:** In the Wyoming big sagebrush type, improper grazing and stressors trigger a threshold to sagebrush/annual dominance. **Annual state:** Fire, disturbances, or management treatments that remove sagebrush result in annual dominance. Perennial grass is rare and repeated fire causes further degradation. **Seeded state:** Active restoration results in dominance of perennial grass/forb/shrub. Treatment effectiveness and return to the annual state is related to site conditions, post-treatment weather, and seeding mixture. **Invaded grass/forb state:** In the mountain big sagebrush type, fire results in a transition to annual invaders and perennial grass/forb. Proper grazing and time may result in return to the invaded state given adequate perennial grass/forb. Increases in climate suitability for cheatgrass and other annual invaders may shift vegetation dynamics of cooler and moister mountain big sagebrush ecosystems towards those of warmer and drier Wyoming big sagebrush ecosystems. Although not shown here, woodland expansion and infill in mountain big sagebrush sites with conifer potential can result in transition to woodland-dominated or eroded states leading to crossing of biotic and abiotic thresholds (adapted from Chambers et al. 2014a)

4. WILDFIRE AND VEGETATION MANAGEMENT STRATEGIES

Michele R. Crist, Douglas W. Havlina, and Jeanne C. Chambers

Introduction

Wildfire has always played a role as an ecosystem process across the sagebrush biome. Yet, the scale of sagebrush ecosystem loss and fragmentation due to a combination of uncharacteristic wildfire, invasive annual grasses, piñon and juniper expansion, and anthropogenic use and development, requires a strategic approach to fire management that focuses available resources in the places that will maximize conservation return on investment. Wildfire management has the potential to increase that return on investment by enhancing the resilience of native sagebrush ecosystems to stress and disturbance and/or resistance to conversion to invasive annual grasses, which will aid in maintaining ecosystem connectivity and ecological processes. Similarly, vegetation management and post-fire restoration can help maintain functionally diverse plant communities with the capacity to persist and stabilize ecosystem processes under altered disturbance regimes. When placed in the context of large landscapes, these actions can be part of strategy to help maintain the necessary ecosystem processes and connectivity, allowing ecosystems and species to adapt to increasing pressure from anthropogenic land use and development, and fluctuations in climate

Managing for Wildfire Resilient Ecosystems

An understanding of the linkages among ecosystem resilience to disturbance and resistance to invasion, priority areas and habitats for management, and the predominant threats can be used to more effectively target wildfire and habitat management actions while maximizing their benefits. In the context of the Science Framework Part 1, wildfire processes may have varying negative and positive effects on sagebrush communities depending on the relative resilience of a site to disturbance and resistance to invasive annual grasses (see Chambers et al. 2017, sections 5.1 and 6). Geospatial analyses can be used to assess the relative resilience and resistance, and thus recovery potential, of areas that support species or resources at-risk. They can also be used to assess the probability of wildfire occurring within these same areas and the interactions of wildfire with resilience and resistance of sagebrush habitats (table 1.2 and 1.3; and see Chambers et al. 2017, sections 8 and 9). Identifying sagebrush habitats at risk from wildfire involves overlaying key data layers to both visualize and quantify: (1) species locations and abundances; (2) the probability that an area has suitable habitat for the species of interest; (3) the likely response of the area to either wildfire or management treatments; and (4) the dominant threats, such as wildfire. Calculating the areas within different resilience and resistance and habitat categories along with the different burn probabilities by ecoregion (fig 1.1), or Priority Areas of Conservation (PACs) within Management Zones (MZs) for Greater sage-grouse (GRSG), can be another step in the process.

A wildfire risk assessment (fig. 4.1) was conducted using GIS data layers to understand how resilience and resistance in GRSG habitat may inform wildland fire management related to preparedness, suppression, fuels management, and post-fire restoration across the sagebrush biome. Three GIS datasets were used: burn probability (Short et al. 2016), GRSG breeding habitat probabilities (Doherty et al. 2016), and resilience and resistance as indicated by soil temperature and moisture regimes (Maestas et al. 2016a) (See Appendix 10, Chambers et al. 2017). The wildfire risk assessment identifies areas where ecosystem resilience and resistance interact and where sagebrush and GRSG habitats are at highest risk from wildfire across the sagebrush biome and current GRSG range. The wildfire risk assessment can be used to help (1) evaluate the level of risk to vegetation types and species to wildfire, (2) target areas for wildfire management, and (3) determine the most appropriate types of fire management actions. Incorporating information on the land cover of juniper expansion and invasive annual grasses further informs the type of management actions and the allocation of resources at broad (e.g. national) and mid- (e.g. regional or state) scales as well as specific types of treatments at local (e.g. project) scales. It is noteworthy that in the eastern part of the GRSG range, invasive annual grass/fire cycles are an emerging problem (Floyd et al. 2004, 2006; Baker 2011; Mealor et al. 2012, 2013) that burn probabilities, based on historic burn areas, do not illustrate.

The following sections provide information on how to incorporate the concepts of resilience and resistance, and information from the Science Framework Part 1 (Chambers et al. 2017) at multiple management scales.

Broad to Mid- Scale Considerations

Wildfire Preparedness and Suppression

Optimizing wildfire preparedness and suppression response is highly complex and considers fire danger, availability of suppression resources, access to- and remoteness of fire, and many other ecological, social, political, and economic variables. Across the sagebrush biome, federal land management agencies and their partners are building sagebrush conservation into all fire management decisions. When coupled with fire simulation modeling, fire operations and integrated vegetation management programs contribute to a strategic, landscape approach based on the likelihood of fire occurrence and potential fire behavior (Finney et al. 2010, Oregon Department of Forestry 2013). Numerous factors influence wildfire preparedness and suppression activities and placement of fire management resources, including safety, human values, infrastructure, and natural resource considerations. In the sagebrush biome, wildfire managers use the Integrated Rangeland Fire Management Strategy (IRFMS; USDOI 2014) to assess preparedness and suppression responses based on the location of GRSG habitats and populations, resilience and resistance information, and other factors.

Information from the Science Framework Part 1 (Chambers et al. 2017) and the GRSG fire risk assessment (fig. 4.1) can provide a spatial framework for prioritizing wildfire suppression efforts. This information combined with other risk factors (e.g., Wildland Urban Interface) is used in the decision-making processes for preparing and responding to wildfires across the nation. Differences in environmental characteristics and management strategies across the sagebrush biome are included to further refine prioritizations. In addition, combining results of the fire risk assessment with NIFC Predictive Services seven-day potential fire forecasts may help inform where to pre-position fire crews, equipment, and aircraft in areas predicted to experience fire ignitions and relative risk of large fire growth, for rapid response in GRSG habitat when fire activity is high.

Suppression priorities for GRSG and their habitats identified in mapping efforts are used during periods of fire activity in order to respond to incidents and assign resources at regional scales (e.g., within states or national forests). Wildfire managers can distribute and share the wildfire risk assessment and other geospatial data layers with dispatch offices, incident commanders, wildfire crew bosses, and other fire responders. Recently, cooperators such as rural, city, and state agencies as well as partners such as Rangeland Fire Protection Associations, have contributed to suppressing wildfire in sagebrush habitats. Sharing these mapping resources may help improve initial attack effectiveness during periods of increased fire activity.

Considerations for wildfire operations aimed specifically at prioritizing response to wildfires burning in GRSG habitat within assessment areas are presented below:

- In general, areas that support medium to high GRSG breeding habitat probabilities (or other important resources) and have moderate to high wildfire risk are higher priorities for preparedness and suppression efforts, especially in low resilience and resistance categories (fig. 4.1).
- Areas with moderate and high resilience and resistance often have the potential to recover through successional processes without management intervention (table 1.2; cells 1B, 1C, 2B, 2C). Fire suppression priority typically increases from low to moderate as resilience and resistance decreases from high to moderate.
- Areas with low resilience and resistance often lack the potential to recover without significant intervention. Fire suppression priority typically increase from moderate to high as GRSG breeding habitat increase from moderate to high (table 1.2; cells 3B, 2C).
- Newly rehabilitated areas and areas that provide sagebrush habitat connectivity are conservation priorities and may be considered fire suppression priorities.

Managing wildfires in areas that are at risk of ecosystem conversion to piñon and juniper woodland (Phase 1) and are characterized as having high resilience to fire and high resistance to invasive annual grasses can be part of a vegetation management strategy, but only when and where: (1) weather and fuel conditions allow for managing the fire with acceptable limits to values at risk; and (2) high priority GRSG breeding habitats and the associated populations are not at risk from loss. Recently (since 2000), several large wildfires burned in sagebrush and grass ecosystems where juniper expansion was occurring in highly resilient and resistant sagebrush communities and helped achieve reductions in juniper expansion (Romme et al. 2009; Bukowski and Baker 2013).

Geospatial data layers from the Science Framework Part 1 (Chambers et al. 2017) may be useful for identifying priorities for road maintenance and updates to standards in travel and recreation management planning efforts. In preparedness and suppression efforts, the road network is a key element for quick fire response. It also functions as a fuel break network by disrupting fuel continuity across large scales (Agee et al, 2000; Syphard 2011; Narayanaraj and Wimberly 2013). Travel and recreation planning processes identify a minimum road network needed to maintain access for all aspects of land management. Prioritizing roads in travel planning for wildfire management access and maintenance based on close proximity to GRSG habitat areas that are at high risk of fire and characterized by low resilience and resistance can contribute to an effective response to wildfire (fig. 4.1).

Vegetation Management and Post-Fire Recovery

The IRFMS establishes key objectives for vegetation management and post-fire rehabilitation. Meeting objectives for vegetation management can include improving the prioritization and siting of fuels reduction/management opportunities and resource restoration projects. Considerations for post-fire rehabilitation objectives can include promoting long-term restoration efforts and natural recovery, updating prioritization criteria, and incorporating science to promote resilience and resistance. Integral to these objectives are considerations of sagebrush, GRSG habitat, ecosystem resilience and resistance, and persistent ecosystem threats, including fire, the current distribution and abundance of invasive annual grasses, and juniper expansion.

The methods for geospatial analyses described in Chambers et al. 2017, sections 8 and 9 can help target areas for fuels reduction and post-fire rehabilitation. Key data layers include not only resilience and resistance as indicated by soil temperature and moisture regimes and GRSG breeding habitat probabilities and densities, but also burn probabilities, land cover of invasive annual grasses, and land cover of juniper expansion areas, other sagebrush obligate habitats, and their habitat corridors and movement pathways (where available). Primary considerations in prioritizing areas for management within assessment areas are presented below and also follow table 1.3. Guidelines for conducting treatments using resilience and resistance concepts are in Chambers et al. 2017, table 9 and Miller et al. (2014, 2015), and are discussed in more detail in “Local Scale Considerations”:

- In general, areas that support medium to high GRSG breeding habitat probabilities or other important resources and have moderate to high fire risk (fig 4.1) are higher priorities for vegetation management.

- Areas with moderate and especially high resilience and resistance often respond favorably to vegetation management projects (table 1.2; cells 1B, 1C, 2B, 2C). The risk of invasive annual grasses increases as resilience and resistance decrease.
    - Areas exhibiting piñon and juniper expansion in or adjacent to high GRSG breeding habitat probabilities are high priorities for conifer removal treatments.
    - Prescribed fires may also be used to help with juniper expansion and trade-offs need to be considered in making the decision to use this tool. Trade-offs include: (1) when weather and fuel conditions allow for managing the fire with acceptable implications to values at risk; and (2) where high priority GRSG populations and corresponding habitats are not at risk from loss.
- Areas with low resilience and resistance typically are more challenging to restore and take a longer time to respond to vegetation management projects (table 1.3; cells 3B, 3C). The risk of invasive annual grasses increases as resilience and resistance decrease.
    - High quality GRSG breeding habitats with moderate to high fire risk and low resilience and resistance may be prioritized for wildfire protection activities *but* should not be prioritized for vegetation management activities that could degrade habitat quality and connectivity.
    - Low breeding habitat quality areas in and adjacent to high GRSG breeding habitat probabilities with moderate to high fire risk and lower resilience and resistance may have higher priorities for fuel breaks (Maestas et al. 2016b).
    - Sagebrush reduction (prescribed fire, mechanical removal, chemical treatment) requires caution and is generally not recommended (Chambers et al. 2017, table 9; Davies et al. 2011; Beck et al. 2012; Chambers et al. 2014b).
    - Prescribed fire is also used on occasion in conjunction with other treatments to reduce invasive perennials and annual grasses as part of a sagebrush ecosystem restoration strategy. Similar trade-offs as those stated above can be considered in the decision in using this tool in these areas.

- In general, areas that support moderate to high GRSG breeding habitat probabilities, or other important resources, and have low to moderate resilience and resistance are priorities for post-fire rehabilitation. In many cases, areas of high or moderate resilience and resistance, that are relatively cool and moist, can recover without management intervention and are low priorities for post-fire rehabilitation.

Vegetation Management. Strategic placement of vegetation management projects across large landscapes is an important step to mitigate the collective effects of fires interacting over broad spatial and temporal extents and help conserve vegetation patterns. Assessments for prioritizing fuel reduction and restoration activities may include potential fire behavior and spread, effects on threatened and endangered flora, habitat fragmentation thresholds (e.g. science is available on GRSG lek buffers and habitat thresholds (Knick et al. 2013; Manier et al. 2014a; Crist et al. 2015)), minimum habitat patch sizes, corridors and movement pathways in between seasonal and dispersal habitats. These assessments can help site restoration and fuel reduction actions across the landscape to maintain or increase connected sagebrush areas while increasing capacity to protect areas at high risk from fire.

From a fire behavior perspective, the siting of vegetation management projects can take into account the likelihood of spread around large sagebrush dominated patches to reduce the potential for unwanted fire behavior or effects. In the arid sagebrush and woodland ecosystems, increased continuity of invasive annual grasses cover, such as cheatgrass, can inhibit the natural re-seeding of native vegetation after wildfire and lead to more continuous cheatgrass fuel loads. Once cheatgrass patchiness is eliminated, the invasive/fire cycle leads to more frequent and larger wildfires, which can subsequently allow cheatgrass to dominate. Where GRSG densities are high and sagebrush ecosystems are intact but at risk of invasive annual grasses due to low resilience and resistance, strategically-placed fuel reductions and fuel breaks could help maintain landscape and habitat resilience to wildfire (Gray and Dickson 2016). For example, relatively intact sagebrush patches may be located next to large patches of annual invasive grasses that have a high likelihood of igniting and facilitating the spread of fire into the larger landscape. Sites already dominated by annual grasses that are lower value GRSG habitat, could be priorities for prepositioning fire resources and proactive fuels management practices such as fuel breaks, green stripping, and targeted grazing to avoid future spread into higher-value habitat in the surrounding landscape.

Piñon and juniper woodlands have exhibited range expansions into sagebrush ecosystems due to favorable climate periods for tree establishment, increases in CO_2, fire suppression, and livestock grazing (Miller et al. 2011; Romme et al. 2009; Miller et al. 2013). This expansion, however, is not uniform across the sagebrush biome where some areas show substantial expansion and other regions show minimal expansion and infilling (Manier et al. 2005; Romme et al. 2009). While rates of piñon and juniper expansion have slowed in recent decades due to less favorable climatic conditions, fewer suitable sites for tree establishments, and an increase in wildfire and bark beetle activity in some regions (Breshears et al. 2005; Miller et al. 2008; Romme et al. 2009); infilling of trees appears to continue in expansion areas, most noticeably in the Great Basin (Miller et al. 2008). In general, early to mid-phase (i.e, Phases I and II) piñon and juniper that have expanded into occupied GRSG breeding habitat with high to moderate resilience and resistance should be targeted first for vegetation treatments (table 1.2; cells 1B, 1C, 2A, 2B). Treatments should be conducted in areas with sufficient grasses and forbs to promote recovery and with low risk of increases in invasive annual grasses. Prescribed fire can be used selectively in consultation with wildlife and habitat managers. When considering piñon and juniper removal treatments, the broader context of longer-term trends in wildfire activity, past conifer removals, bark beetles, and climate can also be helpful in evaluating the need for management treatments (Romme et al. 2009; Arendt and Baker, 2013; Allen et al. 2015).

Post-fire recovery. Large fires occur across varying environmental gradients and conditions and are often composed of varying resilience and resistance sites. These variable environmental conditions (including resilience and resistance), as well as an understanding of dominant vegetation types pre-fire, can help identify areas where restoration efforts have a higher likelihood of success in achieving restoration of ecosystem composition, function, and processes. Resilience and resistance concepts coupled with information on non-native invasives threat and appropriate seeding strategies (See Section 5. Nonnative Invasive Plant Species Management, and 6. Application of National Seed Strategy Concepts) can help determine the strategic placement of post-fire recovery efforts, and inform the likely time frames for recovery among and within large burned areas. In addition, this type of approach ensures limited rehabilitation funds are placed in the appropriate areas.

In lower resilience and resistance areas, sagebrush restoration after a wildfire can take several decades or more and presents a serious challenge for managers seeking to maintain stable populations of sagebrush dependent wildlife. Strategic placement of post-fire recovery efforts to expand sagebrush patch refugia (unburned islands within a burned area) and reconnect existing sagebrush patches outside burned areas to refugia will help restore large and contiguous sagebrush patches needed by GRSG and sagebrush obligates (Pyke 2011; Williams et al. 2011). This type of strategic seeding mimics natural succession where fire tolerant plants generally resprout and fire intolerant plants like sagebrush establish from the available seedbank or from seeds that disperse into the disturbed area from nearby unburned patches (Meyer and Monsen 1990; Baker 2006; Pyke 2011; Rottler et al. 2015). Restoration of shrub cover across burned areas will provide habitat, cover, and connectivity to reduce exposure to predators for many sagebrush wildlife obligates.

Adaptive Management and Monitoring in Wildfire Management

Agencies that implement monitoring strategies can increase their understanding of the effectiveness associated with various management actions (including but not limited to fuels management and post-fire rehabilitation; see Section 2. Adaptive Management and Monitoring). Monitoring at the broad and mid-scales can be used to evaluate changes in fire characteristics and ecosystem responses to management actions implemented to address these threats (such as invasive annual grasses). Fire-related monitoring indicators across all scales are being identified and developed through agency monitoring programs to measure the effectiveness of managing wildfire in sagebrush ecosystems. Monitoring results can be incorporated into future assessments to help understand where fuels reduction and restoration efforts are successful and where changes in management strategies are needed. This information can be used in an adaptive management context to determine shifts in fire management priorities and reallocate resources.

Climate Adaptation and Wildfire Management

Given climate variability and longer fire seasons across the western U.S., resilience and resistance concepts may offer a proactive approach for modifying trends toward larger fires and maintaining resilient ecosystems (see Section 3. Climate Adaptation and Mitigation). Wildfire risk assessments can help identify where land-uses and weather patterns have contributed to increases in large, severe wildfires and conversion to new alternative states (Westerling et al. 2006; Miller et al. 2008; Littell et al. 2009; Abatzaglou and Kolden 2013). Identifying areas where current and forecasted GRSG habitat has a high potential to exist through time under differing climate variability scenarios may help identify habitats that can be prioritized for protection or adaptive management that maintain or improve their current habitat quality.

Local Scale Considerations

Wildfire Preparedness and Suppression

The key to effective local wildfire management is strategic placement of fuel reduction projects in relation to wildfire risk combined with the placement of wildfire preparedness resources for the upcoming wildfire season. The combination of these two efforts are integral to improving the chances of reducing wildfire size and effects during suppression efforts. Opportunities for exchanging data and maps between resource and fire managers occurs during meetings for pre-season fire preparations to develop local suppression priorities based on likelihood of wildfire, resilience and resistance, locations of completed vegetation and fuel reduction projects, and key habitats. Across jurisdictional units, this information can be integrated into pre-planned dispatch procedures used to allocate fire suppression resources during the fire season. This information can help local fire managers discern where wildfire may achieve local ecological benefits compared to areas where wildfire may have negative ecological effects because of high ecological sensitivities. In addition, suppression of fires adjacent to or within recently restored ecosystems to promote recovery and increase capacity to absorb future changing conditions.

In wildfire suppression, tactics used when managing a fire can have major consequences to the resultant burned area. Practices such as burning out unburned patches of sagebrush on the interior of the fire perimeter instead of extinguishing "mop up" fire hotspots within the burn perimeter reduces the opportunity of a sagebrush seeding source that is already established. Best management practices used during wildfire incidents can include the following practices to help preserve large patches of sagebrush habitat: (1) the suppression of wildfire for large interior islands of unburned sagebrush, and (2) directing suppression efforts on the front of a fire when safety or fire spread is not an issue.

Based on wildfire weather forecasts, preparedness resources are commonly staged or "prepositioned" in anticipation of wildfire occurrence at certain fire weather thresholds. "Severity" funding is provided to units having high wildfire danger based upon local forecasts and conditions to obtain additional resources for initial attack. BLM units also may acquire additional aviation resources, engines, crews, and other assets when known weather events or high fire danger conditions are anticipated to protect key GRSG habitats. Data and maps contained in the Science Framework Part 1 and the wildfire risk assessment (fig. 4.1) may be incorporated in the prioritization and allocation of severity funding to BLM state offices and national forests that contain large areas of sagebrush and GRSG habitat at risk of loss from fire.

Vegetation Management and Post-Fire Recovery

Vegetation management and post-fire recovery activities can influence ecosystem resilience to disturbance and resistance to invasive annual grasses by improving and/or restoring the structure and composition of vegetation communities at the project scale. Fuel reduction treatments focuses on removing or modifying wildland fuels to reduce fuel loads to decrease fire size and severity. Both fuel reductions and post-fire recovery activities can increase perennial grasses and forbs, which in turn determines resilience to disturbance (recovery potential) and resistance to invasive annual grasses, as they lower the longer-term risk of conversion to invasive annual grass dominance, and increase soil stability and reduce erosion.

Vegetation Management. Individual fuel reduction treatments aimed at reducing the continuity of cheatgrass through targeted grazing, herbicides, and native cheatgrass diseases and fungi (See Section 5. Nonnative Invasive Plant Species Management) can collectively fragment fuels potentially reducing fire connectivity within a project boundary. These fuel reduction methods help modify individual fire behavior by reducing fine fuel connectivity to slow or stop fire spread between cheatgrass patches and into intact native vegetation (See section 6. Nonnative Invasive Plant Species Management). Resilience and resistance concepts can be incorporated in fuel reduction methodologies (table 1.2; cells 2A, 2B, 2C, 3A, 3B, 3C); and concepts and strategies for prioritizing areas for management and determining appropriate fuel reduction strategies at Management Zone and Ecoregional scales are also generally applicable at local scales (tables 1.2 and 1.3).

Roads play a significant role in influencing wildfire ignition and cessation at the local scale. Fire boundaries tend to occur near roads because roads facilitate fire suppression by providing access and act as fuel breaks because the road footprint is vegetation free providing a no burn zone that reduces the spread of fire (Syphard et al. 2011; Narayanaraj and Wimberly 2011, Narayanaraj and Wimberly, 2013; Price and Bradstock, 2010). In the sagebrush ecosystem, fuels reductions have been focused on using road-sides in low to moderate resilience and resistance areas to create linear fuel breaks that disrupt fuel continuity along roads by reducing fuel accumulation (Williams et al. 2015; Maestas et al. 2016b). Removal of vegetation usually occurs in widths no greater than 300 feet based on landscape conditions, wildfire spotting potential, and expected flame length. Fuel breaks are intended to reduce flame lengths, fire line intensity, and rates of fire spread in order to enhance firefighter access, improve response times, and provide safe and strategic anchor points for wildland fire-fighting activities (e.g., back burning).

While anecdotal evidence suggests that properly designed fuel breaks can help with fire operations, the ecological and economic consequences of linear fuel breaks are relatively unknown. There are concerns that fuel breaks may serve as conduits for invasive annual grasses, fragment wildlife habitat, disrupt wildlife movement pathways, and incur annual maintenance costs in conjunction with ongoing road maintenance costs. As a result, the area influenced by roads and their edge effects is markedly larger than the area covered by roads themselves (Forman and Alexander 1998; 2003; Naranaraj and Wimberly 2013). The invasion of nonnative invasive plant species initiated by roads frequently becomes a source of combustible fuels (Arienti et al. 2009; D'Antonio and Vitousek 1992; Parendes and Jones 2000; Trombulak and Frissell 2000). Subsequently, these fuels may contribute to a greater incidence of human- and lightning-caused ignitions near roads (Arienti et al. 2009; Syphard et al. 2007, 2008; Yang et al. 2007, 2008a,b).

In the design of linear fuel breaks, site assessments focused on soil conditions are helpful in determining which species are best suited to plant (Maestas et al. 2016b). Typically, species such as forage kochia and crested wheatgrass are used to provide fire resistant green strips and to prevent soil erosion in fuel breaks. However, native perennial grasses may fill this management niche as well or better on certain sites because: (1) the low stature of native grasses such as Sandberg bluegrass reduces the fuel height and fuel loading; (2) native grasses can compete well with invasive annual grasses and reduce fine fuels and fuel continuity; (3) many native grasses are drought tolerant and local seed sources may establish better on dry sites than forage kochia and crested wheatgrass; (4) many native grasses are tolerant of disturbance; and (5) the potential for spread into adjacent areas is not problematic (Williams 2015; Gray and Muir, 2013). Other techniques include modifying existing roadbeds, herbicides, intensive grazing, juniper woodlands removal, or prescribed fire to reduce vegetation (Moriarti et al. 2015).

For sagebrush ecosystems exhibiting piñon and juniper expansion and infill, Miller et al. (2014) provide a framework for selecting treatment areas and appropriate treatments based on resilience and resistance concepts and is consistent with the Science Framework Part 1 (Chambers et al. 2017). Specific criteria for determining suitable sites and treatments are based on (1) the phase of juniper expansion, (2) temperature and moisture regimes, (3) the relative abundance, type, and fire tolerance of the native perennial grasses and forbs, and (4) the relative abundance of invasive annual grasses. Other factors should be considered in treatment design: (1) juniper and piñon response to past removal and other management activities; (2) variation in long-term weather patterns (e.g. warmer temperatures and less precipitation; see Section 3 Climate Adaptation and Mitigation Section); and (3) presence and relative abundances of invasive annual grasses, and (4) tradeoffs for sharply declining populations of piñon and juniper obligates (e.g., pinyon jay). In addition, designing juniper removals that mimic stand structure after natural disturbance such as fire (e.g. creating a convoluted edge and small gaps in mature woodland stands) will help mitigate the effects of treatments on piñon and juniper obligates.

Post-fire Recovery. Miller et al. (2015) provide a framework for evaluating the resilience and resistance of post-fire sites in the Great Basin and make recommendations for post-fire recovery methods based on ecological site characteristics that can be modified for the eastern portion of the sagebrush biome. The decision to seed post-fire is based on rapid assessments of the ecological sites within the project area. Information on temperature and moisture regimes, pre-burn vegetation (including sagebrush species), perennial grasses and forbs, invasive annual grasses, and fire severity are used to rate the relative resilience and resistance of the ecological site(s). Specific criteria for determining the need to seed and appropriate seeding methods are provided based on temperature and moisture regimes and the relative abundance and type of native perennial grasses and forbs and invasive annual grasses. In general, higher resilience and resistance sites (table 1.2; Cells 1A, 1B, 1C) are more likely to recover without seeding than lower resilience and resistance sites (table 1.2; Cells 3A, 3B, 3C, Miller et al. 2015). If native perennial grasses and forbs are sufficient to promote recovery after fire, seeding is not needed. If native perennial grasses and forbs were depleted or absent prior to the fire and/or invasive annual grasses were abundant, seeding is likely needed. In areas with severely depleted native species and abundant invasive annual grasses, integrated management approaches may be necessary that include herbicide application prior to seeding.

An understanding of resilience and resistance as indicated by precipitation and temperature regimes can be used to inform seeding decisions in vegetation management and post-fire rehabilitation. In the past, nonnative species or aggressive native cultivars were often seeded in post-fire recovery efforts because many germinate and establish quickly, are less expensive than native species, provide livestock forage, and can compete with nonnative, invasive species (Davison and Smith 2005; Monaco et al. 2003; Pyke and McArthur 2002; Brooks and Pyke 2001; Richards et al. 1998; Pellant 1994). However, in the last two decades native seeds have become more available, the trade-offs between seeding native and nonnative species are better understood, and resource managers are using more native species in fuels management and post-fire recovery applications (see Section 6. Application of National Seed Strategy Concepts).

Monitoring Vegetation Treatments

Monitoring to evaluate site recovery after fuel treatments and post-fire rehabilitation provides the necessary information to determine if management objectives were met and if treated sagebrush ecosystems have recovered a composition, structure, and function that is sustainable over time (see Section 2. Adaptive Management and Monitoring). Monitoring also can be used to inform where fuel reductions and post-fire recovery efforts were successful, as well as identify areas where further restoration or adaptations to management strategies may be needed over time to help lower fire risk (e.g., Knudtson et al. 2014). Monitoring survey plots (e.g. NRI, AIM, and FIA) as well as remote sensing can provide understanding of the ratio of woody to herbaceous plant abundance, and transitions that may occur between dominance of woody plants and herbaceous species (especially highly flammable invasive annual grasses). The calculated ratios between woody and herbaceous abundance can be linked to fire potential, fire behavior, and fire severity. Quantifying the results of monitoring metrics will be useful in developing fuels treatments that address build-up of fuels, as well as preparing for certain hazardous fire behavior.

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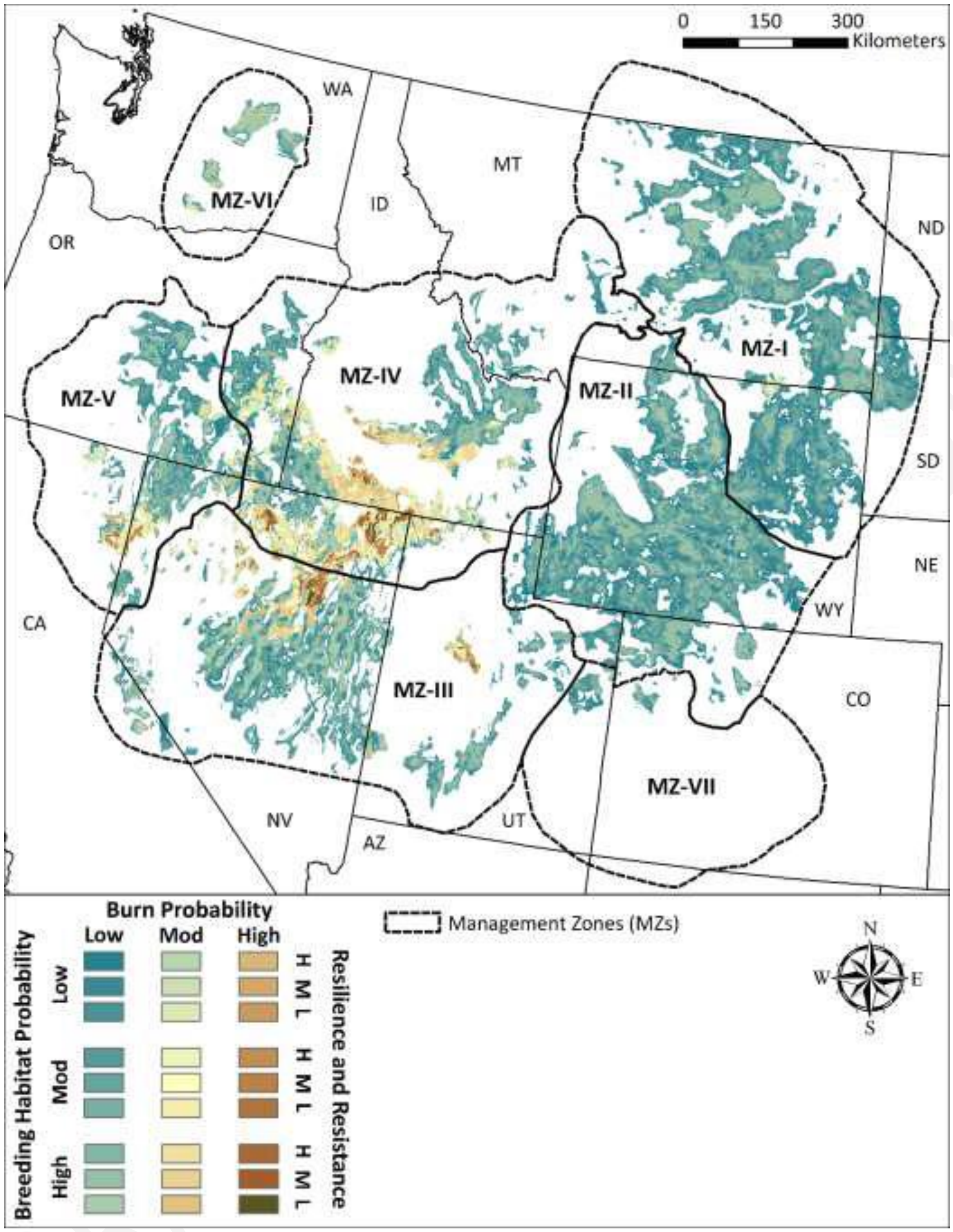

Figure 1—Wildland fire risk map (Crist et al. 2016; See Appendix 10 in Chambers et al. 2017) depicting 27 different combinations of Greater sage-grouse breeding habitat probability (Doherty et al. 2016), resilience and resistance (Maestas et al. 2016a), and large fire probability (Short et al. 2016).

5. NONNATIVE INVASIVE PLANT SPECIES MANAGEMENT

Lindy Garner, Jeanne C. Chambers, Kenneth Mayer, Michele R. Crist, and Mike Ielmini

Introduction

One of the most significant stressors to the sagebrush biome is expansion and dominance of ecosystem-transforming invasive plants, particularly invasive annual grasses. Invasive plant species colonize new areas in response to disturbance (e.g., human development, inappropriate grazing practices, and wildfires), and spread through various pathways and vectors, such as roads and vehicles (Trombulak and Frissell 2001). Once established, invasive plant species often continue to spread across the landscape in areas where suitable conditions exist. Invasive plant species can become ecologically dominant creating near-monocultures that result in reduced wildlife habitat, recreational opportunities, livestock forage, and altered fire regimes (Pyke et al. 2016). Invasions can degrade ecosystem function by affecting geomorphic processes, hydrology, nutrient cycling, community structure, composition, and productivity, and regeneration of native species (Germino et al. 2016).

Invasive plant species range from state-listed noxious species (named under state law) to unlisted species (e.g., cheatgrass) and differ in the magnitude of the threat they pose to sagebrush ecosystems. Invasive annual grasses, most notably cheatgrass (*Bromus tectorum*), medusahead rye (*Taeniatherum caput-medusae*) and red brome (*Bromus rubens*) are arguably the most widespread ecosystem disrupters across the sagebrush biome. Yet many other invasive species are also responsible for environmental damage. For example, leafy spurge disperses into riparian and wet meadow areas important to Greater sage-grouse (*Centrocercus urophasianus;* hereafter, GRSG) brood-rearing habitat. Tap-rooted species such as spotted knapweed (*Centaurea maculosa*), Russian knapweed (*Acroptilon repens*), and yellow salsify (*Tragopogon dubius*) spread into upland sagebrush ecosystems, especially in areas that experience heavy livestock grazing and other disturbances (Hill et al. 2006; Prevey et al. 2010). Also, species such as dalmatian toadflax (*Linaria dalmatica*) are spreading into moist areas throughout the sagebrush biome (Ielmini et al. 2015).

Land managers are tasked with controlling the various species of invasive plants, but limited resources are available for invasive plant management. Invasive species ranking systems (see review in Olsen et al. 2015) can assist land managers in ranking invasive plant species for level of threat, feasibility of control, and degree of negative impact, but often information is lacking for several species. The need to manage multiple invasive plants while considering ecological impacts and social and political priorities often results in significant challenges in determining how to partition resources for invasive plant management.

Integrating Resilience and Resistance Concepts into Invasive Plant Species Management

An understanding of ecosystem resilience to disturbance and resistance to invasive plants can be used to help prioritize invasive species management and determine effective management strategies. Information on how and why resilience and resistance differ across the sagebrush biome are described in Part 1 of the Science Framework, Section 6 (Chambers et al. 2017a). Resistance to invasive plants is of particular relevance to this section. The resistance of an ecosystem to an invasive plant is a function of (1) the suitability of the ecosystem's climate and soils for establishment and persistence of the invasive plant, and (2) the capacity of the native plant community to prevent increases in the invasive plant's population through factors such as competition or herbivory (Chambers et al. 2014a). Soil temperature and moisture regimes are a primary determinant of a species ability to establish and persist in a given ecosystem and, thus, are an important indicator of ecosystem resistance to an invasive species (Chambers et al. 2014a, b, c). In areas with suitable climate and soils for invasion, increases in invasive plant populations are strongly influenced by interactions with the native perennial plant community. Disturbances or management activities that reduce abundance of native perennial grasses and biological soil crusts and increase the distances among perennial grasses often are associated with higher resource availability and increased competitive ability of invasive annual grasses (Collins and Uno 1985; Salo et al. 2005; Chambers et al. 2007; Reisner et al. 2013; Roundy et al. 2014) and invasive forbs like spotted knapweed (*Centauria stoebe ssp. micranthos* syn. *C. maculosa*) (Willard et al. 1988). Reductions in native perennial grasses and herbaceous species coupled with increases in nonnative invasive plant species can decrease the resilience of an ecosystem or its capacity to recover following disturbances such as wildfire.

The Science Framework Part 1 (Chambers et al. 2017a) is based on the concepts of resilience and resistance and provides scientific information to help land managers determine cost-effective management strategies and methods for invasive species management. Specifically, the Science Framework provides decision-making criteria for land managers to consider at multiple scales when managing invasive plants, especially in the context of GRSG and other species and resources at-risk.

The following questions identify the basic invasive plant management information needs with examples of how the Science Framework Part 1 (Chambers et al. 2017a) ecological information (resilience and resistance) can inform management decisions:

1) Where are your priority areas for management, how are they defined (e.g., GRSG habitat, mule deer wintering habitat, particular ranch for forage production, community at risk of wildfire, etc.), and where can resources be leveraged with partners and stakeholders for the greatest chance of success and?
2) What is the current state of invasion and how high is the risk for new or further invasion of priority management areas (e.g., low resilience and resistance, significant disturbance, high density of vectors, other invasions in the area, etc.)?
3) Which management strategies (e.g., prevention, early detection rapid response, suppression, containment, restoration) are feasible and can provide the highest return on investment (e.g., a containment strategy may be the only feasible strategy for a low resilience and resistance site dominated with invasives)?
4) Which tool(s) are most appropriate for the site conditions and level of invasion (e.g., herbicide for eradication strategy, biocontrol for suppression when several hundred acres infested, restoration for moderate infestations in moderate resilience and resistance)?
5) Is a monitoring plan in place to determine if the management objective was achieved and the invasion threat reduced, and if follow-up actions are needed?

The following sections provide summaries on how best to incorporate the concepts of resilience and resistance and the scientific information from Chambers et al. (2017a) in addressing these questions at the broad to mid-scale and project to site (local scale).

Invasive Species Management Considerations at Broad and Mid-Scales

Using the Science Framework Approach to Inform Invasive Species Management

Many nonnative invasive plant species, like invasive annual grasses, represent persistent ecosystem threats (Chambers et al. 2017a) and are widely distributed across the sagebrush ecosystem. The extensive nature of the invasion threat and limited resources for invasive species management preclude feasibility of addressing invasive species across the entire biome The Science Framework Part 1 provides an approach based on ecosystem resilience and resistance that uses assessments at the ecoregional or GRSG Management Zone scale (mid-scale) to help prioritize areas for management and determine effective management strategies (Chambers et al. 2017a). The approach is based on: (1) the likely response of an area to disturbance or stress due to threats and/or management actions (i.e., resilience to disturbance and resistance to invasion by nonnative plants), 2) the capacity of an area to support target species and/or resources, and 3) the predominant threats. The approach uses a geospatial process that involves overlaying key data layers including resilience and resistance as indicated by soil temperature and moisture regimes (Maestas et al. 2016), sage-grouse breeding habitat probabilities (Doherty et al. 2016) or other sagebrush obligate habitats, and the primary threats for the ecoregions or Management Zones in the assessment (See sections 8.1 and 8.2; Chambers et al. 2017a).

Geospatial data on invasive species distributions and abundances can be used similarly to other threats in the analyses. Geospatial analyses of the locations and magnitudes of invasive plant species can be used to help (1) evaluate the level of risk of vegetation types and species to invasive plant species, (2) further refine target areas for management, and (3) determine the most appropriate types of management actions. Data layers on roads and other invasive vectors can be used to evaluate the level of risk for future spread of the invasives. Also, data on interacting threats (e.g., wildfire) can help provide an understanding of the patterns and spread of invasive plant species. Available data layers are in Science Framework Part 1, section 8.1 and Appendix A.8 (Chambers et al. 2017a).

The sage-grouse habitat resilience and resistance matrix (table 1.2) illustrates an area's relative resilience to disturbance and resistance to invasive annual grasses in relation to its probability of providing breeding habitat for GRSG. This matrix is a decision support tool that helps to prioritize areas for invasive plant management actions and develop effective management strategies. Management strategies to address the predominant threats for sagebrush ecosystems including invasive plant species are found in table 1.3. The maps and analyses that managers derive from the geospatial approach described in the Science Framework Part 1 are used along with table 1.2 to prioritize areas for management actions and develop management strategies.

Coordination

Collaboration across landownerships and jurisdictions to develop shared priorities and leverage resources provides an effective strategic approach for managing invasive plant threats. Collaborative spatial analyses conducted with partners and stakeholders can help identify the extent and scope of invasives and priority areas for management. Then, a participatory process guided by a single strategic approach can be used to prioritize who, what, where, how, and when actions are implemented at the project level.

Area-wide invasive plant management problems provide an opportunity for diverse interests to work collaboratively to develop mutually beneficial management strategies. Formally establishing cooperative weed management area (CWMA) partnerships across the sagebrush biome can help coordinate this type of effort. CWMAs could have county, state, federal and private members, with adequate operational funding to address regional and project level invasive species management. Geographically defined CWMAs could be strategically located to maximize their ability to address the highest priority areas for invasive species management. A web-based networking system to connect the activities of individual CWMA's and share information across the biome could be established and supported through partnerships with State Departments of Agriculture, Landscape Conservation Cooperatives, federal land management agencies, tribes, and other stakeholders in the public and private sector.

Management Strategies

Invasive plant management strategies are based on an understanding of the ecological conditions of the site, current level of invasion, and control/restoration potential. In 1998, the invasive plant management community in the United States, led by the Federal Interagency Committee for the Management of Noxious and Exotic Weeds, developed a comprehensive strategic approach called the Pulling Together Initiative (PTI; FICMNEW 1998). The management strategies in the approach are consistent with those in the Science Framework Part One (table 1.3; Chambers et al. 2017a). In the next sections, these strategies are detailed for areas with high, moderate and low resilience and resistance with different levels of invasion. The emphasis is on invasive annual grasses, primarily cheatgrass. The strategies are *prevention, early detection and rapid response, suppression, containment and restoration.*

In general, invasive species management priorities are often ranked as follows:

1) Prevent new infestations and maintain areas without invasive plant infestations that are ecologically intact.
2) Suppress densities and cover where there are native plant communities available to respond.
3) Consider containment of large, well-established infestations to prevent spread.
4) Conduct re-vegetation efforts with active seeding in high priority areas with a high probability of success based on ecological condition and when significant, multi-year resources are available.

There are certain pitfalls to be aware of and strategize around when thinking through any broad-scale approach such as:

1) Competing priorities among land managers that prevent common regional and local prioritization of project areas. For example, state law associated with state-listed noxious weeds require the “limited” state resources to be used on listed noxious species rather than species like cheatgrass that is not a state listed species in most states.
2) Many invasive species lack detailed ecological knowledge on climatically suitable areas for their establishment and spread. Thus, it is difficult to characterize ecosystem resistance to these species, identify areas most at risk of invasion, or determine the most appropriate and effective management tools and methods.
3) Inconsistent and incompatible administrative procedures for operations, datasets, and databases among partners can slow or hinder effective communication and implementation (Ielmini et al. 2015).

Prevention, Early Detection, and Rapid Response

Prevention is the key to a successful invasive species program. It is a strategy that is generally low cost and has a high return because infestations are not added to existing management burdens. Identifying invasion free areas allows land managers to focus resources for treatment where they are most needed and will have the greatest chance of success. Coordination with partners can help identify invasion free areas across regions by conducting collaborative monitoring inventories and surveys (Rew and Pokorny 2006; Mealor et al. 2013). Considering consequences for new invasions when implementing management activities and development in invasion free areas can help keep them invasion free.

Geospatial analyses of the locations of invasive species can help identify uninvaded areas and areas that are at increased risk for invasion based on data layers such as current invasion extent, resilience and resistance to invasive annual grasses (fig. x), and vectors such as roads (fig. 20, Chambers et al. 2017a), oil and gas wells (fig. 17, Chambers et al. 2017a) and human development (figs 16, Chambers et al. 2017a), and disturbance such as wildfires (fig. 34, Chambers et al. 2017a). Uninvaded areas determined more vulnerable to invasion, such as those with low resilience and resistance or higher densities of disturbance, could be considered for more frequently monitoring for new plant invasions to help keep them invasion free. The Great Basin portion of the sagebrush biome has substantial invasive annual grass invasions and a larger area with low resilience and resistance to invasion. Here, prevention strategies are important to minimize the risk of expansion of invaded areas and maintain connectivity of intact uninvaded areas. The eastern portion of the sagebrush biome is less invaded by annual invasive grasses yet have other species such as leafy spurge and Russian knapweed that should be monitored for expansion and prevented from further spread. Eastern portion contains more areas of higher resilience and resistance yet, uninvaded areas and those areas of low resilience and resistance, even if uninvaded, are still at risk and can be identified to keep “clean areas clean” or to “hold the line” to prevent another range-wide annual grass situation as in the Great Basin.

Early Detection Rapid Response (EDRR) is a strategy to survey and identify new invaders to an area and pursue treatment as quickly as possible. An overview of the National Framework for Early Detection and Rapid Response (USDOI 2016) is available on the National Invasive Species Council website (https://www.doi.gov/invasivespecies/edrr). Early detection and rapid response strategies are the most cost effective and most successful because they focus on eliminating new invasions and small patches of invasives that are easier to eliminate (Chippendale 1991 in Hobbs and Humphries 1995; Leung et al. 2002; Keller et al. 2007; Frid et al. 2011). The removal of small, separate populations of invasives is a high priority because they often expand more rapidly and potentially cover greater areas than the edge of a large, single source population (Cousens and Mortimer 1995; Moody and Mack 1988). Since most invasive plants have a long lag period following introduction, they can usually be eradicated if detected when first introduced. Early detection can make the difference between employing feasible offensive strategies versus retreating to a defensive strategy that usually results in an infinite financial commitment (Rejmanek and Pitcairn 2004).

Extensive outreach and communication on new invaders and their associated identification and life history characteristics and identifying which areas are most at risk and why, will foster detection, reporting, and rapid response. Establishing a communication network among landowners, public land management agencies, recreation groups, conservation organizations, botanists, horticulturalists, and weed organizations to report new invasive plant infestations will help meet detection and monitoring objectives. The focus for detection can be on species of known concern and high-risk invasion pathways, such are roads, and locations such as areas disturbed by human development.

Agency programs such as grazing, energy development, recreation, and wildfire management have opportunities to build in invasive species management strategies and/or coordinate management actions with invasive species programs to help address invasives. These management programs can identify geographic areas within their program jurisdictions that have known populations of invasive plants and that are known to have low resistance to these species. They can also identify areas that serve as sources of invasive plants and as conduits for their spread. Source areas for invasive plants include recent ecosystem disturbances, like wildfire or die-offs due to drought, and anthropogenic developments, such as oil and gas wells or cropland conversion. Well-known conduits for invasive plant spread are roads and others means of access (e.g. trails) (Trombulek and Frissell 2001). GIS overlays of resilience and resistance with known populations of invasive plants, disturbed areas, and road and trail networks can provide a broad-scale assessment for where to focus invasive plant prevention and control measures. For example, suppression and control of invasives along roads that link invaded areas to non-invaded areas can help to prevent or minimize movement along this vector. Similarly, the potential for spread of invasives can be considered when siting linear firebreak networks and determining follow-up actions. Monitoring programs that involve multiple management jurisdiction and program areas can be used to evaluate both the spread of invasive plants and the success of control measures.

Invasive Species Management Considerations at Project and Site Scales

On-the-ground management of invasive plants and restoration of native species requires the capacity to address the full suite of management activities spanning inventory and mapping, prevention, early detection and rapid response, control and containment, collaboration and partnership development, data collection and sharing, and restoration and rehabilitation. Project priorities for invasives species management should ultimately align with regional strategic goals for conservation and restoration of sagebrush ecosystems and have the involvement of partnerships (e.g., CWMA, state, and county governments).

Resilience and resistance concepts and decision matrices can be used in project selection and design for invasive species management. At the project scale, specific ecological site description information (precipitation and temperature regimes, soil characteristics, vegetation composition, etc.) and invasive species assessment data (inventory and monitoring data, risk assessments, observations, etc.) help set priorities for management actions within project areas (see Miller et al. 2014, 2015). Invasions can vary in distribution and abundance from site to site. Therefore, a critical first step in diagnosing the level of threat is to complete inventories and assessments within the project boundary.

Once the size and impact of the invasion is determined, an evaluation of the recovery potential (resilience and resistance) of the site will help to determine and prioritize the treatment activities with the highest chance of success for invasives species eradication, suppression/ reduction or containment. New invasions, low density invasions, and invasions in areas of high resilience and resistance align well with the strategies of eradication (EDRR) and suppression or reductions. It may be possible to treat new and/or small infestations long enough to achieve eradication. Larger, well-established infestations will likely need long-term treatment measures for potential suppression and/or containment on the perimeter of the large invaded patch. If funding is available and it is a high priority conservation area, it may be feasible to try to restore large, well-established infestations using an integrated approach with invasive control measures. Site restoration to desired conditions may be feasible in areas with potential for recovery (medium or high resilience and resistance). However in areas with lower potential for recovery (low resilience and resistance) repeated interventions and greater levels of financial resources may be necessary.

Invasive Species Management

The conservation value of a site and the associated cost/return and likelihood of success is used to determine where to place resources (table 5.1) for invasive species management. Identification of treatment options is then based on site-specific characteristics, degree of the invasion, potential for native plant recovery, and resources available.

Maintain Intact Native Communities. The most successful tool for maintaining ecosystem resistance to plant invasions is to manage for sufficient densities and covers of perennial grasses and forbs and biological soil crusts to prevent the establishment or population growth of the invader (Chambers et al. 2014a, b). Research shows that about 20% cover of perennial native grasses and forbs in Wyoming big sagebrush site types is needed prior to treatment (sagebrush mowing and prescribed fire) to prevent significant increases in cheatgrass and other exotic annuals post-treatment (Chambers et al. 2014b). Similarly, about 18% cover of perennial native grasses and forbs or 10 perennial grasses per meter squared are needed to exclude medusahead rye from these sagebrush types (Davies 2008).

Decreases in perennial herbaceous species and biological crusts and reductions in resistance to invasion result primarily from inappropriate livestock grazing (Adler et al. 2005; Reisner et al. 2013, 2015), high severity wildfire, and expansion of piñon and juniper into sagebrush ecosystems (Miller et al. 2013). Reductions in perennial native grasses and forbs can result in increases in sagebrush density and cover (Cooper 1953; Chambers et al. 2017b) and piñon and juniper densities, canopy cover, or basal area (Madany and West 1983; Guenther et al. 2004; Soule et al. 2004; Shinneman and Baker 2009). The increases in woody fuels can cause higher severity wildfires with the potential to increase mortality of perennial natives (Miller et al. 2013).

Carefully managed livestock grazing is crucial to maintain perennial herbaceous species and biological crusts and thus resistance to cheatgrass and medusahead rye invasion and expansion (Davies and Johnson 2015; Riley et al. 2016). The grazing strategies identified in Part 1 of the Science Framework are broadly applicable to the sagebrush biome (table 1.3; Chambers et al. 2017a).

1) Managing livestock grazing to maintain a balance of native perennial grasses (warm and/or cool season species as described in Ecological Site Descriptions for that area), forbs, and biological soil crusts will allow natural regeneration and promote resilience

and resistance to invasive plants. Native cool-season grasses are highly competitive with invasive annual grasses (Chambers et al. 2007) and strategies to increase or maintain native cool-season grasses are particularly important in areas with low to moderate resilience and resistance that support GRSG habitat (table 1.2, cells 2A, 2B, 2C, 3A, 3B, 3C).

2) Implementing grazing strategies that incorporate periodic deferment from use during the critical growth period, especially for cool season grasses, can help ensure maintenance of a mixture of native perennial grasses. This strategy is important across all sites, but particularly on areas with low to moderate resilience and resistance (table 1.2; cells 2B, 2C, 3B, 3C).
3) Ensuring that grazing strategies are designed to promote native plant communities can help decrease nonnative invasive plants. In ephemeral drainages and higher precipitation areas in the West-Central Semiarid Prairies that receive more summer moisture and have populations of nonnative invasive plant species, too much rest may inadvertently favor species such as field brome, Kentucky bluegrass, and smooth brome. Adjustments in timing, duration, and intensity of grazing may be needed to reduce these species.

Other threats to maintaining intact native communities will require diligence in monitoring for new invasions in response to land use and land management practices. Oil and gas development, road maintenance, construction, and even fuel breaks may create disturbance fostering colonization of new invasions, or bring in material contaminated with weed seed. Measures for preventing new invasions include sanitizing equipment/vehicles pre- and post-access, requiring certified weed-seed free seed/gravel/topsoil/hay for and construction or access, education and outreach to public, staff and partners in identification of invaders (Mealor et al. 2013; Pyke et al. 2016).

No Action Post-Disturbance. Areas characterized as having moderate to high resilience and resistance (table 1.2; cells 1B, 1C, 2B, 2C) and no current invasions may not require management intervention following disturbances such as wildfire. If these areas have sufficient perennial native grasses and forbs prior to disturbance, they likely will maintain resistance to invasions and invasive species management resources may not be necessary and resources may be better spent in other areas. For example, in relatively cold and moist areas with high ecosystem resilience and resistance, allowing the area to recover after wildfire without intervention may be the most effective strategy for preventing increases in invasives. However, if there were current invasions in the area, or there was significant fire management response with access and vehicles, then resources will be well spent on a monitoring strategy to determine if invasions increase or colonize,

Invasive Removal and Control. There are a number of control measures that have been shown to be successful in reducing and removing invasives, including biological, cultural, physical, and chemical. For cheatgrass and other invasive plant species, the Cheatgrass Management Handbook (Mealor et al. 2013) and Cal-IPC (2013) provide summaries of the requirements and advantages of different tools. Selection of the appropriate tool will vary based on the invasive plant species, extent of the invasion, and resilience and resistance of the site. The integration of different controls in treating invasives spatially and temporally may offer more success over the long-term at the project-scale. Use of these controls needs to consider health, environmental, and economic risks. Also, selection of controls based on consensus building, biology, monitoring, environmental factors, and best available technology can achieve desired outcomes while minimizing effects to non-target species and the environment. Individual controls that can be used at the project scale are summarized below.

1) Biological Control is the use of *natural enemies*—predators, parasites, pathogens, and competitors—to control pests and their damage over multiple years. Invasive plant species have many natural enemies including insects and plant pathogens. Biological control is often considered when the invasion is large and well-established because host plant density is a determinant of whether the biological control agent can become established (table 1.2; cells 1A, 1B, 2A, 2B, 3A, 3B). Site conditions are important for selecting the appropriate agent. Biological control agents for invasive annual grasses, especially cheatgrass, may include fungal pathogens (Meyer et al. 2016) and bacterial agents (Kennedy et al. 1991). Although multiple trials are underway, there is currently little published scientific information demonstrating the effectiveness of either fungal pathogens or bacterial agents for cheatgrass control or the potential effects of these controls on native species. Fungal pathogens resulting in large cheatgrass die-off areas may provide restoration opportunities. Species such as knapweeds and leafy spurge also have several biological control agents that may provide support for strategies of containment and suppression (Bourchier et al. 2006; Story et al. 2006; Winston et al. 2010; Setter and Lym 2013).

Integration of tools can provide advantages and disadvantages. For example, herbicides could be used around the perimeter with biocontrols released in center of large invaded patches with increased overall control. In contrast, release of the biocontrol with herbicide application at time when biocontrols emerge may result in loss of the biocontrol.

2) Cultural Controls are management practices that reduce establishment, reproduction, dispersal, and/or survival of the invasive plant. For example, management actions that maintain or increase native perennial herbaceous species can help control many invasive plant species. Other cultural controls, such as prescribed fire or targeted grazing, can impact the native communities and are best applied in areas dominated by the invasive plant. Typically, these are lower priority areas for sagebrush conservation and restoration (table 1.2; cells 2A and 3A), but may be used to meet habitat objectives such as increasing habitat connectivity or establishing fuelbreaks.

Prescribed fire may serve as a cultural control for cheatgrass dominated areas if applied during seed maturation in the spring, however, it is rarely an option due to narrow implementation requirements (Mealor et al. 2013). Prescribed fire may also be used as part of an integrated management strategy. Prescribed fire implemented when conditions are safe for burning can reduce standing litter and litter mats in cheatgrass-dominated areas (Jones et al. 2015a, b). Reducing the litter in areas dominated by invasive plants can improve effectiveness of certain types herbicide applications by allowing the herbicide to reach the soil surface (DiTomaso and Johnson 2006). It can also facilitate an integrated restoration approach that includes reducing litter through repeated burning (Jones et al. 2015a) or through prescribed grazing (Frost and Launchbaugh 2003), seeding with sterile cover crops like common wheat to decrease cheatgrass reproduction and, thus, seed banks, and then seeding the desired native perennial species (Jones et al. 2015b). Prescribed fire if properly implemented can work well for removal of both invasive perennial and annual grasses and annual forbs, but does not work well for perennial and biennial invasive forbs (DiTomaso and Johnson 2006).

The removal of cheatgrass by fire or livestock grazing may create conditions that allow release of perennial invasives resulting in a bigger issue. In addition, prevention and early detection methods may be needed for recent prescribed fire (and wildfire) operations to ensure that suppression activities do not inadvertently increase risk for invasive colonization and spread.

Targeted grazing is the application of a specific kind of livestock at a determined season, duration, and intensity to accomplish defined vegetation or landscape goals (Launchbaugh and Walker 2006; Mosely 2006). Sheep and goats are effective tools for reducing invasive plants such as leafy spurge, spotted knapweed, and cheatgrass (Mosely 1996; Mosely et al. 2016). Intense sheep grazing of cheatgrass-dominated sites can effectively suppress or even eliminate cheatgrass stands in as little as two years as was done in the urban interface above Carson City, NV (Mosley 1996). However, the effects of correctly applied targeted grazing are generally slow and cumulative (Launchbaugh and Walker 2006). A minimum of three years is usually required before noticeable differences in perennial herbaceous species are apparent, and woody species may take much longer.

Managed grazing may also reduce the risk and extent of wildfire in cheatgrass dominated areas (Diamond et al.2009, 2012; Walker 2006). Because livestock grazing reduces herbaceous vegetation (fine fuels), grazing may reduce the extent of wildfire (Walker 2006). Also, because livestock tend to graze some areas more intensely than others, grazing may create patchy vegetation that reduces the continuity of fuel loads and the fires that might burn those fuels (Walker 2006). In sagebrush ecosystems, high intensity targeted grazing may best be used to create firebreaks by confining livestock to a strip of land with temporary fencing. In a fenced Wyoming big sagebrush ecosystem, cattle removed 80–90% of cheatgrass biomass in May during the boot (phenological) stage (Diamond et al. 2009). Grazing resulted in reductions in flame length and rate of spread compared to non-grazed plots in the first year; cheatgrass biomass and cover were reduced to the point that fires did not carry in the grazed plots in the second year. Grazing also resulted in an increase in invasive annual forbs and the low-growing, perennial native grass, such as *Poa secunda* (Diamond et al. 2012).

Effective grazing programs for invasive plant control require a clear statement of the kind of animal, timing, and rate of grazing necessary to suppress the invasive plant (Launchbaugh and Walker 2006). A successful grazing prescription should: 1) cause significant damage to the target plant; 2) limit damage to the surrounding vegetation; and 3) be integrated with other control methods as part of an overall management strategy. Because targeted grazing by livestock is typically focused on heavily invaded areas, follow-up management such as seeding the target area with the desired species may be needed. In big sagebrush areas with a cheatgrass understory where grazing is used to suppress cheatgrass, it may be possible to interseed the sagebrush with perennial grasses and forbs after treatment (Huber-Sannwald and Pyke 2005).

3) Mechanical and Physical Controls kill invasives directly, block establishment, or make the environment unsuitable for establishment. To date, these methods have not been widely applied in sagebrush ecosystems.

4) Chemical Control is the use of herbicides. Herbicides are typically used only when needed and in combination with other approaches for more effective, long-term control. Ecological type/site descriptions and state-and-transition models that integrate resilience and resistance information (see Appendices 5 and 6 from Chambers et al. 2017a) can help determine if herbicides are the best control method for larger invasions. Herbicides can be very useful for eradicating small patches or interrupting the spread of large patches along advancing fronts by containing the perimeter (Rinella et al. 2009) regardless of resilience and resistance category (table 1.2; cells 1B, 1C, 2B, 2C, 3B, 3C.) Evaluating the degree and extent of neighboring invasions can provide information on whether the invasive species can recolonize from a neighboring untreated area. Also, evaluating the existing seedbanks within a treated area can provide information to help determine if repeated treatments are needed and for how long (e.g., 3 or 15 years).

Important considerations for the use of herbicides are the potential effects on native communities, including the loss of native forbs, as well as on humans, non-target organisms, air, soil, and water quality. For example, minimizing the effects of herbicide applications may involve spot-spraying of localized invasive patches rather than spraying an entire area. Also, while broad-cast spray is a method for treating large, well-established invasions, evaluating closely the level of reduction in density or coverage accomplished and the effects on non-target native plant communities, soils or biological crusts, and costs of multi-year treatments needed should be carefully considered prior to implementation.

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Table 5.1–Management strategies for cheatgrass based on the invasion state and relative resilience to disturbance and resistance to cheatgrass. Cheatgrass invasion state is adapted from Mealor et al. (2013) and CSU (2013). Invasion state categories and associated general management strategies can apply to other invasive pant species, even though resilience and resistance associations are not developed yet.

Cheatgrass Invasion State					
	Cheatgrass Free	**Trace (1-5%) with perennials**	**Mild (6-25%) with perennials**	**Moderate (26-50) with perennials missing**	**Cheatgrass Dominated Annual State perennials rare or nonexistent**
Management strategies based on invasion level	-Prevention -BMPs -Monitor high risk priority areas	**EDRR** -Eradication -Early Detection monitoring -Rapid Response treatment to any new invasion	Control treatments to reduce and inhibit spread; follow-up with passive or active restoration	Aggressive treatment with active restoration	Containment and/or Restoration
Cost:Benefit	Low cost: Highest return	Low cost: Very High return	Mod cost: High return	Mod-High cost: High return	High cost: Moderate return (pending on site and neighboring conditions)
High R&R	-Monitor priority areas with relatively warm soils and land use and disturbance -Minimize development, roads, and fuelbreaks to prevent invasive introductions -Manage livestock to maintain or increase perennial native grasses	-EDRR within 3 years -Herbicide appropriate with repeated application if needed	-Spot herbicide treatment for 3-5 years -Manage for native perennials, -Consider drill seeding natives post herbicide	-Spot and/or broadcast herbicide treatment for 5-10 years -Seed with natives post-control	Restoration success possible both prior to and after fire -Treat with herbicides -Seed with natives post control -Consider sagebrush transplants
Recovery Potential		Very High	High	High	Moderate
Moderate R&R	Management for moderate strategies depend on soil temperature and moisture regimes. Treat relatively cool and moist areas similarly to high R&R areas. Treat relatively warm and dry areas similarly to low R&R areas.				
Recovery Potential	Very High	High	Moderate	Moderate	Moderate to Low
Low R&R	-Prevention highest priority -Monitor all high priority areas and those connected to high priority areas -Use strategic fuelbreaks to maintain intact uninvaded priority areas	-EDRR annually -Herbicide appropriate	-Aggressive treatment where high risk of cheatgrass dominanting -Manage for perennials -Minimize disturbance -Prevent fire	-Aggressive treatment to prevent crossing threshold into cheatgrass-dominated state -Potential for targeted grazing to reduce densities	Restoration not feasible or realistic for most areas unless livelihoods or communities in danger -Targeted grazing to reduce density, -Herbicide application to perimeter to prevent spread -Fuelbreaks around perimeter -Restoration after fire difficult, may require repeated intervention -Seeding of non-natives acceptable if risk high for repeat burns and lack of neighboring perennials
Recovery Potential		Moderate	Low	Low	Low to none

6. APPLICATION OF NATIONAL SEED STRATEGY CONCEPTS

Fred Edwards, Sarah Kulpa, and Francis Kilkenny

Introduction

Native plant species are the foundation of sagebrush ecosystems and provide essential habitat for wildlife species, like Greater sage-grouse (*Centrocercus urophasianus;* hereafter, GRSG). The National Seed Strategy for Rehabilitation and Restoration (Seed Strategy) provides a coordinated approach to improving the use of native seed, building federal and private capacity, and increasing the supply of genetically appropriate native seed (PCA 2015). Restoring the sagebrush biome poses significant logistical challenges for collecting, evaluating, increasing, procuring, and using genetically appropriate native seed. The logistics of procuring and using native seed pose unique challenges, opportunities, and considerations at the biome, mid, and local (project) scales which are addressed in this document.

Conceptual Basis

Most gardeners and growers are familiar with the 2012 USDA Plant Hardiness Zone map (http://planthardiness.ars.usda.gov/PHZMWeb/) that is found on the back of almost every seed pack sold in the US. This is the standard by which gardeners and growers can determine which plants are most likely to thrive at a location based on average annual minimum winter temperature, divided into 10-degree F zones. In this context, seed transfer guidelines are just a more sophisticated and accurate way to understand what seeds and plants thrive best at a location. The seed transfer guidelines (fig. 6.1) described in Appendix 11 in Part I of the Science Framework (Chambers et al. 2017), are management tools that define acceptable distances seed can be moved from the point of origin, while considering genetic adaptation (Kilkenny 2015; Bower et al. 2014; St. Clair et al. 2013).

Variations in biotic and abiotic factors cause plants to experience natural selection across their range. When adaptive evolution occurs in response to local selective pressures, populations are considered to be locally adapted (Leimu and Fischer 2008; McKay et al. 2005). Common garden studies and reciprocal transplant studies have shown that plant populations are often adapted to local environmental conditions (e.g., Joshi et al. 2001; Hiesey et al. 1942; Clausen et al. 1941; Turesson 1922). For restoration projects, this means locally adapted plants can generally outperform non-local plants (e.g., Rowe and Leger 2012; Leimu and Fischer 2008; Rice and Knapp 2008; Bischoff et al. 2006; Humphrey and Schupp 2002).

Ecosystem resilience to disturbance and resistance to invasive annual grasses can be increased by considering both seed source and genetic diversity when selecting seeds and plant materials. Besides project failure, poor seed mix choices may have long-term consequences including genetic degradation of the surrounding plant population, loss of fitness, loss of evolutionary potential and, consequently, reduction of future plant community resilience and resistance (Schröder and Prasse 2013; Crémieux et al. 2010; Mijnsbruggea et al. 2010; McKay et al. 2005). The Seed Strategy provides a path forward for developing and procuring native and genetically appropriate seed sources that have the best genetic fit for individual restoration and vegetation management projects, but also identifies the research, technology, and monitoring needs for integrating and managing genetic diversity across the sagebrush biome.

Considerations for Enhancing Resilience and Resistance Using Seed Strategy Concepts

Broad to Mid-Scale

In this section, broad scale refers to all native plant communities in the western U.S. where sagebrush species in the genus *Artemisia* are the dominant shrub species. Mid-scale refers to activities within an individual level III ecoregion.

Prioritizing Native Seed Development

The geospatial data layers and analyses described in sections 8.1 and 8.2 of Part 1 of the Science Framework (Chambers et al. 2017) can help prioritize sagebrush ecosystems for native plant materials development, post-fire rehabilitation, and restoration. Analyses are conducted at the ecoregion scale because similarities in ecoregional climate, soil properties, resilience to disturbance, and resistance to invasive species can provide economies of scale compatible to seed development. Collectively, the sagebrush biome includes about 14 different Omernik (1987) level III ecoregions including: Eastern Cascades Slopes and Foothills, Columbia Plateau, Blue Mountains, Idaho Batholith, Snake River Plain, Northern Basin and Range, Central Basin and Range, Wasatch and Uinta Mountains, Middle Rockies, Wyoming Basin, Colorado Plateaus, Southern Rockies, Northwestern Great Plains, and Northwestern Glaciated Plains. Omerick's level III ecoregions served as the basis for the EPA level III ecoregions described in Part 1 and are synonymous to EPA level III ecoregions (fig. 1.1). For example, warmer and drier areas with low resilience and resistance might require additional seeding after a disturbance to supplement natural recovery. Therefore, ecoregions with predominantly warm and dry soil temperature and moisture regimes, such as the Columbia Plateau, Northern Basin and Range, Central Basin and Range, Snake River Plain, and, Colorado Plateaus, may be a higher priority for the development of native plant materials.

Key data layers for prioritizing areas for native plant materials development include resilience and resistance as indicated by soil temperature and moisture regimes, GRSG breeding habitat probabilities, and densities or other sagebrush obligate habitats (see Part 1, Section 8 of the Science Framework; Chambers et al. 2017). They also include the primary threats for the ecoregions. In the western range, data layers include burn probabilities, land cover of invasive annual grasses, and land cover of juniper expansion areas. For example, Jensen (2012) reported that over the last 30 years, 90% of fire rehabilitation projects on federal land in the Great Basin occurred in three major generalized or provisional seed zones (as described in Bower et al. 2014). In the eastern range greater focus is placed on land use and development threats such as oil and gas drilling and cropland conversion. For example, 78% of oil and gas development in the eastern portion of the range occur in six major generalized or provisional seed zones see Part 1, Appendix 8 of the Science Framework, Chambers et al. 2017 for data sources). Thus, initial seed development efforts could focus on developing native plant materials for the most in demand and used species (most likely native perennial bunchgrasses) for these provisional seed zones.

Primary considerations in prioritizing areas for native plant materials development within assessment areas follow (see table 1.1 and table 1.2, especially the sections on post-fire rehabilitation and climate change).

- In general, area with moderate and especially high resilience and resistance often recover without seeding following wildfire and vegetation management and are relatively low priority for native plant material development (cells 1B, 1C, 2B, 2C).

- Priority increases as resilience and resistance decrease and habitat probability for sage-grouse increase. High priorities include ecological types with low to moderate resilience and resistance that (1) may lack sufficient native perennial grasses and forbs to recover on their own, but (2) have nearby areas still supporting sage-grouse habitat (cells 2B, 2C, 3B, 3C).
- Areas of low habitat probability for sage-grouse (cells 1A, 2A, 3A) are generally lower priority, but may become higher priority in areas that support other species at risk or resource values or that increase connectivity among areas with intact sagebrush.
- Areas may be considered for prioritization regardless of resilience and resistance if repeated large fires or other habitat disturbances are causing habitat fragmentation and seeding or transplanting of sagebrush is needed to maintain habitat connectivity.

Because resilience and resistance increase along soil temperature and moisture gradients, an understanding of the relationship of major sagebrush taxa to soil temperature and moisture regimes can help in prioritizing sagebrush and their associated species for seed development by seed transfer zone. Within the big sagebrush complex in the western portion of the range, mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) occurs on cold-cool moist sites, while in the eastern portion of the range it occurs on cold-cool wet, summer moist, or winter moist sites. In the western portion of the range, Wyoming big sagebrush (*A. tridentata* ssp. *wyomingensis*) and basin big sagebrush (*A. tridentata* ssp. *tridentata*) typically occur on relatively warm-dry sites, whereas in the eastern portion of the range, these species occurs on a spectrum of sites, ranging from cool-summer moist to warm-dry. Thus Wyoming big sagebrush and basin big sagebrush may be considered a higher priority for native plant materials development in the western portion of the range based on low resilience and resistance on the sites where they grow. Some dwarf sagebrush species, like warm springs low sagebrush (*Artemisia arbuscula* ssp. *thermopola*), alkali sagebrush (*A. longiloba*) and Wyoming threetip sagebrush (*A. tripartita* ssp. *rupicola*) occur on relatively cold-cool sites with high resistance and resilience (Miller et al. 2014) and, therefore, are a lower priority for native plant materials development and restoration. However, other Dwarf sagebrush species (i.e., black sagebrush (*A. nova*), pygmy sagebrush (*A. pygmaea*), and low sagebrush (*A. arbuscula* ssp. *arbuscula*) grow on relatively warm-dry sites (Miller et al. 2014). Although this appears to indicate that the ecosystems where these species are most abundant have low resilience and resistance, soil and vegetation community characteristics need to be taken into account. For example, black sagebrush grows on shallow, stony, calcareous soils which are sparsely vegetated, thus having a low fuel load and low likelihood for a restoration need. Therefore black sagebrush is typically a lower priority for native plant materials development and restoration. However, monitoring of all sagebrush ecological types is needed to determine if declines are occurring due to climate, insects, disease, or other perturbations.

Developing the Mechanism for Seed Increase

Vegetation community lists can be used to identify the native shrub, grass, and forb species needed to restore ecosystem function from within NRCS Major Land Resource Areas (MLRAs) from the available ecological site descriptions. Development of lists can be prioritized based on resilience and resistance concepts and the considerations described above. Vegetation community lists can be further used to prioritize species for native plant materials development and regional procurement objectives.

Intact sagebrush communities with low and moderate resilience and resistance can be identified for wildland seed collection or the establishment of commercial seed collection areas or seed orchards. These sagebrush communities can provide reliable, source-identified sagebrush seed for restoration projects.

Potential Tradeoffs and Management Challenges at the Broad and Mid-Scale

Changes in precipitation and temperature regimes are projected to have large consequences for species distributions across the sagebrush biome (Chambers et al. 2017). This is a challenge for management because the vegetation communities we currently mange may or may not be the same in the future. Developing native plant materials that include the genetic diversity of a species (especially by particular seed zones) can help species adapt to future climates. Predictive models of changes in climate can be used to assess threats to important restoration species and identify opportunities for targeting, prioritizing, and implementing restoration projects that consider potential changes in species distribution and plant community composition. Modeling changes in species distributions and seed zone boundaries will help identify potential refugia areas, bottlenecks to species' movement, and selection of appropriate plant populations for inclusion in restoration projects to reduce the risk of future maladaptation.

At the broad scale, prioritizing ecoregions and sagebrush ecological types within them (for example, Wyoming big sagebrush ecological types in the Columbia Plateau), may mean that seed needed for restoration within high and moderate resilience and resistance areas may not be as readily available as seed for areas with low resilience and resistance. In high resilience and resistance areas, passive restoration treatments may be more practical (Pyke et al. 2015). However, if seed is needed for areas with high resilience and resistance, individual project planning can help to mitigate this need. By building reasonable timelines within individual projects, local seed collection and seed increase can be conducted and will ensure sufficient genetically appropriate seed is available.

Because they are prevalent at the mid-scale, land managers may want to rehabilitate and restore rangelands that have low sage-grouse habitat value, but are currently cheatgrass (*Bromus tectorum*) or crested wheatgrass (*Agropyron cristatum*) monocultures. Under these circumstances, where range management objectives have a higher priority than sage-grouse management objectives, the financial costs to procure genetically appropriate plant material may be outweighed by the size and scale of the project or adverse impacts that may be incurred to remaining local native seed sources. Under these circumstances, nonnative species and native cultivars that originate from sites with similar temperature and precipitation regimes may provide an acceptable management tradeoff (see local scale tradeoff section below).

Local Scale

In this section, local (project) scale refers to individually funded vegetation management activities within a district or field office. At this scale, managers need to carefully consider seed mixes and seed sources because of the critical role they play in managing for resilience and resistance. The decision to seed or not to seed should be tied to site specific assessments and an analysis of the potential for a site to recover without management intervention. For the western range, Miller et al. (2014, 2015) provide a framework for evaluating post-wildfire resilience and resistance, potential successional pathways, and the need to seed at the site to local scale. A similar framework can be developed for the eastern range. General seeding strategies by resilience and resistance category are:

- ***High Resilience and Resistance***: The potential for native shrubs, grasses, and forbs to recover after disturbance without seeding is typically high. If sites require seeding, the use of locally sourced or source identified seed from the same seed transfer zone will improve project success while maintaining genetic adaptation and diversity.

- ***Moderate Resilience and Resistance***: The potential for native shrubs, grasses, and forbs to recover after disturbance is usually moderately high, especially on cooler and moister sites. Seeding following disturbance or treatment may be needed in areas with depleted perennial grasses and forbs. Including perennial grasses in seed mixes is recommended to compete with and provide resistance to invasive annual plants. Including locally sourced or source identified forbs from the same seed zone may be necessary to meet habitat management objectives.

- ***Low Resilience and Resistance***: Recovery potential after overlapping disturbances (wildfire, inappropriate grazing, etc.) is usually low and seeding is needed in areas with depleted native shrubs, grasses, and forbs. The use of perennial grasses in seed mixes is recommended to compete with and provide resistance to invasive annual plants. On degraded sites, forbs may be absent. Including locally sourced or source identified forbs from the same seed zones may be necessary to meet habitat management objectives. Decisions on the use of native (locally sourced or source identified from the same seed zone), native cultivars, or nonnative grasses depends on whether or not nonnatives are already locally abundant. Collection and long-term storage of seed from these at risk sites is important for future native plant materials development management.

Good species selections and seed source choices can strengthen community resilience and resistance, while poor species selections and seed source decisions can erode long-term community resilience and resistance. Management considerations for resilience and resistance at the local scale include:

- ***Incorporate native perennial grasses in all seed mixes used on moderate and low resilience and resistance sites***. Native perennial grasses compete directly with cheatgrass and other introduced annual grasses for space, water, and nutrients (Chambers et al. 2007; Leger 2008; Blank and Morgan 2012). Including genetically appropriate native perennial grasses adapted to site specific temperature and precipitation regimes can further increase resilience and resilience by providing a seed source capable of reproducing on site following disturbance.
- ***Design a diverse seed mix of native shrubs, grasses, and forbs for all project seed mixes.*** Species diversity is the hallmark of a healthy ecosystem; diverse seed mixes of native shrubs, grasses, and forbs can increase site resistance by filling ecological niches and competing with nonnative, invasive annual grasses. The temperature and precipitation conditions that favor seed germination and seedling establishment vary from year to year, so seeding a diverse mix of native shrubs, grasses, and forbs will increase resilience by providing a range of species capable of germinating and establishing in response to a variety of environmental conditions.
- ***Use the right sagebrush in the right place.*** With 27 sagebrush species and subspecies across the sagebrush biome, using the correct sagebrush species or subspecies in restoration projects is essential to creating resilient and resistant sagebrush communities. Variations in biotic and abiotic factors cause plants to experience natural selection and adaptive evolution, thus individual sagebrush species and subspecies have evolved to grow best under different soil environments, temperature, and precipitation regimes (Dumroese et al. 2015; Miller et al. 2011). The result is that sagebrush species and subspecies are not interchangeable in a restoration seed mix. Further, long term survivorship data indicate local adaptation in sagebrush plays an important role in long term survivorship. In an Idaho Department of Fish and Game study, Sands and Moser (2012) found locally sourced Wyoming sagebrush seed had a 100 percent survivorship after 20 years, while non-locally sourced seed had less than 50 percent survivorship.
- ***Include native forbs to create healthier food webs.*** Complex and diverse food webs are a hallmark of intact ecosystems with high resistance and resilience. Native forbs are a major component of sage-grouse chick diets (Dumroese et al. 2015), are critical to native pollinators (Pollinator Health Task Force 2015), and can be abundant in sagebrush

communities (James et al. 2014; Humphrey and Schupp 2001). In healthy sagebrush ecosystems, native forbs have continuous and overlapping flowering and seed production throughout the growing season — meaning that a variety of ecological niches are filled by a diversity of species. On degraded sites, land managers can attempt to create or repair flowering phenology and reproduction through carefully planned seed mixes. Restoring the native plant community, especially the native forb component, will likely result in a cascading response. Thus, native forbs are an important component of sagebrush ecosystem restoration and should be included in seed mixes.

- ***Consider using ruderal or annual native forbs in project seed mixes to increase resistance to cheatgrass where they are naturally abundant***. Some native annual species (such as bristly fiddleneck (*Amsinckia tesselata*)) have been shown to compete well and suppress nonnative, invasive annual species due to phenological similarities (Leger et al. 2014; Uselman et al. 2014). Developing competitive, native annual species for use in future seed mixes may improve seeding outcomes in disturbed rangeland ecosystems.
- ***Consider long-term planning at the local scale to preserve seed sources from low resilience and resistance sites that are at high risk of cheatgrass invasion or wildfire.*** In these cases, long-term planning can provide seed sources adapted at the seed zone level which will be adapted to site conditions within a seed zone.

Potential Tradeoffs and Management Challenges at the Local Scale

If a decision is made to seed, there are five major tradeoffs related to resilience and resistance concepts and implementation of Seed Strategy concepts. Tradeoffs should not be considered individually, but rather in the context of meeting project objectives while best maintaining site resistance and resilience. Figure 6.2 summarizes these local level tradeoffs in the context of seed source choices. These are discussed briefly below.

The Tradeoff between Seed Source and the Need for Follow-up Management to Meet Sage-Grouse Habitat Objectives*:* Nonnative species, like crested wheatgrass and forage kochia, are widely seeded for rangeland re-vegetation, post-fire rehabilitation, invasive plant control, and green stripping, because they germinate and establish quickly, are easy to buy, cheaper than native species, provide good livestock forage, and compete with nonnative, invasive species

(Davidson and Smith 2005; Monaco et al. 2003; Brooks and Pyke 2001; Harrison et al. 2000; Richards et al.1998; Pellant 1994). Often times, nonnative species, like crested wheatgrass, are used as placeholder or bridge species to convert annual invasive grass dominated rangelands into native perennial-dominated plant communities (Cox and Anderson 2004; Monaco et al. 2003). Putting this concept into practice, however, has not been widely realized and some of the positively perceived attributes of these species can negatively impact native plant communities.

The wide use of nonnative species in some circumstances represents a tradeoff for achieving diverse ecosystem and habitat management objectives for sage-grouse, pollinators, and other sagebrush dependent species. For example, crested wheatgrass can be highly competitive with native sagebrush and perennial grasses, and may in some cases prevent their establishment (Asay et al.2001; Hull and Klomp 1967). Attempts to reintroduce native species into crested wheatgrass monocultures suggest costly and time intensive repeated treatments are essential to control both plants and seed in the soil seed bank (McAdoo et al. 2016; Davies et al. 2013; Fansler and Mangold 2011; Hulet et al. 2010). Efforts to convert crested wheatgrass monocultures into more diverse wildlife habitat are difficult because this species dominates the soil seed bank (Marlette and Anderson 1986), limits the growth and establishment of native plants (Gunnell et al. 2010; Hendersen and Naeth 2005; Heidinga and Wilson 2002), and rapidly recovers from mechanical and chemical control treatments (Davies et al. 2013; Fansler and Mangold 2011; Hulet et al. 2010). Short and long-term studies (13 years) suggest even if seeded at low rates in a seed mix, crested wheatgrass may subsequently become the most abundant bunchgrass in a mixed bunchgrass community (Nafus et al. 2105; Bakker and Wilson 2004).

The Tradeoff between Seed Source and Potential Impacts to the Adjacent Plant Community: Plants established as part of a seeding project, interact or interbreed with the surrounding environment which includes native (local), resident plant populations. Local seed or seed source identified by seed zone are advantageous because they are unlikely to be invasive or overly competitive with other native plants. Local seed or seed source identified by seed zone should be the best genetic fit to the existing, native plant populations and have the lowest potential for adverse genetic impacts.

Seeding with nonnatives may represent an ecological tradeoff because they have the potential to invade and spread beyond a project boundary. For example, Gray and Muir (2013) found that forage kochia has the potential to spread (up to 710 meters) into both intact and disturbed plant communities at an estimated rate of 25 meters a year.

Just as individual plants may spread, genes are also capable of spreading into adjacent, resident plant populations. Seeding with native cultivars may represent a genetic tradeoff because of potential adverse impacts to local population genetics through hybridization, potentially affecting overall species fitness (Hereford 2009; Leimu and Fischer 2008). Seed source is often not a criterion for developing native cultivars. Native cultivars have been developed over many years in an agronomic setting, and are often selected for specific traits (as described above), which may or may not align with restoration success (Leger and Baughman 2015; Johnson et al. 2010; Jones and Larson 2005). Introduced seed has the potential to hybridize with native populations and result in maladaptation or negative long-term impacts that could affect a plant community's ability to adapt to changing environmental conditions.

The Tradeoff between Seed Sources and Seed Germination, Establishment, and Reproduction: Traits selected for and often prioritized in native cultivars are: forage quality and yield, seed yield, seedling vigor, ability to establish and persist, and drought tolerance (Leger and Baughman 2015). Nonnative species are selected for traits similar to those selected in native cultivars. For example, the crested wheatgrass germplasm 'Ephraim' was selected for forage quality and yield, ability to establish, and rhizomatous development for site stabilization (USDA-NRCS 2012). In contrast, locally sourced native seed and seed source identified by seed zones are more likely respond to variations in temperature and precipitation to which they are adapted.

Locally sourced, native seed may need one or more growing season to germinate and establish on a site due to seed dormancy or other physiologic mechanisms. Seed of nonnatives and native cultivars typically germinate and establish quickly because they are selected for little or no seed dormancy. However, this represents a tradeoff because nonnatives and native cultivars may not meet long-term habitat objectives for sage-grouse, pollinators, or other wildlife species. Additionally, using a nonnative species like crested wheatgrass will support site resistance because it is a good competitor with cheatgrass; however, it is less likely to support long-term site resilience because of the low species diversity it maintains (see discussion above).

The Tradeoff between Seed Sources and Procurement: Until the seed market can be fully developed, there is a tradeoff between the species desired for a seed mix and their availability. Anticipating and planning for native species needed to develop a seed mix is an important aspect of project management because more often than not, seed of desired native plant species and seed sources are not immediately available. At the local scale, it is possible to plan and collect local seed that can be sent to a grower to increase it into the desired quantities. Advance planning will make species more available, but this represents a tradeoff from how quickly a project can be implemented. Purchasing and using native cultivars or nonnative species is a tradeoff that saves time and money, allowing a project to move forward quickly. Native cultivated varieties (such as 'Anatone' germplasm of bluebunch wheatgrass) or nonnative species (such as crested wheat grass and forage kochia) are often immediately available and can be bought from the commercial market in large quantities. However, using native cultivars or nonnative species results in tradeoffs regarding potential adverse impacts to future resilience and resistance and a need for follow-up management (see discussion above).

Conclusions: Balancing locally adapted seed sources, cultivars, and nonnative species against the realities of implementing a project in the field is a series of tradeoffs. Every project is unique and a one size fits all approach will not work. Sometimes seeding is used as a way to mitigate management risk or simply as insurance. Regardless of why and what is being seeded, the judicious use of seed will not only save money, but also minimizes the risk of unintended ecological consequences to naturally recovering native plant communities. As part of any decision to seed, potential tradeoffs should be carefully weighed against the potential future economic and ecosystem costs. Seeding should not always be the first choice; where prescriptive treatments are desired to minimize erosion risks to infrastructure, one time physical barriers (such as straw wattles and silt fencing) may be more desirable and cost effective in the long-term.

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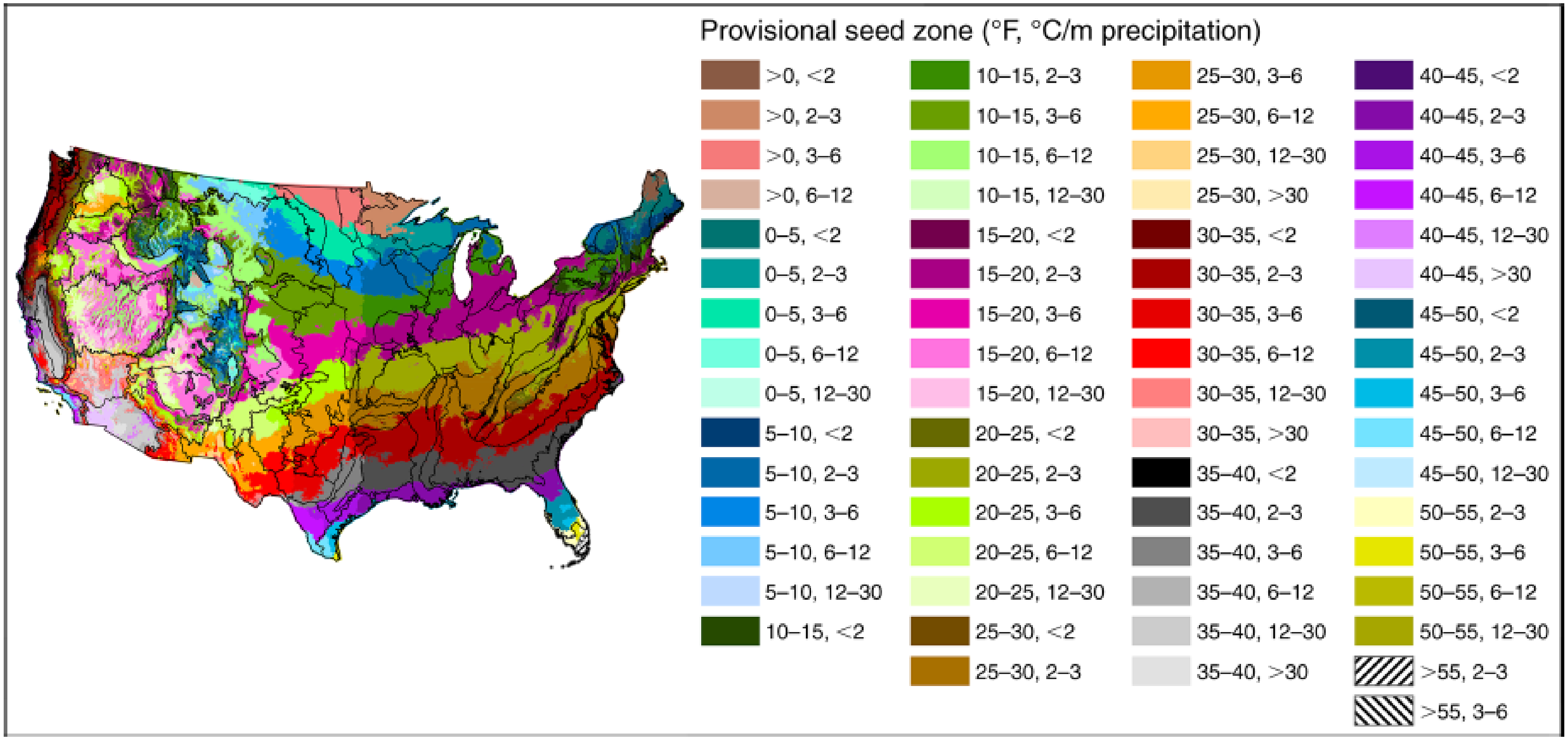


Figure 6.1−Provisional seed zones for native plants (color polygons) overlain with Omernik's (Omernick 1987) level III ecoregion boundaries (black lines). Provisional seed zones are the first step in defining seed transfer guidelines, and level III ecoregions can be used to refine seed movement within a provisional seed zone. In the legend, the first range of numbers is the temperature class band (°F) and the second range of numbers is the AH:M index class bands (°C/m precipitation) (from Bower et al. 2014). (Appendix figure A.11.1 from Part 1 of the Science Framework, Chambers et al. 2017).

Project Seed Options	Will follow-up management be needed to meet sage-grouse habitat objectives?	Could there be negative affects to the adjacent plant community?	Will established plants reproduce?	Will seed establish?	Can seed be procured quickly?
Locally sourced seed	High certainty additional management not needed	High certainty there will be no impacts	High certainty will reproduce	Moderate certainty will establish	Requires advance planning and dedicated funding
Source identified to the same seed zone	High certainty additional management not needed	Moderate certainty there will be no impacts	Moderate certainty will reproduce	Moderate certainty will establish	Seed availability unknown; depends on species and project seed zone
Native cultivated commercial variety	Moderate certainty additional management not needed	Low or unknown certainty due to potential genetic dilution or hybridization of local populations	Reproduction depends on germplasm origin and climactic similarities to target site	Establishment depends on germplasm origin and climactic similarities to target site	High certainty seed available
Persistent nonnative species like crested wheatgrass or forage kochia	Additional management needed to diversify the plant community and meet habitat objectives	Low or unknown certainty because can potentially spread beyond the project area	High certainty will reproduce but has potential to form a monoculture	High certainty will establish	High certainty seed available
Non-persistent, nonnative place holder species (such as sterile wheatgrass)	Additional management needed to diversify the plant community and meet habitat objectives	Moderate certainty there will be no impacts	Not expected to reproduce	Moderate certainty will establish	High certainty seed available

Local Level Implementation Considerations

High certainty

Moderate certainty

Low or unknown certainty

Not applicable

Figure 6.2−Seed source and project level considerations for selecting seed sources and type

7. LIVESTOCK GRAZING MANAGEMENT

Michael G. "Sherm" Karl and Jeanne C. Chambers

Introduction

The Science Framework identifies livestock grazing as the most widespread land use in the sagebrush biome (Chambers et al. 2017a). In the Conservation Objectives Team Report (FWS 2013) improper livestock grazing was considered a present and widespread threat to Greater sage-grouse (*Centrocercus urophasianus;* hereafter, GRSG) for the majority of GRSG populations. Livestock grazing affects the composition and structure of plant communities across the sagebrush biome and, consequently, the habitats of sage-grouse and other species at-risk as well as high value resources (Boyd et al. 2014). Livestock grazing has the greatest potential to affect GRSG habitat by changing the composition, structure, and productivity of the herbaceous plants used by GRSG for nesting and early brood-rearing (See Part 1, Section 5.3.7; Beck and Mitchell 2000; Boyd et al. 2014; Cagney et al. 2010; Hockett 2002).

A review of grazing authorization (permits and leases) and processing in GRSG habitat is ongoing within the BLM (USDOI BLM 2016) and other agencies. The habitats most important to GRSG (Sagebrush Focal Areas, Priority Habitat Management Areas, Important Habitat Management Areas in Idaho, General Habitat Management Areas, and Other Habitat Management Areas in Nevada and northeast California) (USDOI BLM 2015a, b), 46% of which are managed by BLM, are being prioritized for grazing authorization review and processing by the BLM to ensure that current livestock grazing is properly managed in these areas. If BLM finds that habitat objectives for GRSG are not achieved because of improper livestock grazing, then BLM must modify the livestock grazing management practices to ensure progress toward achieving the habitat objectives for GRSG.

An understanding of resilience to disturbance and resistance to invasive annual grasses can be used to help understand the responses of sagebrush ecosystems and thus GRSG habitat to livestock grazing across the landscape and to prioritize areas for management. Sagebrush ecosystem resilience and resistance is a criterion to be considered in prioritizing allotments for grazing permit or grazing lease review and processing. In addition, information on relative resilience and resistance coupled with state-and-transition models for the dominant ecological types (sites) can help in selecting grazing practices with the potential to improve overall ecosystem functioning and habitat conditions.

Managing for Resilient Ecosystems

Resilience to disturbances such as improper livestock grazing and wildfire and resistance to annual invasive grasses typically increase along elevation gradients in sagebrush ecosystems (Chambers et al. 2007; Condon et al. 2011; Davies et al. 2012; Chambers et al. 2014a, b; 2017c). More favorable environmental conditions for native plant establishment and growth and greater productivity due to cooler temperatures and higher precipitation result in greater resilience at higher than lower elevations (Condon et al. 2011; Davies et al. 2012; Knutson et al. 2014; Chambers et al. 2014a, b). Consequently, cooler and moister sites with higher resilience show smaller changes in plant species composition and more rapid recovery after disturbances and management treatments than warmer and drier sites with lower resilience. Also, less favorable environmental conditions for annual invasive grass establishment and growth due to colder soil temperatures coupled with greater competition due to more productive plant communities result in greater resistance to annual invasive grass at higher than lower elevations (Chambers et al. 2007; Condon et al. 2011; Chambers et al. 2014a, b; Brooks et al. 2016; Chambers et al. 2016). Thus, cooler and moister sites with higher resistance are less likely to exhibit increases in density and cover of invasive annual grasses following disturbances or management treatments.

Livestock grazing can influence resilience and resistance along these gradients through its effects on vegetation structure and composition. Perennial herbaceous species, especially deep-rooted grasses, play key roles in ecosystem resilience or recovery following disturbances, such as improper livestock grazing and wildfire (Chambers et al. 2007; Chambers et al. 2014a; Roundy et al. 2014). Sagebrush and other fire intolerant shrubs are killed by wildfires. In contrast, many perennial native grasses are fire tolerant and can survive wildfires, regrow once conditions are suitable, and stabilize soils and hydrologic processes where they are sufficiently abundant (Leffler et al. 2016; Miller et al. 2013). However, perennial native grasses differ in terms of fire tolerance and can be killed by high severity wildfires (Conrad and Poulton 1966; Wright 1977; Sapsis 1990).

Perennial native grasses are highly effective competitors with widespread annual invasive grasses, such as *Bromus tectorum* L. and *Taeniatherum caput-medusae* (L.) Nevski, and can prevent the population growth of these invaders (Chambers et al. 2007; Davies et al. 2008; Chambers et al. 2014b). Perennial native shrubs also compete for resources and decreases in deep-rooted bunchgrasses, such as *P. spicata* and *A. thurberianum*, due to improper livestock grazing can result in increased density and cover of the dominant shrubs, *A. tridentata* ssp. (Cooper 1953; Harniss and Murray 1973; Burkhardt and Sanders 1992; Hanna and Fulgham 2015).

Decreases in perennial native grasses and forbs can result from improper livestock grazing (Mueggler 1972; Reisner et al. 2013); the intensity of livestock use is directly and negatively associated with abundance and cover of native perennial grasses (Adler et al. 2005; Reisner et al. 2013). The effects of specific grazing systems on sage-grouse habitat likely depend on their longer-term effects on composition, structure, and productivity of herbaceous plants, especially the relative abundance of perennial grasses and forbs versus sagebrush (Dahlgren et al. 2015). Decreases in resilience and resistance generally occur when competition from perennial native forbs and especially grasses for available resources no longer prevents dominance by *A. tridentata* and other shrubs and/or annual invasive grasses (Chambers et al. 2017b). Managing livestock grazing to maintain or increase perennial herbaceous species, especially deep-rooted grasses which contribute to resilience along elevation gradients, can help prevent threshold crossings to undesirable states and retain critical habitat and ecosystem services following disturbances such as wildfire.

Broad to Mid Scale Considerations

Use of the Science Framework Approach to Inform Livestock Grazing Management

The Science Framework provides an approach that uses assessments at the ecoregional or GRSG Management Zone scale (mid scale) to help prioritize areas for management and determine effective management strategies for areas that provide habitat for species and values at-risk such as GRSG (Chambers et al. 2017a). The approach is based on: 1) the likely response of an area to disturbance or stress due to threats and/or management actions (i.e., resilience to disturbance and resistance to invasion by nonnative plants), 2) the capacity of an area to support target species and/or resources, and 3) the predominant threats. The geospatial data layers and analyses used in the approach are described in sections 8.1 and 8.2 of Part 1 of the Science Framework (Chambers et al. 2017a). Key data layers used to illustrate the approach include resilience and resistance as indicated by soil temperature and moisture regimes (Maestas et al. 2016), sage-grouse breeding habitat probabilities (Doherty et al. 2016), and the primary threats for the ecoregions or Management Zones in the assessment area. Although the BLM is using a different approach for prioritizing livestock grazing management for GRSG habitat, many of the data layers such as soil temperature and moisture regimes and the primary threats can be used to help inform livestock grazing programs and identify appropriate livestock grazing strategies. The approach can also be used to help prioritize areas for management for other species and values at risk.

Considerations for livestock grazing management based on the Science Framework approach are based on tables 1.2 and 1.3 (Chambers et al. 2017a). In general, areas that support sage-grouse habitat or other important species or resources are high priorities for improved livestock grazing management. Areas with moderate and especially high resilience and resistance often have the potential to recover from disturbances through successional processes. These areas represent significant opportunities to use livestock grazing management to improve habitat. Areas with low resilience and resistance often lack the potential to recover from improper grazing without significant intervention, and are among the highest priorities for improved livestock grazing management.

Managing livestock grazing to maintain a balance of native perennial grasses (warm and/or cool season species), forbs, and biological soil crusts, as described in ecological site descriptions for the area, allows natural regeneration and promotes resilience to disturbance and resistance to invasive plants. Native cool-season grasses are highly competitive with invasive annual grasses (Chambers et al. 2007; Davies 2008; Blank and Morgan 2012) and strategies to increase or maintain native cool-season grasses are particularly important in areas with low to moderate resilience and resistance. Implementing livestock grazing strategies that incorporate periodic deferment from use during the critical growth period, especially for cool season grasses, can help ensure maintenance of a mixture of native perennial grasses. This strategy is important across all sites, but particularly on areas with moderate to low resilience and resistance.

Livestock grazing strategies based on the ecological conditions of the area and designed to promote native plant communities can help decrease nonnative invasive plants. For example, in ephemeral drainages and higher precipitation areas in the West-Central Semiarid Prairies that receive more summer moisture and have populations of nonnative invasive plant species, too much rest may inadvertently favor species such as field brome, Kentucky bluegrass, and smooth brome. Adjustments in timing, duration, and intensity of livestock grazing may be needed to reduce these species.

Newly rehabilitated burned areas and areas that provide sagebrush habitat are conservation priorities and thus livestock grazing management priorities. Grazing rest and deferment schedules should be used to ensure the recovery of bunchgrasses and other herbaceous species after fire (Veblen et al. 2016). Failure to implement a program of grazing rest or deferment may slow recovery (Kerns et al. 2011) and promote invasive annual grasses and other undesirable plants.

Mid to Local Scale Considerations

Review of Grazing Authorizations (permits and leases) and Processing in Greater sage-grouse Habitat by BLM

BLM is implementing a priority for completing a review of grazing authorizations (permits and leases) and processing in GRSG habitat, that is found in BLM Washington Office Instruction Memorandum 2016-141 "Setting Priorities for Review and Processing of Grazing Authorizations in Greater Sage-Grouse Habitat" (USDOI BLM 2016). The highest priority areas for completing the grazing permit and grazing lease review and processing will be allotments within Sagebrush Focal Areas and allotments that substantially overlap in Sagebrush Focal Areas. The second highest priority is allotments within Priority Habitat Management Areas that are outside of Sagebrush Focal Areas. The third highest priority is allotments within Important Habitat Management Areas in Idaho. The fourth highest priority is allotments lying within General Habitat Management Areas. The last priority is allotments within Other Habitat Management Areas in Nevada and northeast California.

BLM is prioritizing the areas most important to GRSG (Sagebrush Focal Areas, Priority Habitat Management Areas, Important Habitat Management Areas in Idaho, General Habitat Management Areas, and Other Habitat Management Areas in Nevada and northeast California) for grazing authorization review and processing, to ensure that current livestock grazing is properly managed in these areas. If BLM finds that habitat objectives for GRSG are not achieved because of improper livestock grazing, then BLM must modify the livestock grazing management practices to ensure progress toward achieving the habitat objectives for GRSG. These considerations are currently made primarily at the Land Use Plan scale within BLM and USFS. Future assessments could look at larger landscapes to better identify considerations such as landscape functioning and connectivity.

The tables in Appendix 3 provide specific vegetation habitat objectives for breeding and nesting seasonal habitat, and brood-rearing/summer seasonal habitat, for GRSG in the Wyoming Basin Ecoregion, Oregon and Washington, Utah, Nevada and Northeastern California, and Idaho and Southwestern Montana.

Potential Livestock Grazing Management Practices

Potential livestock grazing management practices can be incorporated into livestock grazing management alternatives during the grazing authorization (grazing permits and grazing leases) renewal process. When current livestock grazing management is the cause of not achieving vegetation habitat objectives for GRSG and land health standards, livestock grazing management must be changed to ensure significant progress toward achieving the vegetation habitat objectives for GRSG and achieving land health standards.

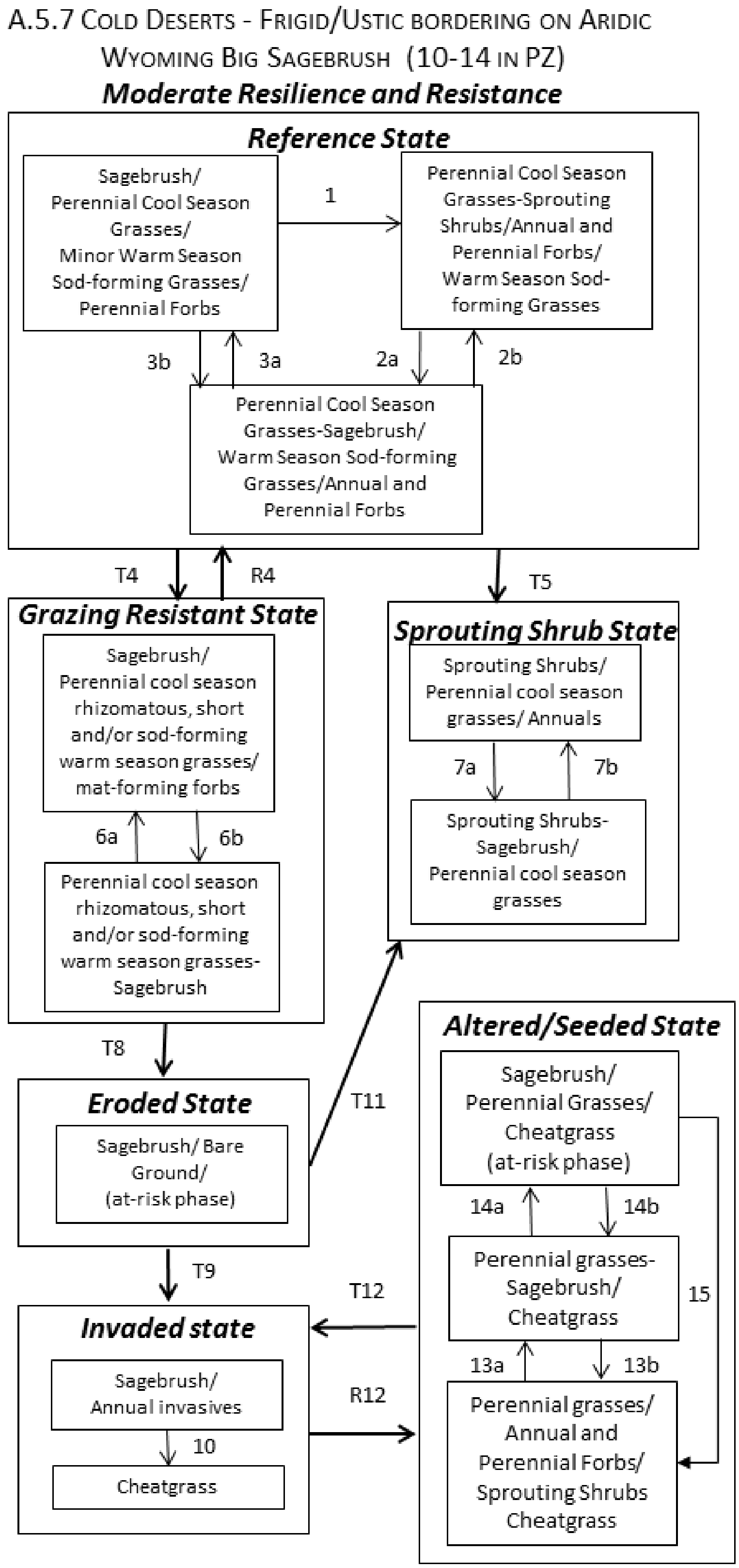
Potential livestock grazing management practices could be based on: 1) identifying the different ecological types (sites) that occur across the management area and determining their relative resilience to disturbance and resistance to invasive annual grasses, 2) evaluating the current ecological dynamics of the ecological types (sites) and, where possible, their restoration pathways, and 3) selecting livestock grazing strategies with the potential to increase overall ecosystem functioning and habitat conditions (Part 1, Section 9; Chambers et al. 2017a). An understanding of ecological type (site) descriptions and state-and-transition models can help provide the basis for selecting appropriate livestock grazing strategies (Part 1, Section 9; Chambers et al. 2017a).

Monitoring information can help determine needed changes in livestock grazing management over time. The BLM’s Assessment Inventory and Monitoring (AIM) can be coupled with habitat indicator assessments by grazing allotment to track changes in GRSG habitat. Once habitat indicator analyses have been conducted, this information can be coupled with the Science Framework data layers and state-and-transition models to help determine needed changes in livestock grazing management.

Some examples of potential livestock grazing management practices are provided that are taken from research and observations and can be implemented to improve the resilience and resistance of sagebrush plant communities and the quality of sage grouse nesting and early brood-rearing habitat. The examples of potential livestock grazing management practices are based on generalized state-and-transition models for the predominant sagebrush ecological types in Appendices 5 and 6 of Part 1 of the Science Framework (Chambers et al. 2017a). In the Science Framework, ecological type is defined in a broad sense and refers to ecological site/type groups. The dominant sagebrush ecological types are characterized according to soil temperature and moisture regimes, major characteristics, and resilience to disturbance and resistance to invasive annual grasses (see table 6 in Part 1 of the Science Framework; Chambers et al. 2017a). State-and-transition models based on soil temperature and moisture regimes, ecological type characteristics, and relative resilience and resistance were developed for those ecological types that represent the greatest area in the eastern and western portion of the range (Appendices 5 and 6, respectively, Part 1 of the Science Framework). These state-and-transition models provide information on the alternative states, ranges of variability within states, and processes that cause plant community shifts within states as well as transitions among states.

Some states within the state-and-transition models, and plant community phases within the states, do not provide the vegetation necessary for nesting and early brood-rearing habitat for GRSG as identified in the Vegetation Habitat Objectives for Breeding and Nesting Seasonal Habitat, and Brood-Rearing/Summer Seasonal Habitat by BLM for the different management areas (USDOI BLM 2015a-e; see Appendix 3). Some examples of these states and plant community phases are identified for the state-and-transition models in Part 1 of the Science Framework (Chambers et al. 2017a) and potential livestock grazing management practices are presented that can be implemented to help improve ecological conditions and achieve the vegetation habitat objectives for nesting and early brood-rearing habitat for greater sage-grouse.

Cold Deserts (WAFWA Management Zones II and VII)



(1) Perennial grass, sprouting shrubs, and forbs become dominant due to disturbances that decrease sagebrush like prolonged or severe drought, freezing, flooding, wildfire, insects, disease, and pathogens.

(2a) Sagebrush increases with time until co-dominant with the herbaceous understory.

(2b) Perennial grass, sprouting shrubs, and forbs become dominant due to disturbances that decrease sagebrush.

(3a) Sagebrush increases with time until dominant.

(3b) Perennial grass and forbs increase due to disturbances that decrease sagebrush.

(T4) Continuous spring grazing with cattle during the critical growth period of cool season grasses results in dominance of grazing tolerant species that may include warm season grasses (e.g., blue grama). As bare ground increases, surface erosion (e.g., rills, sheet erosion) and pedestalled plants (especially bunchgrasses) may result.

(R4) Light to moderate grazing with periodic rest during critical growth periods along with fire, herbicides, and/or mechanical treatments can result in return to reference state.

(T5) An increase in the disturbance cycle by fire, fire surrogates, mechanical types of disturbance, and/or high density/frequency grazing will favor sprouting shrubs such as rabbitbrush. Annual invasives can occur.

(6a) Sagebrush increases with time. Cheatgrass and other weeds can be present, but do not dominate.

(6b) Perennial cool season grasses increase due to disturbances that decrease sagebrush. A temporary flush of annual invaders is expected.

(7a) Sagebrush increases with time and removal of disturbances until co-dominant with herbaceous understory.

(7b) Perennial cool season grasses and sprouting shrubs increase due to disturbances that decrease sagebrush.

(T8) Perennial grasses and forbs are eliminated and sagebrush increases with high density/frequency grazing by cattle, resulting in altered biotic, hydrologic, and soil function. This state is at-risk to invasion by annuals such as cheatgrass, especially after a stand-replacing, sagebrush killing event.

(T9) If a cheatgrass seed source is introduced, and weather conditions are conducive to establishment (warm wet spring), it will invade, especially after a stand-replacing event that eliminates sagebrush.

(10) Fire and fire surrogates that kill sagebrush will dramatically increase cheatgrass.

(T11) Multiple chemical and/or mechanical treatments or biological disturbances that reduce sagebrush will result in a shift toward sprouting shrub dominance with potential for cheatgrass to invade.

(T12) Catastrophic climatic events and/or fire can result in cheatgrass dominance, especially when in the sagebrush dominant phase of the altered state.

(R12) A restoration treatment, including chemical treatment for cheatgrass and seeding can restore a perennial grass community and eventually support an altered sagebrush community with invaders.

(13a) Sagebrush increases with time and no disturbances until co-dominant with the herbaceous understory, but cheatgrass will be present.

(13b) Perennial grass and forbs become dominant due to disturbances that decrease sagebrush.

(14a) Sagebrush increases with time and no disturbances until dominant, but cheatgrass may be present.

(14b) Perennial grass and forbs become dominant due to minor disturbances that decrease sagebrush.

(15) Perennial grass and annual/perennial forbs become dominant due to disturbances that decrease sagebrush.

Figure 1–State-and-transition model for a Wyoming big sagebrush 10 to 14 inch precipitation zone ecological type applicable to the Cold Deserts in the eastern part of the sagebrush biome and greater sage-grouse range in the Wyoming Basin in the western and central portions of Wyoming (Management Zones II and VII). Large boxes illustrate states that are comprised of community phases (smaller boxes). Transitions among states are shown with arrows starting with T; restoration pathways are shown with arrows starting with R. The "at risk" community phase is most vulnerable to transition to an alternative state. Figure is from Appendix 5 in Part 1 of the Science Framework (Chambers et al. 2017a).

REFERENCE STATE

Figure 2–Example of a plant community phase in the reference state in the Wyoming big sagebrush 10 to 14 inch precipitation zone ecological type (fig. 1) in Wyoming. The site is dominated by Wyoming big sagebrush with an herbaceous understory dominated by cool-season perennial bunchgrasses. This plant community phase provides nesting and early brood-rearing habitat for Greater sage-grouse. Photo from Cagney et al. (2010).

Potential Livestock Grazing Management Practices

Livestock grazing management practices in the reference state in the Wyoming big sagebrush 10 to 14 inch precipitation zone ecological type (figs. 1, 2) have two primary goals. The first is to maintain the reference state and prevent a transition to the grazing resistant state. The second is to achieve the vegetation habitat objectives for breeding and nesting seasonal habitat, and brood-rearing/summer seasonal habitat, for GRSG in the Wyoming Basin ecoregion (Appendix 3, table 1). Plant communities in the reference state provide nesting and early brood rearing habitat for sage grouse.

A livestock grazing strategy that prevents grazing of the cool-season perennial bunchgrasses during the critical growing season (mid-May through mid-June) in at least two out of every three consecutive years will likely maintain the reference state and prevent a transition to a grazing resistant state (Cagney et al. 2010).

Late season and winter grazing of the reference state may help facilitate the long-term persistence of cool-season perennial bunchgrasses, but can cause a reduction in the residual herbaceous material of the cool-season perennial bunchgrasses that is needed for nesting cover for sage-grouse the next spring. Residual grasses remaining from the previous year provide the initial herbaceous cover available to nesting sage-grouse. Thus, late season and winter grazing is not always a grazing management practice that would allow for achieving nesting habitat objectives for sage-grouse (Cagney et al. 2010).

GRAZING RESISTANT STATE

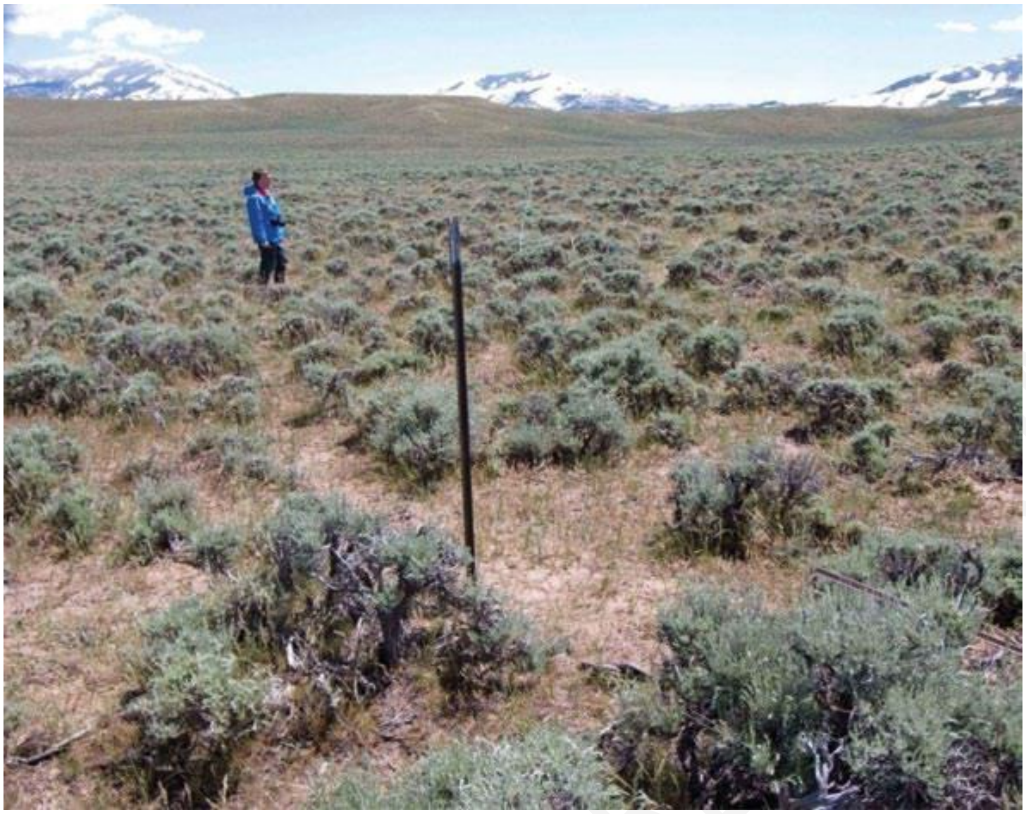


Figure 3–Example of a plant community phase in the grazing resistant state in the Wyoming big sagebrush 10 to 14 inch precipitation zone ecological type (fig. 1) in Wyoming. The site is dominated by Wyoming big sagebrush with an herbaceous understory dominated by rhizomatous grasses and bluegrasses. If the herbaceous understory is not depleted, this plant community phase can provide nesting habitat for Greater sage-grouse. With a depleted herbaceous understory, this plant community phase does not provide nesting habitat for greater sage-grouse. Photo from Cagney et al. (2010).

Potential Livestock Grazing Management Practices

Livestock grazing management practices in the grazing resistance state (figs. 1, 3) have the goal of stimulating a transition of the grazing resistant state to a reference state. Plant communities in the reference state provide improved nesting and early brood-rearing habitat for GRSG. Livestock grazing management practices should facilitate achieving the vegetation habitat objectives for breeding and nesting seasonal habitat, and brood-rearing/summer seasonal habitat, for Greater sage-grouse in the Wyoming Basin ecoregion (Appendix 3, table 1).

The grazing resistant grasses, specifically rhizomatous grasses and bluegrasses, are unlikely to decrease in abundance with changes in livestock grazing management alone (Cagney et al. 2010). Also, changing livestock grazing management, or eliminating grazing, is likely to have a limited effect on increasing the abundance of large bunchgrasses (Cagney et al. 2010). However, light to moderate grazing with periodic rest during critical growth periods along with fire, herbicides, and/or mechanical treatments may result in return to reference state. If the grazing resistant state is burned or is treated with herbicides, causing a decrease in the canopy cover of sagebrush, it is advisable to defer livestock grazing during at least the first two growing seasons after the fire or herbicide disturbance on these sites. Grazing deferment for two or more growing seasons will allow the remaining cool-season bunchgrasses in this grazing resistant state to increase in abundance (Cagney et al. 2010). Heavy, continuous livestock grazing can cause a decrease in the herbaceous species and a more rapid increase in sagebrush, which will cause the site to progress back to the grazing resistant state (Cagney et al. 2010).

Targeted livestock grazing by domestic sheep in the grazing resistant state can cause browsing of sagebrush that decreases the canopy cover of sagebrush and opens up niches for establishment and an increase in abundance of the grazing resistant rhizomatous grasses and bluegrasses as well as any residual remaining cool-season perennial bunchgrasses (Cagney et al. 2010). This treatment is applied in fall or winter when cool-season perennial bunchgrasses are not actively growing. Supplemental feeding of livestock in the winter on this grazing resistant state may be necessary to effectively implement this strategy.

ERODED STATE

Figure 4–Example of a plant community phase in the eroded state in the Wyoming big sagebrush 10 to 14 inch precipitation zone ecological type (fig. 1) in Wyoming. The site is dominated by Wyoming big sagebrush and bare ground. Herbaceous vegetation is located primarily beneath shrubs or cactus. This plant community phase is not providing nesting or early brood rearing habitat for Greater sage-grouse. Photo from Cagney et al. (2010).

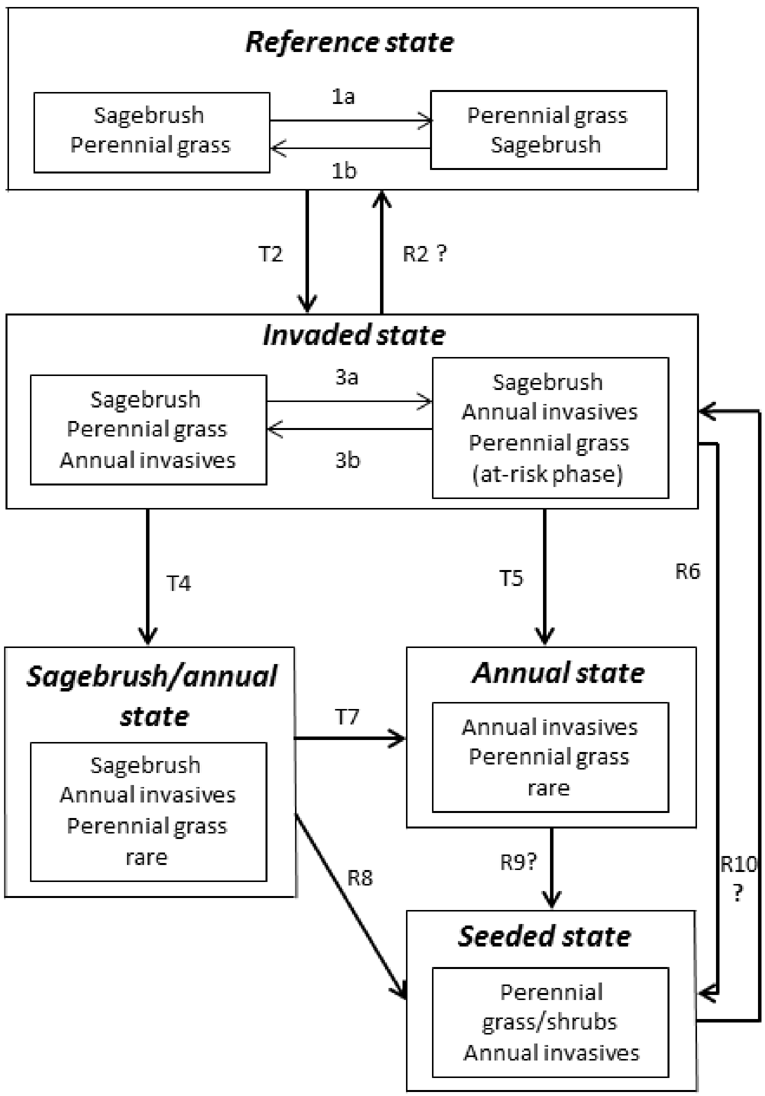
Potential Livestock Grazing Management Practices

Changes in livestock grazing management alone is unlikely to cause an increase in perennial grasses on the eroded state (figs. 1 and 4; Cagney et al. 2010). Also, livestock grazing management practices alone, cannot be used to achieve the vegetation habitat objectives for breeding and nesting seasonal habitat, and brood-rearing/summer seasonal habitat, for GRSG on the eroded state in the Wyoming Basin ecoregion (Appendix 3, table 1). Interseeding with native perennial grasses and forbs may be needed to meet habitat objectives (Huber-Sannwald and Pyke 2005).

Cold Deserts (Management Zones III, IV, and V)

A.6.6 Cold Deserts - Mesic/aridic bordering on Xeric Wyoming big sagebrush (8-12 in PZ)

Low to moderate resilience and low resistance



(1a) Perennial grass increases due to disturbances that decrease sagebrush like wildfire, insects, disease, and pathogens.

(1b) Sagebrush increases with time.

(T2) An invasive seed source and/or improper grazing trigger an invaded state.

(R2) Proper grazing, fire, herbicides and/or mechanical treatments are unlikely to result in return to the reference state on all but the coolest and wettest sites.

(3a) Perennial grass decreases and both sagebrush and invasives increase with improper grazing resulting in an at-risk phase. Decreases in sagebrush due to insects, disease or pathogens can further increase invasives.

(3b) Proper grazing and herbicides or mechanical treatments that reduce sagebrush may restore perennial grass and decrease invaders on wetter sites (10-12"). Outcomes are less certain on drier sites (8-10") and/or low abundance of perennial grass.

(T4) Improper grazing triggers a largely irreversible threshold to a sagebrush/annual state.

(T 5 and T7) Fire or other disturbances that remove sagebrush result in an annual state. Perennial grass is rare and recovery potential is low due to low precipitation and competition from annual invasives. Repeated fire can cause further degradation.

(R6, R8 and R9) Seeding following fire and/or invasive species control results in a seeded state. Sagebrush may recolonize depending on patch size, but annual invasives are still present.

(R10) Seeding effectiveness and return to the invaded state are related to site conditions, seeding mix, and post-treatment weather.

Figure 5–State-and-transition model for a Wyoming big sagebrush 8 to 12 inch precipitation zone ecological type applicable in the Cold Deserts in the western part of the sagebrush biome and greater sage-grouse range in the Snake River Plain, Northern Basin and Range, and Central Basin and Range ecoregions (Management Zones III, IV, and V). Large boxes illustrate states that are comprised of community phases (smaller boxes). Transitions among states are shown with arrows starting with T; restoration pathways are shown with arrows starting with R. The "at risk" community phase is most vulnerable to transition to an alternative state. Figure is from Appendix 6 in Part 1 of the Science Framework (Chambers et al. 2017a).

INVADED STATE

Figure 6–Example of a plant community phase in the invaded state in the Wyoming big sagebrush 8 to 12 inch precipitation zone ecological type (fig. 5) in Nevada. The plant community phase is dominated by Wyoming big sagebrush and cheatgrass with some perennial grasses. This site is not providing optimum nesting or early brood-rearing habitat for Greater sage-grouse. BLM photo.

Potential Livestock Grazing Management Practices

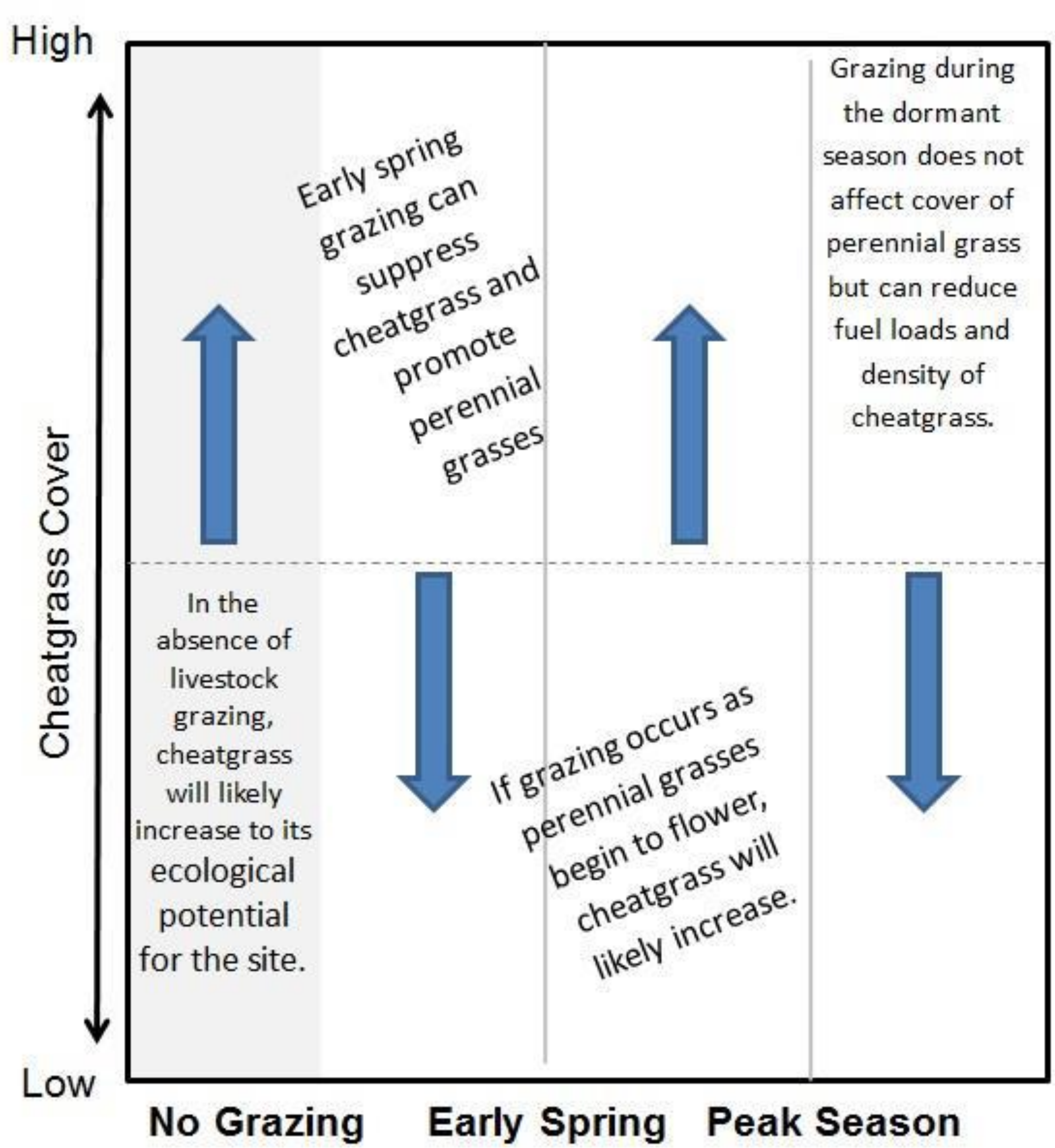
Livestock grazing management practices in the invaded state (figs. 5, 6) can be used to promote an increase of perennial grasses to increase resistance to invasive annual grasses. Livestock grazing management practices can also help achieve the vegetation habitat objectives for nesting and brood-rearing seasonal habitat for GRSG in Oregon/Washington (Appendix 3, table 2), Utah (Appendix 3, table 3), Nevada and northeastern California (Appendix 3, table 4), and Idaho and southwestern Montana (Appendix 3, table 5).

Effects of grazing on the abundance of annual grasses such as cheatgrass depend on multiple factors including: (1) the relative resilience of the site as indicated by soil temperature and moisture regimes, (2) the relative resistance of the site as indicated by its climatic suitability for cheatgrass (Strand et al. 2014; fig. 7), and (3) the relative abundance of competitive, perennial grasses and forbs (Chambers et al. 2014a, b). If sufficient perennial native grasses remain on the site, managed livestock grazing may result in an increase in perennial grasses and forbs and decrease in invasive annual grasses, especially on relatively cool and moist sites. Grazing during the time when perennial grasses are beginning to flower will likely cause a decline in perennial grasses and an increase in cheatgrass (Strand et al. 2014; see fig. 7). Early spring grazing can suppress the abundance of cheatgrass and promote an increase of perennial grasses if the early spring grazing is applied when the annual grasses are starting to produce seeds but before the perennial grasses begin to bolt (Strand et al. 2014; see fig. 7). Livestock grazing persisting into the time when perennial grasses are beginning active growth can be detrimental to the perennial grasses (Strand et al. 2014; see fig. 7). Early spring grazing of cheatgrass can be difficult to plan for year after year and can be difficult to implement in a livestock grazing permit or lease on federal land. This is because the amount of cheatgrass forage available in the early spring depends on the amount and timing of precipitation and varies considerably from year to year (West and Yorks 2002; Chambers et al. 2014b). Thus, the length of time that cheatgrass forage is available to be grazed in the early spring will vary from year to year, and permittees/lessees will have a difficult time planning ahead of time for how many animals will be required to consume the cheatgrass (Schmelzer et al. 2014).

Grazing with cattle during the fall at appropriate levels repeatedly year after year may reduce the abundance of cheatgrass and will probably not decrease the abundance of the perennial grasses although little longer term data exist (Schmelzer et al. 2014; Strand et al. 2014; see fig. 7).

Once the perennial native herbaceous species have been depleted, recovery of perennial native grasses is likely to be a slow process in this ecological type even with long-term rest from livestock grazing (e.g., West et al. 1984). Also, once the perennial native herbaceous species have been depleted, sagebrush and other shrubs may continue to increase in abundance for a decade or more even with removal of livestock (West et al. 1984; Chambers et al. 2017b). Thus for areas within the invaded state with moderate cover of perennial native grasses, grazing practices to maintain or increase the cover of these species is a priority.

The effects of livestock grazing on wildfire potential in the annual and other states depends on the relative proportion of sagebrush to herbaceous fuels combined with weather conditions. Figure 8 illustrates that the potential for grazing to be effective in reducing the risk of fire initiation and spread is greatest when sagebrush cover is low and fire weather severity is low to moderate (Strand et al. 2014). In big sagebrush types with high productivity and heavy fuels, like many mountain big sagebrush types, long-term removal of grazing in sagebrush rangelands may cause an increase in fine fuels (grasses and forbs) that may increase fire severity and extent when these systems burn (Davies et al. 2014; Strand et al. 2014). Long-term removal of grazing may also increase the likelihood of wildfire-induced mortality of perennial bunchgrasses because of fuel buildup on the root crown of perennial bunchgrasses (Davies et al. 2009; Davies et al. 2010). While grazing may decrease fuels and reduce wildfire severity or extent in some cases (fig. 8), as weather conditions become extreme, the potential role of grazing on wildfire behavior decreases and may become meaningless (Strand et al. 2014).



4621 **Figure 7**–Conceptual depiction of how livestock grazing can influence cheatgrass abundance in sagebrush-dominated ecosystems with a significant component of perennial grasses. Grazing can suppress or promote cheatgrass depending primarily on the season of grazing. Grazing suppresses cheatgrass: 1) when applied in early spring when annuals begin to produce seeds and before native perennial grasses initiate bolting, and 2) when applied during the dormant season. Figure from Strand et al. (2014).

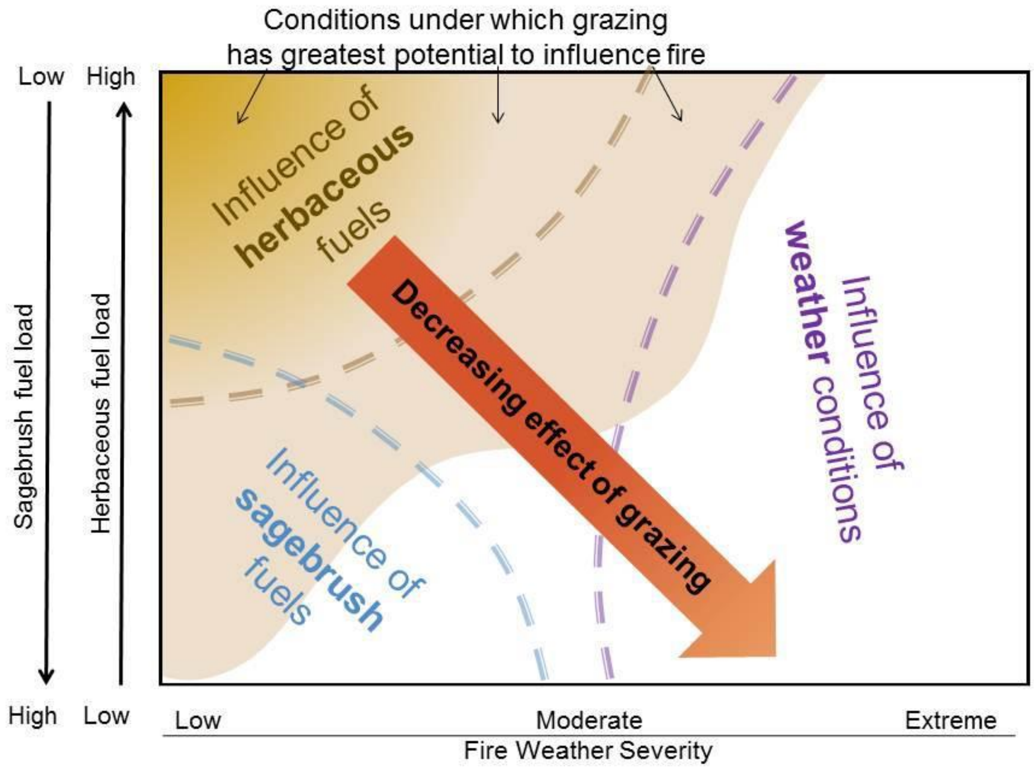


Figure 8–The potential for grazing to influence fire behavior occurs along continuums of fuel and weather conditions. In this conceptual model, fuel composition is displayed on the y-axis and fire weather condition is displayed on the x-axis. Low fire weather severity is characterized by high fuel moistures, high relative humidity, low temperature, and low wind speeds, while extreme fire weather is characterized by the opposite conditions. The potential for grazing to be effective in reducing the risk of fire initiation and spread is greatest when the sagebrush cover is low and the fire weather severity is low to moderate. From Strand et al. 2014.

ANNUAL STATE

Figure 9–Example of a plant community phase in the annual state in the Wyoming big sagebrush 8 to 12 inch precipitation zone ecological type (fig. 5). The plant community phase is dominated by exotic annual grasses and forbs such as cheatgrass, medusahead, and tumblemustard. The site is located in the Jackies Butte allotment in the Jordan Resource Area of the Vale District BLM in Oregon. This site is not providing nesting or early brood-rearing habitat for greater sage-grouse. Photo by Jon Sadowski.

Potential Livestock Grazing Management Practices

Shifts in plant communities in sagebrush ecosystems toward invasive annual grass dominance were caused in part by historical improper grazing (Davies et al. 2014). However, changes in grazing practices in the annual state (figs. 5, 9) will not likely facilitate the conversion of annual grass-dominated plant communities back to native-dominated communities (Davies et al. 2014; Strand et al. 2014). Similarly, changes in grazing practices in the annual state cannot be used to achieve vegetation habitat objectives for nesting and brood-rearing seasonal habitat for greater sage-grouse in Oregon/Washington (Appendix 3, table 2), Utah (Appendix 3, table 3), Nevada and northeastern California (table 4), and Idaho and southwestern Montana (Appendix 3, table 5).

Targeted grazing, or the application of a specific kind of livestock at a determined season, duration, and intensity, can be used to accomplish defined vegetation or landscape goals within annual states (Launchbaugh and Walker 2006; Mosely 2006). For example, intense sheep grazing of cheatgrass-dominated sites can effectively suppress or even eliminate cheatgrass stands in as little as two years as was done in the urban interface above Carson City, NV (Mosley 1994). Managed grazing may also reduce the risk and extent of wildfire in cheatgrass dominated areas (Diamond et al.2009, 2012; Walker 2006).

In sagebrush ecosystems, high intensity targeted grazing may best be used to create firebreaks by confining livestock to a strip of land with temporary fencing. Grazing may reduce the extent of wildfire because livestock grazing reduces herbaceous vegetation (fine fuels) (Walker 2006). Also, because livestock tend to graze some areas more intensely than others, grazing may create patchy vegetation that reduces the continuity of fuel loads and the fires that might burn those fuels (Walker 2006).

Effective grazing programs for invasive plant control require a clear statement of the kind of animal, timing, and rate of grazing necessary to suppress the invasive plant (Launchbaugh and Walker 2006). A successful grazing prescription should: 1) cause significant damage to the target plant; 2) limit damage to the surrounding vegetation; and 3) be integrated with other control methods as part of an overall management strategy. Because targeted grazing by livestock is typically focused on heavily invaded areas, follow-up management such as seeding the target area with the desired species may be needed.

SEEDED STATE

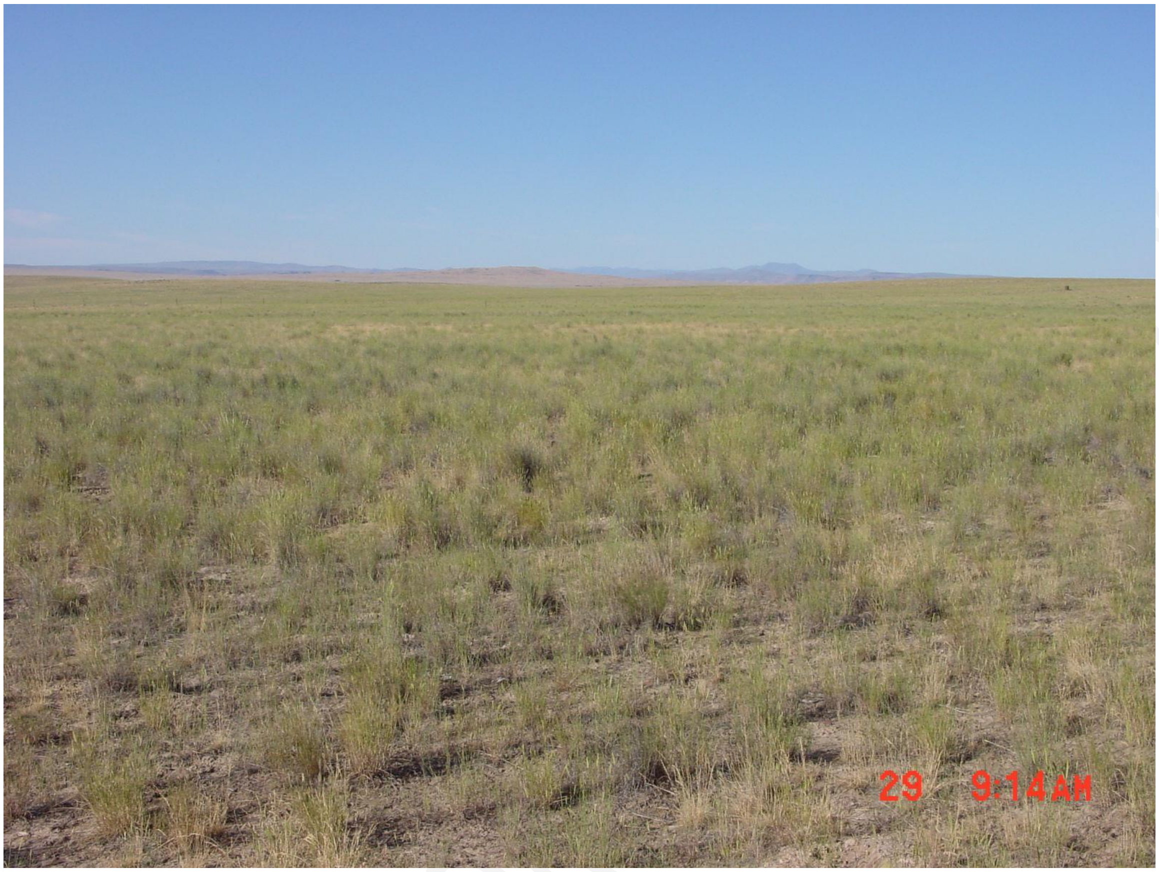


Figure 10–Example of a plant community phase in the seeded state in the Wyoming big sagebrush 8 to 12 inch precipitation zone ecological type (fig. 5). Plant community phase is a seeding dominated by Fairway crested wheatgrass. Located in the Jackies Butte allotment in the Jordan Resource Area of the Vale District BLM in Oregon. This site is not providing nesting or early brood-rearing habitat for greater sage-grouse. Photo by Jon Sadowski.

Potential Livestock Grazing Management Practices

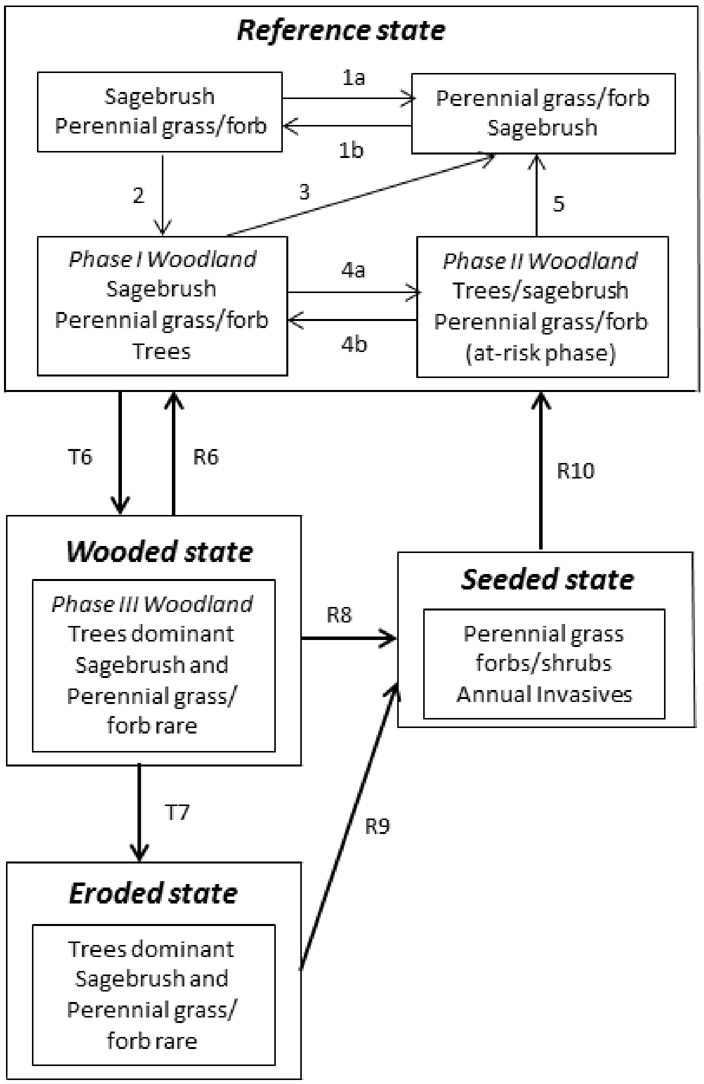
Following wildfire, areas within the Wyoming big sagebrush 8 to 12 inch precipitation zone that support GRSG are often a priority for seeding because perennial native grasses are typically insufficient to promote recovery. Diverse seed mixes of native shrubs, grasses, and forbs can increase resilience to disturbance as well as resistance to invasive annual grasses through increased competition with the invaders (see Section 6). Seeding with sagebrush, native perennial grasses, and the appropriate native forbs can also provide the habitat conditions needed to meet GRSG objectives for nesting and brood-rearing seasonal habitat. However, seeding with a high proportion of introduced grasses, like crested wheatgrass, or introduced shrubs, like forage Kochia, will not provide the habitat conditions needed to meet GRSG objectives for nesting and brood-rearing seasonal habitat (fig. 10). Because areas within the Wyoming big sagebrush 8 to 12 inch precipitation zone have inherently low resilience and resistance, integrated rehabilitation methods such as herbicide application followed by seeding may be required. Also, the warmest and driest sites may need to be seeded more than once to achieve management objectives.

Grazing rest and deferment schedules are needed to ensure establishment of the seeded species and recovery of the site after post-wildfire rehabilitation. Newly seeded and surviving plants are at risk of repeated defoliation due to animal preference for foraging in burned areas (Veblen et al. 2016). Thus, grazing should be resumed only after perennial grasses have established and are producing viable seed at levels equal to grasses on unburned sites. Failure to implement a program of grazing rest or deferment may slow or prevent site recovery (Kerns et al. 2011) and promote invasive annual grasses and other undesirable plants.

Once post-fire grazing resumes on a site, use should be deferred until after seed maturity or shatter to promote bunchgrass recovery (Bates et al. 2009; Bruce et al. 2007). Also, post-fire grazing after rest or during deferment periods will likely need to be lighter than grazing recommendations for unburned areas, which are no more than 50 percent utilization during active growth, and no more than 60 percent during dormancy (Guinn and Rouse 2009). Under certain conditions (e.g., in warm or dry areas, after high severity fires, or during low precipitation years), even lower utilization may be required to allow seeded species to establish and soils to recover. Options for mitigating livestock distribution problems in large grazing units include fencing, herding, and strategic placement of water, salt, and supplements.

Careful monitoring and assessment is an integral part of a grazing program to determine when grazing may be resumed, whether post-fire grazing management has been effective, and if changes in grazing management are needed.

A.6.2 Cold Deserts – Frigid/Xeric-Typic
Mountain big sagebrush (12-22 in PZ)
Piñon pine and/or juniper potential
Moderately high resilience and moderate resistance



(1a) Disturbances such as wildfire, insects, disease, and pathogens result in less sagebrush and more perennial grass/forb.

(1b) Sagebrush increases with time.

(2) Time combined with seed sources for piñon and/or juniper trigger a Phase I Woodland.

(3 and 5) Fire and or fire surrogates (herbicides and/or mechanical treatments) that remove trees may restore perennial grass/forb and sagebrush dominance.

(4a) Increasing tree abundance results in a Phase II woodland with depleted perennial grass/forb and shrubs and an at-risk phase.

(4b) Fire surrogates (herbicides and/or mechanical treatments) that remove trees may restore perennial grass/forb and sagebrush dominance.

(T6) Infilling of trees and/or improper grazing can result in a biotic threshold crossing to a wooded state with increased risk of high severity crown fires.

(R6) Fire, herbicides and/or mechanical treatments that remove trees may restore perennial grass/forb and sagebrush dominance.

(T7) An irreversible abiotic threshold crossing to an eroded state can occur depending on soils, slope, and understory species.

(R8 and R9) Seeding after treatments or fire may be required on sites with depleted perennial grass/forb, but seeding with aggressive introduced species can decrease native perennial grass/forb. Annual invasives are typically rare. Seeded eroded states may have lower productivity.

(R10) Depending on seed mix and grazing, return to the reference state may be possible if an irreversible threshold has not been crossed.

Figure 11–State-and-transition model for a mountain big sagebrush 12 to 22 inch precipitation zone ecological type applicable in the Cold Deserts in the western part of the sagebrush biome and Greater sage-grouse range in the Snake River Plain, Northern Basin and Range, and Central Basin and Range ecoregions (Management Zones III, IV, and V). Large boxes illustrate states that are comprised of community phases (smaller boxes). Transitions among states are shown with arrows starting with T; restoration pathways are shown with arrows starting with R. The "at risk" community phase is most vulnerable to transition to an alternative state. Figure is from Appendix 6 in Part 1 of the Science Framework (Chambers et al. 2017a).

REFERENCE STATE—PHASE II WOODLAND

Figure 12–Example of a phase II woodland plant community in the reference state of the mountain big sagebrush 12 to 22 inch precipitation zone ecological type (fig. 11) in Oregon. This Phase II woodland is dominated by western juniper. Western juniper is continuing to expand and increase in density and canopy cover, and mountain big sagebrush and bluebunch wheatgrass are declining in canopy cover. This plant community phase is not providing nesting or early brood-rearing habitat for greater sage-grouse. Photo by Jon Bates.

Potential Livestock Grazing Management Practices

Managing grazing in Phase II reference areas (figs. 11, 12) in piñon and juniper ecosystems to maintain perennial grasses can decrease the rates of piñon and juniper expansion into adjacent sagebrush ecosystems (Madany and West 1983; Guenther et al. 2004; Soule et al. 2004; Shinneman and Baker 2009). Grazing management to maintain perennial grasses can also increase their resilience and capacity to recover after wildfire (Chambers et al. 2014a).

There is a lack of consensus in the grazing literature as to the role of livestock grazing in relation to the magnitude of recent expansion of piñon and juniper into sagebrush ecosystems. However, in those studies that compared adjacent grazed and historically ungrazed areas, piñon and juniper densities, canopy cover, or basal area were greater in the grazed pastures (Madany and West 1983; Guenther et al. 2004; Soulé et al. 2004; Shinneman and Baker 2009). Also, shrubs often act as nurse plants for piñon and juniper by modifying temperatures and increasing resource availability (Johnson 1962; Miller and Rose 1995; Soulé and Knapp 2000, Chambers et al. 2000; Soulé et al. 2004) and shrub dominance often increases after fire in response to grazing that removes perennial grasses (Chambers et al. 2017b). A recent simulation model that evaluated woodland expansion across the Intermountain West identified grazing as the key factor leading to juniper expansion through reduction of perennial grass and shrub cover as well as decreases in fire occurrence (Caracciolo et al. 2016).

Greater sage-grouse do not use piñon and juniper expansion areas with land cover greater than about 2-4% (Coates et al. 2017; Severson et al. 2016). Thus, changes in grazing management in Phase II reference areas (figs. 11, 12) cannot be used to achieve vegetation habitat objectives for nesting and brood-rearing seasonal habitat for greater sage-grouse in Oregon/Washington (Appendix 3, table 2), Utah (Appendix 3, table 3), Nevada and northeastern California (Appendix 3, table 4), and Idaho and southwestern Montana (Appendix 3, table 5), on this Phase II woodland in the reference state. However, Phase II expansion woodlands are often targeted for conifer removal treatments to improve GRSG habitat. Depending on the severity of the treatment, bunchgrasses and other perennial vegetation may take several years to fully recover and exhibit increases in cover (Williams et al. *in press*). During the recovery period, many of the same grazing management practices as used after fire and rehabilitation seeding may be used including rest and deferment, decreased levels of utilization, and increased emphasis on livestock distribution.

WOODED STATE—PHASE III WOODLAND

Figure 13–Example of a plant community phase in the wooded state in the mountain big sagebrush 12 to 22 inch precipitation zone ecological type (fig. 11), in Oregon. The site is a Phase III woodland dominated by western juniper that was dominated in the past by sagebrush and Thurber needlegrass. This plant community phase is not providing nesting or early brood-rearing habitat for greater sage-grouse. Photo by Jon Bates.

Potential Livestock Grazing Management Practices

Because GRSG do not use piñon and juniper expansion areas with the amounts of land cover in Phase III woodland (figs. 11 and 13; Severson et al. 2017), changes in grazing management cannot be used to achieve vegetation habitat objectives for nesting and brood-rearing seasonal habitat for greater sage-grouse in Oregon/Washington (Appendix 3, table 2), Utah (Appendix 3, table 3), Nevada and northeastern California (Appendix 3, table 4), and Idaho and southwestern Montana (Appendix 3, table 5), on this Phase III woodland in the wooded state. However, following wildfire and post-fire rehabilitation seeding or tree removal in these areas to increase connectivity, many of the same grazing management practices as used after wildfire and post-fire rehabilitation seeding may be used.

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8. WILD HORSE AND BURRO CONSIDERATIONS

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Introduction

The presence of wild horses (*Equus caballus*) and, to a limited extent, wild burros (*Equus asinus*), can have substantial effects on the capacity for habitat restoration efforts to achieve landscape conservation and restoration goals. This section relates to management of federal lands and the terms ‘wild horses’ and ‘wild burros’ are used throughout. However, the specific legal status for any given horse or burro population has a large influence on management objectives and on the ability of managers to manage wild horse and burro impacts. In the biological sense, all free-roaming horses and burros in North America are feral, meaning that they are descendants of domesticated animals. Burros evolved in Eurasia (Geigl et al. 2016) and horses, which evolved in the Americas, went extinct in the Americas during the last ice age (Webb 1984). Both species were domesticated roughly 6,000 years ago and brought to the Americas by European colonists. The published literature refers to free-roaming horses as either feral or wild. In the ecological context the terms are interchangeable, but the term wild horse is associated with a specific legal status. Wild and free-roaming horses and burros under the jurisdiction of the Bureau of Land Management (BLM) and U.S. Forest Service (USFS), are “wild” as legally defined by the Wild Free Roaming Horses and Burros Act of 1971 as amended (WFRHBA), and are under the protection, management and control of the BLM (43 CFR 4700.0–5[l]) and USFS (36 CFR 222). Only those horses whose unbranded and unclaimed ancestors were present on BLM and USFS lands at the time of the passage of the WFRHBA are managed in accordance with the WFRHBA. Other populations of horses and burros (i.e., those on lands administered by the U.S. Fish and Wildlife Service, National Park Service, etc.) are generally subject to other federal regulations and relevant state laws, but are not subject to provisions of the WFRHBA. This section of the Science Framework, Part 2, draws on scientific studies of feral horses, some of which also have wild horse or wild burro legal status. Clarification of which horses and burros are considered federally protected is provided in the BLM regulation (43 CFR 4700), BLM Wild Horse and Burro Management Handbook (USDOI BLM 2010a), BLM Wild Horse and Burro Manuals; 4710 Management Considerations (USDOI BLM 2010b), 4720 Removals (USDOI

BLM 2010c), 4740 Motor Vehicles and Aircraft (USDOI BLM 2010d), USFS Forest Service Manual (FSM 2260.5) and USFS regulation (36 CFR 222.20(b)(13), 36 CFR 2263).

Landscapes in which wild horse and burro abundance is greater than targeted ‘appropriate management levels’ will tend to have lower resilience to disturbance and lower resistance to invasion than similar landscapes with herds at or below target levels, for reasons summarized below. The presence of wild horses and burros (WH&B) was considered in the Conservation Objectives Team (COT) report to be a threat to Greater sage-grouse (*Centrocercus urophasianus*; hereafter GRGS) habitat quality, particularly in the species’ western range (USFWS 2013). Wild horse population sizes on federal lands have almost doubled in the three years since that report was published. On lands administered by the BLM, there were an estimated 72,674 BLM-administered WH&B as of March 1, 2017. Approximately 60% of those are present within 13 million acres of GRSG habitat. On USFS-administered lands, an estimated 6,000 wild horses and 900 wild burros occupy approximately 2 million acres, of which approximately 446,065 acres of active administrative territories contain general and priority GRSG habitat (no sage grouse focal areas), occupied by an estimated 3,400 wild horses and burros. An additional approximately 70,000 USFS-administered acres and 82,403 BLM acres on five Herd Management Areas are classified as Bi-state sage-grouse habitat, occupied by over 1000 wild horses. Some wild horses also inhabit other federal lands in the sagebrush biome, including lands administered by the National Park Service, the U.S. Fish and Wildlife Service, the Department of Defense and Native American reservation and tribal trust lands. Most of those animals do not have protected status under the WFRHBA.

Wild burros are not nearly as numerous as wild horses in the sagebrush biome so this section refers mainly to wild horses. Beever and Aldridge (2011), suggest that the tendency of burros to use low-elevation habitats throughout the year may lead to a higher degree of overlap between burros and sage-grouse habitat, where they co-occur. Wild burros can also substantially affect riparian habitats (e.g., Tiller 1997), native wildlife (e.g., Seegmiller and Ohmart 1981), and otherwise contribute to grazing and trampling impacts in ways similar to wild horses (Carothers et al. 1976; Hanley and Brady 1977; Douglas and Hurst 1983).

Wild horse populations pose long-term challenges to habitat management, conservation, and improvement efforts that differ in several key ways from the challenges posed by managed livestock grazing. Wild horse management is primarily limited to managing numbers of animals and, by extent, their distribution. Wild horses live on the range year round, they roam freely, the locations and timing of wild horse grazing are not regulated like those of livestock grazing, and wild horse populations have the potential to grow on the order of 15-20% per year (Wolfe 1980; Eberhardt et al. 1982; Garrott et al 1991; Dawson 2005; Roelle et al. 2010; Scorolli et al. 2010). Although this annual growth rate may be lower in some areas where mountain lions can take foals (Turner and Morrison 2001), horses tend to favor use of more open habitats (Schoenecker 2016) that are dominated by grasses and shrubs and where ambush is less likely. For the majority of wild horse herds, there is little overall evidence that population growth is significantly affected by predation. As a result of the potential for wild horse populations to grow rapidly, impacts from wild horses on water, soil, vegetation, and native wildlife resources can increase exponentially unless there is active management to limit their population sizes. Thus, despite the challenges that wild horses can present to achieving desired habitat conditions, wild horse management is a necessary requirement of planning for long-term sagebrush ecosystem and GRSG conservation.

Ecological Effects of Wild Horses on Sagebrush Ecosystems

USFWS (2008) and Beever and Aldridge (2011) summarize much of the literature that quantified direct ecosystem effects of wild horse presence. Beever and Aldridge (2011) provide a conceptual model for effects of wild horses on sagebrush ecosystems. Wild horse presence is generally associated with lower overall plant cover, but greater relative abundance and cover percentages of grazing-tolerant, unpalatable, and invasive plant species (Smith 1986), including cheat grass (*Bromus tectorum*). In the Great Basin, areas without wild horses had greater measures of shrub cover, plant cover, species richness, native plant cover, and overall plant biomass, compared to areas with horses (Beever et al. 2008; Davies et al. 2014; Zeigenfuss et al. 2014). There were also measurable differences in soil penetration resistance, erosion, and invertebrate, small mammal, and reptile communities (Beever et al. 2003; Beever and Brussard 2004; Ostermann-Kelm et al. 2009), suggesting that horse presence has broad effects on ecosystem function. Wild horses also cause measurable differences in soil structure (Belnap et al. 2001; Beever and Herrick 2006).

Many studies corroborate the general conclusion that overabundant wild horse populations can lead to biologically significant changes in rangeland ecosystems. Although horses are primarily considered to be grazers (Hanley and Hanley 1982), upland communities can be affected because shrubs – including sagebrush (*Artemesia spp.*) – can represent a large part of their diet in summer in the Great Basin (Nordquist 2011). Grazing by wild horses can have severe impacts on aquatic ecosystems and riparian communities as well (Beever and Brussard 2000; Barnett 2002; Nordquist 2011; USFWS 2008; Earnst et al. 2012; USFWS 2012; Kaweck 2016). In addition to damaging water source quality, wild horses can monopolize limited water sources in arid western lands, behaviorally excluding ungulates and other native wildlife (e.g., pronghorn) from water sources (Ostermann-Kelm et al. 2008; USFWS 2008; Perry et al. 2015; Hall et al. 2016; Gooch et al. 2017). Bird nest survival may be lower in areas with wild horses (Zalba and Cozzani 2004), and bird populations have been shown to substantially recover after both livestock and wild horses have been removed (Earnst et al. 2005; Earnst et al. 2012). Wild horses are potential agents for the spread of nonnative plant species (Beever et al. 2003; Couvreur et al. 2004; Loydi and Zalba 2009). Feral horses may limit the effectiveness of reseeding projects, and horse use may foster cheat grass growth in seeding project areas (Jessop and Anderson 2007). Even in areas with long histories of livestock grazing, once domestic livestock are removed, continued wild horse grazing can cause ongoing detrimental ecosystem effects (USFWS 2008; Davies et al. 2014) In sagebrush ecosystems, plant communities can take several decades to recover from such impacts (e.g., Anderson and Inouye 2001).

Most analyses of wild horse effects have contrasted areas with wild horses to areas without. Analyses have generally not included horse density as a continuous covariate; therefore ecosystem effects have not been quantified as a linear function of increasing wild horse density. This is a topic needing further study. One exception is an analysis of satellite imagery confirming that varied levels of feral horse biomass were negatively correlated with average plant biomass growth (Ziegenfuss et al. 2014).

Overview of Wild Horse and Burro Management Structure

In most cases, each BLM-administered Herd Management Area is intended to only support either wild horses or wild burros, but there are some Herd Management Areas that contain both. USFS-administered Wild Burro Territories, Wild Horse Territories and/or Wild Horse and Burro Territories are designated depending on whether burros, horses and burros, or only horses occupy the territory.

BLM and USFS manage wild horse populations at a spatial scale that usually falls between the regional and project levels. BLM manages wild horses and burros within a total of 177 Herd Management Areas, 105 of which are within GRSG habitat. Of those, 22 Herd Management Areas are within Sagebrush Focal Areas (SFA, 2 million acres), 65 Herd Management Areas fall within Priority Habitat (PHMA, 4.5 million acres), and 18 Herd Management Areas are within General Habitat (GHMA, 4.5 million acres). The USFS manages wild horses and burros within a total of 34 active territories, 13 of which are within GRSG habitat. Of these 13, none are in Sagebrush Focal Areas, 12 Wild Horse and Burro Territories fall within Priority Habitat (93,528 acres), and 13 Wild Horse and Burro Territories are within General Habitat (352,537 acres). An additional 3 Wild Horse Territories and 5 Herd Management Areas (approximately 152,400 acres, combined) fall within Bi-state sage-grouse habitat.

USFS manages wild horses and burros in 34 active administrative units (and 19 inactive units) called Wild Burro Territories (7 active units, 3 inactive units), Wild Horse Territories (37 units, 13 inactive units) and/or Wild Horse and Burro Territories (3 units). The active units range in size from 5.4 mi^2 to 530.4 mi^2. Wild horses and burros, though, often roam outside the boundaries of Wild Horse Territories, Wild Horse and Burro Territories, and Wild Burro Territories.

When two or more Herd Management Areas or Wild Horse Territories are located close to one another, with the potential for WH&B to move freely between them, it is appropriate for those areas to be managed collectively, as a ‘complex,’ or ‘joint management area.’ Complexes sometimes cross administrative boundaries between BLM field or district offices and USFS districts.

A National Academies of Science report (National Research Council 2013) suggested that wild horse management should be focused on meta-populations, in which Herd Management Areas and Wild Horse Territories where interchange occurs are grouped, regardless of administrative boundaries. The spatial scales of wild horse management are: the entire population at the west-wide scale, complexes or groups of Herd Management Areas and/or Wild Horse Territories/Wild Burro Territories/Wild Horse and Burro Territories with interchange for the regional scale, and individual herds for the local scale. The actual spatial scale for any given wild horse population should be determined in consultation with the local staff that manages those populations (i.e., BLM wild horse and burro specialist, USFS rangeland management specialist).

Each Herd Management Area, Wild Burro Territory, Wild Horse Territory, and Wild Horse and Burro Territory has an established target population range for wild horses (and a separate target for wild burros, if they are present), known as the appropriate management level (AML; 43 CFR 4710.3–1; 36 CFR 222.61(a)(6)). AML generally is a range between a low and high value, to allow for variability in population growth across years (USDOI BLM 2010a). AML is typically determined at the activity planning level through site specific analysis or, in some cases, through the land use planning process. When establishing AML, analyses typically have included an in-depth evaluation of intensive monitoring data and/or land health assessment. Monitoring data includes studies of grazing utilization, range ecological condition and trend, actual use, and climate (weather) data. Wild horse and burro population inventory data, use patterns and animal distribution, and projected effects of climate change are also considered. Progress toward attainment of site-specific and landscape-level management objectives or multiple use objectives are also considered. AML represents a target population range that allows for long-term wild horse populations in a “thriving natural ecological balance” with other multiple uses on the landscape. BLM and USFS view AML as a target population size which, if maintained, should allow for a thriving ecological balance and multiple use relationship (36 CFR 222.60(b)(3), 36 CFR 222.61(a)(1), 36 CFR 222.69(a), USFS regulation; 43 CFR 4770.3(c), BLM regulation); this view reflects an assumption that AML should allow for land health standards to be met (USDOI BLM 2010a).

For lands administered by the BLM, Herd Areas are areas where wild horses and burros existed at the time of the passage of the WFRHBA. Wild Horses and Burros can only be managed on lands they were found when the WFRHBA was passed. Herd Management Areas can only be designated within Herd Areas during land use planning activities. Herd Management Areas are for active management of wild horses and burros as part of the multiple use setting. For Herd Areas that do not have a Herd Management Area designation it generally has been determined that resources are limiting, and that WH&B populations cannot be maintained for the long term. The USFS has no similar designation although there are some territories without wild horses or burros (these are considered “inactive”), where it has been determined that there aren’t sufficient resources to maintain WH&B there.

Management Actions to Maintain Appropriate Management Levels (AMLs) of Wild Horses and Burros

The 1971 WFRHBA directs the BLM and USFS to remove excess animals from the range (43 CFR 4720.1) in order to maintain a thriving natural balance. The number of wild horses or burros greater than a Herd Management Area- or Wild Burro Territory-, Wild Horse Territory-, and/or Wild Horse and Burro Territory- designated AML is considered to be the number of ‘excess’ animals in the area. USFS provides direction under the WFRHBA for setting population goals relative to ecological thresholds in the Forest Service Manual Chapter 2260 and within 36 CFR 222.60-222.76. In order to take management action the agency must make two determinations: (1) that an overpopulation exists, and (2) whether or not it will be necessary to remove excess animals.

Historically, BLM and USFS reduced herd population sizes to the low value of AML, removing excess animals and offering them to the public for adoption. The population would then typically grow to reach the high value of the AML range within 3-4 years, unless some form of contraception was used to limit population growth rates. Natural regulation via starvation, or dehydration, is generally not acceptable to many members of the public (NRC 2013). In more recent years, because the over 45,000 BLM-administered, captive wild horses currently in long-term holding (of which approximately 954 are horses from USFS territories) require more than $50 million per year to maintain, the BLM has not had the budgetary capacity to remove more than approximately 3,500 animals per year from the range. Removing all excess wild horses and holding them in off-range facilities for the remainder of their lives would be prohibitively expensive (Garrott and Oli 2013). As a result, populations of WH&B across BLM-administered lands (and on some USFS territories) are now more than three times greater than the high end of the cumulative AML, and growing. In many areas, wild horses have expanded far outside of Herd Management Area and Wild Horse Territory boundaries, and onto Herd Areas, nonHerd Areas, BLM land and other federal, state, tribal, and private lands.

In 2015, BLM established a series of Sagebrush Focal Areas identified as critical habitat for GRSG and other sagebrush obligates. There are no areas where Sagebrush Focal Areas overlap with USFS-administered wild horse and/or wild burro populations. On those 22 Herd Management Areas where Sagebrush Focal Areas overlap with wild horse populations, BLM developed a five-year gather schedule to achieve AML by 2020. However the BLM will not have the capacity to conduct gathers within Priority Habitats until 2020 and has no capacity to manage wild horse populations that overlap with General Habitats; it is expected the wild horse population within GRSG habitat could be more than 65,000 horses by 2020. Furthermore, maintaining any wild horse population at or below AML will require an active and ongoing program of population growth suppression and/or scheduled removals of excess animals. Without such a program, habitat restoration will quickly be at risk as wild horse populations again grow to exceed AML.

Currently accepted population growth suppression methods include the immunocontraceptives porcine zona pellucida (PZP) and GonaCon (National Research Council 2013). Both of these may only be effective for one year, unless annual booster doses are given (National Research Council 2013). Repeated PZP boosters could require annual darting or recapture to the vast majority of wild horses under BLM/USFS management, which is infeasible and could quickly lead to fiscal insolvency. BLM is supporting ongoing research initiatives to foster the development of longer-term contraception for wild horses and burros (USDOI BLM 2015). However, planning decisions that propose to remove excess horses and/or utilize population growth suppression are repeatedly appealed and litigated by interested members of the public. This results in a high degree of uncertainty about the ability of designated federal agencies to maintain wild horse populations within AML, even within identified Sagebrush Focal Areas.

Considerations for Wild Horse and Burro Management based on the Science Framework Approach

Information on relative ecosystem resilience to disturbance and resistance to invasive species can be used to help understand the responses of sagebrush ecosystems, species at-risk, and other resources to wild horse and burro use and to the interactions of wild horse and burro use with other threats like wildfire and invasive plant species. Resilience and resistance information coupled with information on wild horse and burro target populations or appropriate management levels (AMLs) and the other predominant threats can be used to inform conservation and restoration strategies in sagebrush ecosystems at broad, mid, and local scales.

The Science Framework Approach

The Science Framework provides an approach based on an understanding of ecosystem resilience and resistance that uses assessments at the ecoregional or GRSG Management Zone scale (mid scale) to help prioritize areas for management and determine effective management strategies (Chambers et al. 2017). The approach is based on: 1) the likely response of an area to disturbance or stress due to threats and/or management actions (i.e., resilience to disturbance and resistance to invasion by nonnative plants), 2) the capacity of an area to support target species and/or resources, and 3) the predominant threats. The geospatial data layers and analyses used in the approach are described in sections 8.1 and 8.2 of Part 1 of the Science Framework. The process involves overlaying key data layers including resilience and resistance as indicated by soil temperature and moisture regimes (Maestas et al. 2016), sage-grouse breeding habitat probabilities (Doherty et al. 2016) and densities or other sagebrush obligate habitats, and the primary threats for the ecoregions or Management Zones in the assessment. The maps and analyses that managers derive from this process are an essential component of prioritizing areas for management actions and developing management strategies.

WH&B densities and appropriate management levels can be used similarly to other threats in the analyses. Managers can devise categories to evaluate the degree to which WH&B populations are within or exceed AMLs for Herd Management Areas. For the Wild Horse and Burro Management Consideration Section of Part 2of the Science Framework, three AML categories were developed based on published March 1, 2017 abundance estimates (USDOI BLM 2017): within AML, >100 to 200% of AML, and >200% of AML. (See figure 8.1 for the wild horse Herd Management Areas overlaid with the three AML categories.) These categories were then overlaid with (1) the three resilience and resistance categories derived from soil temperature and moisture regime information, and (2) the GRSG breeding habitat probabilities (see Part 1, sections 8.1 and 8.2).

Analyses of Appropriate Management Levels (AMLs), Ecosystem Resilience and Resistance, and Breeding Bird Habitat Probabilities

The analyses and maps of the wild horse Herd Management Areas show that most of the wild horse populations are in low resilience areas – 61%, 33% and 6% of the wild horse populations in the Herd Management Areas are in low, moderate, and high resilience and resistance areas, respectively (fig. 8.2, table 8.1). Also, 60% of the wild horse populations are >200% of AML. For the low, moderate, and high resilience and resistance areas, 37%, 19% and 4% of the total population is >200% of AML.

Differences in both resilience and resistance and AMLs exist among Management Zones for wild horses (fig. 8.2, table 8.1). The few wild horses in MZ I are in moderate resilience and resistance areas and are 100% to 200% of AML. Most wild horse populations in Management Zone II are within moderate resilience and resistance areas, and mostly at >100% to 200% of AML (31%) or >200% of AML (51%). The wild horse populations in Management Zone III, where the majority of wild horses are found, are primarily within low resilience and resistance areas (53%) and are mostly at >200% of AML (53%). In Management Zones IV and V, wild horse populations are also primarily within low resilience and resistance areas – 77% and 56% respectively. While wild horse populations in Management Zone IV have similar numbers within the three AML categories, those in Management Zone V have higher numbers at >100% to 200% of AML (29%) and >200% of AML(58%) than within AML (13%). In Management Zone VII, wild horse populations are small and most occur in low resilience and resistance areas (65%) and are at AML (48%) or at 100% to 200% of AML (52%).

Analyses of the wild burro Herd Management Areas indicates that most of the populations are in low resilience and resistance areas (81%) followed by moderate resilience and resistance areas (17%) (fig. 8.3, table 8.2). Also, 72% of the wild burro population is >200% AML. Most of the wild burro populations in Management Zone III are in low resilience and resistance areas at >200% AML. In Management Zone V, wild burro populations in low resilience and resistance areas (59%) are primarily at >200% AML (52%), while those in moderate resilience and resistance areas (37%) are mostly at >100% to 200% AML (29%). In Management Zone VII, the few wild burros are in low resilience and resistance areas at >100% to 200% AML.

Overlaying the wild horse AMLs with the sage-grouse breeding habitat probabilities for the Herd Management Areas shows that 41% the horse populations occur in both the low and moderate breeding habitat probabilities, and 19% occurs in the high breeding habitat probability (fig. 8.4, table 8.3). Within high breeding habitat probability areas, which are the highest priority for protection, 13% of the Herd Management Areas overall and 68% of the high breeding habitat area alone is at >200% AML. Within moderate breeding habitat probabilities, which often provide opportunities for conservation actions, 28% of the Herd Management Areas overall and 68% of the high breeding habitat area alone is at >200% AML. These trends are generally similar to those for the individual Management Zones, except for Management Zone VII where most wild horses are in high breeding bird probability areas at >100% to 200% AML.

The wild burro AMLs overlaid with the sage-grouse breeding habitat probabilities for the Herd Management Areas shows that 44%, 46%, and 19% of the wild burro populations occur in in the low, moderate, and high breeding habitat probability areas, respectively (table 8.4). Within high breeding habitat probability areas, 4% of the Herd Management Areas overall and 38% of the high breeding habitat area alone is at >200% AML. Within moderate breeding habitat probability areas, 33% of the Herd Management Areas overall and 72% of the high breeding habitat area alone is at >200% AML. Management Zone V has a higher proportion of the wild burro population in moderate and high breeding bird probability areas (60%) than Management Zone III (40%), but in both Management Zones most populations in these areas are at > 200% AML.

Implications for Management

Primary considerations for WH&B management from the Science Framework approach are presented below (see tables 1.2 and 1.3).

- In general, areas that support medium to high sage-grouse breeding habitat probabilities or other important resources are high priorities for management (table 1.2; 2A, 2B, 2C, 3A, 3B, 3C), especially low resilience and resistance categories that lack the potential to recovery from disturbances like inappropriate wild horse and burro use without significant intervention (table 1.2; 2C, 3C). These areas could be considered priorities for wild horse and burro gathers and fertility control where horse and burro abundance exceeds target AMLs and the area is not highly degraded.
- Areas with moderate and especially high resilience and resistance often have the potential to recover through successional processes (table 1.2; cells 1B, 1C, 2B, 2C).
    - These areas represent significant opportunities to improve habitat and could also be considered priorities for wild horse and burro gathers and fertility control where horse and burro abundance exceeds target AMLs and removals will likely result in habitat improvement.

- In those areas where wild horses and burros exceed target AML levels, managers should carefully consider the current spatial extent, and growth potential, of any nearby wild horse population, and its potential effect on management actions to improve habitat.

- New post-fire rehabilitation areas and areas that provide sagebrush habitat connectivity for Greater sage-grouse and other species at-risk are conservation priorities and thus could be priorities for wild horse and burro gathers, where abundance exceeds AMLs.

Data on Population Estimates and Spatial Distribution of Wild Horses and Burros

Population estimates for each Herd Management Area and Herd Area are reported annually in the Public Land Statistics (http://www.blm.gov/public_land_statistics/), and include spatial data available via the BLM GeoCortex (https://webmaps.blm.gov/Geocortex/Html5Viewer/Index.html?viewer=whb), which is useful for analysis and planning. BLM and USFS have recently adopted a statistically-valid, standardized methodology for estimating wild horse population sizes (Lubow and Ransom 2009; Ransom et al. 2012; Lubow and Ransom 2016) that includes reliable measures that account for animals that were present, but not seen by observers. In most cases, reported population estimates are based on the statistical analysis of aerial survey data, and it is BLM agency policy to survey each Herd Management Area and Wild Horse Territory/Wild Burro Territory/Wild Horse and Burro Territory at least once every three years (USDOI BLM 2010e). Population size estimates for intervening years are projected, based on the best available information about expected population growth rates for each area. As previously discussed, wild horse growth rates can typically be assumed to be on the order of 15% to 20% per year (National Research Council 2013) unless there is a contraceptive project to limit reproduction. The range-wide population estimates are used to develop geospatial data which is available to managers and is useful in determining the number of excess animals present on the range and the status of a population relative to both target and high AML within a particular Herd Management Area. These datasets can be accessed at the BLM GeoCortex site noted above.

Although it is the intended management goal that wild horses remain only on Herd Management Areas and Wild Horse Territories, the current reality is that federally protected wild horses are also present on many Herd Areas, and on other federal, state, tribal, and private lands outside of these administrative boundaries. As a result, the user must be cautiously aware that the data representing boundaries of and populations within Herd Management Areas, Herd Areas, and Wild Horse Territories/Wild Burro Territories/Wild Horse and Burro Territories do not portray the actual spatial distribution of all WH&B populations. It is generally safe to assume that WH&B populations will be more widespread, the more overpopulated the Herd Management Area, Herd Area, Wild Horse Territory, Wild Burro Territory or Wild Horse and Burro Territory is, relative to AML. In areas where road or trail access allows for observations and on-the-ground documentation of horse sign (e.g., trailing, scat piles, evidence of horse grazing and browsing), the local designated staff are likely to have a broad understanding of where the animals tend to go in different seasons, which water sources they rely on, and the general pattern of their movements.

Management Considerations at the Project Scale

WH&B can have significant effects on project success. Horses require access to large amounts of water; an individual can drink an average of 7.4 gallons of water per day (Groenendyk et al. 1988). Despite a general preference for habitats near water (e.g., Crane et al. 1997), wild horses will routinely commute long distances (e.g., 10+ miles per day) between water sources and palatable vegetation (Hampson et al. 2010). Riparian and wildlife habitat improvement projects that intend to increase the availability of grasses, forbs, riparian habitats, and water will likely attract and be subject to heavy grazing and trampling by wild horses that live in the vicinity of the project. The severity of grazing pressure should be expected to correlate with the number of wild horses that can access the site. If the project site is located within a Herd Management Area or Wild Horse Territory/Wild Burro Territory/Wild Horse and Burro Territory, then grazing and trampling pressure from wild horses should be expected in most cases. Even if the project area is outside any Herd Management Area or Wild Horse Territory/Wild Burro Territory/Wild Horse and Burro Territory, then managers should carefully consider the current spatial extent, and growth potential, of any nearby wild horse population. If the number of wild horses is at AML, and there are measures in place to limit the population's growth rate, then wild horse use across the landscape might be distributed enough that a conservation or restoration project could achieve habitat quality goals. Project success would also be expected to be influenced by distance to the nearest drinking water source for wild horses. The greater the distance, the lower the grazing pressure could be expected. Horses routinely move 10 miles per day (Hampson et al. 2010), so managers should expect that any restoration project less than 5 miles from water will be subject to use by wild horses in the area. However, as noted above, higher population sizes tend to lead to an expanded spatial area used by the wild horse population. Thus, managers should carefully evaluate the reasonable likelihood of success of planned restoration activities if there is no ability to keep a local or adjacent wild horse population at AML.

Managers need to understand and consider the potential effects of WH&B on conservation and restoration projects, and plan accordingly. For certain habitat restoration projects, managers might want to consider installing fencing to discourage use by wild horses, particularly around riparian areas. On BLM lands, temporary fencing for habitat rehabilitation is generally acceptable, but permanent fencing often requires environmental assessment, and should be designed in a way that allows for WH&B movement throughout the rest of the Herd Management Area. Fencing enclosures of riparian areas are generally acceptable as long as water from the area continues to be available to WH&B. Fencing that excludes WH&B from riparian areas, or water development projects that are designed to disperse both riparian and upland use by WH&B would both seem to be particularly important management tools.

If AML cannot be achieved, it may be more reasonable to forego the project entirely instead of spending time and resources on projects with a low probability of success. Managers deciding about any project that is in the vicinity of a WH&B population should consider population size of WH&B relative to the specified AML, including explicit schedules for WH&B removals or population growth suppression treatment that is adequate to limit population growth.

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Table 8.1 – The area and percentage of Herd Management Areas broken down by percent wild horse Appropriate Management Level (AML) classes and resilience and resistance classes. Percentages within a Management Zone add to 100.

% Horse AML Class	Resilience and Resistance					
	Low		Moderate		High	
	Acres	%	Acres	%	Acres	%
MZ I						
<100%	0	0	0	0	0	0
>100-200%	0	0	4,326	57	3,200	43
>200%	0	0	0	0	0	0
Total	0	0	4,326	57	3,200	43
MZ II						
<100%	0	0	414,831	8	2,204	0
>100-200%	182,045	4	1,578,883	31	63,773	1
>200%	108,086	2	2,548,764	51	166,862	3
Total	290,131	6	4,542,478	82	232,839	4
MZ III						
<100%	1,082,123	8	181,196	1	89,393	1
>100-200%	2,856,557	20	273,256	2	124,492	1
>200%	7,475,524	53	1,476,253	10	508,952	4
Total	11,414,204	81	1,930,705	13	722,837	6
MZ IV						
<100%	560,601	27	67,981	3	19,771	1
>100-200%	490,895	23	198,977	9	89,076	4
>200%	560,706	27	90,401	4	49,144	2
Total	1,612,201	77	357,359	16	157,991	7
MZ V						
<100%	188,689	4	402,097	9	12,923	0
>100-200%	942,681	20	336,100	7	85,331	2
>200%	1,500,796	32	1,006,900	21	245,172	5
Total	2,632,166	56	1,745,097	37	343,426	7
MZ VII						
<100%	130,987	48	0	0	0	0
>100-200%	47,132	17	64,758	24	29,502	11
>200%	0	0	0	0	0	0
Total	178,119	65	64,758	24	29,502	11
All MZs						
<100%	1,962,400	7	1,066,105	4	124,291	0
>100-200%	4,519,310	17	2,456,300	9	395,374	2
>200%	9,645,112	37	5,122,318	19	970,130	4
Total	16126821	61	8644723	33	1489795	6

Table 8.2 – The area and percentage of Herd Management Areas broken down by percent wild burro Appropriate Management Level (AML) classes and resilience and resistance classes. Percentages within a Management Zone add to 100.

% Burro AML Class	Resilience and Resistance					
	Low		Moderate		High	
	Acres	%	Acres	%	Acres	%
MZ III						
<100%	18,063	1	0	0	0	0
>100-200%	162,160	8	9,563	1	0	0
>200%	1,634,051	88	27,762	2	4,076	0
Total	1,814,280	97	37,326	3	4,076	0
MZ V						
<100%	77,478	5	44,492	3	0	0
>100-200%	30,008	2	442,165	29	20,651	1
>200%	795,307	52	80,589	5	51,215	3
Total	902,793	59	567,246	37	71,865	4
MZ VII						
<100%	0	0	0	0	0	0
>100-200%	130,987	100	0	0	0	0
>200%	0	0	0	0	0	0
Total	130,987	100	0	0	0	0
All MZs						
<100%	95,541	3	44,492	1	0	0
>100-200%	323,155	9	451,728	13	20,651	0
>200%	2,429,358	69	108,351	3	55,291	0
Total	2,848,054	81	60,4571	17	75,942	0

Table 8.3– The area and percentage of Herd Management Areas broken down by percent wild horse Appropriate Management Level (AML) classes and GRSG breeding habitat probability classes. Percentages within a Management Zone add to 100.

% Horse AML Class	GRSG Breeding Habitat Probability					
	Low		Moderate		High	
	Acres	%	Acres	%	Acres	%
MZ II						
<100%	92,230	2	198,329	4	77,042	2
>100-200%	573,836	13	557,183	13	255,275	6
>200%	924,545	21	1,298,137	29	462,370	10
Total	1,590,610	36	2,053,649	46	794,686	18
MZ III						
<100%	283,183	5	99,286	2	67,788	1
>100-200%	256,584	4	240,796	4	223,943	3
>200%	1,942,673	32	1,884,706	31	1,159,489	18
Total	2,482,439	41	2,224,788	37	1,451,221	22
MZ IV						
<100%	234,091	16	208,371	14	10,955	1
>100-200%	293,756	20	160,647	11	33,053	2
>200%	212,954	14	224,679	15	95,330	7
Total	740,802	50	593,697	40	139,338	10
MZ V						
<100%	257,047	8	160,938	5	94,638	3
>100-200%	334,833	11	320,755	11	142,127	5
>200%	743,681	24	819,585	27	178,115	6
Total	1,335,561	43	1,301,278	43	414,880	14
MZ VII						
<100%	0	0	0	0	0	0
>100-200%	252	3	2,494	29	5,748	68
>200%	0	0	0	0	0	0
Total	252	3	2,494	29	5,748	68
All MZs						
<100%	866,551	6	666,924	4	250,423	2
>100-200%	1,459,261	10	1,281,875	8	660,146	4
>200%	3,823,853	25	4,227,107	28	1,895,303	13
Total	6,149,664	41	6,175,906	40	2,805,873	19
All MZs						
<100%	866,551	6	666,924	4	250,423	2
>100-200%	1,459,261	10	1,281,875	8	660,146	4
>200%	3,823,853	25	4,227,107	28	1,895,304	13
Total	6,149,665	41	6,175,906	41	2,805,873	19

Table 8.4– The area and percentage of Herd Management Areas broken down by percent wild burro Appropriate Management Level (AML) classes and GRSG breeding habitat probability classes. Percentages within a Management Zone add to 100.

% Burro AML Class	GRSG Breeding Habitat Probability					
	Low		Moderate		High	
	Acres	%	Acres	%	Acres	%
MZ III						
<100%	107	0	0	0	0	0
>100-200%	9,882	4	12,082	5	8,717	4
>200%	134,679	56	71,061	30	2,291	1
Total	144,668	60	83,142	35	11,008	5
MZ V						
<100%	23,217	2	68,662	7	18,022	2
>100-200%	147,908	14	91,557	8	50,412	5
>200%	263,516	24	364,745	34	44,423	4
Total	434,640	40	524,964	49	112,857	11
All MZs						
<100%	23,324	2	68,662	5	18,022	1
>100-200%	157,790	12	103,639	8	59,129	5
>200%	398,195	30	435,806	33	46,714	4
Total	579,309	44	608,107	46	123,865	10

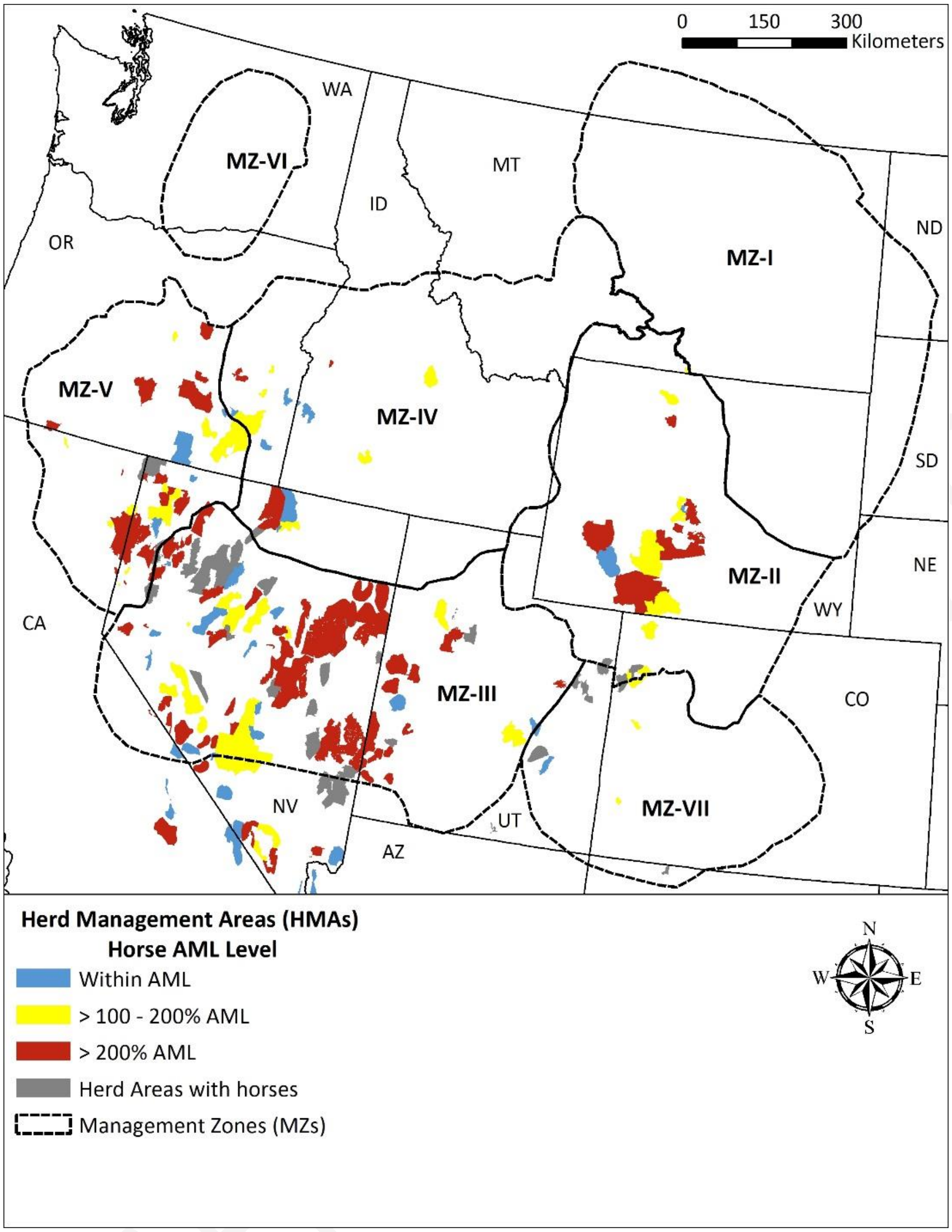

Figure 8.1−Map of March 1, 2017, estimated wild horse abundance, as percentage classes relative to Appropriate Management Level (AML), for wild horse Herd Management Areas.

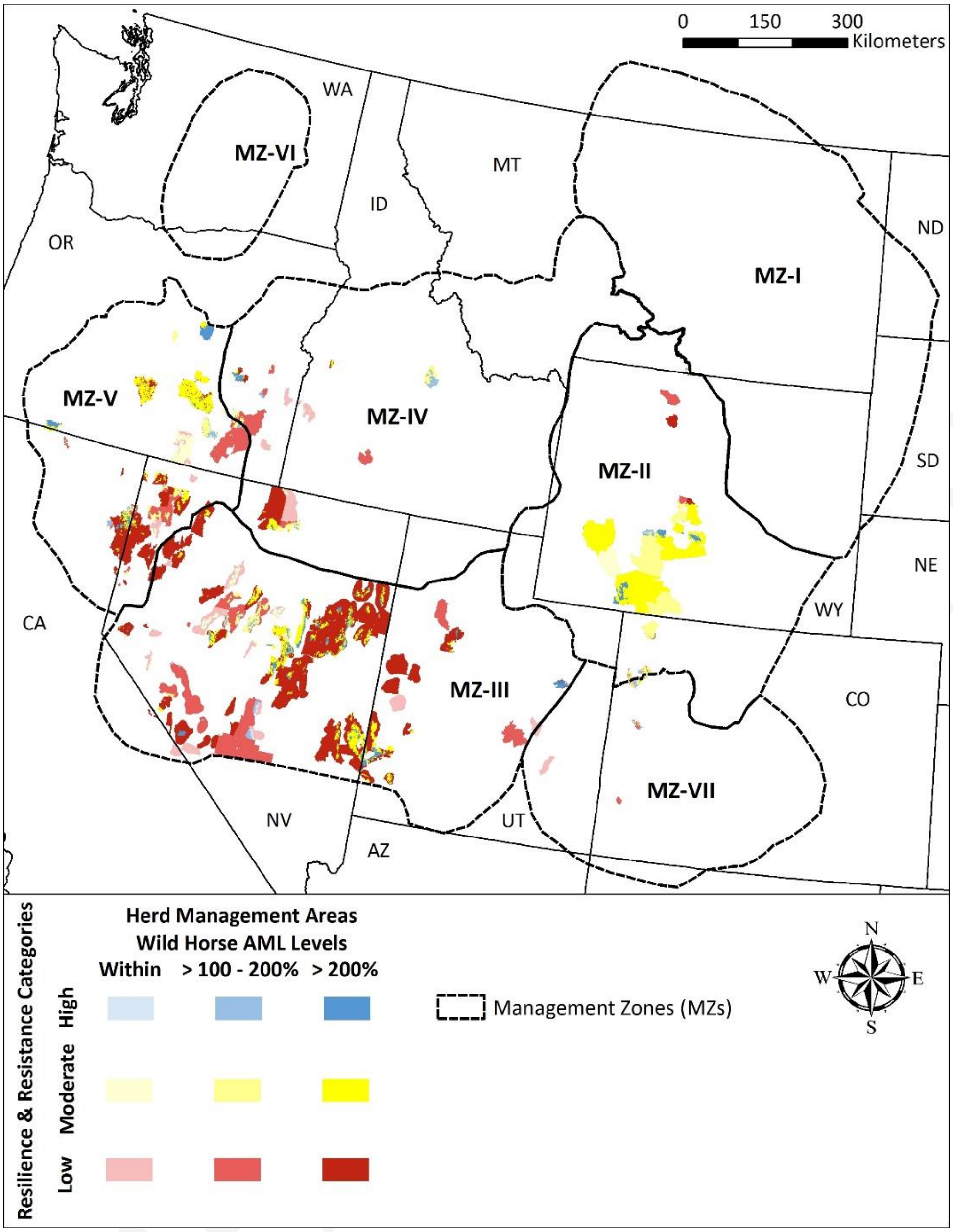

Figure 8.2−Map of March 1, 2017, estimated wild horse abundance, as percentage classes relative to Appropriate Management Level (AML), overlaid with the resilience and resistance classes within wild horse Herd Management Areas.

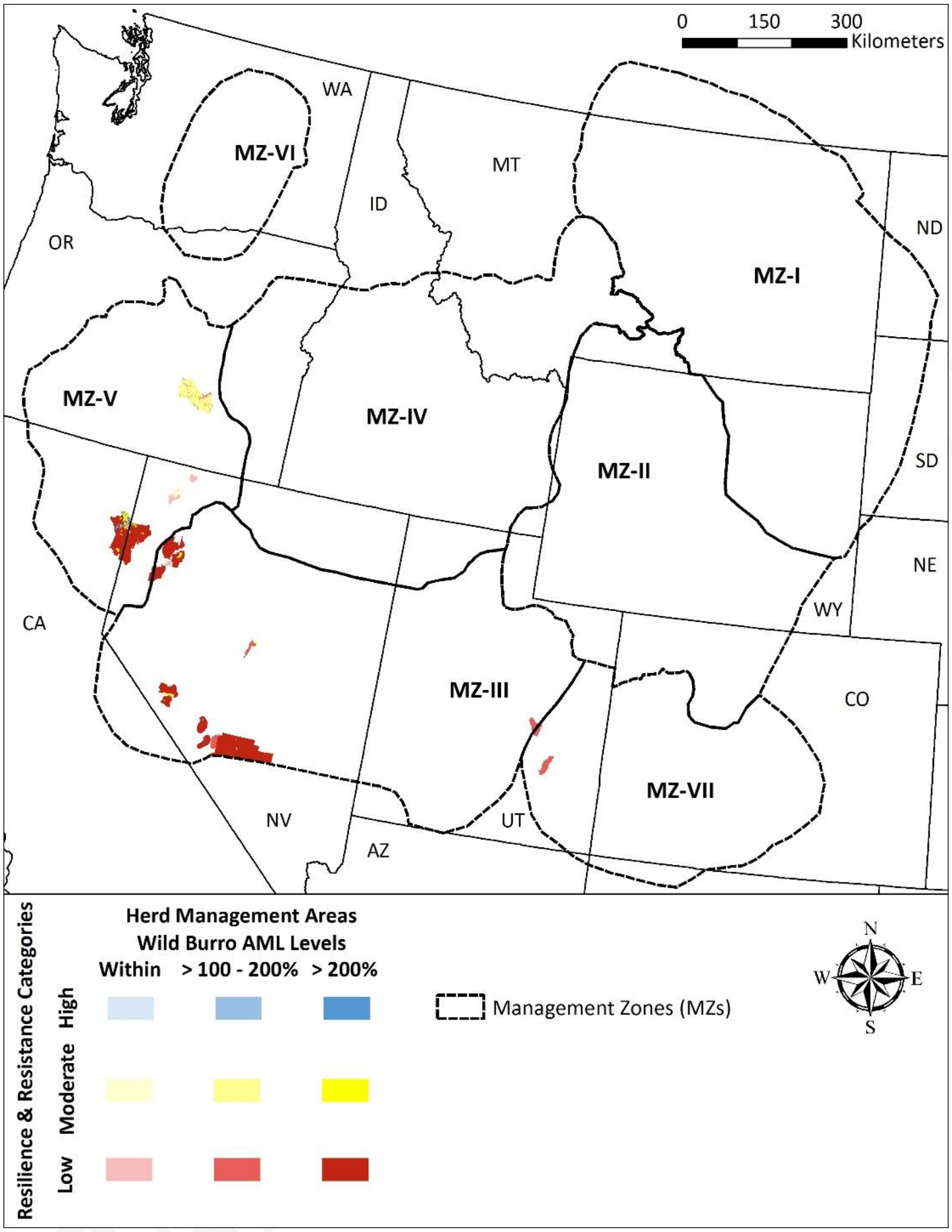

Figure 8.3–Map of March 1, 2017, estimated wild burro abundance, as percentage classes relative to Appropriate Management Level (AML), overlaid with the resilience and resistance classes within wild burro Herd Management Areas.

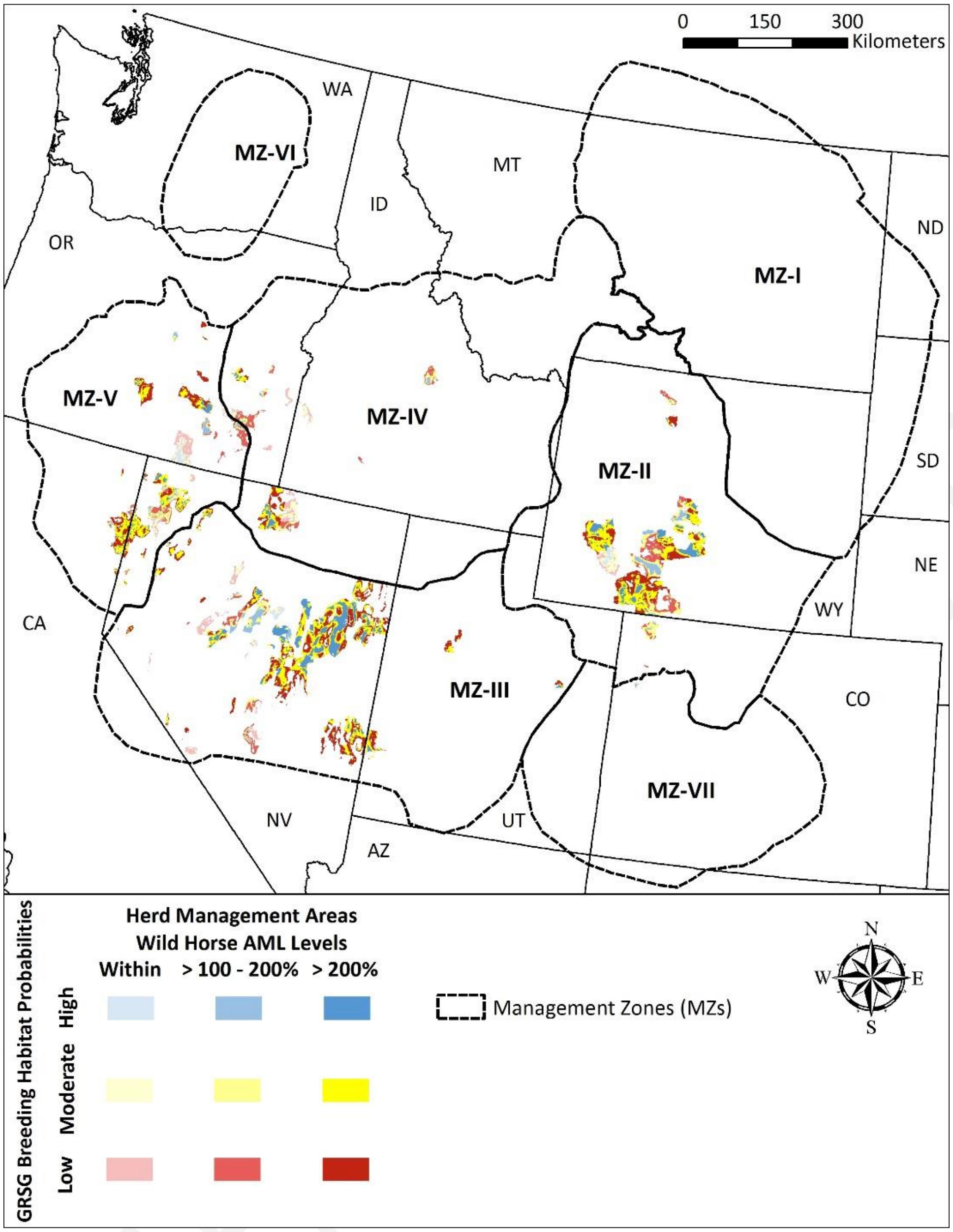

Figure 8.4–Map of March 1, 2017, estimated wild horse abundance, as percentage classes relative to Appropriate Management Level (AML), overlaid with the GRSG breeding habitat probabilities within wild horse Herd Management Areas.

APPENDIX 1. DEFINITIONS OF TERMS USED IN THIS DOCUMENT

Fire regime — The patterns of fire seasonality, frequency, size, spatial continuity, intensity, type (crown fire, surface fire, or ground fire), and severity in a particular area or ecosystem (Agee 1994; Heinselman 1973; Sugihara et al. 2006). A fire regime is a generalization based on the characteristics of fires that have occurred over a long period. Fire regimes are often described as cycles or rotations because some parts of the fire histories usually get repeated, and the repetitions can be counted and measured.

Focal species — Sagebrush obligate, near-obligate, dependent, or associated species identified as: (1) at-risk, (2) influencing management actions and regional economies, (3) potentially being negatively influenced by management actions, and/or (4) serving as indicators of habitat quality or habitat niches such as riparian areas in sagebrush ecosystems.

Improper livestock grazing — Grazing that impedes progress toward or maintenance of ecological processes and the desired plant community composition and structure within a given set of site conditions and the natural range of variability, including climatic variability and natural disturbance regimes, expected within a management planning time horizon.

Invasive plant species — An invasive species is: 1) nonnative (or alien) to the ecosystem under consideration, and 2) its introduction causes or is likely to cause economic or environmental harm or harm to human health (Presidential Executive Order 13112, 1999).

Management strategies — Coordinated management activities conducted at mid- to local scales to achieve vegetation and habitat objectives (e.g., strategically locating firefighting resources to protect habitat, coordinating Early Detection and Rapid Response activities for invasive plant species, positioning treatments to increase connectivity).

Projects — Projects are comprised of multiple treatments.

Resilience — Capacity of an ecosystem to reorganize and regain its fundamental structure, processes, and functioning when altered by stressors such as invasive plant species and disturbances such as improper livestock grazing and altered fire regimes (Holling 1973)

Resistance — Capacity of an ecosystem to retain its fundamental structure, processes and functioning (or remain largely unchanged) despite stresses, disturbances, or invasive species (Folke et al. 2004).

Resistance to invasion — Abiotic and biotic attributes and ecological processes of an ecosystem that limit the population growth of an invading species (D'Antonio and Thomsen 2004**)**.

Treatments — Local scale management actions that directly manipulate vegetation to achieve a vegetation or habitat objective (e.g., conifer removals, invasive annual grass controls, fuel treatments, or revegetation).

Woodland (Piñon and Juniper) phase I, II, III – In phase I trees are present but shrubs and herbs are the dominant vegetation influencing ecological processes on the site; in phase II trees are codominant with shrubs and herbs and all three vegetation layers influence ecological processes; in phase III trees are the dominant vegetation on the site and the primary plant layer influencing ecological processes on the site (Miller et al. 2005, 2014).

APPENDIX 2. WEBSITES AND RESOURCES FOR CLIMATE ADAPTATION AND MITIGATION

Websites

*Climate Change Resources Center (CCRC***)**

The CCRC (http://www.fs.usda.gov/ccrc/home) is a U.S. Forest Service Sponsored portal is a web-based, national resource that connects land managers and decision makers with useable science to address climate change in planning and application (USFS 2011). The website contains links to numerous reports, papers, tools, and data for assessing climate change and climate change impacts.

National Fish, Wildlife and Plants Climate Adaptation Strategy

The US Fish and Wildlife Services leads this program (https://www.fws.gov/home/climatechange/), and through its national training center, the agency offers interagency courses, both classroom and web-based, on climate change, climate change adaptation, vulnerability assessment, scenario planning, and communications. It offers a weekly web conference on safeguarding wildlife from climate change and has produced several reports and guidance documents on potential impacts and responses to protect wildlife and wildlife habitat from climate change.

Climate Data and Analysis tools

Historical and projected climate and climate change impacts data are available through a wide variety of sources and at different scales, although data at the mid-scale is most common. In some cases, data may be limited to part of the sagebrush biome.

Climate Impacts Group (CIG)

Hosted by the University of Washington, this group provides climate data and analyses of potential climate change impacts at a variety of scales, ranging from local communities to the western U.S. Most of the work to date is focused on the Pacific Northwest. Website: https://cig.uw.edu/.

Climate Science Centers (CSC)

The CSCs provide a variety of climate change impact studies generally specific to the coverage area of the individual CSC. Each CSC maintains a listing of on-going and completed projects funded wholly or in part by the CSC. Websites for project listings and data access:

- Northwest CSC: https://nccwsc.usgs.gov/display-csc/4f8c64d2e4b0546c0c397b46
- North Central CSC: https://nccwsc.usgs.gov/display-csc/4f83509de4b0e84f60868124
- Southwest CSC: https://nccwsc.usgs.gov/display-csc/4f8c6580e4b0546c0c397b4e

Conservation Biology Institute (CBI) Integrated Climate Scenarios

The CBI projected changes in biomes in the Northwest (Oregon, Washington, Idaho, western Montana) using MACA downscaled climate projections in combination with the MC2 dynamic vegetation model. Model results are available for the entire area or by ecoregion. The site provides guidance and frequently asked questions to assist users. Website: http://consbio.webfactional.com/integratedscenarios/

Multivariate Adapted Constructed Analogs (MACA)

This site is hosted by the University of Idaho and provides statistically downscaled climate projections for the continental U.S. using the most current emissions scenarios, several global climate models, and multi-model means. The website provides a number of options for viewing and downloading the data. Website: http://maca.northwestknowledge.net/

PRISM historical climate data

PRISM uses weather and climate observations from a wide range of monitoring networks to create wall-to-wall spatial climate datasets from 1895 to the present. PRISM datasets are widely used in a variety of climate and natural resource studies to describe historical climate. Website: http://www.prism.oregonstate.edu/

State Climate Offices

Nearly every state has a climate office that provides access to state and local climate data from a variety of weather stations such as the National Weather Service Co-Op network, CoCoRaHS, and the Agricultural Meteorological network (AgMet).

WestMap Climate Analysis Toolbox

WestMap delivers PRISM historical climate data at a variety of spatial scales ranging from west-wide to a single pixel, including user created polygons, and a variety of temporal scales. Climate data provided are precipitation, mean temperature, maximum temperature, and minimum temperature. Website: http://www.cefa.dri.edu/Westmap/westmappass.php.

Western Regional Climate Center (WRCC)

The WRCC provides access to climate and weather data across the western U.S. from several weather sources, include the NOAA co-op network, remote automated weather stations (RAWS), the Snotel network, and the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS). Website: http://www.wrcc.dri.edu/

New weather and climate tools are being developed that will help managers in the sagebrush biome integrate weather and climate tools into planning and implementation at local scales.

Weather and Climate Tools for Sagebrush Managers

This project, still in development by the Conservation Biology Institute, will deliver web-based weather and climate data that land managers in sagebrush ecosystems of the northern Great Basin specifically identified as desirable through interviews and one-on-one demonstrations. The types of short-term information managers identified as desirable were historical weather, drought status, soil moisture, temperature, and timing of precipitation events. In addition to facilitating delivery of near-term and short-term forecasts for use in planning projects such as post-fire seeding, it will also deliver projections of climate change in a variety of ways, including a 3-D visualization tool based on the MC2 model. The project covers the sagebrush biome but is intended for use at the local scale. The project should be completed by 2018.

Great Basin Weather Applications for Rangeland Restoration

Under development by the Agricultural Research Service, and in cooperation with the University of Idaho, USGS, Utah State University, and the Great Basin Fire Science Exchange, this set of tools provides access to restoration-specific weather and microclimatic information that can be used for analysis of historical planting data, to expand inferences derived from short-term field studies, and to develop long-term contingency-based adaptive management plans for rangeland restoration. These tools will be accessible through the Great Basin Fire Science Exchange website and will include educational modules for learning about weather variability and microclimatic effects on seedbed favorability and potential mortality factors from water and temperature stress. Future enhancements will include seasonal forecasts for real-time planning and management, and disaggregated weather data from climate change projections for running current ecological-process models.

Carbon Storage Tools

Because of the emphasis on forest management in climate change programs, and the fact that most research and information on carbon storage focuses on the mid to biome scale, field personnel in semiarid lands generally lack the baseline information and impact estimation tools they need to conduct either quantitative or qualitative analyses. The USGS, through their LandCarbon website (http://landcarbon.org/), and NRCS, through their CarbonScapes website (http://carbonscapes.org/), attempt to provide baseline carbon storage information. The LandCarbon site attempts to project how carbon storage may change by mid-century under different greenhouse gas emissions scenarios. Limitations are that the scales of the data provided by LandCarbon and CarbonScapes are too coarse for land use plan and project scales, and data provided by LandCarbon is outdated (2005 vintage). Also, data provided by CarbonScapes uses only on USFS Forest Inventory and Analysis (FIA) data for aboveground carbon, and watershed scale data in CarbonScapes is not universally available due to lack of completed soil surveys. The Fire and Fuels Tools (http://www.fs.fed.us/pnw/fera/fft/index.shtml) and First Order Fire Effects Model (FOFEM) (https://www.firelab.org/project/fofem) provide estimates of aboveground carbon by carbon pool for standardized fuelbeds and community types. Users can adjust the estimated fuel loadings manually based on local information or plot data. Both tools predict changes in aboveground carbon storage and greenhouse gas emissions from burning. However, these tools are designed to operate at the treatment block scale and only cover fire. Batch processing is theoretically possible with Fire and Fuels Tools, but can be difficult to conduct.

APPENDIX 3. VEGETATION HABITAT OBJECTIVES FOR BREEDING AND NESTING SEASONAL HABITAT, AND BROOD-REARING/SUMMER SEASONAL HABITAT FOR GREATER SAGE-GROUSE

The following tables provide the vegetation habitat objectives for breeding and nesting seasonal habitat, and brood-rearing/summer seasonal habitat, for Greater sage-grouse in the Wyoming Basin Ecoregion, Oregon and Washington, Utah, Nevada and Northeastern California, and Idaho and Southwestern Montana. The highest priority areas for completing the grazing permit and grazing lease review and processing will be allotments within Sagebrush Focal Areas and allotments that substantially overlap in Sagebrush Focal Areas[i]. The second highest priority is allotments within Priority Habitat Management Areas[ii] that are outside of Sagebrush Focal Areas. The third highest priority is allotments within Important Habitat Management Areas in Idaho[iii]. The fourth highest priority is allotments lying within General Habitat Management Areas[iv]. The last priority is allotments within Other Habitat Management Areas in Nevada and northeast California[v].

Table 1–Vegetation habitat objectives for breeding and nesting seasonal habitat, and brood-rearing/summer seasonal habitat, for Greater sage-grouse in the Wyoming Basin ecoregion, applicable to the BLM Casper, Kemmerer, Newcastle, Pinedale, Rawlins, and Rock Springs Field Offices (USDOI BLM, 2015e).

Attribute	Indicators	Desired condition (habitat objectives)
Breeding and nesting (seasonal use period March 1-June 15)		
cover	sagebrush cover (%)	5 to 25
	sagebrush height (inches) arid sites[1] mesic sites[2]	 4 to 31 12 to 31
	predominant sagebrush shape	predominantly spreading shape
	perennial grass cover (such as native bunchgrass) (%) arid sites[1] mesic sites[2]	 ≥10 ≥15 (cool season bunchgrasses preferred)
	perennial grass and forb height (including residual grasses) (inches)	Adequate nesting cover of ≥7 inches or as determined by ecological site description site potential and local variability
	perennial forb cover (%) arid sites[1] mesic sites[2]	 >5 >10
Brood-rearing/summer (seasonal use period June 16-October 31)		
cover	sagebrush cover (%)	5 to 25
	sagebrush height (inches)	4 to 32
	perennial grass and forb cover (%) arid sites[1] mesic sites[2]	 >5 >10
	upland and riparian perennial forb availability	preferred forbs are common with several preferred species present

[1] Arid corresponds to the 10–12 inch precipitation zone; Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) is a common big sagebrush subspecies for this type site.

[2] Mesic corresponds to the ≥12 inch precipitation zone; mountain big sagebrush (*Artemisia tridentata vaseyana*) is a common big sagebrush subspecies for this type site.

Table 2–Vegetation habitat objectives for breeding (includes lekking, pre-nesting, nesting, and early brood-rearing) seasonal habitat, and brood-rearing/summer (includes late brood-rearing, summering, and early autumn) seasonal habitat, for Greater sage-grouse in Oregon and Washington (USDOI BLM, 2015c).

Attribute	Indicators	Desired condition (habitat objectives)
Breeding including lekking, pre-nesting, nesting, and early brood rearing (seasonal use period March 1- June 30)		
cover	sagebrush cover (%)	10 to 25
	sagebrush height (inches) arid sites (warm-dry) mesic sites (cool-moist)	 11 to 31 15 to 31
	predominant sagebrush shape	spreading
	perennial grass cover (such as bunchgrass) (%) arid sagebrush warm-dry shallow-dry mesic sagebrush cool-moist warm-moist	 10 to 30 10 to 25 20 to 45 20 to 50
	perennial grass and forb height (inches, including residual grasses)—most important and appropriately measured in nest areas: excludes shallow-dry sites[1] arid sites (warm-dry) mesic sites (cool-moist)	 ≥7 ≥9
	perennial forb cover (%)[2] arid sagebrush warm-dry shallow-dry mesic sagebrush cool-moist warm-moist	 2 to 10 2 to 10 6 to 12 5 to 15
food	preferred forb diversity and availability	preferred forbs are common with 5 to 10 species present[2]
Brood-rearing/summer including late-brood rearing, summering, and early autumn (seasonal use period July 1-October 31)		
cover	sagebrush cover (%)	10 to 25
	sagebrush height (inches)	15 to 31
	perennial herbaceous (grass and forbs) cover (%) arid sagebrush warm-dry shallow-dry	 15 to 30 10 to 25

	mesic sagebrush cool-moist warm-moist riparian[3]	 20 to 45 30 to 55 ≥50
food	upland and riparian perennial forb availability	preferred forbs are common with 5 to 10 species present

[1] Perennial grass and forb minimum height may not be achievable in years with below normal precipitation. Other indicators of desired condition may still render the site suitable however.

[2] In very dry years, forb cover and availability may not be at the desired condition, and in certain plant associations such as Wyoming big sagebrush/needle-and-thread, these indicators may rarely be achieved even in years with normal precipitation.

[3] Riparian includes swales, wet meadows, and intermittent/ephemeral streams.

Table 3–Vegetation habitat objectives for breeding and nesting seasonal habitat, and brood-rearing/summer seasonal habitat, for Greater sage-grouse in Utah (USDOI BLM, 2015d).

Attribute	Indicators	Desired Condition
Breeding and nesting (February 15-June 15)		
cover	sagebrush cover	≥15%
	total shrub cover	15-30% (Box Elder, Parker Mountain, Bald Hills, Hamlin Valley, Panguitch, Uintah south of highway 40) 15-35% (Rich, Carbon, Emery, Sheeprocks, Ibapah, Uintah north of highway 40)
	sagebrush height	>12 inches (30 cm) (Box Elder, Bald Hills, Hamlin Valley, Sheeprocks, Ibapah) >10 inches (25 cm) (Rich, Carbon, Emery, Uintah north of highway 40) >8 inches (20 cm) (Parker Mountain, Panguitch, Uintah south of highway 40)
	predominant sagebrush shape	>50% in spreading (applicable to the specific sagebrush types prone to columnar vs. spreading shape e.g. Wyoming, not black sage)
	perennial grass cover (such as native bunchgrasses, rhizomatous grasses called for on applicable ecological site descriptions, or other perennial grasses that provide similar functionality)	>10% (Box Elder, Bald Hills, Hamlin Valley, Rich, Carbon, Emery, Sheeprocks, Ibapah, Uintah north of highway 40) >5% (Parker Mountain, Panguitch, Uintah south of highway 40)
	perennial grass and forb height (includes residual grasses)	provide overhead and lateral concealment from predators
	perennial forb canopy cover	>5% (Box Elder, Bald Hills, Hamlin Valley, Rich, Carbon, Emery, Sheeprocks, Ibapah, Uintah north of highway 40) >3% (Parker Mountain, Panguitch, Uintah south of highway 40)
Brood-rearing/summer (April 15-August 15)		
cover	sagebrush cover	>10%
	total shrub cover	10-25% (Box Elder, Bald Hills, Hamlin Valley, Panguitch, Rich, Parker Mountain, Uintah) 10-30% (Carbon, Emery, Sheeprocks, Ibapah)

	sagebrush height	>12 inches (30 cm) (Box Elder, Bald Hills, Hamlin Valley, Sheeprocks, Ibapah) >10 inches (25 cm) (Rich, Carbon, Emery, Uintah north of highway 40) >8 inches (20 cm) (Parker Mountain, Panguitch, Uintah south of highway 40)
	perennial grass cover and forb cover	>15% (grass >10%; forb >5%) (Box Elder, Rich, Sheeprocks, Ibapah, Parker Mountain, Panguitch, Uintah, Carbon, Emery) >15% (grass >8%; forb >7%) (Bald Hills, Hamlin Valley)
	upland and riparian perennial forb availability	preferred forbs are common with several preferred species present

Table 4–Vegetation habitat objectives for nesting seasonal habitat, and brood-rearing/summer seasonal habitat, for Greater sage-grouse in Nevada and northeastern California (USDOI BLM, 2015b).

Attribute	Indicators	Desired Condition (Habitat Objectives)
Nesting (seasonal use period April 1-June 30)		
cover	sagebrush cover	≥20%
	residual and live perennial grass cover (such as native bunchgrasses)	≥10% if shrub cover is <25%
	annual grass cover	<5%
	total shrub cover	≥30%
	perennial grass height (includes residual grasses)	provide overhead and lateral concealment from predators
Brood-rearing/summer (seasonal use period May 15-September 15; early seasonal use period May 15-June 15; late seasonal use period June 15-September 15)		
Upland habitats		
cover	sagebrush cover	10%-25%
	perennial grass and forb cover	>15% combined perennial grass and forb cover
	deep rooted perennial bunchgrass height (within 522 feet [200 meters] of riparian areas and wet meadows)	7 inches[1,2]
cover and food	perennial forb cover	≥5% arid, ≥15% mesic
Riparian/meadow habitats		
security	upland and riparian perennial forb availability and understory species richness	Preferred forbs are common with several species present[1] High species richness (all plants)

[1] relative to ecological site potential

[2] In drought years, 4-inch perennial bunchgrass height with greater than 20 percent measurements exceeding 5 inches in dry years

Table 5–Vegetation habitat objectives for nesting/early brood-rearing seasonal habitat, and late brood-rearing/summer seasonal habitat, for Greater sage-grouse in Idaho and southwestern Montana (USDOI BLM, 2015a).

Attribute	Indicator	Desired Condition
NESTING/EARLY BROOD REARING (Seasonal Use Period May 1 – June 30)		
cover and food	sagebrush cover	15%-25%
	sagebrush height arid sites[1] mesic sites[2]	 12-31 inches (30-80 cm) 16-31 inches (40-80 cm)
	predominant sagebrush shape	predominantly spreading shape[3]
	perennial grass cover (such as native bunchgrasses) arid sites[1] mesic sites[2]	 ≥10% ≥15%
	perennial grass (and forb) height (includes residual grasses)	≥ 7 inches
	perennial forb cover arid sites[1] mesic sites[2]	 ≥5% ≥10%
	perennial forb availability	preferred forbs are common with several species present
LATE BROOD-REARING/SUMMER (July-October) Late brood-rearing areas, such as riparian, meadows, springs, higher elevation mesic uplands, etc. may occur within other mapped seasonal habitat areas. Apply late brood rearing/summer habitat desired conditions locally as appropriate.		
cover and food	sagebrush cover	uplands 10%-25%
	sagebrush height	16 to 32 inches (40-80 cm)
	perennial grass and forb cover	>15%
	upland and riparian perennial forb availability	preferred forbs are common with appropriate numbers of species present

[1] Arid corresponds to the 10–12 inch precipitation zone; Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) is a common big sagebrush subspecies for this type site (Stiver et al. 2015).

[2] Mesic corresponds to the >12 inch precipitation zone; mountain big sagebrush (*Artemisia tridentata vaseyana*) is a common big sagebrush subspecies for this type site (Stiver et al. 2015).

[3] Sagebrush plants that are more tree or columnar-shaped provide less protective cover near the ground than sagebrush plants with a spreading shape (Stiver et al. 2015). Some sagebrush plants are naturally columnar (e.g., Great Basin big sagebrush), and a natural part of the plant community. However, a predominance of columnar shape arising from animal impacts may warrant management investigation or adjustments at site specific scales.

[i] Sagebrush Focal Areas are a subset of Priority Habitat Management Areas that are areas of highest habitat value for GRSG as originally identified by the Fish and Wildlife Service in a memorandum to the BLM and the Forest Service, Memorandum: Greater Sage-Grouse: Additional Recommendations to Refine Land Use Allocations in Highly Important Landscapes. October 27, 2014, https://www.fws.gov/greaterSageGrouse/documents/ESA%20Process/GRSG%20Strongholds%20memo%20to%20BLM%20and%20USFS%20102714.pdf. Accessed 13 June 2017.

[ii] Priority Habitat Management Areas are areas identified as having the highest habitat value for maintaining sustainable GRSG populations and include breeding, late brood-rearing, and winter concentration areas.

[iii] Important Habitat Management Areas in Idaho are areas in Idaho that provide a management buffer for and that connect patches of Priority Habitat Management Areas. Important Habitat Management Areas encompass areas of generally moderate to high habitat value habitat or populations but that are not as important as Priority Habitat Management Areas.

[iv] General Habitat Management Areas are areas that are occupied seasonally or year-round and are outside of Priority Habitat Management Areas.

[v] Other Habitat Management Areas in Nevada and northeast California are areas in Nevada and northeast California, identified as unmapped habitat in the Proposed RMP/Final EIS, that are within the Planning Area and contain seasonal or connectivity habitat areas.