



United States Department of Agriculture

# Sage-Grouse Conservation Science Strategy

## USDA Forest Service



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### **Executive Summary**

In 2010, the U.S. Fish and Wildlife Service determined that the Greater Sage-Grouse was warranted for listing under the Endangered Species Act. As part of a 2011 court settlement for candidate species, the Service stated it would further evaluate this decision and propose the Greater Sage-Grouse for listing by September 30, 2015 if threats to the species could not be ameliorated. USDA Forest Service scientists have studied sagebrush ecosystems and sage-grouse biology and habitat requirements throughout sage-grouse and sagebrush ranges for several decades.

Given Forest Service science capacity, germane publications, research facilities and strategic locations, and the importance of National Forest System lands for breeding and brood-rearing habitats for sage-grouse, we recommend that research and science delivery by the Forest Service be continued and expanded in response to widespread concerns and calls for science-based conservation to prevent further declines of sage-grouse populations and loss of sagebrush ecosystems throughout the western United States.

A team of scientists and managers prepared this science strategy to summarize Forest Service strengths, capabilities, partners, past and current research, and potential future priority areas for sagebrush ecosystems and sage-grouse conservation science. Four Strategic Priorities were identified in the science strategy based on Forest Service strengths, areas of leadership, and reviews of knowledge:

- (1) Evaluate sage-grouse ecology, monitoring, and habitat linkages,
- (2) Understand disturbances and stressors in sagebrush ecosystems,
- (3) Analyze and design landscapes,
- (4) Develop methods, models and plant materials to restore sagebrush habitats

Our strategy also identifies Research Priorities and Goals, facilities and locations, science-based needs of the National Forest System, and the unique niche of Forest Service science relative to plans and strategies of other agencies and organizations.

Cover Photo. Females of the bi-state population of Greater Sage-Grouse observed at 10,000 ft, White Mountains, Inyo National Forest. Credit: Chris Balzotti.

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## Overview

Numerous federal and state agencies, research institutions and stakeholders have undertaken tremendous conservation and research efforts across 11 States in the western United States to reduce threats to Greater Sage-Grouse (*Centrocercus urophasianus*) and sagebrush (*Artemisia* spp) habitats. In 2010, the U.S. Fish and Wildlife Service (USFWS) determined that the Greater Sage-Grouse was warranted for protection under the Endangered Species Act, but that action was precluded by higher priority listing actions. As part of a 2011 court settlement, USFWS agreed to make an initial determination on whether to propose the species for listing by September 30, 2015 fiscal year. The Draft FY 2015 Omnibus Appropriations Bill contains a rider that currently prevents USFWS from publishing a proposed listing rule regarding greater sage-grouse, but it does not relieve USFWS of its obligation to determine whether the species still warrants protection under the ESA. Consequently, USFWS is moving forward with a determination by the end of 2015. The Service also found that the bi-state population of Greater Sage-Grouse bordering California and Nevada, considered a distinct population segment (DPS), also warranted protection as a threatened species under ESA (Federal Register 2013).

Two of the primary factors for listing Greater Sage-Grouse were: 1) threats to habitats important to sage-grouse populations, and 2) the lack of regulatory mechanisms, primarily in land use plans that would ensure protection for the species and its habitats. In response to these findings, the Bureau of Land Management (BLM) and the USDA Forest Service (FS) have undertaken land use plan revisions and amendments to incorporate measures to conserve, enhance, and restore greater sage-grouse habitat by reducing, eliminating, or minimizing threats to that habitat. With consideration for climate change, development of suitable habitat outside of their current range may be necessary to conserve the species. Collaboration and activities among state and Federal partners to proactively identify and implement actions to reverse current trends (USFWS 2010, 2013) have substantially increased since 2010. As an example, in January 2015, the Department of Interior released a Secretarial Order for a comprehensive science-based policy to prevent and suppress rangeland fire and to restore sagebrush landscapes impacted by fire across the West. Actions to prevent fire and restore habitats were deemed essential for conserving habitat for Greater Sage-Grouse in the Great Basin's sagebrush ecosystems.

USFWS also determined that Gunnison Sage-Grouse (*Centrocercus minimus*), a smaller sage-grouse species found only in southwestern Colorado and southeastern Utah, required protection under the Endangered Species Act (ESA) as a threatened species, effective December 22, 2014 (Federal Register 2014). The most substantial threats to Gunnison Sage-Grouse habitat decline were identified to be human disturbance, small population size and structure, drought, climate change, and disease.

Success in conserving sage-grouse and sagebrush habitats centers on “maintaining viable, connected, and well-distributed populations and habitats across their range, through threat amelioration, conservation of key habitats, and restoration activities” (USFWS 2013). USDA Forest Service (FS) scientists have contributed to these conservation efforts owing to their history of research and collective expertise in studying sagebrush ecosystems and the existence of FS research station facilities in strategic locations for studying sagebrush ecosystems and sage-grouse. To document these contributions, FS scientists prepared this science strategy that

summarizes FS Research and Development (FS R&D) capabilities, partners, past and current research, and potential future priority areas for FS R&D sage-grouse conservation science.

Since the mid-1980's, the FS R&D Mission Area has addressed key science and management questions regarding sagebrush ecosystems. Concerns regarding the role of sagebrush genetics in restoration science, and the impacts and control of pinyon juniper encroachment and annual grass invasions on sagebrush ecosystems were already important issues, especially in the Great Basin. As threats to the greater sage-grouse became a dominant consideration for managing sagebrush habitats, FS R&D began integrating findings from this initial research into assessments, models and new research for understanding and managing sage-grouse populations and habitats, for controlling cheatgrass (*Bromus tectorum* L.) invasions in sagebrush ecosystems, for treating and managing fire and post-fire landscapes, for restoring ecosystems impacted by multiple disturbances, and for linking sage-grouse biology and habitat requirements to management of plant communities and landscapes. Research expanded after 2000 to include evaluations and control of the spread of other invasive species and stressors such as energy development, drought, and climate change, assessments of the effectiveness of sagebrush restoration actions, assessments of habitat and bird vulnerabilities, and evaluation of sage-grouse and sagebrush genetics for improving restoration strategies and landscape design.

Sage-grouse conservation concerns have grown in recent years, creating expectations for natural resource agencies to demonstrate their ability to conserve the Greater Sage-Grouse, which currently exist in 11 western States, including up to 35 National Forests or Grasslands, as well as the Gunnison Sage-Grouse, a species whose small population occurs in only 2 states and on 1 National Forest, the Grand Mesa/Uncompahgre/Gunnison in Colorado. This ability is largely dependent on the integration of relevant and applicable scientific information. FS R&D has demonstrated strong leadership in identifying threats to natural resources, developing methods and models to address those threats, and providing managers tools and options based on science. FS R&D is committed to ensuring its relevant and applicable science findings are available and delivered into the hands of practitioners through publications, conferences, webinars, partnerships, and consultations. Where FS R&D has unique research capabilities, it is committed to effectively responding to requests for additional information and needs for additional science and testing of hypotheses.

The primary purpose of this FS R&D Sage-Grouse Conservation Science Strategy is to promote understanding and recognition of FS strengths, science leadership and collaborative opportunities in key areas of sagebrush and sage-grouse science, identify Research Priorities and Goals based on a review of existing knowledge and future needs, stimulate increased development and delivery of sage-grouse conservation knowledge, and serve as a communication and planning guide for managers, staff, and scientists working on or concerned about sage-grouse related issues. The strategy aims to improve awareness of our collective expertise, partnerships, and existing facility resources by summarizing the sage-grouse conservation science conducted by FS R&D.

Another purpose of this strategy is to foster synergistic collaborations among fellow FS R&D scientists and their partners and with the management community. Sagebrush and sage-grouse scientists were invited to share what they do across locations and disciplines and succinctly

synthesize their efforts into a single document. Coordination among scientists was enhanced through developing the conservation strategy using a team approach.

The third purpose is to serve as a communication aide in support of our colleagues in National Forest Systems (NFS) in achieving sage-grouse conservation objectives. Much of FS R&D sage-grouse and sagebrush science is being developed to aid management decisions on NFS and other federal lands. FS has 8% of sage-grouse occupied lands while the majority of the remainder is on BLM lands. These two agencies are the leads for developing management action plans for the Greater Sage Grouse.

A fourth purpose is to provide clarity to sister agencies (NRCS, BLM, USFWS, and USGS, in particular) by identifying niches of expertise that FS R&D is currently filling and can expand in the future.

This strategy presents Strategic Research Priorities where Forest Service scientists have demonstrated significant leadership and strengths, as reflected by an assessment of FS R&D publications, science delivery, applications by stakeholders, and future research needs. Research Goals based on the recognition of significant future needs support each Strategic Research Priority.

Four Strategic Priorities were identified based on existing knowledge and future needs.

1. Evaluate Sage-grouse Population Ecology, Monitoring, and Habitat Linkages
2. Understand Disturbances and Stressors in Sagebrush Ecosystems
3. Analyze and Design Landscapes
4. Develop Methods, Models and Plant Materials to Restore Sagebrush Habitats

The framework for this strategic plan is divided into 5 sections. The first section assesses existing knowledge developed by FS R&D scientists that exemplify their strengths and science leadership. This section frames assessments within the context of each of the four Strategic Priorities. These reviews clarify and emphasize how FS R&D scientists are experts in these priority areas and how their research leadership complements other efforts. The second section identifies Strategic Research Priorities and Goals identified by team members of this science strategy. The third section reviews key facilities and locations having relevant science expertise and capacity. The fourth section identifies NFS needs for future science and science delivery methods to meet NFS needs. The last section reviews how the FS Sage-Grouse Conservation Science Strategy complements strategies and plans of other organizations.

## **FS R&D Strengths and Leadership: A Review of Knowledge**

### **Sage-grouse Population Ecology, Monitoring, and Habitat Linkages**

Several comprehensive publications describe basic ecology and habitat requirements of greater sage-grouse (Connelly et al. 2000, Schroeder et al. 1999). A landmark contribution was the 2011 book, *Greater Sage-Grouse: Ecology and Conservation of a Landscape Species and its Habitats*, which includes management and conservation status, basic sage-grouse ecology, sagebrush

ecology, and factors associated with extirpation of greater sage-grouse (Connelly and Knick, eds. 2011). FS research findings contributed to specific chapters in this book (e.g. Wisdom et al. 2011). FS scientists have developed a plethora of sage-grouse models, many of which were subsequently used in broad-scale assessments of the species and its habitat. Other research focuses on links between sage-grouse demographics and habitat status or human disturbance. Below we describe primary lines of FS research on these topics.

#### *Modeling greater sage-grouse and its habitat*

Mechanistic models that clearly tie animal distributions and performance to habitat variables are useful tools for species conservation and management. Forest Service scientists have developed a variety of models that address greater sage-grouse ecology and habitat requirements. As part of the Interior Columbia Basin Ecosystem Management Project (ICBEMP) in the late 1990s, the science strategy team developed >30 Bayesian Belief Network (BBN) models for key species of conservation concern, including greater sage-grouse. These models combined empirical and hypothesized relations in probability-based projections of conditions, and were subsequently used to estimate abundance and distribution of habitat and population outcomes across the 58 million ha of the Great Basin under a suite of management alternatives (Marcot et al. 2001, Raphael 2001). Wisdom et al. (2002) validated two restoration models by using areas of extirpated vs. occupied range. One restoration scenario assumed a 50% reduction in detrimental grazing effects and a six-fold increase in areas treated with active restoration compared with future management proposed by the FS–BLM, and the second scenario assumed a 100% reduction in detrimental grazing effects and the same increase in active restoration as the first scenario. In an ecoregional assessment in the Wyoming Basins, Hanser et al. (2011a) developed a statistical model relating greater sage-grouse occurrence and abundance to environmental covariates.

#### *Assessment and monitoring of sage-grouse habitat*

Connelly et al. (2000) published recommended guidelines to manage sage-grouse populations and habitats and followed this publication with guidance on habitat monitoring for sage-grouse (Connelly et al. 2003). More recently, BLM and FS collaborated to develop a comprehensive monitoring framework with methods to monitor habitat and evaluate effectiveness of FS and BLM land management plans to conserve sage-grouse and its habitat (BLM and USDA Forest Service 2014). Rowland and Vojta (2013) recently published a technical guide describing standardized methods of wildlife habitat monitoring for use on National Forest System and other lands; recommendations from this document have been widely adopted, including use in State Wildlife Action Plans and land management units revising Forest Plans under the 2012 FS planning rule (Federal Register 2012). One chapter features example habitat monitoring programs for 3 species, including greater sage-grouse (Goldstein et al. 2013). This example illustrates conceptual models at landscape and site scales for processes acting as stressors on greater sage-grouse and projected impacts on grouse habitat. The authors also provide specific monitoring objectives and indicators at each scale, including fragmentation and connectivity.

Forest Service scientists have spearheaded large-scale habitat assessments for sage-grouse. Through the ICBEMP, scientists evaluated habitat conditions for Greater Sage-Grouse across the Basin under various management scenarios (Wisdom et al. 2000, 2002; Raphael et al. 2001; Hemstrom et al. 2002). In recognition of that work, the BLM requested that FS researchers lead

a broad-scale habitat assessment for greater sage-grouse and other sagebrush associated species in the Great Basin ecoregion; this project resulted in publication of a book (Wisdom et al. 2005) and other publications (Rowland et al. 2006, 2010a, 2010b). Using methods developed in the Great Basin, Wisdom and Rowland then co-led an ecoregional assessment of sage-grouse and sagebrush communities in the 350,000 km<sup>2</sup> Wyoming Basins. A second book was published (Hanser et al. 2011b) that included chapters on selection of sagebrush-associated species of concern (Rowland et al. 2011), a model of sage-grouse occupancy and abundance, (Hanser et al. 2011a), and management considerations (Knick et al. 2011).

#### *Quantification of core and edge habitats across sage-grouse range*

Patterns of species occurrence can help in evaluating factors associated with population losses. Wisdom et al. (2011) evaluated environmental conditions in areas of former range (extirpated range) and areas still occupied (occupied range) by Greater Sage-Grouse and Gunnison Sage-Grouse. The purpose of the evaluation was to identify those environmental conditions most strongly associated with landscape scale extirpations, based on the strongest environmental differences between areas of current occupation versus extirpation.

A wide variety of landscape metrics were considered in the evaluation that relate to concepts of “core areas” versus “edge” areas. Mean size of core areas (defined as the mean size of contiguous sagebrush patches) were >12 times larger in occupied range ( = 3,964 ha) versus extirpated range ( = 332 ha). Mean size of core areas was included in the second-best model that provided >80% accuracy in discriminating between occupied and extirpated range. The single-best factor in correctly classifying occupied versus extirpated range was the percent area of sagebrush (sagebrush area), as estimated for 100,000-ha blocks within each range. Almost twice as much sagebrush area was present in occupied range ( = 46%) in contrast to extirpated range ( = 24%), results that served as an additional indicator suggesting that the size of core areas were substantially larger in occupied range. These results further corroborated results by Aldridge et al. (2008). Finally, Wisdom et al. (2001) identified “strongholds” of occupied range that were characterized by large core areas, minimal edge, and far from areas of extirpated range. By contrast, areas estimated to be associated with a high risk of extirpation had small core areas, often isolated and disjunct. The identification of landscape strongholds versus less intact areas of occupied range by Wisdom et al. (2011) provided a strong management framework for landscape designs to maintain and restore desirable characteristics of sage-grouse range across the historical range of both species.

#### *Linking sage-grouse populations and demography to habitat change*

Understanding the demographics of life history stages and linking these to environmental factors can improve management to positively influence sage-grouse populations and conservation planning. FS R&D has extensive experience evaluating demographic parameters and environmental covariates at multiple scales throughout the range of greater sage-grouse. Responses of sage-grouse populations to habitat alteration may vary from site occupancy or size of leks (e.g., Hess and Beck, Smith et al. 2005, Wisdom et al. 2011) to survival during individual life history stages such as juveniles or brood-rearing. Forest Service Research collaborated with multiple partners, including several state wildlife agencies (SD, ND, WY) and two universities to link sage-grouse habitat and demographic parameters in the eastern portion of the sage-grouse

range (Herman-Brunson et al. 2009; Kaczor et al 2011a, 2011b; Swanson et al 2012), and the team is currently studying effects of wind energy developments.

Managers used the BBN models developed for sage-grouse as part of ICBEMP to explicitly evaluate population outcomes across the range of the species within the Basin, with potential outcomes ranging across a gradient from well-distributed and abundant to scarce, patchy, and at risk of extirpation (Raphael et al. 2001). Managers then applied model results to guide alternative selection in the Environmental Impact Statement for the Interior Columbia Basin.

## **Disturbances and Stressors in Sagebrush Ecosystems**

Sage-grouse are “landscape” species and declines in populations can often be attributed to the loss, fragmentation, and degradation of sagebrush ecosystems (Connelly et al. 2011). Primary drivers of change in sagebrush ecosystems are the direct effects of human land use and development and their interactions with more complex factors (e.g., altered fire regimes, invasive species, tree encroachment, drought stress, and livestock grazing) (Connelly et al. 2011). Effects of these disturbances and stressors are manifest at temporal scales ranging from years to centuries and spatial scales ranging from sites to large landscapes (Doherty et al. 2010; Arkle et al. 2014). Superimposing rapid climate changes over these disturbances makes assessment and management of these ecosystems and their services increasingly difficult. The influences of a changing climate potentially have profound implications on the distribution of sagebrush ecosystems. Kitchen et al. (*in prep*) shows the historical environmental settings for the development and establishment of sagebrush communities, their trajectories since the Pleistocene, and the implications for current and future distribution of sagebrush communities. Balzotti et al (*in prep*) models climate envelopes which is useful in identifying those areas that are mostly likely to change in a warming climate. This information is valuable in understanding implications to sage-grouse habitat changes and identifying those areas where management effort can best conserve habitat connectivity for this species. A primary strength of FS research is in developing the required understanding of the effects of disturbance on sagebrush ecosystems over the scales necessary to develop effective management strategies. Key areas of science leadership in the FS are highlighted below.

### *Invasion of annual grasses into sagebrush ecosystems*

Invasion and expansion of annual grasses is resulting in an annual grass fire cycle and progressive conversion of lower elevation, warmer and drier sagebrush ecosystems to annual grass dominance. Successful management strategies require a detailed understanding of attributes of sagebrush ecosystems that determine resistance to invasion. To gain that understanding, FS scientists examined effects of climatic factors (temperature and precipitation) and common disturbances (fire, grazing) on soil water and nutrients, and on establishment, reproduction and persistence of the most widespread annual invader – cheatgrass (Blank et al. 2007; Chambers et al. 2007; Chambers et al. 2014d; Roundy et al. 2007; Beckstead et al. 2010; Jones et al. 2014; *in press*). They examined interactions of cheatgrass with native plant species (Goergen et al. 2009) and sagebrush plant communities (Jones 2014). They also evaluated differences in germination characteristics and genetic structure among cheatgrass populations, and implications for adaptation and spread of the annual invader (Merrill et al. 2012). This information has been used to develop conceptual and statistical models of factors that influence resistance to annual grass invasion across the environmental gradients that characterize

sagebrush ecosystems (Brooks and Chambers 2011; Brooks et al. *in press*; Chambers et al. 2014a). It is widely used to develop management strategies for sagebrush ecosystems (Miller et al. 2013; 2014a; 2015 *in press*).

#### *Expansion of pinon and juniper into sagebrush ecosystems*

Conifer encroachment, particularly pinon and juniper, is a primary threat to the loss of sagebrush communities on national forest lands. Expansion of pinon and or juniper trees into sagebrush ecosystems typically results in (1) a decrease in understory sagebrush, grasses, and forbs (fine fuels), (2) an increase in woody fuels, and (3) less frequent but more intense fires (Miller et al. 2013). FS researchers and collaborators have examined the changes that occur in soil resources (Rau et al. 2007, 2008) and plant community composition (Chambers 2005), reductions in sagebrush cover in relation to pinyon-juniper expansion (Rowland et al. 2010a), and the consequences for fuel loads with progressive tree expansion and infilling (Miller et al. 2008, Miller et al. 2014a; Roundy et al. 2014a,b). They also have examined resilience of these areas to wildfire and management treatments, and resistance to invasive annual grasses, over the environmental gradients that characterize these ecosystems (Chambers et al. 2014a,b). This information has been used to develop management guides for prioritizing the most appropriate areas for treatment and selecting the most appropriate treatments (Chambers et al. 2014c; Miller et al. 2014b).

#### *Altered fire regimes and post-fire recovery*

Fire is a dominant disturbance process regulating composition and structure of big sagebrush ecosystems. Understanding variability in natural and altered disturbance regimes and their effects on vegetation is critical for developing effective management and restoration strategies. FS scientists and collaborators have characterized historic (multi-century) fire regimes for big sagebrush ecosystems and in evaluating the changes that are occurring in these fire regimes (Kitchen and McArthur 2007; Miller et al. 2008; Miller and Heyerdahl 2008; Heyerdahl et al. 2006). They also are assessing the drivers of and variability in big sagebrush ecosystem recovery and tree occupation across a diverse range of sites (Goodrich et al. 2008; Nelson et al. 2014). This is particularly important because big sagebrush recovery after fire is dependent on seedling establishment. On landscapes prone to tree invasion, sagebrush dominance is facilitated by fire-free intervals long enough for sagebrush recovery and short enough to prevent tree invasion and dominance (Miller and Rose 1999, Miller et al. 2013).

Landscape scale vegetation dynamics across a range of fire frequencies and climate scenarios are being modeled in order to assess the resilience of big sagebrush ecosystems at various spatial and temporal scales. Fire frequency is expected to increase with increasing air temp/drought (which may decrease cheatgrass cover). If fire frequency is too great, it may stimulate a phase change from sagebrush dominated vegetation to steppe and will likely become unsuitable for sage-grouse. Even without fire in the system, climate change is highly likely to deteriorate current habitat, especially in the northern Great Basin. Preparation of new sites for sage grouse to occupy may be needed at slightly higher elevations where more woody cover may be available.

#### *Sage-grouse response to disturbance impacts on habitat*

Forest Service researchers have extensive experience in evaluating effects of landscape change and land management actions on wildlife species, including sage-grouse, through direct

evaluations of movement patterns, and demographics and resource selection models that are applied to evaluate various types of disturbance. This expertise is particularly relevant in the evaluation of land disturbance from invasive species, fires, or anthropogenic development (e.g., energy developments, roads, power lines), and stems from a long history of integrating wildlife populations with vegetation patterns and how changes to the vegetation influence wildlife populations. A key example was the Forest Service-led evaluation of factors associated with extirpation of sage-grouse by Wisdom et al. (2011). In this evaluation, the authors identified a wide variety of anthropogenic and vegetation factors that were strongly associated with extirpation of the species. Their results are being used for conservation planning across the range of the species on both public and private lands. Another example is wind energy. This energy source is projected to compose about 20% the U.S. energy demand by 2030 (U.S. Department of Energy 2008) and high quality wind resources coincide with the range of sage-grouse, particularly in the eastern portion of the range (Becker et al. 2009). Forest Service scientists have the expertise to evaluate effects of these developments on populations and habitat. Rowland (2004) identified and synthesized effects of a large suite of management activities on sage-grouse habitats and populations across the species range, including prescribed fire, livestock grazing, and land use change.

In a new study, degradation of sagebrush habitat during a drought year was observed using MODIS imagery (ForWarn, Hargrove et al., 2013). In the field, there was significant loss of leaves and branches from decadent old sagebrush at this south central Oregon site which was experiencing a single year of severe drought (a 25% of average precipitation year). A dynamic vegetation model (MC1; Drapek et al., 2014) will be used to show expected end of century sagelands distribution and their productivity levels in the region (Grulke, Kim, and Lesko, *in prep*).

FS researchers also have a long history of evaluating gene flow of sensitive species and how gene flow is altered by changes in the landscape. Of particular value is using spatially explicit genetic data to test various hypotheses of how genes move across landscapes and how this movement will be impacted by disturbances (Manel et al. 2003; Cushman et al. 2006; Schwartz et al. 2009). Currently, FS researchers are analyzing thousands of feather samples from sage-grouse leks to evaluate gene flow and genetic continuity across the northern portion of the species range (See Landscape Analysis and Design subsection) ) and assess how stressors such as land conversion, energy development, and fire may impact movement.

#### *Assessments of Sage-grouse Vulnerability to Stressors*

Forest Service researchers have conducted numerous assessments of the vulnerability of wildlife species to stressors. Recent efforts have focused on assessing the vulnerability of sage-grouse and their habitat to the effects of climate change and natural and anthropogenic factors in the Intermountain Region (Balzotti *in prep*). A key example is the Forest Service assessment of habitat threats in the Great Basin, which included a broad-scale evaluation of the risks of sagebrush loss from pinyon-juniper and cheatgrass invasions (Wisdom et al. 2005, Rowland et al. 2010b). This assessment included a detailed evaluation of the risks of future loss of sage-grouse habitats posed by invasive plant species. Contemporary and projected future conditions are evaluated from the context of past distribution patterns reconstructed from paleo and historic data. Specific objectives include: 1) describing pre-Euroamerican settlement sagebrush

distribution and changes over the last several millennia, 2) providing climate and sagebrush ecological niche models and their implications for sage-grouse habitat occupancy and use, 3) identifying natural and anthropogenic causes for sagebrush degradation and loss, with emphasis on those associated with wildfire, invasive species and conifer expansion on NFS lands, 4) identifying those habitats that are at greatest risk for loss and disruption of sage-grouse population connectivity, and 5) providing management options, including identifying and prioritizing those areas where sagebrush restoration efforts that could best conserve habitats and connectivity of sage-grouse habitats.

## **Landscape Analysis and Design**

FS R&D has been instrumental in studying changes in sage-grouse and the landscapes they inhabit. Fragmentation of the species' preferred habitat and effects of this fragmentation on sage-grouse themselves have made these studies paramount. This research spans multiple scales and uses multiple approaches, from experiments to species distribution modeling to landscape genetic approaches. Recent analyses also are addressing the influence of climate change on these systems and the implications for connectivity of habitats important to sage-grouse.

### *Landscape connectivity and corridors*

A variety of natural and anthropogenic disturbances have fragmented sage-grouse habitats, including removal of sagebrush through prescribed fire and mechanical means, natural fire, energy development and mining, exurban development, agricultural development, and road and powerline corridors. These disturbances must also be viewed in light of a changing climate. Forest Service scientists have evaluated broad-scale fragmentation in sagebrush ecosystems through several projects. As part of the Interior Columbia Basin Ecosystem Management Project, Hann et al. (2003) developed a spatially explicit disturbance departure and fragmentation index across the Basin. They found high levels of departure and fragmentation in low elevation rangelands. Other ICBEMP analyses included evaluations by Hemstrom et al. (2002) and Wisdom et al. (2002 *a,b*) who projected future trajectories and effects of land management on "habitat outcomes" and "population outcomes" that indexed the persistence of sage-grouse habitats and populations in the Interior Columbia Basin. These evaluations included consideration of landscape configurations related to landscape connectivity, as measured by habitat size, arrangement, and fragmentation. In the Great Basin ecoregion, Wisdom et al. (2005) evaluated risk of cheatgrass encroachment for habitats of several species groups, including sagebrush-associated species such as Greater Sage-Grouse. Their composite risk map can be used to depict habitat connectivity by highlighting watersheds in the Great Basin with low risk and relatively high habitat abundance. In an additional analysis, Rowland and Wisdom (2009) identified habitat networks in the Great Basin for sagebrush-dependent vertebrate species, including sage-grouse, based on sagebrush habitat area and configurations.

Wisdom et al. (2011) evaluated environmental conditions in areas of former range (extirpated range) and areas still occupied (occupied range) by Greater Sage-Grouse and Gunnison Sage-Grouse. They considered a wide variety of landscape metrics of landscape connectivity, including multiple measures of habitat fragmentation, core size, patch size, edge area, roads, and transmission lines, all of which are part of, or directly influence, measures of landscape connectivity. In addition, they identified habitat "strongholds" for sage-grouse persistence based

on characteristics of landscape connectivity and isolation, which depicted de facto corridors. These Forest Service-led evaluations have been widely used in conservation planning by public and private land managers across the range of sage-grouse.

Estimating potential occupied area of a species and the factors that affect their distribution has become a useful tool in ecological research and management. Like any model, bioclimate models require assumptions and appropriate interpretation (Pearson and Dawson, 2003; Soberon and Nakamura, 2009). Many of the analytical tools (Crookston and Rehfeldt 2008, Iverson et al. 2008) and data (USDA Forest Service, Forest Inventory and Analysis) used to create bioclimate models have been developed by FS R&D. Three bioclimate models of sagebrush have been developed. Two of these models have used land cover imagery to assess the threats from cheatgrass and disturbance (Bradley 2010) and evaluate the effects ecohydrology on sagebrush occurrence (Schlaepfer et al. 2012). Recently, Still and Richardson (2015) used presence and absence data of Wyoming big sagebrush to develop a subspecies model. Data from these bioclimate models can be used in connectivity planning.

As the climate gets warmer, quality sage grouse habitat may potentially shrink in total area and move up slope increasing the importance of the FS-managed portion of existing habitat which tends to be at higher elevations and more mesic sites. To plan for this possibility, Balzotti et al. (*in prep*) modeled and analyzed climate patterns at regional and sub-regional scales and evaluated potential changes in sagebrush and pinyon-juniper communities on national forests in Utah and Nevada as a result of climate change. When overlaid with the distribution of sage-grouse habitats, the model allows managers to evaluate those areas where conservation may have the greatest benefit for retaining population recovery.

#### *Assessment of sage-grouse gene flow and connectivity*

The FS has a long history of evaluating gene flow of sensitive species and how gene flow is altered by changes in the landscape. Of particular value is using spatially explicit genetic data to test various hypotheses of how genes move through the environment and how this movement will be impacted by disturbances (Manel et al. 2003; Schwartz et al. 2009). The discipline that explores how genes move through the environment is called landscape genetics and was developed and advanced by FS researchers (Schwartz 2001; Manel et al. 2003; Cushman et al. 2006). Currently, FS researchers are analyzing thousands of feather samples from sage-grouse leks and tissue samples from research sites to evaluate gene flow across the northern portion of the species range.

Cross et al. (*in prep*) analyzed 16 locus microsatellite genotypes from 2,108 Greater Sage-Grouse from 508 spatially distinct locations ranging across Montana, North Dakota and South Dakota. Spatial principal components analysis and hierarchical Bayesian clustering analysis were used to identify population substructure and the features that led to such substructure. Subpopulation structure aligned closely with ecologically distinctive areas of the landscape created by historical biogeographic processes, suggesting that that contemporary Greater Sage-Grouse fine-scale genetic population structure is shaped by the underlying physiography of the landscape.

Ongoing work is exploring how disturbances, including subdivision, agricultural tillage, sagebrush fragmentation, energy development, and invasive species (Braun 1998; Knick et al. 2003; Naugle et al. 2004; Naugle et al. 2006; Copeland et al. 2009; Naugle 2011; Naugle et al. 2011) affect gene flow across multiple scales. At the smaller scale Cross et al. (*in prep*) is exploring how these potential disturbances influence movement among Core Breeding Areas in Montana. However, a larger collaboration with USGS scientists is asking a similar question across the entire distribution of the species (Hank et al. in review, Oyler-McCance et al. *in prep*, Cross et al. *in prep*).

Finally, new approaches applying graph theory are being used in conjunction with our multi-scale sage-grouse genetics work to explore the impacts of degradation or loss of individual leks to the overall connectivity of the system. This approach should allow managers in FS and other partner agencies the ability to explore the consequences and benefits of various management scenarios.

## **Methods, Models and Plant Materials to Restore Sagebrush Habitats**

Timely restoration of degraded sagebrush plant communities at landscape scales is essential for maintaining sage-grouse habitats. An understanding of factors that regulate plant community resilience to disturbance and resistance to invasion by annual grasses is essential for prioritizing restoration activities and selecting the most effective treatments. Treatments that reduce woody fuel loads, increase herbaceous perennials and decrease annual invasive abundance promote increases in resilience and resistance while restoring structure and function needed for sagebrush dependent wildlife (Brooks and Chambers 2011; Chambers et al. 2014a,b,c). While passive restoration measures such as changes in land use can be effective in improving ecological condition in many cases, these measures alone will not be sufficient to meet the growing restoration needs in the face of (1) altered fire regimes including large high-severity fires, (2) current and projected rates of spread and dominance by trees and exotic annuals, (3) existing poor condition of herbaceous vegetation in many areas and (4) projected increased stress due to climate change. FS researchers and collaborators are instrumental in developing effective restoration approaches and treatments for sagebrush ecosystems. These focus on active restoration methods such as vegetation management to reduce fuels and remove encroached trees, control of exotic annual grasses, and seeding to reestablish native, perennial vegetation in areas where it is depleted.

### *Sagebrush genetic and taxonomic complexity*

Restoration of sagebrush ecosystems is complicated by the taxonomic and genetic variability of sagebrushes. FS research on big sagebrush (*Artemisia tridentata*) has shown that three widespread subspecies (*A. tridentata* var. *tridentata*, *wyomingensis* and *vaseyana*) are genetically distinct (Richardson et al. 2012) and adapted to different habitats (McArthur and Welch, 1982; McArthur et al., 1988; Wang et al., 1997). Correct subspecies identification and use of source plant materials (seed or transplants) is critical for successful sagebrush restoration. Past efforts to identify and match seed sources to planting sites have been hampered by a lack of reliable tests of seed-lot identity. Of particular importance to sage-grouse habitat restoration is proper identification of Wyoming big sagebrush, which is the predominant subspecies seeded following

large wildland fires. Ongoing FS and collaborative research is evaluating promising techniques and technology that could be developed for use by the commercial seed industry to certify seed at the subspecies level.

#### *Adaptive genetic variation and seed transfer guidelines*

Climate is a principal factor affecting adaptation within a plant species. Knowledge of how plants are climatically adapted is fundamentally important to the process of seed collection and transfer to restoration sites. Seed collection should be focused on regions that are most likely to be threatened by disturbance so that restoration can proceed with seed that is appropriately adapted. The research approach to elucidate climatic adaptation is well established with the earliest work reported in the 1920's (Turesson 1925). A large body of research followed with a primary focus on tree species. Over the last decade, FS researchers have begun to apply this approach to native grasses, forbs and shrubs (Bradley St Clair et al. 2013; Johnson et al. 2013; Richardson et al. 2014), a number of which are important species in sage-grouse related plant communities. Genecological research has been used to determine areas where plant species are under threat from climate change and to identify promising seed sources for use in changed climates (Kilkenny 2015). The Western Wildland Environmental Threat Assessment Center managed by FS has a comprehensive seed zone website where seed zones are displayed ([http://www.wwetac.net/index\\_files/seedzone.shtml](http://www.wwetac.net/index_files/seedzone.shtml)). Preliminary work for understanding the adaptive genetic variation in big sagebrush ecosystems is available (Richardson et al. 2013). Along with the body of literature discussed above there is additional research that has addressed other genetic characteristics of sagebrush species (Meyer 1994; Miglia et al. 2007; Smith et al. 2002; Welch and McArthur 1981).

#### *Native plant development – seed and seedling biology and plant propagation*

Active restoration of sagebrush communities generally includes planting seeds and seedlings of native plants. Availability of adequately adapted seed sources of forbs, shrubs and many grasses is limited, creating a bottleneck to large-scale restoration (Roundy et al. 1997). Knowledge of life-history traits is necessary to add new species to the restoration menu (Kitchen 1994; Shaw and Jensen 2014). FS scientists and collaborators have investigated seed dormancy and germination regulation ((Meyer and Monsen 1991; Meyer 1994; Meyer and Kitchen 1994a,b; Meyer et al. 1995; Scholten et al. 2009; Bonner and Karrfalt 2008), seedling emergence and growth (Kitchen 1995; Kitchen and Monsen 1994; Chambers and Linnerooth 2001; Chambers 2002; Shock et al. 2012, 2015), seed dispersal mechanisms, pollination strategies (Cane 2008) and fecundity and plant longevity (Kitchen 1995; Bradley St. Clair et al. 2013; Shock et al. 2015) for numerous species native to sagebrush ecosystems. Specialized equipment and cultural practices are being developed to improve seed yields for species grown in agronomic settings (Shock et al. 2013; Shock et al. 2014, 2015) and managed wildland stands. Scientists have developed standardized seed testing protocols and storage practices needed to stabilize markets and ensure seed quality for many native species (Kitchen 2001; Karrfalt and Shaw 2013). Guidelines for proper collection and certification of seed from natural stands are available (Currans et al. 1997; Young et al. 1995; Adair et al. 2006). Researchers with collaborators continue to investigate species-specific functional traits and to develop cultural practices needed to increase the availability and quality of seed needed for sagebrush ecosystem restoration (Shaw et al. 2012).

### *Restoration methods – practices and equipment for weed control and seeding*

Active restoration of arid and semi-arid sagebrush ecosystems that lack the necessary perennial plants for unassisted recovery is particularly challenging because of low, and highly variable, precipitation, episodic plant establishment and widespread invasion by exotic weeds. FS researchers and collaborators have a rich history of developing the necessary plant establishment methods for restoring sagebrush and its communities and have produced many hundreds of publications on the subject (see Great Basin Native Plant Project (GBNPP)<sup>1</sup>; Monsen et al. 2004a,b; Kiehl et al. 2014). FS research leadership of the Shrubland Research Consortium has kept researchers and practitioners up-to-date on current restoration topics and approaches through biennial symposia and publication of 16 symposia proceedings (1983-2011). Recent plant materials research conducted by GBNPP and others focuses on developing seed zones where plant materials can be transferred with little risk of being poorly adapted to their new location, increasing seed availability, understanding native plant response to climate change, and evaluating native plant interactions with invasive species. Restoration methods research is broadly focused and includes topics such as the use of chaining and drilling to establish native species following fire (Thompson et al. 2006); effectiveness of different types of drills for establishing native mixes containing seeds of different sizes (Taylor et al. 2014, Ott et al. *in prep*); species compatibility and invasion resistance within restored communities (Parkinson et al. 2013, Allen and Meyer 2014); and use of carbon addition and repeated burning to decrease soil nitrogen availability and invasive annual grass (cheatgrass) establishment and reproduction (Mazzola et al. 2008, 2010; Jones et al. 2015, *in process*). Use of seedlings for re-establishing difficult-to-seed species such as sagebrush is increasing (McAdoo et al. 2013).

### *Responding to threats: Loss of habitat through invasive plants, fire, and other stressors and disturbances*

FS researchers and collaborators developed and tested many of the vegetation management treatments currently used to reduce woody fuels and increase native perennial vegetation in sagebrush ecosystems (see Monson et al. 2004). Recent research uses syntheses and regional studies to develop basic information and conceptual models on resilience and resistance of these systems to better target management actions (Chambers et al. 2007; McIver et al. 2010; Brooks and Chambers 2011; Miller et al. 2013; Chambers et al. 2014a,b,c). The Sagebrush Treatment Evaluation Project ([www.SageSTEP.org](http://www.SageSTEP.org)) provides regional information on resilience and resistance of (1) sagebrush ecosystems exhibiting cheatgrass invasion to prescribed fire, mowing, and herbicide treatments (Pyke et al. 2014; Rau et al. 2014), and (2) those exhibiting pinon and/or juniper expansion to prescribed fire, cut-and-leave, and mastication (shredding) treatments (Miller et al. 2014a; Roundy et al. 2014a,b). An interdisciplinary framework is used to couple environmental indicators of resilience and resistance with sage-grouse habitat requirements to prioritize management actions on the landscape (Chambers et al. 2014b). Field guides are being developed that use resilience and resistance concepts to select appropriate sites for treatment and determine the most effective treatments (Miller et al. 2014b, 2015 *in press*).

New work by Kitchen et al. (*in prep*) portrays the influences of climate change in the distribution and abundance of sagebrush communities over the last several millennia, and the implications of climate change on the future. This is intended to provide a valuable backdrop to the

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<sup>1</sup> [www.fs.fed.us/rm/boise/research/shrub/greatbasin.shtml](http://www.fs.fed.us/rm/boise/research/shrub/greatbasin.shtml)

environmental envelope of sagebrush communities, and offers insight to areas where restoration may be most beneficial. Balzotti et al. (*in prep*) has developed climate envelopes for sagebrush, pinon-juniper and invasive species, and models potential changes in the communities as a result of climate change. When coupled with anthropogenic landscape changes, this work offers a portrayal of current and future conservation and restoration opportunities relative to these stressors.

#### *Monitoring effectiveness of restoration treatments*

Understanding the effectiveness of restoration treatments is the basis for adjusting methodology to increase restoration success. FS researchers and collaborators have evaluated restoration treatment effectiveness across the environmental gradients and ecological types that characterize sagebrush ecosystems. This includes (1) effectiveness of broadcast vs drill seeding, (2) success in establishing big sagebrush species, (3) tradeoffs between seeding aggressive introduced species and native species recovery, and (4) effects on invasive plant species (Knutson et al. 2014). It also has involved modeling the predicted probability of sage-grouse occupancy on treated sites based on sagebrush species and establishment, perennial grass cover, and invasive annual cover (Arkle et al. 2014).

#### *Conceptual models – linking habitat restoration to sage-grouse recovery*

Forest Service scientists led the development and implementation of a variety of ground-breaking conceptual models for sage-grouse habitat restoration and recovery as part of the Interior Columbia Basin Ecosystem Management Project (ICBEMP), and later in ecoregional assessments in the Great Basin and across the entire range of Greater Sage-Grouse. Conceptual models developed by FS scientists for sage-grouse restoration and recovery for application across the 58-million ha ICBEMP area include (1) novel state-and-transitions models for sagebrush to evaluate future sagebrush habitat trajectories (Hemstrom et al. 2002); (2) innovative Bayesian belief network models developed and applied by Wisdom et al. (2002a) for evaluating current and future sage-grouse habitats; (3) development of a new habitat network approach for sagebrush-dependent species, including sage-grouse, and demonstration of this conceptual model in restoration planning (Wisdom et al. 2002b); and (4) additional integration and synthesis of sage-grouse models for restoration planning (Wisdom et al. 2005a).

In the Great Basin, FS researchers developed two conceptual models for restoration and recovery of sage-grouse: (1) use of umbrella species concepts for managing sagebrush-dependent species, using sage-grouse requirements as a guide (Rowland et al. 2006), and (2) restoration modeling for sage-grouse (Wisdom and Chambers 2009). Rowland and Wisdom (2009) also developed and applied new habitat network approaches for sagebrush-dependent vertebrate species, including sage-grouse, in the Great Basin. Forest Service-led conceptual models for sage-grouse restoration and recovery across the range of the species include those by Wisdom et al. (2005b), which introduced novel modeling paradigms and management approaches for prioritizing landscape conservation and restoration of sage-grouse across its historical range.

Most recently, an interdisciplinary Western Association of Fish and Wildlife Agencies (WAFWA) working group has developed a strategic, multi-disciplinary approach to reduce impacts of invasive annual grasses and altered fire regimes on sagebrush ecosystems and sage-grouse that builds on this initial work (Chambers et al. 2014c). The approach uses information on factors that influence (1) sagebrush ecosystem resilience to disturbance and invasive annual

grasses (Wisdom and Chambers 2009, Brooks and Chambers 2011, Chambers et al. 2014a, b) and (2) distribution, relative abundance, and persistence of sage-grouse populations to develop management strategies at both landscape and site scales (Aldridge et al. 2008, Doherty et al. 2010, Wisdom et al. 2011, Knick et al. 2013). A sage-grouse habitat matrix links relative resilience and resistance of sagebrush ecosystems with sage-grouse habitat requirements for landscape cover of sagebrush to help decision makers assess risks and determine appropriate management strategies at landscape scales. Focal areas for management are assessed by overlaying matrix components with sage-grouse Priority Areas for Conservation (PACs), breeding bird densities, and specific habitat threats. Decision tools are discussed for determining the suitability of focal areas for treatment and the most appropriate management treatments. Management actions considered include fire operation (preparedness, prevention, and suppression), fuels management, post-fire rehabilitation, and restoration/recovery.

Understanding the role of climate change is an important factor in prioritizing restoration opportunities. Balzotti (*in prep*) has evaluated and modeled the implications of climate change on both regional and sub-regional scales, shifts in sagebrush and pinon-juniper communities, and provides recommendations for identifying areas where conservation is most needed to retain connectivity of sage-grouse habitats.

These many and varied conceptual models developed and applied by Forest Service scientists have been widely used in restoration planning for sage-grouse habitat at both landscape and site scales across the species range, and demonstrate a historical area of strength in Forest Service research on sage-grouse and sagebrush ecosystems.

## **Strategic Research Priorities and Goals**

This section describes Research Goals associated with of the four Strategic Priorities. These goals were identified by team members based on what kinds of research FS R&D scientists can begin to address given their current expertise, cooperators, existing facilities and locations, and stakeholder needs. Additional capacity such as increased numbers of scientists and resources (e.g., funds, technical support) are needed to address many of the goals. Capacity will also need to be replaced as scientists in strategic locations retire in the next few years.

An Action Table of ongoing and more immediate research actions is available on request. The Actions are framed as research, capacity-building and science delivery projects in process, planned, or proposed for funding by specific investigators, each accompanied by metrics, management applications, capacities, and estimated costs. These Actions are not meant to be all-encompassing but provide information on existing projects and recommendations for new research that will be most beneficial for conserving sage-grouse and sagebrush ecosystems in the next five years.

### **Priority 1. Evaluate Sage-grouse Population Ecology, Monitoring, and Habitat Linkages**

- Assess and monitor the contribution of NFS lands to sage-grouse population persistence
- Evaluate the effects of livestock grazing on vital rates of sage-grouse populations
- Determine the contributions of life history stages to sage-grouse population growth (e.g.,

nesting vs brood-rearing).

- Evaluate the impacts of disease and predation on sage grouse survival, nesting success, habitat use and population persistence
- Find cost effective surrogates to help monitor sage grouse populations.
- Determine how establishment of core areas, as identified by Conservation Reserve Program policy and state efforts affects sage-grouse population growth rates and nesting success
- Assess the impacts of restoration efforts such as juniper and pinyon or invasive species removal on sage-grouse growth rates and survival

## **Priority 2. Understand Disturbances and Stressors in Sagebrush Ecosystems**

- Identify factors that influence resistance of sagebrush ecosystems to medusahead grass (*Taeniatherum caput-medusae*), North African grass (*Ventenata dubia*), and other recent annual invaders
- Identify cover of perennial grasses and forbs required for sagebrush ecosystems to recover following disturbance that can resist annual invasive grasses
- Determine potential effects of a warming, drying climate on spread and contraction of invasive annual grasses, pinon and juniper species, sagebrush species, sagebrush communities and sage-grouse
- Assess effects of multiple fires on post-fire big sagebrush persistence and recovery and persistence and recovery of sage-grouse populations
- Assess impacts of past fire on future fire sizes, severity and spatial patterns in big sagebrush ecosystems
- Evaluate effects of livestock grazing on post-fire sagebrush ecosystem recovery and tree expansion rates
- Evaluate effects of livestock grazing on habitat occupancy, use and movement by sage- grouse
- Assess effects of tree expansion on shrub species (e.g. bitterbrush, *Purshia tridentata*) known to co-dominate with big sagebrush
- Assess effects of energy (e.g., wind, oil, gas) development and associated infrastructure (roads, pipelines) on sage-grouse habitats and populations and interpopulation movements
- Study effects of communication towers and associated roads on sage-grouse land use patterns.
- Determine effects of transmission power lines and other linear infrastructure, such as livestock fences, on habitats, dispersal (gene flow) and population dynamics of sage-grouse
- Evaluate effects of agriculture and suburban developments, within and adjacent to current sage-grouse range, on population persistence
- Project the effects of climate change on vegetation composition and fuels characteristics and how these changes will affect future fire regimes of big sagebrush habitats

## **Priority 3. Analyze and Design Landscapes**

- Evaluate the use of foundational species and core landscape elements as habitat indicators

for sage-grouse and sagebrush obligate species.

- Evaluate additional biophysical indicators of ecosystem resilience and resistance that can be used to prioritize management activities and select appropriate management actions.
- Determine functional genetic variants that are identified to be under selection and assess how these vary in the different sage-grouse DPSs (e.g., subspecies) and among different core areas.
- Understand the relative contributions of environmental, demographic, and genetic effects on the decline of sage-grouse at the periphery of their range where populations are declining.
- Assess how fire management and other land management and restoration activities influence the movement of sage-grouse among core breeding areas.
- Evaluate potential changes in sage-grouse habitat connectivity and fragmentation under a variety of climate change scenarios
- Conduct a spatial analysis of contributions by landowner to core sage-grouse habitats, to better understand management limitations and opportunities
- Conduct large-scale analyses of overlaps in sage-grouse populations with those of other sage-dependent wildlife to better understand the species' role as an "umbrella" species
- Evaluate the individual and cumulative effects of all human activities and land uses on resistance and resilience of sage-grouse habitats at ecoregional scales

#### **Priority 4. Develop Methods, Models and Plant Materials to Restore Sagebrush Habitat**

- Identify the climate envelope for sagebrush, pinon-juniper, and annual invasive communities and model their current and potential future distributions.
- Corroborate sage-grouse habitats with those areas that will potentially be most affected by climate change to identify those areas where conservation and restoration will have the greatest benefits
- Develop protocols for incorporating climate change analyses into landscape assessments.
- Create high resolution models of resilience to disturbance and resistance to invasive annual grasses that include climate, soils, and vegetation
- Determine successful restoration approaches for recovering sage-grouse habitat and encouraging colonization by sage-grouse
- Design and test restoration approaches and alternatives for warmer and drier sagebrush ecosystems with low resilience and resistance
- Design and test restoration approaches and alternatives for pinon and juniper communities that pose the greatest threats to loss of sage-grouse habitats
- Develop knowledge of the effects of livestock grazing (timing, amount, and duration) on restoration outcomes
- Develop additional information on treatment effectiveness based on regional data and repeated monitoring over time
- Develop information on treatment effectiveness based on new analytical approaches such as meta-data analyses
- Understand climatic adaptation and develop seed transfer zones in big and dwarf sagebrushes

## **Facilities, Centers, and Projects Having Key Locations, Contacts and Expertise**

FS R&D has several facilities located in close proximity to sagebrush ecosystems and sage-grouse populations and staffed by scientists and personnel with the history and expertise to conduct continuing and new research and science delivery for the benefit of sage-grouse and sagebrush conservation. Capacity and resources will decline in the next few years as well-known scientists in key facilities retire. Some relevant facilities may close owing to declining availability of resources. Workforce planning efforts, capacity-building and additional funding targeted at key locations will be needed to renew capacity and resources.

Facilities with past or current studies and expertise on sagebrush and sage-grouse include:

- Grassland, Shrubland and Desert Ecosystems Science Program, Albuquerque, NM, RMRS. Contact: Dr. Deborah Finch.
- Great Basin Ecology Laboratory, RMRS, Reno, NV. Contact: Dr. Jeanne Chambers.
- Great Basin Native Plant Project, RMRS, Boise, ID. Contact: Dr. Francis Kilkenny.
- LaGrande Forestry and Range Sciences Laboratory, PNW, LaGrande, OR. Contacts: Mary Rowland, Dr. Michael Wisdom.
- Missoula Fire Sciences Laboratory, RMRS, Missoula, MT. Contact: Dr. Colin Hardy.
- National Genomics Center for Wildlife and Fish Conservation, RMRS. Missoula, MT. Contact: Dr. Michael Schwartz.
- National Reforestation, Nurseries and Genetics Resources Program (RNGR) Science, Moscow, ID. Contacts: Dr. Kasten Dumroese, Dr. Jeremy Pinto.
- Rapid City Forest and Grassland Research Laboratory, Rapid City, SD. Contact: Dr. Mark Rumble.
- Shrub Sciences Laboratory, RMRS, Provo, UT. Contacts: Dr. Stanley Kitchen, Dr. Susan Meyer, Dr. Bryce Richardson, Dr. Steven Warren.
- Western Wildland Environmental Threats Assessment Center, PNW, Prineville, OR. Contact: Dr. Nancy Grulke.
- Wildlife and Terrestrial Ecosystems Program, RMRS, Flagstaff, AZ and Missoula, MT. Contact: Dr. William Block

## **Science and Communication to Aid Management Decisions on NFS Lands**

National Forests and Grasslands across the western U.S. support key habitats for sage-grouse, especially higher elevation brood-rearing habitats in mountain big sagebrush communities. As the Forest Service and Bureau of Land Management work to evaluate sage-grouse conservation measures in their land use plans prior to the listing decisions for the Greater Sage-Grouse, and the bi-state Distinct Population Segment of Greater Sage-Grouse by the U.S. Fish and Wildlife Service, it is important to understand the kinds of knowledge and tools that Forest Service land managers need to address sage-grouse and sagebrush conservation. It is equally

important to identify the knowledge gaps to improve or establish conservation measures that are informed by the best available science.

#### *Questionnaire to Determine Knowledge Needs and Gaps*

In May 2013, a working group tasked with addressing Forest Service issues related to sage-grouse and sagebrush management initiated an internal questionnaire to identify information needs for these components on National Forest System (NFS)-administered lands. The purpose of the questionnaire was to identify the kinds of information and tools needed by Forest Service land managers to address sage-grouse and sagebrush conservation, identify priorities and needs for new knowledge, and identify appropriate conservation measures that are informed by the best available science. The questionnaire was routed to Forest Service employees in the Washington Office, several regions (1, 2, 4, 5 and 6), 3 research stations (PNW, RMRS, and PSW), and all National Forests that potentially manage sage-grouse and their habitats. The working group targeted an array of resource management disciplines and employees working at all levels of the organization.

The questionnaire asked participants to respond to 37 questions in the following categories: 1) system dynamics of sagebrush communities on NFS lands; 2) contribution of sagebrush communities on NFS lands in supporting broader species/system conservation; 3) Greater Sage-Grouse; 4) habitat management and restoration; and 5) conservation guidance for sage-grouse. Results of the survey will inform those involved in developing Environmental Impact Statement's (EIS's) and help in decision-making regarding National Forest Management Act (NFMA) compliance and sage-grouse and sagebrush management.

#### *Results of Sage-grouse/Sagebrush Questionnaire*

Key results of the questionnaire based on statistical analysis can be summarized into 5 primary areas (see Appendix): (1) System dynamics of sagebrush communities on NFS lands, (2) Contribution of sagebrush communities on NFS lands in supporting broader species/system conservation, (3) Greater Sage-Grouse, (4) Habitat management and restoration, and (5) Conservation guidance for sage-grouse. Respondents agreed that understanding sagebrush community dynamics and ecological relationships, especially for high-elevation mountain big sagebrush, was important, but disagreed about how much is known about effects of management on sagebrush restoration and whether sagebrush will be able to re-establish naturally as climate changes. They agreed that more attention should be given to managing sagebrush plant and animal communities on NFS lands and that knowledge of disturbance processes on sagebrush landscape patterns was needed. Respondents thought that more knowledge was needed about the contributions of NFS lands and habitats to sage-grouse population health and persistence. There was strong agreement that research and monitoring were needed to assess the effects of disturbances, including those from land management, and the effectiveness of habitat restoration on sage-grouse and sagebrush ecosystems. Syntheses of research findings that provided guidance to managers were viewed positively. Opinions varied about the sufficiency of information to address threats and risks to sage-grouse habitats and whether sage-grouse are an appropriate surrogate for monitoring other species.

#### *Identifying new areas of FS research and science delivery to meet management needs*

Results of the questionnaire demonstrate that many new avenues of research can be initiated to meet the needs identified by National Forest System managers. Several of these needs

corroborate those identified under “Future research needs” in section 2 on strengths and leadership of the FS Research and Development branch. Additional needs and gaps in information identified by survey respondents can be addressed through collaborative projects with NFS employees, and via consultations, syntheses, tool development, assessments and science delivery and communication mechanisms.

#### *Role of syntheses, decision support tools and assessments*

FS R&D scientists are well-known for developing syntheses of existing literature in order to support management needs and many examples are cited in the Literature section of the plan. These often take the form of Forest Service General Technical Reports and other agency serial publications but they can also be published by journals and in monograph series of professional societies. Syntheses are usually collaborative efforts involving numerous scientists and experts from within the Forest Service as well as from other institutions such as universities, other federal agency researchers, state and federal natural resources agencies, and non-governmental organizations. The need for a synthesis on a topic such as sage-grouse habitat restoration or landscape ecology is often requested by or aimed at the management community based on expressions of interest and need.

Decision support tools and assessments can take many different forms to help meet needs for management of sage-grouse, habitats and landscapes. Tools can include field guides and publications that identify models, methods, GIS maps, and approaches to address questions about sage-grouse biology, disturbances, landscapes and restoration. Tools can also be instruments, devices, models, methods, maps, databases and approaches that are available directly to practitioners who access them online, by video or through consultations, lectures, presentations, and training sessions. Tools are typically developed to meet a management or science application need and are designed to eliminate the necessity of designing new techniques for routine management projects. Routine tools are also often used to test hypotheses where the question is not about the tool type but rather about how new findings can be revealed using the tool. Typical tools are those that solve problems, provide outcomes, generate maps, enable consistency in inventory and monitoring, count populations, model future projected changes in land cover, climate and disturbances such as likelihood of fire or invasions. The results of assessments are often considered to be tools.

An assessment is an evaluation or estimation of the nature, quality, quantity or response of organisms, habitats, landscapes, communities, and stressors and disturbances at any given time or space or over a period of time and space. Assessments associated with sage-grouse may focus on their populations in an area as small as a forest or as large as their entire range, or they may address the amount of occupied habitat or availability of habitat with potential for occupancy, or they may evaluate the effects of changes on habitat or grouse populations from stressors such as fire, invasive species, grazing, or climate change.

#### *Enhance science delivery and communication – what more can be done*

Modern communication tools have enhanced the delivery of science enormously over the last 20 years. In addition to traditional methods for delivering science findings such as meeting presentations, posters and lectures, more and more managers and scientists are using vehicles such as webinars, videoconferences, websites, social media, and interactive databases to access

information. Online newsletters have replaced printed newsletters and journal publications are often “online early” in addition to print copies, and many are going or starting up as “online only”.

Conferences, workshops, special sessions at professional society meetings, and training sessions are excellent interactive modes for communicating new science findings, establishing researcher and manager connections, discovering new techniques and learning new knowledge. Libraries now make articles available online and articles are now accessed using easily using online search tools such as Google. Online chat sessions are available on many subjects and literature resource services can be easily found on the web.

A productive way for managers to engage scientists in communication is when they are in the early stages of planning management projects such as a habitat restoration project or during forest plan revisions. Another approach to ensure communication and use of science results is for scientists to involve managers during the proposal and implementation phases of science studies and assessments through collaborations on shared goals and with shared funding.

## **How this Strategy Complements Other Science Strategies and Conservation Planning Efforts**

This Forest Service Science Strategy identifies specific and in many ways unique niches relative to other science strategies including the following:

- 1) Application of Landscape Analyses to Planning.
- 2) Genomics for Conserving Plant and Animal Populations.
- 3) Effects, Prevention and Control of Fire and Invasive Species.
- 4) Restoration Science and Applications.
- 5) Seed and Plant Materials Development Sciences
- 6) Application of Resilience and Resistance Concepts.
- 7) Climate Change Adaptation Science and Models.
- 8) Effectiveness Monitoring and Adaptive Management.

For each, FS R&D provides unique services or products to partners needing the information.

### **Relevant oversight committees, science strategies, and conservation and management plans**

The following descriptions summarize some of the many oversight committees, science strategies, conservation plans and management plans aimed at conserving sage-grouse and their habitats. This review is not meant to be exhaustive.

*Western Association of Fish and Wildlife Agencies (WAFWA) Sage-grouse Executive Oversight Committee*

Western state and provincial wildlife agencies have the authority for managing populations of Greater and Gunnison sage-grouse. The Sage Grouse Executive Oversight Committee of WAFWA facilitates communications among State and federal agencies responsible for the management of sage grouse and sage grouse habitat. WAWFA instituted a *Range-wide Interagency Sage-Grouse Conservation Team (RISCT)* for the application of the best available science to meet their primary responsibility which is the technical implementation of the 2006 Greater Sage-Grouse Comprehensive Conservation Strategy. The Rangewide Interagency Sage-Grouse Conservation Team (RISCT) includes an FS R&D member. This team was developed under the 2008 MOU between federal agencies and WAFWA to further the conservation sage-grouse and their habitats.

### *Sage Grouse Task Force*

<http://www.westgov.org/initiatives/wildlife/411-sage-grouse>

The group includes designees from the 11 western states as well as representatives from BLM, USFWS, NRCS and USFS, commissioned by the Secretary of Interior. The purpose is to identify and implement high priority conservation actions and integrate ongoing actions necessary to preclude the need for the sage grouse to be listed under the Endangered Species Act in 2015. An annual report provides information on existing state and local actions to conserve sage-grouse.

- FS R&D information will be useful to this Task Force and efforts to deliver FS R&D science are recommended.

### *The Greater Sage-Grouse Comprehensive Conservation Strategy (2006)*

<http://www.wafwa.org/documents/pdf/GreaterSage-grouseConservationStrategy2006.pdf>

This interagency document provides the strategy to develop the associations among local, state, provincial, tribal, and federal agencies, non-governmental organizations, and individual citizens necessary to design and implement cooperative actions to support robust populations of sage-grouse and the landscapes and habitats upon which they depend. There are 7 primary components to the strategy, including: Conservation planning, monitoring the implementation of conservation actions, monitoring the effectiveness of conservation actions, adaptive management, research needs and technology, communication and outreach and funding.

- FS R&D regularly provides updates to the Sage Grouse Executive Oversight Committee and has a member on the *RISCT*. The most unique scientific arenas of FS R&D relevant to WAFWA's needs are: restoration, application of ecological principles, effectiveness monitoring, and climate change adaptation.

*US Fish and Wildlife Service: Greater Sage-grouse (Centrocercus urophasianus) Conservation Objectives: Final Report*

<http://www.fws.gov/mountain-prairie/species/birds/sagegrouse/COT/COT-Report-with-Dear-Interested-Reader-Letter.pdf>

The USFWS provided a conservation framework that consisted of (1) identifying sage-grouse population and habitat status and threats, (2) defining a broad conservation goal, (3) identifying priority areas for conservation, and (4) developing specific conservation objectives and measures. They identified 14 major threats to sage grouse: Fire, Non-native, Invasive Plant Species, Energy Development, Sagebrush Removal, Grazing, Range Management Structures, Free-Roaming Equid Management, Pinyon-juniper Expansion, Agricultural Conversion, Mining, Recreation, Ex-Urban Development, Fences.

- FS R&D science can best support the conservation objectives in this report that are tied to fire, invasive plants (native and non-native), and energy development.

*Natural Resources Conservation Service (NRCS): Sage-Grouse Initiative (SGI)*

<http://www.sagegrouseinitiative.com/>

The Sage-Grouse Initiative (SGI), launched in 2010 by the NRCS, is a pro-active program strategically harnessing Farm Bill programs to address conservation on private lands for sage-grouse. To date, SGI is focused on improving grazing systems, removing encroaching conifers, and adding conservation easements, as well as working to improve our scientific knowledge of threats and their amelioration. SGI uses NRCS programs to strategically focuses budgets and partner matches to provide assistance to private landowners through existing programs, and new positions to assist in on-the-ground efforts. The goal of SGI is to shore up the best private land habitat for sage-grouse by helping landowners make improvements and remain as viable operations within the sagebrush landscape.

- SGI is utilizing the work we produced on the application of ecological principles; resistance and resilience, to prioritize areas for their conifer removal projects.

*Bi-State (CA and NV) Distinct Population Segment Environmental Impact Statement and Management Plan*

<https://www.federalregister.gov/articles/2013/11/01/2013-26261/notice-of-availability-of-the-nevada-and-northeastern-california-greater-sage-grouse-draft-land-use>

The FS and BLM Plan amendments update management direction to conserve, enhance, and restore habitat for the sage-grouse. The objectives focus on land management actions to restore habitats impacted by fire and invasive species. NRCS and National Forest Systems will lead the restoration effort.

- FS R&D scientists are working to ensure that resilience and resistance concepts are integrated into planning and implementation. Restoration science and effectiveness monitoring and adaptive management science contributions could also be useful.

### *Great Basin and Rocky Mountain BLM and FS Environmental Impact Statements*

The BLM and FS are jointly working to complete 15 Final Environmental Impact Statements (FEISs) and associated Records of Decisions (RODs). The Forest Service is a cooperating agency in six of these efforts. The FS and BLM Plan amendments will update Forest Plan management direction to conserve, enhance, and restore habitat for the sage-grouse based on the final EIS' that are currently in preparation. Direction will also be include on monitoring and adaptive management guidance to ensure management practices meet desired goals and objectives for sage-grouse habitat recovery.

### *USGS Greater Sage-Grouse National Research Strategy (Hanser and Manier 2013)*

USGS convened an interagency team to identify key research issues pertaining to Greater Sage-Grouse. The Forest Service participated in the review and prioritization of these topics. The approach used a framework that focused on three primary research areas: 1) Increasing knowledge of sage-grouse biology to inform adaptive management of populations in a complex and changing environment, 2) Understanding the components of sage-grouse habitat and sagebrush ecosystems, and identify effective management practices to improve habitat conditions, and 3) Identifying factors (change agents) that affect sage-grouse populations and their habitats, and identify management practices that ameliorate negative effects. Research topics were developed, assessed and prioritized, as related to these themes.

### *Use of the Fire and Invasives Species Assessment Team (FIAT) Report Greater Sage-Grouse Wildfire, Invasive Annual Grasses & Conifer Expansion Assessment (2014)*

In 2014, an interagency team was conscripted to prioritize conservation and management guidance to reduce threats of invasive annual species, wildfire and conifer encroachment into those habitats considered most important to the Great Basin Greater Sage-Grouse metapopulation. The primary focus areas for the FIAT analysis were the Priority Areas for Conservation (PACs) documented in the Conservation Objectives Team Report (COT) (USFWS 2013). Forest Service research was involved in the development of the analysis tools used in this process.

## **Summary**

FS scientists are contributing to the restoration of sage-grouse habitat and providing specific recommendations for future conservation and management efforts. Immediate research efforts are needed to establish a scientific foundation for effective management responses that minimize threats

stemming from fire and invasive species, and for restoring functioning sagebrush ecosystems in the western portion of the range and for minimizing threats from energy development in the eastern portion of the range. Given that for more than 30 years FS R&D has been studying sagebrush ecosystem dynamics as well as mechanisms to manage for resilient and resistant sagebrush ecosystems, it is logical for FS R&D to play a relevant role in sage-grouse conservation. When this is combined with our sage-grouse genetics, biology, and ecology research along with that of other agencies, FS R&D's expertise will be key to any efforts for making progress on sage-grouse habitat management, with the goal to serve the needs of managers striving to retain, regain, or return sage-grouse and sage-grouse habitat to sustainable conditions.

Given FS science capacity, germane publications, research facilities and strategic locations, and the importance of National Forest System lands for breeding and brood-rearing habitats for sage-grouse, we recommend that research and science delivery by the Forest Service be continued and expanded, and capacity retained and improved in response to widespread concerns and calls for science-based conservation to prevent further declines of sage-grouse populations and loss of sagebrush ecosystems throughout the western United States. Our strategic priorities and goals were developed by applying the unique strengths and areas of science leadership that FS R&D has to offer to the sage-grouse question, and an action plan with more specifics is available on request.

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## **Appendix**

### **Results of Sage-grouse/Sagebrush Questionnaire**

Respondents:

- 126 employees completed the questionnaire
- Most respondents were from middle management (GS9-GS13)
- Forest Service senior managers (GS14-GS15) accounted for 12% of respondents
- Respondents represented a wide array of research and management disciplines
- Among disciplines, wildlife biologists were the dominant responders (40%)
- About 75% of the respondents were from NFS and 25% from FS R&D
- Nearly 30% of respondents work at the District level, vs. 21% at the Supervisor's Office level

#### Selected Key Findings by Subject Area:

##### *1) System dynamics of sagebrush communities on National Forest System (NFS) lands*

- Strong agreement that understanding system dynamics of sagebrush communities is important, including effects of climate change, conifer encroachment, invasive species, and wildfire.

- Better understanding of ecological relationships in high-elevation mountain big sagebrush communities is especially important.
- Respondents disagreed about how much is known about effects of management, including livestock grazing and fire, on sagebrush maintenance and restoration.
- Strong disagreement that sagebrush will be able to re-establish naturally under changing climate regimes.

## 2) *Contribution of sagebrush communities on NFS lands in supporting broader species/system conservation*

- Strong agreement that more attention be given to managing sagebrush plant and animal communities and identifying species found disproportionately on NFS lands.
- Strong agreement of importance of understanding disturbance processes on patterns of sagebrush on NFS lands.

## 3) *Greater Sage-Grouse*

- More knowledge is needed about: seasonal habitats of sage-grouse on NFS lands, effects of habitat management and restoration on sage-grouse, habitat connectivity for sage-grouse, and effects of energy development.
- Strong agreement of need to better understand 1) contribution of sage-grouse that utilize NFS lands to larger populations of this species, 2) contributions of seasonal habitats to overall species persistence, and 3) landscape and community characteristics where sage-grouse populations are robust.
- Disagreement among respondents that sage-grouse are an appropriate indicator of sagebrush community condition; however, respondents generally agreed that sage-grouse could be useful in assessments of other terrestrial species dependent on sagebrush habitats.
- Disagreement that seasonal habitats for sage-grouse on NFS lands are used disproportionately to those on other land ownerships.
- Strong disagreement that sage-grouse will be able to adapt to rapid climate change.

## 4) *Habitat management and restoration*

- Strongly agreed that new research is needed about effects of management on sagebrush systems, such as vegetation composition and structure, on NFS lands.
- Strongly agreed that monitoring was important to ascertain effectiveness of management, and that disturbances should be monitored to understand recovery timeframes.
- Agreed that research findings need to be synthesized to provide management guidance.
- Respondents strongly agreed that more information was needed on restoration of sagebrush communities, especially at the periphery of current sage-grouse range, and in systems invaded by non-native species.
- Disagreement about current understanding of effects of livestock grazing on sage-grouse habitats.

## 5) *Conservation guidance for sage-grouse*

- Most respondents disagreed that we have sufficient conservation guidance for sage-grouse and sagebrush systems in current Forest Plans, and thought that a synthesis of the literature would be useful in providing that guidance.
- Opinions varied about the sufficiency of information to address threats and risks to sage-grouse habitats and whether sage-grouse are an appropriate surrogate for monitoring other species.