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Sage Advice for Managers: A new, collaborative science framework for conservation and restoration of the sagebrush biome

Sagebrush country, the sweeping iconic backdrop across large parts of western North America, feels eternal and unchanging — it is easy to assume that it will persist in place for the appreciation of countless future generations. But it is, in fact, one of the most imperiled ecosystems in the U.S. —under assault on many different fronts — currently comprising only about 59 percent of its historical range. And when sagebrush habitat disappears or is degraded, it also has a negative impact on the many species inexorably linked with these ecosystems, including Greater sage-grouse.

The USDA Forest Service Rocky Mountain Research Station (RMRS) has published a two-part guide to managing sagebrush ecosystems across the West called 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."* This Science Framework provides a new, multi-scale approach to management that uses science on ecosystem resilience to disturbance and resistance to invasive annual grasses along with information on the distributions and habitats of sagebrush-obligate species to improve conservation planning and help prioritize management actions. The emphasis is on sagebrush ecosystems and Greater sage-grouse, a widespread, at-risk bird managed as an umbrella species for the many species that depend on sagebrush ecosystems.

The imperiled sagebrush biome is inexorably linked with the Greater sage-grouse, which relies on sagebrush for every stage of its life history. Photo by Jeannie Stafford, USFWS.

The Science Framework was developed by an extensive interagency team of scientists and managers. RMRS research ecologist Jeanne Chambers represented the Forest Service, serving as the team leader and lead author for Part 1, which is focused on the scientific basis behind the framework and

SUMMARY

The two-part Science Framework for Conservation and Restoration of the Sagebrush Biome published by the U.S. Forest Service Rocky Mountain Research Station is a new, multiscale approach to management of sagebrush ecosystems. The product of an extensive collaboration between State and Federal agencies and universities, it employs science on ecological resilience to disturbance and resistance to invasive species (like cheatgrass), along with Greater sage-grouse habitat requirements, to improve conservation planning and help prioritize management actions. Prioritized areas and management strategies can be refined by managers and stakeholders at the local scale based on higher resolution data and local knowledge.

Part 1 of the Framework describes a geospatial approach for overlaying information on ecosystem resilience and resistance, species habitats, and predominant threats. A resilience and resistance matrix is provided to help managers evaluate risks and determine appropriate management strategies. Part 2 focuses on specific management concerns, including: adaptive management and monitoring, climate adaptation, wildland fire and vegetation management, invasive plant management, National Seed Strategy concepts, livestock grazing management, wild horse and burro considerations, and integration and tradeoffs. The Science Framework (and this article) include links to data, maps, and models that are useful in sagebrush ecosystem and Greater sage-grouse management. The Science Framework is intended to be adaptive and will be updated as additional data become available on other values and species at risk.

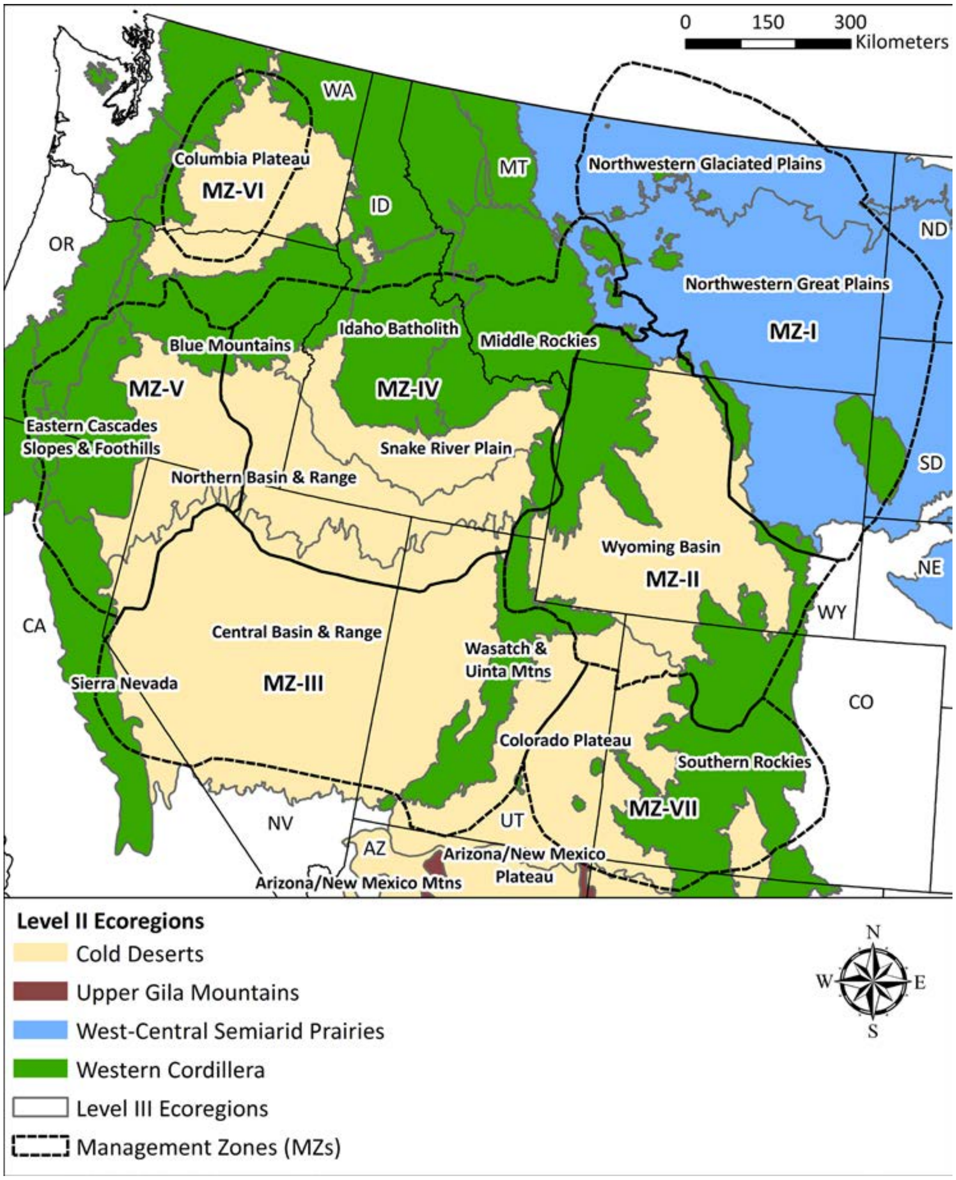
was published in April 2017. A team of editors including Jeanne Chambers, Michele Crist, and Karen Prentice from the Bureau of Land Management (BLM), Sue Phillips from the U.S. Geological Survey (USGS), and Lief Wiechman from the U.S. Fish and Wildlife Service (USFWS) led Part 2, which provides the management considerations for applying the information and tools in Part 1. This was published in April 2019.

Unprecedented collaboration: Cooperative conservation planning kept the Greater sage-grouse from being listed as endangered

The need for a comprehensive plan to effectively manage the sagebrush biome was borne out of concerns about habitat loss and population decline of the Greater sage-grouse. This chicken-sized bird, the largest grouse in North America, is known for elaborate and showy courtship rituals. The birds gather in the spring on "leks" in sagebrush openings where the males perform strutting displays meant to impress potential mates. This species nests on the ground and depends upon sagebrush habitat at all life stages for cover, nesting, and food.

Declines in the population of Greater sage-grouse have concerned biologists and land managers for over 30 years. Although it is impossible to accurately estimate their historical population numbers, the birds were once much more prolific in the West than they are today — explorers, settlers, and government surveyors reported seeing huge flocks of them. Recent estimates put the bird's current total population at fewer than one-half million across 11 western States and parts of Canada, with an estimated 30 percent decline in population since 1985. Because of widespread habitat loss and population declines, the Greater sage-grouse was considered for listing as an endangered species by the USFWS and was first petitioned in 2002. In 2006, the Western Association of Fish and Wildlife Agencies (WAFWA) created the Greater-sage Grouse Comprehensive Conservation Strategy, which defined seven sage-grouse Management Zones aligned with "ecoregions" that have similar climate and vegetation.

By 2010, USFWS designated the listing "warranted but precluded" by other, higher-priority conservation concerns at the time, but set a 2015 deadline for a decision on whether or not to list the Greater sage-grouse as endangered. Ultimately, the agency determined that listing was "not warranted." Importantly, this was based on the expectation of effective implementation of Federal and State land-use plans and increased efforts to control invasive plants and wildfire in the Great Basin. According to Chambers, "The



This map shows the Environmental Protection Agencies' Level II and Level III Ecoregions overlaid with the sage-grouse Management Zones (dotted lines) developed by the Western Association of Fish and Wildlife Agencies. Figure from the Science Framework, Parts 1 and 2.

decision not to list emphasized the importance of interagency collaboration and working together across jurisdictions and across ownerships for effective management. Individuals in the agencies started shifting the focus from Greater sage-grouse to sagebrush ecosystems and to thinking about developing effective tools and methods for conserving and restoring sagebrush ecosystems in general. This is what we address in the Science Framework."

The need to manage sagebrush habitat and protect not only Greater sage-grouse, but also other sagebrush-dependent species, has sparked an unprecedented collaborative conservation effort among Federal and State agencies, universities, non-profit organizations, and private landowners. Leading up to and since the 2015 decision, there has been a flurry of reports on the status of sagebrush ecosystems and Greater sage-grouse by Federal and State agencies. In May 2015 the Department of the Interior released "An Integrated Rangeland Fire Management Strategy: Final Report to the Secretary of the Interior," which outlined longer-term actions needed to implement policies and strategies for preventing and suppressing rangeland fire and restoring burned rangelands in the Western United States. It also called for developing a science-based conservation and restoration strategy for the sagebrush biome. The 2016 Integrated Rangeland Fire Management Strategy Actionable Science Plan soon followed. In addition, in 2018, WAFWA published a report describing science gaps that hinder current and future management and protection.

Many of the same scientists and managers who were part of these reports and planning efforts were also working on a strategic multi-scale approach for both the western and eastern parts of the sagebrush biome. The new collaborative Science Framework builds on this prior work and focuses on the best practices for managing sagebrush ecosystems based on our most up-to-date scientific understanding. Ken Mayer, a wildlife ecologist with WAFWA, says "In the old days, the federal agencies would have forged ahead and created this Science Framework without much input from the states. But for this management strategy development, state folks have been involved in the planning. This has been one of the most exciting conservation efforts in my 38-year career, where everybody's sitting at the table, and everybody's ideas are being considered."

How using the concepts of ecosystem resilience and resistance can help prioritize sagebrush management actions

The biggest problems facing the sagebrush biome are persistent ecosystem threats — spread of invasive plant species, more frequent and larger fires, conifer expansion, and climate change — as well as changes in human land-use activities — cropland conversion, energy development, mining, roads and other infrastructure, recreation, housing and urban development, and livestock grazing. Some of the main management issues in the eastern part of the sagebrush biome are land-use activities like cropland conversion and energy development.

Invasive annual grasses — in particular cheatgrass and the invasive grass/fire cycle that often results after it invades — are one of the primary issues in the western part of the biome. Exotic, invasive cheatgrass can live out its entire life cycle in just a few weeks early in the growing season. By mid-summer, it becomes a bed of fuel that allows wildfires to spread, killing the overstory sagebrush and paving the way for more cheatgrass in following years. Many native species of sagebrush, forbs,

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Significant management issues in the eastern part of the sagebrush biome are land-use activities like cropland conversion and energy development, as shown in these photos. The top photo shows a deep gas drill rig outside of Pinedale, Wyoming. The bottom shows conversion of a sagebrush ecosystem in the West-Central Semiarid Prairies to agricultural land. Top: Photo by Thomas J. Christiansen; bottom: Photo by John Carlson.

and grasses are not adapted to frequent fires, and when native sagebrush ecosystems burn, they don't recover quickly. On the other hand, cheatgrass seeds can survive and germinate after wildfires and the resulting plants can take advantage of higher levels of post-fire water and nutrients to produce progressively more seeds and plants over time. Increasingly greater amounts of continuous cheatgrass fuels can result in more frequent and extensive fires, and large areas that once were healthy sagebrush communities can come to be fully dominated by cheatgrass. Perhaps the worst part is that cheatgrass is spreading — it is a current or emerging management issue in many areas of the eastern part of the biome. And it is not the only invasive plant species concerning managers.

Invasive annual grasses — in particular cheatgrass and the invasive grass/fire cycle that often results after it invades — are one of the primary issues in the western part of the biome. The top photo shows a wildfire burning through a Wyoming big sagebrush ecosystem with a cheatgrass understory in southern Idaho. The bottom photo is an example of a big sagebrush ecosystem that has converted to cheatgrass and other annual invaders in north-central Nevada. Top: photo by Douglas J. Shinneman; bottom: photo by Nolan E. Preece.

The two-part Science Framework represents a shift in the thinking about how sagebrush ecosystems are managed, with the idea that management at a larger scale is necessary in order to deal with the issues of cheatgrass and fire, as well as energy development and cropland conversion. "For decades," says Chambers, "it was mostly the field office or district-level managers working within their small jurisdiction that decided on and performed conservation and restoration actions. The paradigm shift in the Science Framework is that now we are looking across large

The Three Scales Addressed in the Science Framework

Scale/Area	Data/Tools/Models Scale-Dependent/Additive	Process
Sagebrush biome	Vegetation Soils Population data and models Fire and other threat data	Budget prioritization for rangewide consistency
Sage-Grouse MZs and Ecoregions	Above, plus Assessments and planning docs Regional Data/models/Tools	Assessments to prioritize consistency
Local planning areas	Above, plus Local Data and Information	Selection of treatments within priority planning areas

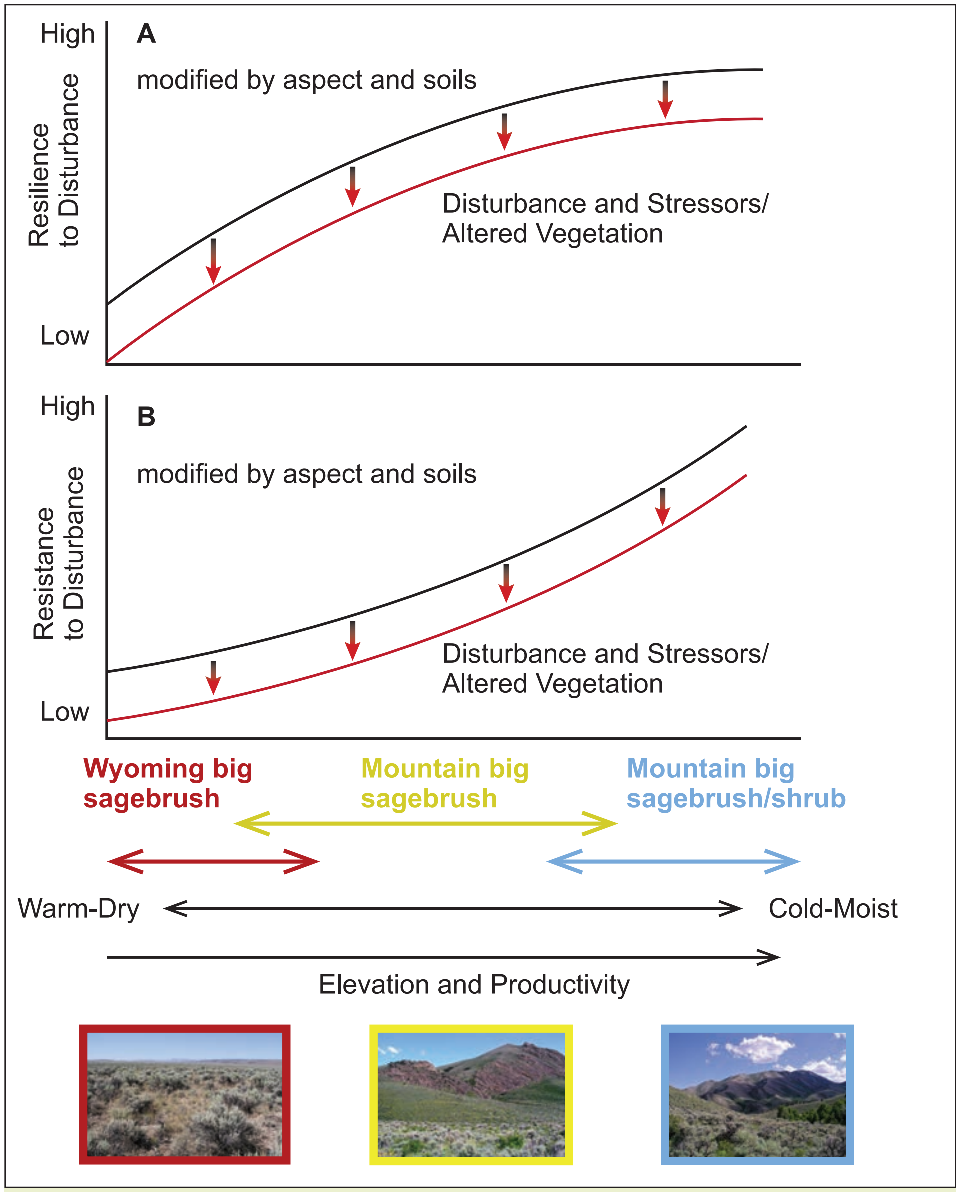
Three scales are included in the Science Framework. These scales inform different aspects of the planning process: 1) the sagebrush biome scale where budget prioritization occurs, 2) the mid-scale (individual or multiple ecoregions/Management Zones) where assessments are typically conducted to inform 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. Many data layers and various population models are available to help with assessments at each scale. Figure based on the Science Framework, Parts 1 and 2.

"The paradigm shift in the Science Framework is that now we are looking across large landscapes, and we're asking, where can we best target our limited resources to benefit conservation and restoration of these ecosystems?"

landscapes, and we're asking, where can we best target our limited resources to benefit conservation and restoration of these ecosystems?" The Science Framework works across scales, from the biome down to the local, by considering which data are most appropriate at each level and how they can be integrated. This approach to science is linked to changing approaches to management. Federal agencies are now prioritizing management areas at the national level, and State agencies are working together to manage across State lines. "

The ecological concepts of resilience to stress and disturbance and resistance to invasion by nonnative plants underpin the Science Framework and are used to help prioritize areas for management. Although it may not be obvious, sagebrush ecosystems vary greatly over the sagebrush biome, with many different species of sagebrush and various plant communities sorting out across gradients of heat and moisture. Resilience to stress and disturbance changes along these environmental gradients. At the landscape scale, sagebrush ecosystems characterized by warmer and drier conditions tend to be more resource limited, slower to recover after disturbances, and therefore less resilient to disturbance than cooler and moister areas. Also, these warmer and drier areas are better suited to the growth and reproduction of cheatgrass and so are more prone to cheatgrass invasion than cooler and moister areas.

Sagebrush ecosystems vary greatly over the sagebrush biome, with many different species of sagebrush and other plant communities sorting out across gradients of heat and moisture. Resilience to stress and disturbance changes along these environmental gradients. The top photo shows the mountain big sagebrush/ mountain brush type with relatively cold and moist soils characterized by high resilience and resistance, the middle photo shows the mountain big sagebrush type with cool and moist soils and moderate resilience and resistance, and the bottom photo is the Wyoming big sagebrush type with warm and dry soils and low resilience and resistance. Photos by Jeanne C. Chambers.



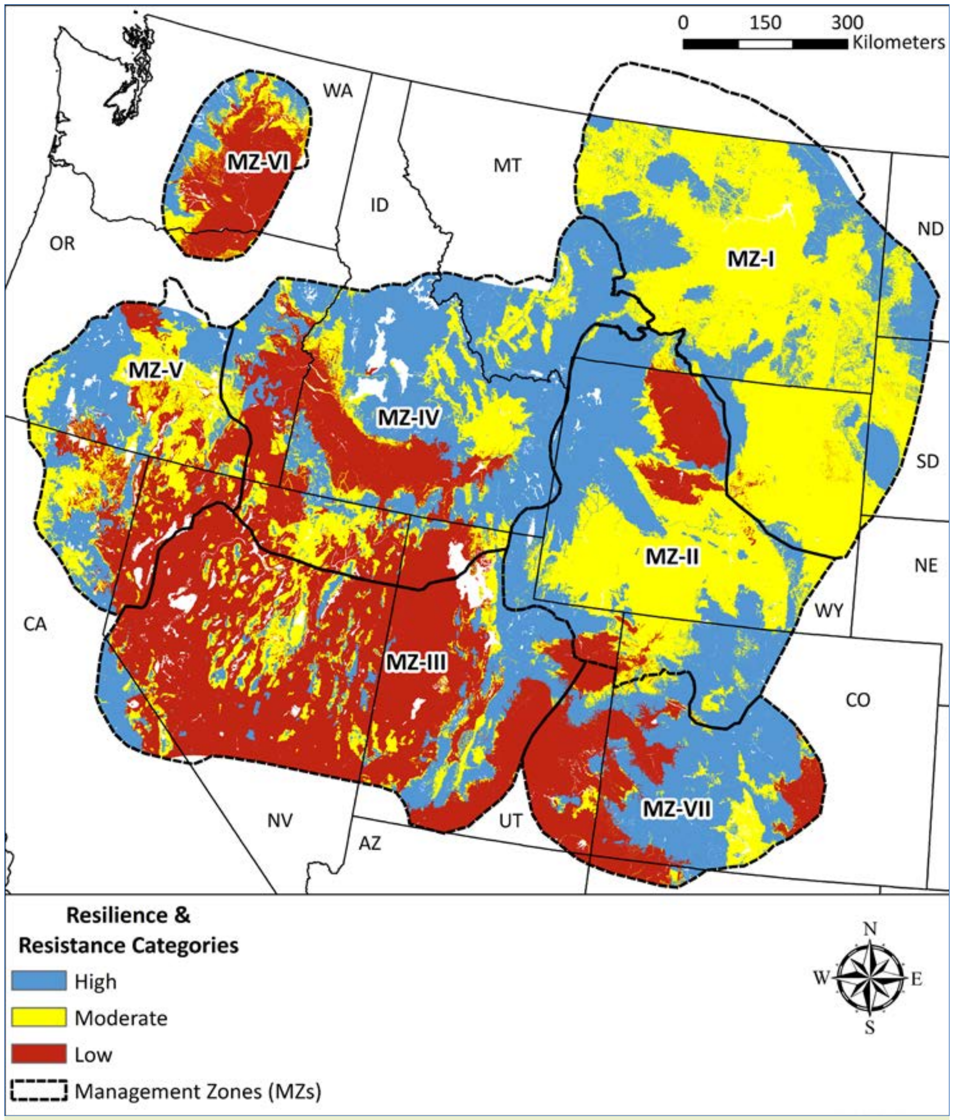
The graphs above illustrate the concepts of resilience (A) and resistance (B) in sagebrush ecosystems over a typical soil temperature and moisture gradient. In these sagebrush ecosystems, resilience to wildfire and resistance to cheatgrass increase over environmental gradients, but are modified by aspect and soils. The relative resilience and resistance of an area are closely related to sagebrush ecological types and soil temperature and moisture regimes. Soil moisture availability and plant productivity increase over environmental gradients resulting in greater recovery potential and more competition with cheatgrass. Also, climate suitability to cheatgrass decreases over these same gradients as soil temperatures decrease. Disturbances that increase soil water and nutrients and reduce competition can decrease both resilience and resistance. Understanding these relationships is useful for determining effective management strategies. Figure from the Science Framework, Part 1.

A strategic, spatially explicit approach

Knowledge of the relative resilience and resistance of the various geographic areas within the sagebrush biome is a critical element of prioritizing areas for management. Information on resilience and resistance can be used to predict how different areas across the landscape will respond to both disturbances and management actions. Areas with low resilience and resistance are typically those where invasive annual grasses are increasing, and restoration following wildfires or other disturbances is more problematic. Areas with moderate-to-high resilience and resistance are where one would expect recovery given proper management. Mayer notes, "When I put the map up of the high resilience and resistance sagebrush sites versus the low sites at a talk I gave, one of the fire experts said, 'Oh my gosh, we're placing our fuel management treatments in the wrong places.' The point is that if you have standing sagebrush and it is a well-functioning ecosystem but it's low in resilience and resistance, you better do every darn thing you can to save that because once it burns, it's not going to come back."

Indicators of resilience and resistance are based on soil moisture and temperature, which is available through the Natural Resource Conservation Service (NRCS) Web Soil Survey. Soil moisture and temperature can be used at biome to local scales to produce maps showing relative resistance and resilience.

Susan Ellsworth, a U.S. Forest Service Natural Resources and Planning Staff Officer, has first-hand experience with the challenges of managing



This map illustrates the use of soil temperature and moisture regimes from the Natural Resource Conservation Web Soil Survey to indicate areas of high, moderate and low resilience and resistance within the sage grouse Management Zones. Relatively warm and dry areas have low resilience and resistance (red), cooler and moister areas have moderate resilience and resistance (yellow), and colder and wetter areas have high resilience and resistance (blue). At regional to local scales, more detailed soils data can be used to assess resilience and resistance and determine effective management strategies. Figure from the Science Framework, Parts 1 and 2.

low-resilience sagebrush ecosystems for the Humboldt-Toiyabe National Forest in Nevada. She explains, “Sage grouse is a hot button topic right now, probably more so for the Humboldt-Toiyabe than other national forests because of the amount of sage grouse habitat that we manage. This is a very water-limited environment, with most of the places that we manage getting less than twelve inches of precipitation a year. Restoring these areas after fires is just very, very difficult to do. They tend not to come back with the type of plant community that we want. They come back with nonnative invasive annual grasses, and things that do not provide habitat for sage-grouse or other native species.”

Knowledge of the relative ability of the various geographic areas within the sagebrush biome to meet species habitat requirements is another critical element of conservation and restoration prioritization. Although the Science Framework focuses on Greater sage-grouse, information and tools are provided that allow managers to address other resource values and at-risk species. Recently, an interagency modeling effort quantified Greater sage-grouse breeding habitat probabilities based on densities of breeding male birds and general habitat characteristics, such as cover of sagebrush and conifers, climate, landform, and disturbance within each Management Zone. The Science Framework links information on resilience and resistance with sage-grouse breeding habitat probabilities to help identify key areas for conservation and restoration management and determine appropriate management strategies.

Field guides, factsheets, and restoration handbooks

These publications step managers through the process of determining resilience and resistance of sagebrush ecosystems and provide other information needed for conservation and restoration projects in their particular planning areas.

A field guide for selecting the most appropriate treatment in sagebrush and pinon-juniper ecosystems in the Great Basin: Evaluating resilience to disturbance and resistance to invasive annual grasses, and predicting vegetation response www.fs.fed.us/rm/pubs/rmrs_gtr322.pdf

A field guide for rapid assessment of post-wildfire recovery potential in sagebrush and pinon-juniper ecosystems in the Great Basin: Evaluating resilience to disturbance and resistance to invasive annual grasses and predicting vegetation response www.fs.fed.us/rm/pubs/rmrs_gtr338.pdf

Common native forbs of the northern Great Basin important for Greater Sage-grouse. www.fs.fed.us/rmrs/publications/common-native-forbs-northern-great-basin-important-greater-sage-grouse

Great Basin Factsheet Series 2016—Information and tools to restore and conserve Great Basin ecosystems. Reno, NV: Great Basin Fire Science Exchange. 79 p. www.fs.fed.us/rmrs/publications/great-basin-factsheet-series-2016-information-and-tools-restore-and-conserve-great

Restoration handbook for sagebrush steppe ecosystems with emphasis on greater sage-grouse habitat—Part 1. Concepts for understanding and applying restoration. U.S. Geological Survey Circular 1416, 44 p. www.fs.fed.us/rmrs/publications/restoration-handbook-sagebrush-steppe-ecosystems-emphasis-greater-sage-grouse-habitat

Restoration handbook for sagebrush steppe ecosystems with emphasis on greater sage-grouse habitat—Part 2. Landscape level restoration decisions: U.S. Geological Survey Circular 1418, 21 p.www.fs.fed.us/rmrs/publications/restoration-handbook-sagebrush-steppe-ecosystems-emphasis-greater-sage-grouse-habitat-0

Restoration handbook for sagebrush steppe ecosystems with emphasis on greater sage-grouse habitat—Part 3. Site level restoration decisions (ver. 1.1, March 2018): U.S. Geological Survey Circular 1426, 62 p. www.fs.fed.us/rmrs/publications/restoration-handbook-sagebrush-steppe-ecosystems-emphasis-greater-sage-grouse-habitat-1

The sage-grouse habitat resilience and resistance matrix below illustrates an area's relative resilience to disturbance and resistance to invasive annual grasses in relation to its probability of providing breeding habitat for Greater sage-grouse. The matrix provides a decision support tool that allows managers to better evaluate risks and decide where to focus specific activities to promote desired species and ecosystem conditions. As resilience and resistance go from high to low, as indicated by the rows in the matrix, the amount of time required for sagebrush regeneration and perennial grass and forb regrowth progressively limits the capacity of sagebrush ecosystems to recover after disturbances without management assistance. Also, the risk of invasive annual grasses increases, and the ability to successfully restore burned or otherwise disturbed areas decreases. As the probability of Greater sage-grouse breeding habitat goes from low to high within these same ecosystems, as indicated by the columns

Sage-Grouse Breeding Habitat Probability Matrix

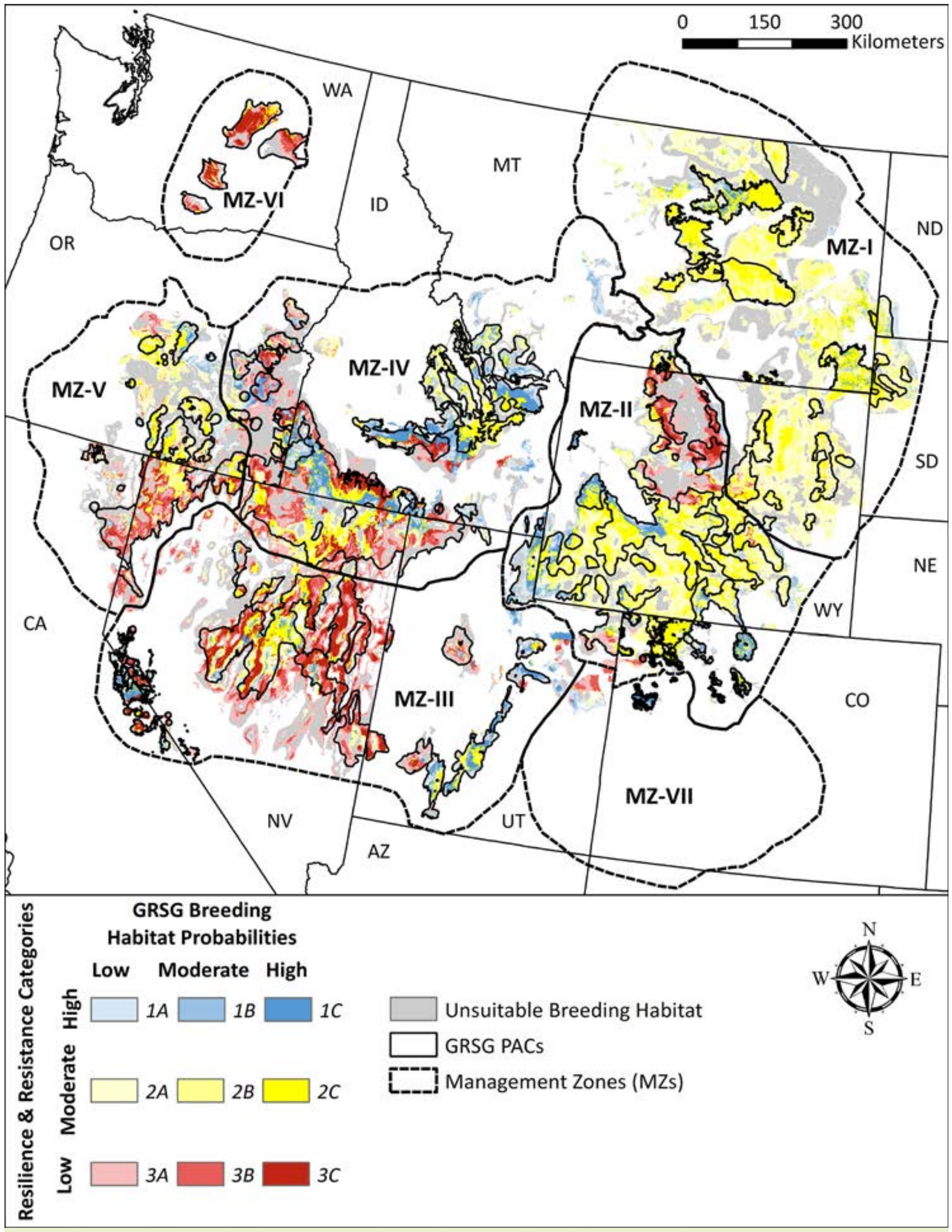
Resilience and Resistance of Sagebrush Ecosystem

	Low = 0.25–0.50	***Moderate = 0.5–0.75***	***High = > 0.75%***
High 	**RESTORATION/RECOVERY POTENTIAL HIGH** *Native grasses and forbs often sufficient for recovery after disturbance* *Risk of annual invasive grasses becoming dominant is low* *Seeding/transplanting success typically high*		
	Longer timeframe for recovery may require moderate intervention	Some intervention to enhance connectivity and improve function	Minimal intervention; preventative management to maintain function
Moderate 	**RESTORATION/RECOVERY POTENTIAL VARIABLE** *Native grasses and forbs often adequate for recovery after disturbance* *Risk of annual invasive grasses becoming dominant is moderate* *Seeding/transplanting success depends on site characteristics*		
	Longer timeframe for recovery may require moderate-to-high intervention	Moderate intervention to minimize invasive risks, enhance connectivity, and improve function	Some intervention needed to minimize risk of invasion; preventative management to maintain function
Low 	**RESTORATION/RECOVERY POTENTIAL LOW** *Native grasses and forbs often inadequate for recovery after disturbance* *Risk of annual invasive grasses becoming dominant is high* *Seeding/transplanting may require multipe interventions*		
	Recovery unlikely without significant intervention over long timeframe	High intervention to minimize invasive risks, enhance connectivity, and improve function	Moderate-to-high amount of intervention to minimize risk of invasion and maintain and enhance function

This sage-grouse habitat resilience and resistance matrix combines resilience and resistance with the probability of an area providing sage-grouse breeding habitat. The matrix allows managers to prioritize areas for management actions across large landscapes and determine appropriate management strategies based not only on the probability of sage-grouse habitat but also on the area's restoration and recovery potential. The rows show relative resilience and resistance of sagebrush ecological types. The columns show the probability of sage-grouse breeding habitat. Figure based on the Science Framework, Part 1.

in the matrix, the capacity to sustain populations of Greater sage-grouse increases. Management strategies can be developed for each cell in the matrix by considering resilience and resistance along with the probability of breeding habitat. Knowledge of the dominant ecosystem and human-caused threats further informs these strategies.

As resilience and resistance go from high to low, as indicated by the rows in the matrix, the amount of time required for sagebrush regeneration and perennial grass and forb regrowth progressively limits the capacity of sagebrush ecosystems to recover after disturbances without management assistance. Also, the risk of invasive annual grasses increases, and the ability to successfully restore burned or otherwise disturbed areas decreases.



This map representation of the sage grouse resilience and resistance matrix overlays the resilience and resistance categories with the sage-grouse breeding habitat probabilities. Areas in blue have high resilience and resistance, yellow have moderate, and red have low. Darker colors have higher probabilities of supporting breeding habitat for sage-grouse. The colors in the map match those in the matrix and therefore the management strategies in the different cells of the matrix can be linked directly to geographical areas on the map. For example, areas in dark red are likely to support grouse but are at high risk of invasive grasses and altered fire regimes and thus are important to consider for management actions such as fire suppression, and early detection and rapid response for invasive plants. Figure from the Science Framework, Part 1.

Web-based tools available for managing Greater sage-grouse habitat and the sagebrush biome

The data layers and information available from the sources below can be used by managers to prioritize areas for management and then further refine actions and goals. For example, sage-grouse habitat can be overlaid with resilience to disturbance and resistance to invasive annuals like cheatgrass, and vulnerable areas can be further defined with data layers on variables like burn probability.

Tools/Data

Science Framework data layers. Geospatial data, maps, and models and the associated references to support the Science Framework are listed in Appendix 8 of Part 1 of the Science Framework and provided through the U.S. Geological Survey (USGS) ScienceBase (www.sciencebase.gov/catalog/item/576bf69ce4b07657d1a26ea2) and BLM Landscape Approach Data Portal (https://landscape.blm.gov/geoportal).

Web Soil Survey Resilience and Resistance report function. A tool developed through the Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/) produces a "Sagebrush Ecosystem Resilience and Resistance Soils Report" that provides managers with relevant soil survey information on site characteristics to aid project-level assessments. It can be used to complete the Score Sheets for rating resilience and resistance found in A field guide for rapid assessment of post-wildfire recovery potential in sagebrush and pinon-juniper ecosystems in the Great Basin: Evaluating resilience to disturbance and resistance to invasive annual grasses and predicting vegetation response and A field guide for selecting the most appropriate treatment in sagebrush and pinon-juniper ecosystems in the Great Basin: Evaluating resilience to disturbance and resistance to invasive annual grasses, and predicting vegetation response. Instructions for generating the report are here: www.sagegrouseinitiative.com/wp-content/uploads/2013/07/WSS_RR_Report-Instructions.pdf

Conservation Efforts Database (CED; conservationefforts.org). An interagency team, led by USFWS and USGS, has developed an easy-to-use, online tool that allows users to track conservation actions aimed at reducing or eliminating the impacts driving habitat loss and degradation in the sagebrush biome. The CED allows multiple-users to securely enter data (single entry or batch upload) from any location; stores supporting documents (e.g., reports, protocols) uploaded by partners; links conservation actions to one or more threats (one-to- many relationships); includes reporting functions that summarize conservation actions at multiple scales (e.g., management zones, populations, priority conservation areas); maps data to user specifications; summarizes actions at multiple scales from easements to state wildlife action plans to regional planning efforts. Contact Lief Wiechman (lief_wiechman@fws.gov) for information.

Sage Grouse Initiative Web Application. (http://map.sagegrouseinitiative.com/) Web tool that allows anyone to quickly and easily visualize and download certain data layers, such as:

- *Ecosystem Resilience and Resistance* (R&R) depicts the range-wide R&R index. (A gridded R&R class layer and detailed soils geodatabase are available for download.)
- *Tree Canopy Cover* provides a high-resolution, 1-m map of tree canopy cover across most sage grouse habitats.
- *Cultivation Risk* depicts suitability for cropping based on climate, soils, and topography in order to assess potential risk of cultivation to sage-grouse habitat in the eastern range.
- *Mesic Resources* depicts the estimated extent and availability of mesic resources through time across the entire range of sage grouse. Mesic resources are defined as sites with higher vegetative productivity during the late growing season (July 15 to September 30) relative to surrounding areas, including temporary wetlands, wet meadows, riparian areas, high-elevation sagebrush uplands, and irrigated fields.

Technology Transfer

On-Demand Videos: Putting Resistance and Resilience Concepts into Practice. This 1.5 hour symposium was presented at the "Sagebrush Ecosystems Conservation: All Lands, All Hands" conference held in February 2016. Presentations help increase land managers' awareness and understanding of how resilience and resistance applications can help them better maintain desired sagebrush ecosystems. Presentations include: Science foundation (Jeanne Chambers), Landscape scale applications (Mike Pellant), Site scale applications (Rick Miller), and Tapping soil survey information (Jeremy Maestas). Videos available here: www.sagegrouseinitiative.com/symposium-replay-putting-resilience-resistance-concepts-practice/

Web-based tools available for managing Greater sage-grouse habitat and the sagebrush biome (continued)

Webinar: Using Resilience and Resistance Concepts to Manage Threats to Sagebrush Ecosystems, Gunnison Sage-Grouse, and Greater Sage-Grouse.
This one hour webinar provides an overview of the concepts, data, and tools as well as the management strategies in the General Technical Report Using resilience and resistance concepts to manage threats to sagebrush ecosystems, Gunnison sage-grouse, and Greater sage-grouse in their eastern range: A strategic multi-scale approach. It was presented on April 29, 2016 by Jeanne Chambers: www.youtube.com/watch?v=aTDIO4NgDvg

Webinar: A Science Framework for Assessing Threats to Sagebrush Ecosystems and Greater Sage-Grouse and Prioritizing Conservation and Restoration Actions.
This one hour webinar provides an overview of the concepts, data, tools, and management strategies in Part 1 of the Science Framework for Conservation and Restoration of the Sagebrush Biome. It was given on Sep 26, 2016 by Jeanne Chambers and Steve Hanser. http://greatnorthernlcc.org/event/867

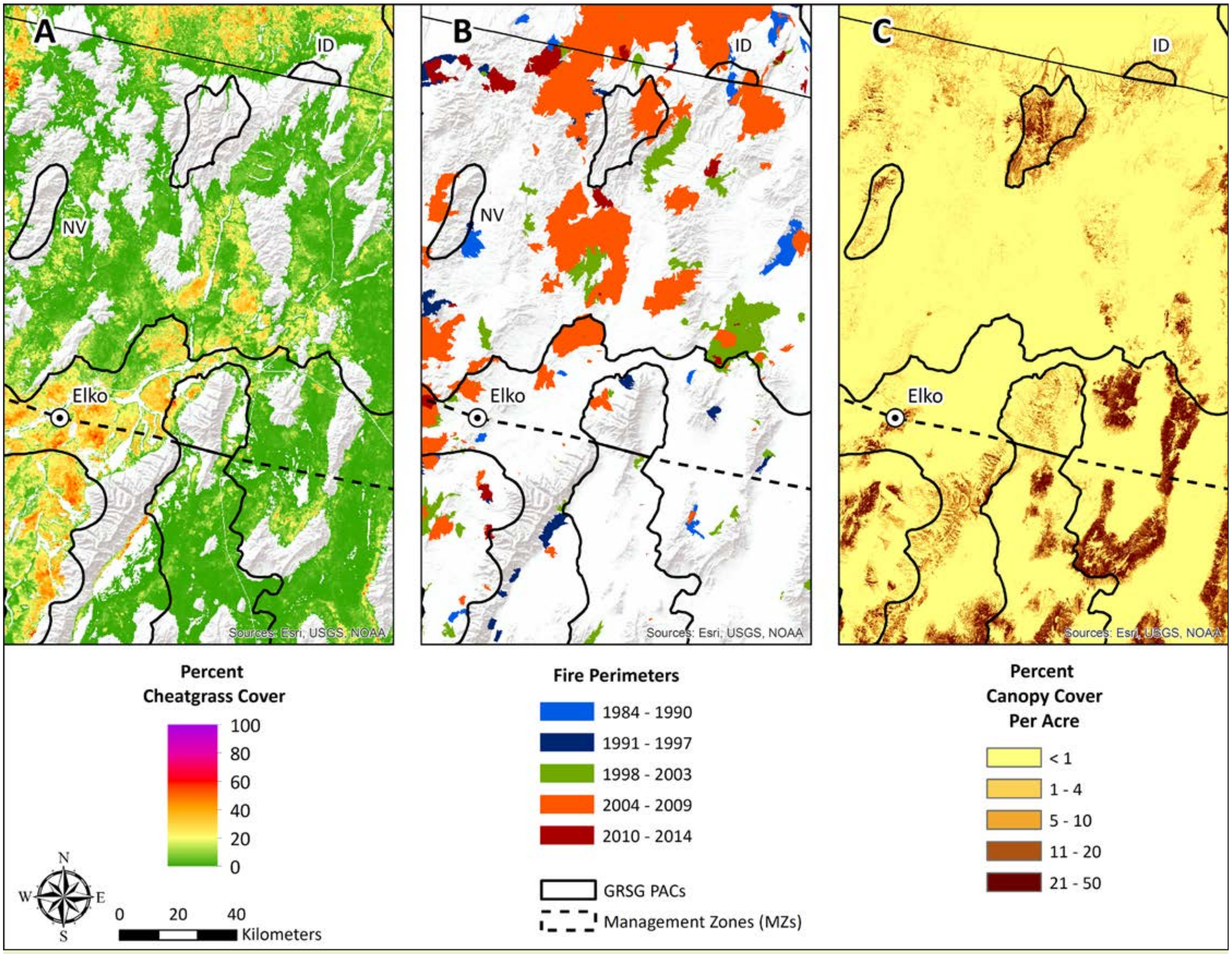
On Demand Videos: A Strategic Multi-Scale Approach for Managing Threats to Sagebrush Ecosystems Based on Resilience and Resistance Concepts. This series of videos is from a symposium at the Society of Range Management on February 1, 2018. The different videos present the key concepts and management strategies from Part 1 and Part 2 of the Science Framework for Conservation and Restoration of the Sagebrush Biome. Topics covered include use of resilience and resistance concepts, threats to sagebrush ecosystems and sagebrush-dependent species, management tools for conservation and restoration, adaptive management and monitoring, climate adaptation, wildland fire and vegetation management, invasive plant management, application of National Seed Strategy concepts, livestock grazing management, and wild horse and burro considerations. The series ends with a panel discussion on Perspectives on Implementing the Science Framework from regional managers. www.partnersinthesage.com/blog/2018/2/9/30-videos-now-available

Overlaying the resilience and resistance categories with the probability of sage-grouse breeding habitat on a map provides a clear picture of which areas should be prioritized for management. The different colors on the map can be related directly to the sage-grouse habitat resilience and resistance matrix and management strategies provided in the Science Framework. For example, areas with high habitat suitability may be considered for protective management — establishing conservation easements, stepping up invasive species control efforts and, where appropriate, fire prevention and conifer removal to maintain or improve habitat connectivity. Areas with low resilience and resistance are at greatest risk following disturbances and those with high habitat suitability are among the highest priorities for active management — fire suppression and fuels management, improved livestock grazing management, and early detection and rapid response management of invasive plant species.

Stepping down to management at the local level

But what about management at a smaller scale? The first part of the Science Framework guides people through the specific methods for taking a broad view of these systems in terms of their relative resilience and resistance, their habitat characteristics with regard to the focal species (such as Greater sage-grouse), and the dominant threats to the area. "And then from this broad view," says Chambers, "the last section of Part 1 and most of Part 2 provide the necessary information for stepping down essentially to the district or field office level, by helping people think through the specific management actions they would use, and discussing the tools that are available, such as ecological site descriptions." Once the larger-scale priority areas and overarching strategies are identified, managers working at a smaller scale can identify project areas and the appropriate management strategies by combining higher resolution spatial data with local information and knowledge.

Part 2 gets into the nitty gritty of some of the specific management considerations. According to Michele Crist, a landscape



Maps such as these of an area near Elko, NV, help step down from the biome level to the local level when evaluating sagebrush habitat management issues. The map on the left (A) illustrates the increasing cheatgrass problem near Elko and to the north. The center map (B) shows that the area has had large fires in recent decades. The map on the right (C) shows localized conifer expansion in some of the sage-grouse Priority Areas for Conservation (PACs). These types of data overlays can be used to develop management strategies at the local level. Figure from the Science Framework, Part 1.

ecologist for the BLM and an editor of Part 2, "Our intent is to help provide the management context for applying the science from Part 1 at broad and regional scales, as well as localized scales. Part 2 focuses on the relevant topics for managing sagebrush ecosystems: adaptive management and monitoring, climate adaptation, wildland fire and vegetation management, invasive plant management, application of National Seed Strategy concepts, livestock grazing management, and wild horse and burro considerations. The last section discusses the integration of the different management topics, what the associated natural resource benefits and tradeoffs may be, and how to mitigate for tradeoffs when applying the management considerations on the ground." The intent is for this information

KEY FINDINGS

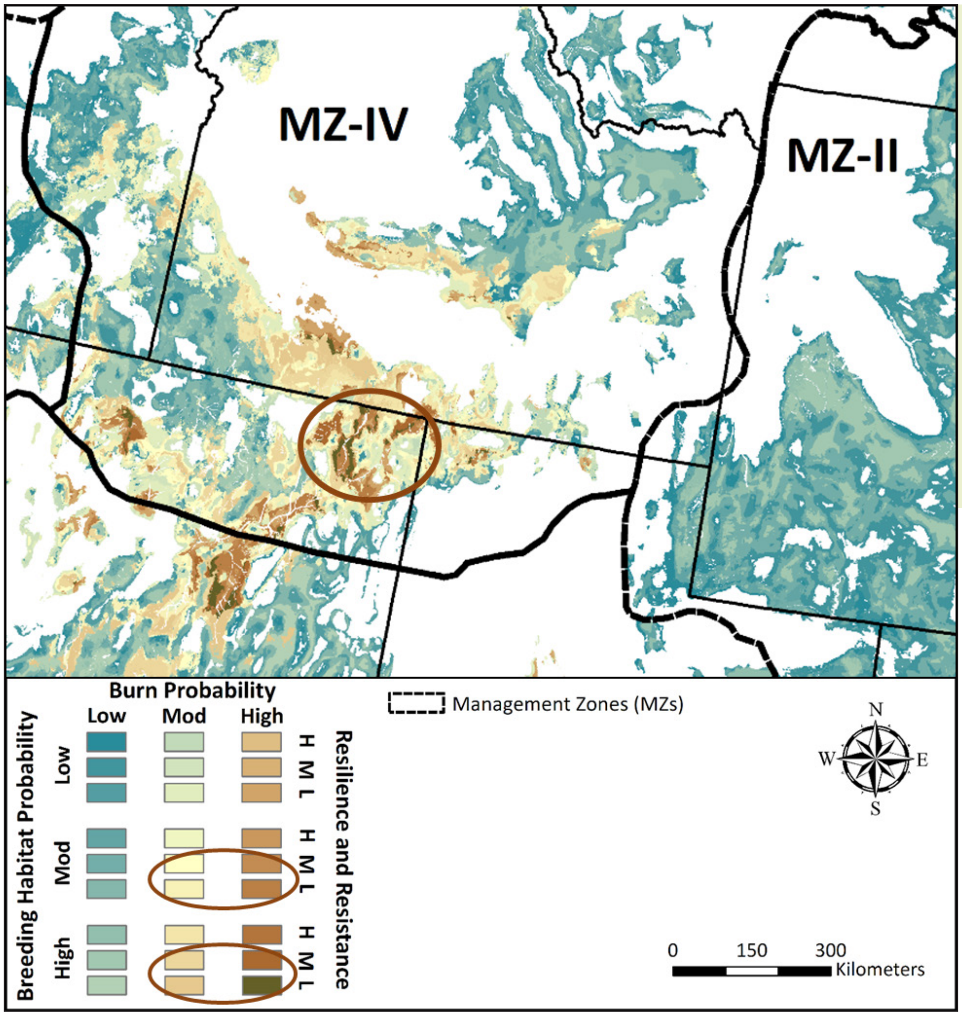
- The ecological concepts of resilience to stress and disturbance and resistance to invasion by nonnative plants can be applied to prioritize areas within the sagebrush biome for conservation and restoration management.
- Sagebrush ecosystems characterized by warmer and drier conditions tend to exhibit greater changes and recover more slowly following disturbances and thus are typically less resilient to disturbance than cooler and moister areas. These warmer and drier areas are better suited to the growth and reproduction of cheatgrass than cooler and moister areas and thus have lower resistance to its invasion.
- Knowledge of species habitat requirements is a critical element of conservation and restoration prioritization. The modeled probability of breeding habitat for Greater sage-grouse identifies general habitat characteristics and important breeding areas for each WAFWA Sage Grouse Management Zone within the sagebrush biome.
- A sage-grouse habitat resilience and resistance matrix provides the ability to evaluate an area's relative resilience to disturbance and resistance to invasive annual grasses in relation to its probability of providing breeding habitat for Greater sage-grouse in order to prioritize areas for management across large landscapes and to determine appropriate management strategies. A map representation of the matrix is used to illustrate which areas should be prioritized.
- Once the larger-scale priority areas and overarching strategies are identified, managers can step down to smaller scales by combining higher resolution spatial data are with local information and knowledge to identify project areas and the appropriate management actions.

to augment existing management direction and objectives.

For example, Part 2 provides considerations and examples for prioritizing fire management activities for sage-grouse habitats and populations. The mapping products described in Part 1, such as the Fire Risk Assessment for the Greater Sage-Grouse, combine the resilience and resistance categories, sage-grouse breeding habitat probabilities, and fire probability to identify priorities for fire prevention and suppression and fuels reduction at broad and mid scales. For example, high priority areas can be defined as those with high- to moderate-burn probability, high- to moderate-sage-grouse breeding habitat probabilities and low to moderate resilience and resistance. As described in Part 2 of the Science Framework, in these areas, higher priorities for management would include placing fuel reduction treatments or fuel breaks strategically around sage-grouse habitats, implementing fire prevention strategies, conducting postfire rehabilitation, and monitoring for spread of nonnative annual grasses. Fire managers can distribute the wildland fire risk assessment and other mapping data layers to dispatch offices, incident commanders, fire crew bosses, and other fire responders to help coordinate and improve initial attack effectiveness during periods of increased fire activity, particularly in areas of low resistance and resilience that may be difficult to restore after a burn.

The importance of adaptive management is a theme throughout the document. "I would say that natural resource management should be strongly tied to adaptive management and monitoring programs," says Crist. "There are many opportunities to learn through assessments of management actions "on the ground" and to identify what worked and didn't work, as well as for achieving management goals for the conservation of sagebrush at regional and broad-scales. Then, needed changes in management strategies can be applied where appropriate."

"I would say that natural resource management should be strongly tied to adaptive management and monitoring programs."



This map from Part 2 of the Science Framework combines a wildland fire risk map (described in Part 1) with sage-grouse breeding habitat probabilities and the resilience and resistance categories to show vulnerable areas having a combination of: high to moderate burn probability, high to moderate sage-grouse habitat probabilities, and low to moderate resilience and resistance. In these areas, higher priorities for management would include strategic placement of fuel reduction treatments or fuel breaks around sage-grouse habitats, implementing fire prevention strategies, conducting post-fire rehabilitation, and monitoring for spread of nonnative annual grasses.

MANAGEMENT APPLICATIONS

- Widespread concern about conservation of sagebrush ecosystems and sage-grouse has created the need for natural resource agencies to effectively manage sagebrush habitat and conserve sagebrush dependent species across the western States within the sagebrush biome. This two-part Science Framework contains powerful, science-based tools to aid managers.
- Part 1 of the Science Framework explains prioritizing areas for management action using an approach that overlays information on resilience and resistance, species habitats, and predominant threats.
- Specific sagebrush biome management considerations, including adaptive management and monitoring, climate adaptation, wildland fire and vegetation management, invasive plant management, National Seed Strategy concepts, livestock grazing management, and wild horse and burro considerations, are addressed in Part 2, along with a discussion of integrating the different considerations and trade-offs involved.
- It is anticipated that the Science Framework will be widely used to inform emerging strategies to conserve sagebrush ecosystems, sagebrush dependent species, and human uses of these ecosystems, and to assist managers in prioritizing and planning on-the-ground restoration and mitigation actions across the sagebrush biome. For example, the concepts and approaches described in the Science Framework have been used by the Forest Service in developing fire risk assessments for all Forest Service lands with Greater sage-grouse and for Region 4. They have been used by the BLM to develop a multi-year program of work for BLM managed lands in the western portion of the sagebrush biome.

More sage advice to come: Linking the Science Framework to emerging strategies

It is anticipated that the core concepts and approaches in the Science Framework will be widely used to inform emerging strategies to conserve sagebrush ecosystems, sagebrush-dependent species, and ecosystem services. The Framework will also assist managers in prioritizing areas for management and planning on-the-ground restoration and mitigation actions across the sagebrush biome. The Science Framework is intended to be adaptive and revised as new information and analyses are developed and as additional data become available on other values and species at risk. Updates of both Part 1 and Part 2 will be linked to periodic updates of the Western Association of Fish and Wildlife Agencies' Sagebrush Science Initiative and Sagebrush Conservation Strategy under development in 2019.

"The bottom line is, never before have we really had the science laid out as clearly as this by a collaborative group, followed up with suggestions on how managers can implement it. It is a very powerful tool."

Will it be useful? According to Mayer, "The bottom line is, never before have we really had the science laid out as clearly as this by a collaborative group, followed up with suggestions on how managers can implement it. It is a very powerful tool." The concepts and approaches in the Science Framework have already been used by the Forest Service in developing fire risk assessments for all Forest Service-managed lands with Greater sage-grouse and for Region 4. They were incorporated into the Department of the Interior's Integrated Rangeland Fire Management Strategy and have been used by the BLM to develop a multiyear program of work for BLM-managed lands in the western part of the sagebrush biome.

FURTHER READING

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SYCU

SCIENCE YOU CAN USE BULLETIN

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POSTAGE

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