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Summary of Science, Activities, Programs, and Policies That Influence the Rangewide Conservation of Greater Sage-Grouse (*Centrocercus urophasianus*)

Open-File Report 2013–1098

U.S. Department of the Interior
U.S. Geological Survey

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By D.J. Manier, D.J.A. Wood, Z.H. Bowen, R.M. Donovan, M.J. Holloran, L.M. Juliusson, K.S. Mayne, S.J. Oyler-McCance, F.R. Quamen, D.J. Saher, and A.J. Titolo

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U.S. Department of the Interior
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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square meter (m^2)	0.0002471	acre
hectare (ha)	2.471	acre
square kilometer (km^2)	247.1	acre
square centimeter (cm^2)	0.001076	square foot (ft^2)
square meter (m^2)	10.76	square foot (ft^2)
square centimeter (cm^2)	0.1550	square inch (ft^2)
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Mass	
gram (g)	0.03527	ounce (oz)
kilogram (kg)	2.205	pound (lb)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) using:
°F=(1.8×°C)+32

Horizontal coordination information (in map figures) is referenced to with World Geographic System (WGS 84) with an Albers Equal Area projection.

Acronyms and Initialisms Used in This Report

AFB	Air Force Base
AFMSS	Automated Fluid Minerals Support System BLM
AUM	animal unit month
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
CCP	Comprehensive Conservation Plan
CIRO	City of Rocks National Reserve
CRMO	Craters of the Moon National Monument and Preserve
CRP	Conservation Reserve Program
DOI	Department of Interior
DPS	distinct population segment
FAA	Federal Aviation Administration
FRA	Federal Railroad Administration
FY	fiscal year
GIS	geographic information system
GSGCCS	Greater Sage-Grouse Comprehensive Conservation Strategy
GSSP	Geospatial Services Strategic Plan (BLM)
HMA	herd management area
ICBEMP	Interior Columbia River Basin Ecosystem Management Project
ID	identification
INL	Idaho National Laboratory
ISR	in situ recovery
LUP	land use plan
LWG	local working group
MOU	Memorandum of Understanding
MSF	master summary file
mtDNA	mitochondrial DNA
MW	megawatt
MZ	management zone
NASECA	North American Sagebrush Ecosystem Conservation Act (proposed)
NIFC	National Interagency Fire Center
NLCS	National Landscape Conservation System
NRCS	Natural Resources Conservation Service
NREL	National Renewable Energy Laboratory

OHV	off-highway vehicle
PEIS	Programmatic Environmental Impact Statement
PGH	preliminary general habitat
PPH	preliminary priority habitat
SAFE	State Acres For Wildlife Enhancement
SGI	Sage-Grouse Initiative
SMA	surface management agency
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
WAFWA	Western Association of Fish and Wildlife Agencies
WNv	West Nile virus

Summary of Science, Activities, Programs, and Policies That Influence the Rangewide Conservation of Greater Sage-Grouse (*Centrocercus urophasianus*)

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Executive Summary

The sagebrush biome, including sagebrush-steppe and Great Basin sagebrush communities, interspersed with grasslands, salt flats, badlands, mountain ranges, springs, intermittent creeks and washes, and major river systems, is one of the most widespread and enigmatic components of Western U.S. landscapes. One of its most charismatic species, the Greater Sage-Grouse, has been observed, hunted, and counted for decades. Habitat conversion, degradation, and fragmentation have accumulated across the entire range such that local conditions as well as habitat distributions at local and regional scales are negatively affecting the long-term persistence of this species. Historic patterns of human use and settlement of the sagebrush ecosystem have contributed to the current condition and status of sage-grouse populations. The current framework of multiple use (including industrial, agricultural, recreation, and other activities) has been imposed over a system that never fully recovered from the intense use prior to the Taylor Grazing Act (1934). Repurposing of the most productive sagebrush ecosystems (regions with deep, loamy soils, for example) for agriculture and urban development means that sage-grouse have already been marginalized on lands they share with domestic livestock, industry, herds of introduced horses and burros, and other sagebrush inhabitants. But in spite of the accumulation of odds against them, many small and large sage-grouse populations persist across the range, albeit population counts have steadily declined in past decades.

The accumulation of habitat loss, persistent habitat degradation, and fragmentation and perforation by industry and urban infrastructure, as indicated by U.S. Fish and Wildlife Service (USFWS) findings, presents a significant challenge for conservation of this species and sustainable management of the sagebrush ecosystem. Because of the wide variations in natural and human history across these landscapes, no single prescription for management of sagebrush ecosystems (including sage-grouse habitats) will suffice. However, specific activities that fall under the general categories of protecting the isolated pieces of intact and well-functioning sagebrush ecosystems, and improving, mitigating, and restoring less functional ecosystems, if well-informed, coordinated, and wide-ranging, should contribute to reducing the impacts of previous land uses and land-use patterns on current habitat conditions and population trends. Across the sage-grouse range, the impacts of extensive infrastructure are widespread, including roads, power transmission lines, pipelines, communication towers, and fencing, and localized human activities such as water retention and vegetation treatments have been recognized, but precise influences and remediation solutions are often not well understood. These activities interact with widespread, but generally less intense, pressures including large herbivores (domestic, introduced, and native ungulate populations) in determining range conditions. Range and habitat conditions may be improved, mitigated, and (or) regulated to reduce impacts and better balance the desires of land users with wildlife needs and conservation of public property and interests (lands and wildlife). Importantly, as recognized by Natural Resources Conservation Service (NRCS) Sage-Grouse Initiative (SGI) and others, continuing to improve habitat management is complementary to sound range management,

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and improving the composition, productivity, and resilience of sagebrush habitats should improve rangeland health for the benefit of all. Although a suite of direct mortality sources have been discussed and investigated, the evidence clearly suggests that critical aspects of population demographics, including nest success, brood-rearing success, predation risk, disease risk, hunting, and poisoning are only significant when habitat restrictions (that is, loss, fragmentation, and degradation) magnify their effects. Thus, concentrating on conservation and improved management of the sagebrush ecosystem as a solution for reducing the decline of sage-grouse requires the critical endorsement of the close relation between habitat availability, condition, and distribution with population fecundity. This relation is foundational in science and management of wildlife. The collective efforts of State wildlife management agencies and State and Federal land management agencies to improve range and habitat conditions, to the benefit of wildlife, public interests, and local landowners (especially public land lessees) are also based on this foundational relation. Current efforts are additionally complicated by evolving knowledge and changing roles of natural processes. For example, understanding of the relation between fire and sagebrush systems has evolved from a theory of purely negative effects to recognition of its importance as a natural process. Re-evaluations of preconceptions and continuing experimentation and observations indicate complicated relations between sagebrush and disturbances and imply a more irregular and lengthy interval between fires than previously described. Current understanding recognizes fire as a relevant tool, albeit with a potentially limited role in some systems, and certainly a complicated role in conserving the distribution and function of sagebrush ecosystems, due to interactions with other factors. Understanding and application of the natural role of fire in sagebrush ecosystems must be tempered by the realization that loss and fragmentation of mature sagebrush communities (given recent disturbance and land-use patterns) is a threat to sage-grouse conservation. Occurrence of large wildfires, often influenced by the distribution of cheatgrass, represents a direct threat to the successful conservation of those habitats and associated populations.

This report documents and summarizes several decades of work on sage-grouse populations, sagebrush as habitat, and sagebrush community and ecosystem functions based on the recent assessment and findings of the USFWS under consideration of the Endangered Species Act. As reflected here, some of these topics receive a greater depth of discussion because of the perceived importance of the issue for sagebrush ecosystems and sage-grouse populations. Though explicit connections to effects on sage-grouse populations are attempted throughout, these connections remain elusive and difficult to document. Understanding that perfect knowledge of these species and ecosystems is impossible due to natural complexity and human limitations, drawing connections between the direct effects on sagebrush ecosystems and the effect of ecosystem condition on habitat condition, and finally the connection between habitat quality and sage-grouse population dynamics remains the lofty goal of science and management. This effort is necessary and important, and despite the perception that these complicated, indirect relations are difficult to characterize and manage, many advances in understanding and application have been documented.

The distributions of habitats, species, and human land uses are notably heterogeneous across large landscapes, and understanding the relations and processes that create these patterns, including both positive and negative associations, will assist in long-term planning by helping to identify risks to habitat and resource conservation success, control and mitigate our activities to reduce impacts and insure resiliency, and protect and conserve our natural heritage and natural resources for future generations. Rather than any single source of habitat degradation, the cumulative and synergistic impact of multiple disturbances, continued spread and dominance of invasive species, and increased impacts of land use continue to have the most significant influence on the trajectory of sagebrush ecosystems and sage-grouse populations. Future patterns of land use, combined with *effective* restoration and management may improve, or degrade, the remaining sage-grouse ranges, but natural dynamics and unforeseen stochasticity promise to add complexity to future plans and landscapes.

I. Social and Political Overview and Introduction

Greater Sage-Grouse (*Centrocercus urophasianus,* hereafter sage-grouse) are large, ground-dwelling birds that reside primarily in sagebrush ecosystems which were, and still are in some respect, ubiquitous across the intermountain regions of western North America. Whereas human settlement of these lands has been slower and more sparse than in more naturally productive parts of the country, conversion to suit human purposes, development of energy and mineral resources beneath the surface, and a long history of dispersed (but sometimes intensive) uses such as domestic grazing and off-highway vehicles (OHVs) have contributed to widespread loss and decline of sagebrush habitat quality and associated wildlife populations, as documented herein. The estimated distribution of contiguous sagebrush habitats, prior to Euro-American settlement (Schroeder and others, 2003), was nearly twice that which is available today (fig. 1). Although early documentation is sparse and potentially biased, it is suspected that similar reductions in sage-grouse abundance have occurred at a continental scale (Schroeder and others, 2004). Sage-grouse population trends are variable across their distribution, and though some populations appear stable, population numbers show long-term declines collectively and in several regions (Connelly and others, 2004). Proximate reasons for population declines differ across the sage-grouse distribution, but ultimately, the underlying cause is loss of suitable sagebrush habitat (Connelly and Braun, 1997; Leonard and others, 2000; Aldridge and others, 2008), which contrasts with direct effects such as predation, hunting, or other incidental mortality (such as collisions).

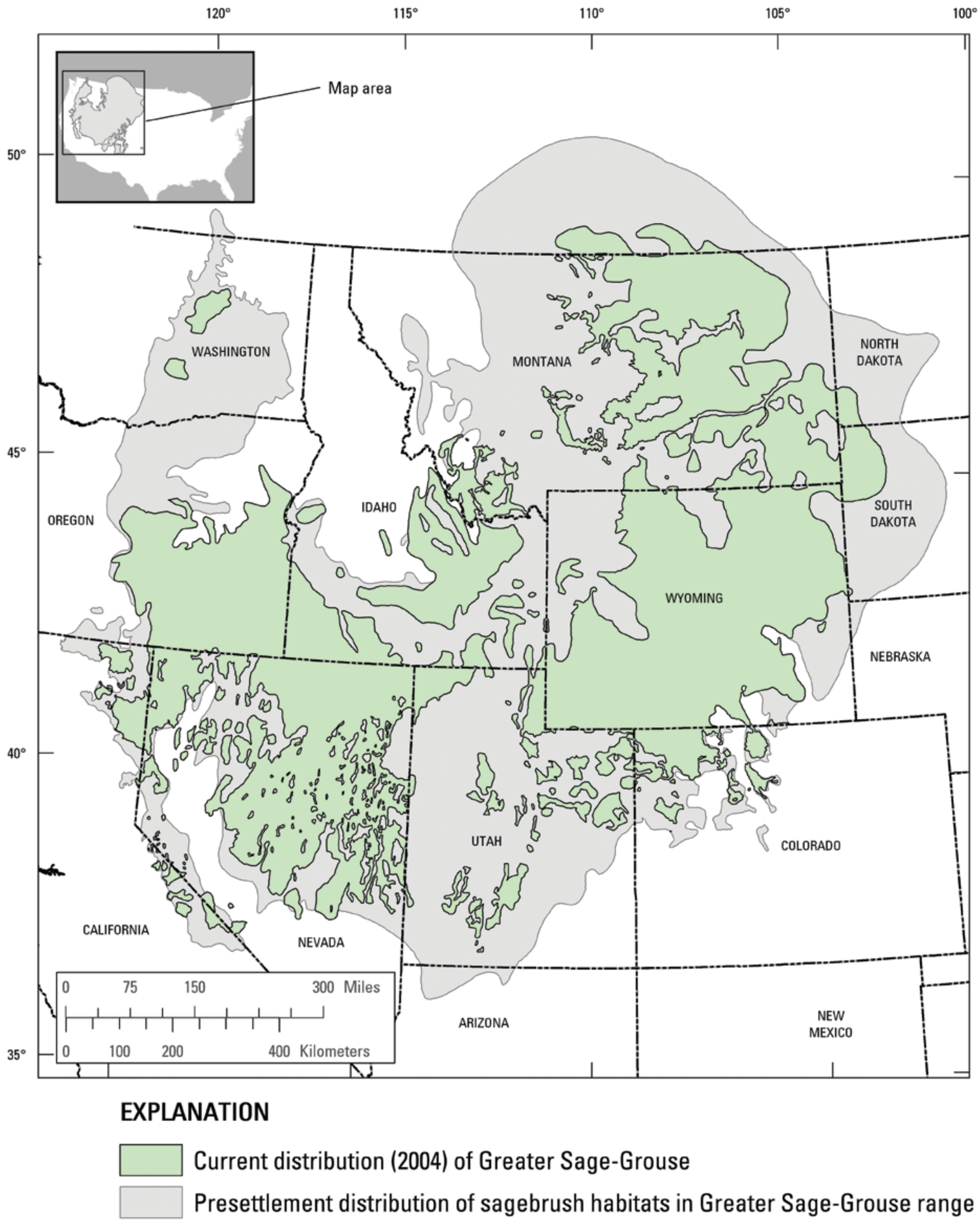


Figure 1. Current distribution (2004) of Greater Sage-Grouse and pre-settlement distribution of sagebrush habitats available for Greater Sage-Grouse across western North America.

Typically, variety in sagebrush-community composition (with variations in subspecies composition, co-dominant vegetation, shrub cover, herbaceous cover, and stand age) is necessary within the landscape to meet seasonal, and interseasonal, requirements for food, cover, and nesting of sage-grouse (Patterson, 1952; Connelly and others, 2000c). In this context, "the landscape" for sage-grouse encompasses large areas, roughly from 10s to 100s of square kilometers, to provide for multiple aspects of species life requirements, such as seasonal habitats (Beever and Aldridge, 2011; Connelly and others, 2011a,b; Leu, 2011). Thus, conserving and managing sage-grouse is as much about the ecology, management and conservation of large, intact sagebrush ecosystems as it is about the dynamics and behaviors of the bird populations (Connelly and others, 2004; Crawford and others, 2004). The large areas used by sage-grouse to meet seasonal habitat needs in these environments, coupled with the mixed land ownership patterns typically found across the west (fig. 2), dictates that a conservation strategy for the species will rely on cooperation across multiple Federal, State, local, and private parties. The basis of these cooperative conservation strategies requires understanding and mitigating the distribution of multiple threats that, in combination, reduce available habitat for sage-grouse.

Compounding the conservation challenge for governmental management agencies and private individuals alike, the sagebrush ecosystem is also important for the social and economic stability of the Western United States. Livestock grazing has been an important part of sagebrush ecosystems since the middle 1800s (Larson, 1978), and it continues to have important implications for the condition and management of these lands. Although grazing is critical for the economic and social structure of the region and an important contributor to the food supplies of the nation, the effects of grazing on public resources remain a contentious source of debate, research, and experimentation. Further, sagebrush rangelands have been steadily constricted by urban and exurban domestic development, mineral and energy industrial development, and a host of other land-use activities (and associated impacts) on surrounding natural areas (U.S. Fish and Wildlife Service, 2010b; Knick and Connelly, 2011b; Leu and Hanser, 2011). Thus, the balance between societal demands, natural capacity, and wildlife conservation is a fundamental component of sagebrush management, but this balance has not always been met. Accumulation of direct and diffuse disturbances has led to limitations in sagebrush systems, as habitats, due to degradation of local shrub and grass cover, diminished size of habitat patches, and wide dispersion of high-quality, seasonal habitats. This indicates that proximity and juxtaposition of habitat patches, as well as condition of the matrix, affect travel effort and mortality risks between habitats and overall habitat quality (Miller, 2011; Knick, 2011).

The multiple-scale attributes of sage-grouse habitat requirements make the current and historic roles of fire and other surface disturbances (for example, roads, industrial developments, agricultural conversion, and habitat treatments) important for monitoring and manipulation at regional scales as plans to manage for functional sagebrush ecosystems are implemented. Though wildfires likely played an important role historically in creating a mosaic of herbaceous dominated areas (recently disturbed) and mature sagebrush (less frequently disturbed), current and historic land-use patterns have defined a new mosaic that has restricted systemic ability to support wildfire regimes. Slow rates of growth and recovery of vegetation after disturbances (driven by low water availability and other environmental constraints) coupled with high rates of disturbance and conversion are largely responsible for the accumulating displacement and degradation of the sagebrush ecosystem, including natural disturbance regimes and patch dynamics that characterized historic landscapes (Christensen, 1985; Pickett and White, 1985).

Finally, the basins where most sagebrush ecosystems reside are also the center of major oil and gas reserves (for example, Denver, Eastern Great, Green River, Niobrara, Powder River, Uinta-Piceance, and Williston Basins), which have a long history of industrial use, particularly on eastern portions of the range, especially Management Zones (MZs) I, II, and VII. The intensity of new energy development has varied through time due to various factors including economics, technology, and national policy, but accumulation of roads, pads, wells, and other infrastructure has greatly outpaced their removal. Current national energy policies and demand for domestic oil and gas indicate that removal and reclamation of these resources will remain an important aspect of multiple-use land management, including habitat and wildlife management, into the future. In addition, national emphasis on "renewable" resource development adds pressure to develop wind, solar, and geothermal energy facilities. Although research on direct effects of these developments on wildlife is still underway, as described here, recognition that these developments alter, degrade or entirely displace native ecosystems is ubiquitous as the basic set of impacts (roads, traffic, equipment noise, and lights) are common among industries.

Imposition of modern land-use pressures on native ecosystems leads to direct habitat loss and habitat degradation. Even without added anthropogenic pressures, ecosystems are balanced between changing environmental conditions and demands for ecosystem services from people *and* wildlife such as clean water, abundant forage and prey, and domestic habitat. According to recent estimates, this combination of influences is tipping the scale, placing the sage-grouse on the verge of Federal listing under the Endangered Species Act (currently classified as "warranted, but precluded").

In the last decade, concern for the species prompted a series of petitions to list the sage-grouse under the Endangered Species Act (Stiver, 2011). The details of these petitions are well documented (U.S. Fish and Wildlife Service, 2010b; Stiver, 2011). More recently, on March 23, 2010, the USFWS released its 12-Month Findings for Petitions to list the Greater Sage-Grouse (*Centrocercus urophasianus*) as Threatened or Endangered ("2010 Listing Decision"; U.S. Fish and Wildlife Service, 2010b). In the 2010 Listing Decision, the USFWS concluded that listing the sage-grouse (rangewide)

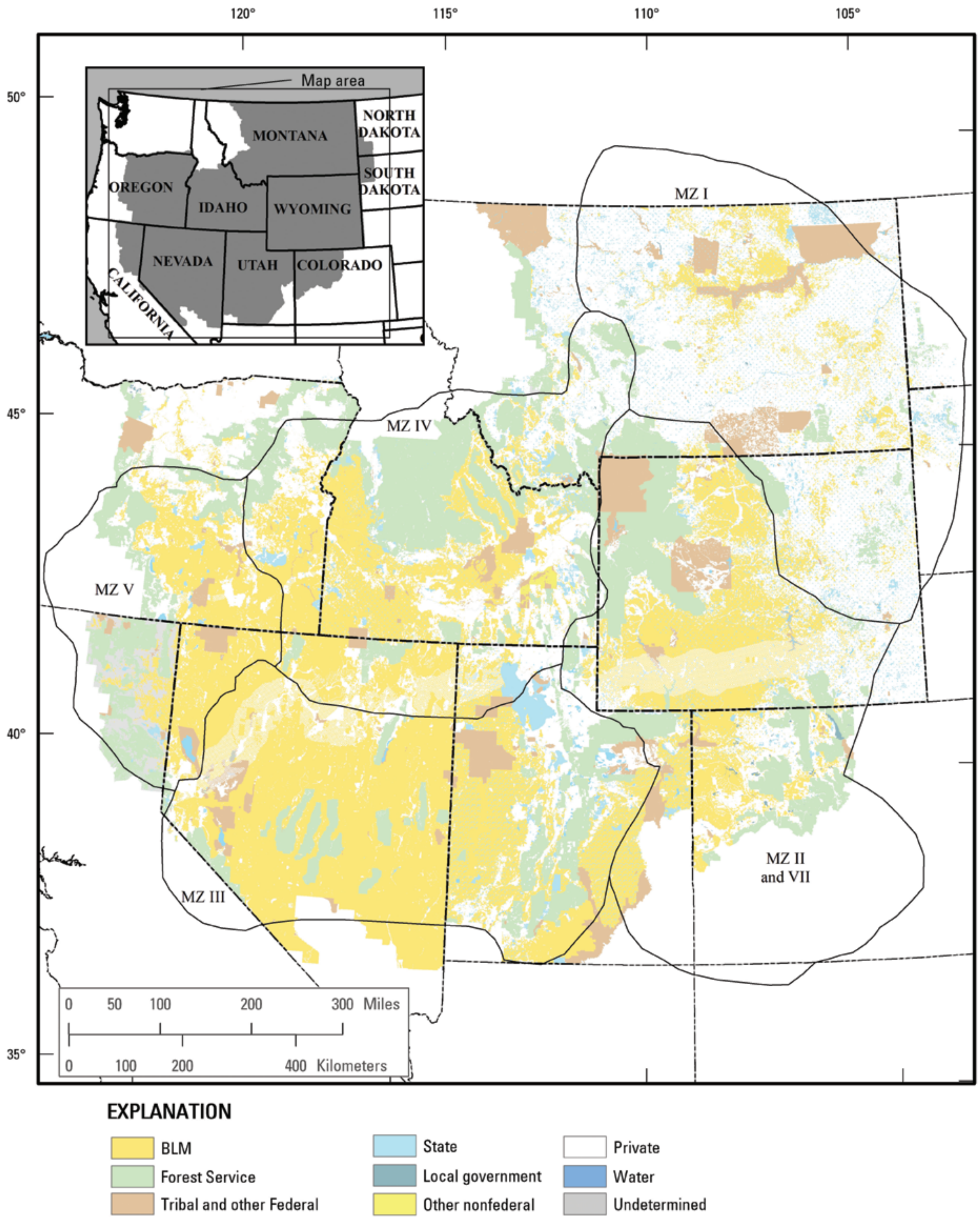


Figure 2. Land ownership or management jurisdiction across sage-grouse Management Zones (MZ). Note that small parcels and many details are omitted from a map of this resolution, in particular, private lands will appear underrepresented. This representation is for explanatory purposes only; it does not imply or infer any legal or other designation, re-designation, ownership rights or right-of-way.

was warranted, but precluded by higher priority listing actions (U.S. Fish and Wildlife Service, 2010b). The listing decision focused on two factors: (1) habitat fragmentation and degradation and (2) inadequate regulatory mechanisms. The USFWS will continue to annually evaluate changes to listing factors and update listing decisions regarding sage-grouse; however, the current urgency (time line) has been dictated by a work plan developed in response to a series of court approved settlement agreements (Judge Emmet Sullivan, U.S. District Court, Washington, D.C., September 9, 2011). Through these agreements and the plan, the agency agreed to make a final listing decision regarding the status of the sage-grouse by the end of fiscal year 2015. (Legal documentation and the work plan are available at *http://www.fws.gov/endangered/improving_ESA/listing_workplan.html*.) Under the terms of the settlement agreements, the USFWS must either determine that sage-grouse are warranted for listing and publish a proposed rule implementing that listing *or* make a not-warranted finding (“warranted, but precluded” will not satisfy legal agreements).

Building upon local working groups and interagency agreements, State and Federal land and wildlife management agencies are developing coordinated conservation strategies to secure the long-term future of the sage-grouse; unprecedented actions aimed at revising management and conservation so that listing (of the sage-grouse under the Endangered Species Act, ESA) is not necessary due to improved regulatory mechanisms providing for long-term sustainability of the species without further regulation. In direct response to concerns over regulatory mechanisms across the sage-grouse range, which transcend local, State, and Federal boundaries, these same entities are engaged in revising population conservation strategies, land management regulations, and management plans. This report provides a critical information source to these efforts by collecting and summarizing the scientific information important for understanding the impact of threats to sage-grouse and the spatial juxtaposition, and therefore relative magnitude of these issues, across the west and for different conservation partners. The primary focus is twofold; it should (1) inform the Bureau of Land Management (BLM) and U.S. Forest Service (USFS) Greater Sage-Grouse Land Use Planning Strategy (Bureau of Land Management, 2011a) with consistent assessment and application of the most recent information and understanding regarding sage-grouse and their habitats, and (2) it should provide a quantitative summary of identified threats to establish a foundation for understanding and managing these impacts at biologically meaningful scales (such as, the Western Association of Fish and Wildlife Agencies, WAFWA, Management Zones). It will be important to address cumulative and interactive impacts of multiple disturbances and impacts in these planning efforts because they have been found, individually and in combination, to contribute to the decline of sage-grouse habitats (Connelly and others, 2004; U.S. Fish and Wildlife Service, 2010b; Connelly and others, 2011d). This summary assessment, along with associated analyses and applications, describe the environmental conditions and characterize the legal, natural resources, and human perspectives at a regional scale to help inform the large-scale context required for planning efforts.

A National Strategy

The National Greater Sage-Grouse Land Use Planning Strategy represents a planning framework and process to incorporate effective regulatory mechanisms (conservation measures) into Land Use Plans (LUP), especially BLM Resource Management Plans (RMP) and USFS Forest Management Plans (FMP), across the range of the sage-grouse (Bureau of Land Management 2011c, 2012). The strategy includes review of existing regulatory mechanisms and revision of these as necessary to conserve and restore the sage-grouse and their habitats on USFS- and BLM-administered lands across the species’ range and to ensure these measures are carried forward into future planning efforts on the public lands. This planning framework includes the following elements:

- The need for science-based objectives, measures, and LUP decisions,
- The need for common data and regional perspectives to support local and regional cumulative impacts analyses,
- Consistency across jurisdictional boundaries and within defined ecoregional areas,
- The principal threats identified by the USFWS within different portions of the range, and
- Objectives expressed by the USFWS and WAFWA directives.

This approach articulates a structure and process capable of responding to national policy as well as the different ecological attributes and threats within regions by dividing the range into two broad regions—Great Basin and Rocky Mountains. As envisioned, each region develops a separate but similar planning strategy based on a cooperative planning effort with State wildlife management agencies and the USFWS. Information in this report is expected to support and inform the planning approach for these five elements of the National Planning Strategy. The primary focus of the planning effort, and hence this report, is Greater Sage-Grouse (*Centrocercus urophasianus*). The Gunnison Sage-Grouse (*Centrocercus minimus*), Greater Sage-Grouse Bi-State Distinct Population Segment (DPS), and Greater Sage-Grouse Columbia Basin DPS will be addressed in separate planning efforts and therefore are outside the scope of this report (Bi-State Local Planning Group, 2004).

This report is focused on providing support and regional consistency among these functional planning and implementation units through compilation, assessment and summary of data, and information from across the species’ range (East and West). Rangewide and subregional distributions were the subject of targeted geospatial analyses to facilitate assessment of cumulative effects of development and other land uses beyond typical planning-unit boundaries. By compiling and summarizing data and technical literature that represent and address resource distributions, conservation units, potential threats, and other factors affecting the health and distribution of sage-grouse populations and habitats, it is anticipated that a common understanding may be carried forward by local working and planning groups.

Purpose and Suitable Application of This Report

Because of their broad range, variations in population traits and characteristics across this range, and the variability in habitat conditions and threats within this range, conservation of sage-grouse is a unique challenge compared to isolated or range-restricted species, primarily due to the scale of the effort. This complexity is increased because sage-grouse have habitat requirements that can be recognized at multiple scales with the broadest transcending traditional management boundaries. An area has suitable habitat if it (a) is large with contiguous acres of sagebrush; (b) contains a mosaic of sagebrush, grass, and forb cover, which provides suitable cover and forage opportunities (good condition) within proximity to allow seasonal movement and use; (c) contains healthy, productive, and sufficiently isolated (safe) local habitats that provide specific seasonal requirements, such as sagebrush, grasses, forbs *and* insects in spring-summer and sagebrush without snow-cover in winter; and (d) has sufficient specific microsite conditions that provide daily needs such as nest sites. Similarly, planning for conservation and management occurs at multiple scales.

Current efforts to prioritize areas across the range for conservation have focused on identifying large expanses of sagebrush for protection (casting a broad net to protect sagebrush ecosystems) or specifying regional expanses based on the "core areas" concept based on breeding density of the birds (numbers of males on leks; Doherty and others, 2010c). The National Greater Sage-Grouse Land Use Planning Strategy focuses at these broader scales; therefore, to accomplish this assessment, local details, for example the amount of shrub canopy, which vary in space and time, are necessarily grouped and averaged within map units (grid-cells or shapes) precluding fine-scale evaluation. However, regional trends and patterns that develop during periods of years may be recognized and highlighted at scales useful for assessment, planning, and management processes. This document is designed to inform and advance large-area, regional conservation efforts by consolidating information regarding rangewide and regional information about sage-grouse populations and habitats and to act as a bridge between these large-area efforts and regional and local management efforts (that is, forest and range management plans) by providing spatial and information context.

Delineation of Preliminary Priority and General Habitats

BLM national policy during the last decade has also focused on delineation and protection of large expanses of sagebrush with high densities of sage-grouse. In 2008, the BLM directed field and State offices to prioritize "key habitat areas" (large expanses of sagebrush) for protection from wildfire (Bureau of Land Management, 2008). Similarly a core-area strategy was proposed in the eastern portion of the range to help delineate landscape planning units by distinguishing areas of high biological value based on location of important breeding areas to help balance habitat requirements with demand for energy development (Doherty and others, 2011b; State of Wyoming, 2011). This core area method was adopted by many State fish and wildlife agencies who used Statewide breeding-bird data supplemented by local knowledge and interpretation to delineate habitat areas, for example Wyoming's Core Areas (State of Wyoming, 2011). The Doherty approach was expanded by the BLM rangewide to create a Breeding Bird Density Map—across the range of the sage-grouse where the highest densities of breeding males were found on leks (Doherty and others, 2010c). Currently, the rangewide map has also been applied by the U.S. Department of Agriculture (USDA) through the NRCS to guide the SGI in prioritization of conservation actions on private lands within the sage-grouse range (Natural Resources Conservation Service, 2011). In an effort to consistently identify highly valuable areas that combine habitat-quality and bird-density approaches to identification and delineation, BLM has adopted "Preliminary Priority Habitat" (PPH) and "Preliminary General Habitat" (PGH) maps; these determinations and products were created cooperatively with State fish and wildlife agencies (Bureau of Land Management, 2011b). PGH and PPH are mutually exclusive habitat classes. PPH represents the habitat designated to maintain distribution and sustainable sage-grouse populations. PGH represents additional sage-grouse habitat with smaller populations, current or imminent threats, or other factors that affect management and conservation opportunities, which may be managed for habitat conservation and (or) restoration based on needs for connectivity, potential for restoration, or other local issues (fig. 3). This approach combines both the bird density and valuable habitat approaches and adopts State-agency knowledge and perspectives to identify the seasonal habitats needed for sage-grouse persistence. It represents a collective of biological, socioeconomic, and management understanding combined to identify areas that need assessment of threats for amelioration or protection, regulatory enforcement mechanisms, monitoring of sage-grouse population trends, and adaptive management as needed, and it should complement, not replace, locally specified priorities when these are aligned with regional issues (Conservation Objectives Team and others, 2013). This cooperative approach identified habitat across 10 States utilizing a planning process that extended across multiple jurisdictions. Ongoing applications through the land-use planning

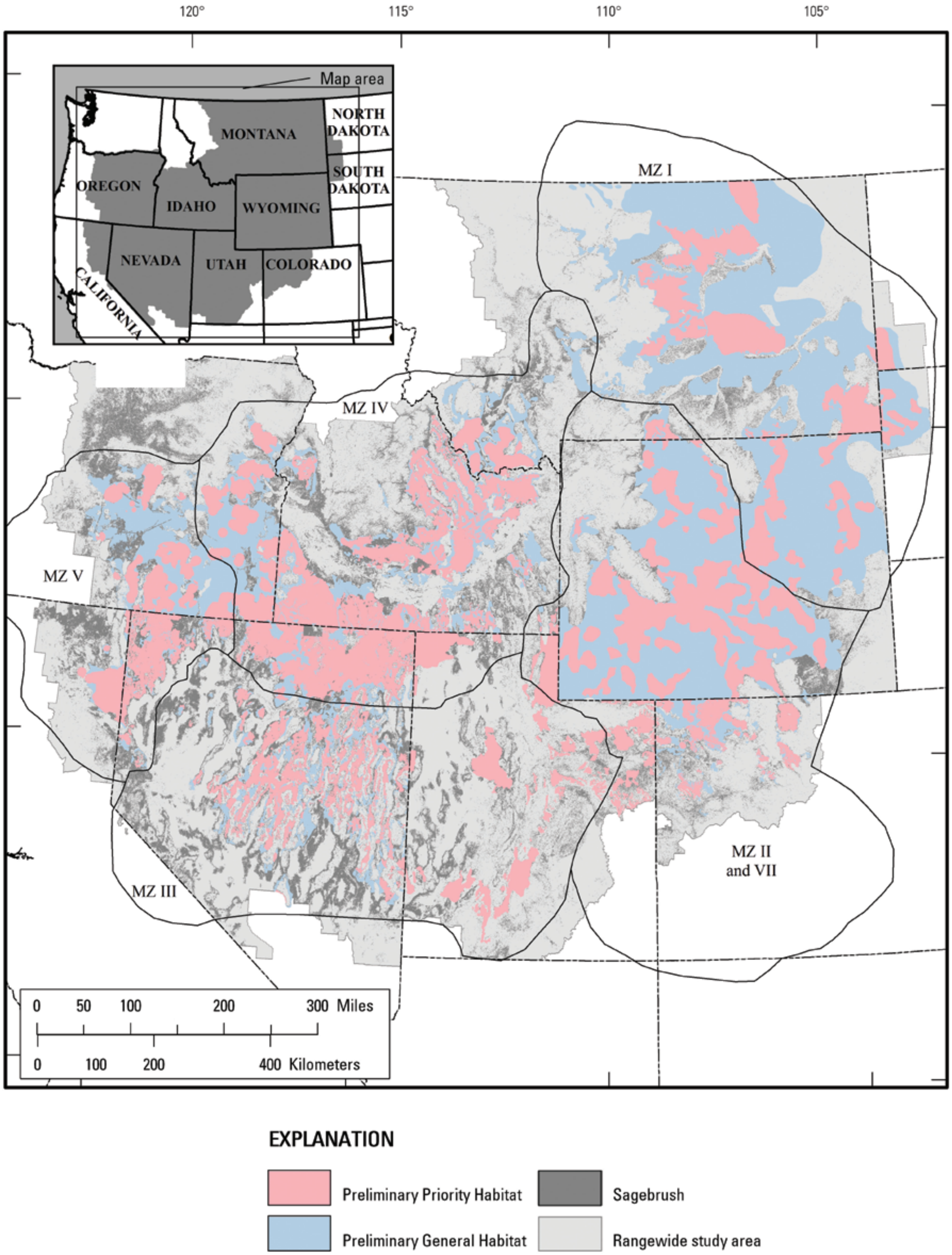


Figure 3. Distribution of preliminary priority habitat and preliminary general habitats (PPH and PGH, respectively) displayed with additional (current) distribution of sagebrush.

process, especially BLM and USFS, may refine PPH and PGH to (1) improve and update Priority Habitat area definitions, (2) analyze actions within Priority Habitat areas to conserve, or improve, sage-grouse habitat functionality, (3) formally recognize General Habitat areas and assess habitat condition and use in these areas, and (4) analyze actions within General Habitat areas that affect the ability of the system to provide important sage-grouse functional requirements (such as suitability for breeding, migration, or winter survival).

Because of the different objectives for priority and general habitat, this report uses the current PPH and PGH delineations (as defined, June 26, 2012) to characterize the relative magnitudes and locations of threats within current management, planning, and assessment units. Potential applications include identification of local habitats within a regional context of PPH and PGH, understanding the distribution of threats within PPH and PGH areas, providing spatial context such that priority habitat can be delineated or adjusted, and management actions can be devised to meet conservation and management objectives.

Geospatial Analysis Methods

Geospatial data were acquired for all threats identified in the USFWS listing decision that can be represented spatially. These data were acquired rangewide, as available, from both internal (BLM and USFS) and external sources beginning in August 2011 (see appendix). All data, both internal and external, were considered the “best available” at the time of data collection. National dataset collection stopped in July 2012 (although verification and adjustments of some of the datsets continued through December 2012), whereas other data (for example, compiled from other sources) were the most current available based on the supplying office, agency, or organization. Internal data were compiled using intra-agency data calls and often included data submitted in segments from different administrative units across the BLM and USFS management areas. These datasets were aggregated and reviewed, but time constraints limited the ability to revise these data for quality and completeness, such as properly addressing all geometry errors (gaps and overlaps) and edge-matching across jurisdictions. After data collection was complete, input datasets were preprocessed. Preprocessing steps included reclassification, attributing, buffering, and other formatting tasks. Categorizing datasets into relevant attributes and supplementing them with additional attributes was necessary for data compatibility. Buffers were developed based on area-of-influence distances provided in peer-reviewed literature to represent direct (footprint) and indirect (buffer distances ranging from 1.5 to11.8 mi [2.5–19 km]) effects on sage-grouse populations. (Also, see Appendix A-1.) Collaboratively developed priority habitat designations (PPH and PGH) were combined with surface management responsibilities and WAFWA Management Zone polygons into one master summary file with a unique identifier reflecting the specific combination of habitat, surface management, and MZ for each polygon to provide for efficient, repeatable, and consistent data summaries. Finally all datasets were clipped to the rangewide study area, and small or superfluous polygons were dissolved to reduce the number of features and remove unnecessary attributes. Finally, data was sorted into point, line, and polygon features for different analyses that reflected the footprint and effects representation.

Overlay comparisons were generated using ArcGIS Model Builder (version 10.0) with separate models created for point, line, and polygon input data (see appendix for details). In brief, these models intersected the input data with the master summary file, which included representation of the spatial summary units (MZs, and so forth), and dissolves extra boundaries based on the unique identification assigned in the intersection. Finally, summary data were calculated for each threat overlay using the number of points, linear miles, or area within the specific combination of habitat type, land management, and MZ. Attribute data were exported to spreadsheets for summary calculations.

Key Assumptions and Limitations

The data and information included here are the most accurate available; however, these data and associated risk assessments remain based in present knowledge. Simulation of future conditions was not a component of this assessment, and these data are not predictions of future events or conditions. Spatial data informing these analyses were compiled to establish a consistent information and analytical basis across the entire region (Sage-Grouse Management Area), but in order to attain this consistently across State, ownership, and management boundaries, some local details have been omitted. As such, these data and analytical approaches provide a regional assessment tool suitable for guiding regional mid- to long-term planning scenarios over broad spatial scales. Local expertise and data are needed to complement these landscape data when developing specific management plans using these regional guides.

Because of the scale of summary and the existence of other guiding documents, this report was developed to play a particular role in organizing and assessing the character and distribution of threats to the persistence of sage-grouse. Data and summary information were compiled rangewide providing sufficient resolution to address relative distribution and magnitude of effects within the seven sagebrush Management Zones (MZs) defined to support sage-grouse conservation planning, but these may require local supplementation. Within these Management Zones, current delineations of PPH and PGH cross management entities and represent Federal and State perspectives on the areas needed to maintain sustainable populations and the areas to evaluate to maintain connectivity between these populations (see tables for summary statistics representing PPH and PGH by Management Zone and entity). For the purposes of this report, focus on the Greater Sage-Grouse (without the Bi-State and Columbia Basins populations) includes BLM and USFS units within sage-grouse range. The study area roughly follows the Management Zone boundaries, but limits analyses to overlapping areas within specific planning unit boundaries (fig. 3). Therefore, this assessment concentrates on currently occupied habitats and uses slightly different delineations than found in previous, related works (for example, Stiver and others, 2006; Knick and others, 2011). The natural and human processes of interest are active across multiple spatial-temporal scales; therefore this assessment necessarily includes topics and discussion that cross between national-, regional-, and local-level planning and implementation. However the primary goal of this report is to provide broad-scale perspective (in data and literature), which may be combined, subsequently, with local knowledge and directives to develop specific forest and resource management plans.

II. Populations, Distributions, Trends, and Natural History

Species Description and Taxonomy (Rangewide)

Sage-grouse (*Centrocercus* spp.) are the largest grouse found in North America. They are a ground-dwelling, sagebrush-obligate species. Historically, sage-grouse were considered to be one species with a pre-settlement range that included 14 U.S. States and 3 Canadian Provinces (fig. 1; Aldrich, 1963; Johnsgard, 1983; Connelly and others, 2004; Schroeder and others, 2004). In 1946, Aldrich described two subspecies, an eastern (*C. u. urophasianus*) and western sage-grouse (*C. u. phaios*) based on slight color differences in 11 individuals collected from Washington, Oregon, and California (Aldrich, 1946). In the 1990s, research in southwestern Colorado revealed morphological (Hupp and Braun, 1991) and behavioral (Young and others, 1994) evidence suggesting that the sage-grouse in southwestern Colorado and southeastern Utah were distinct from sage-grouse elsewhere across their range and might be a new species. Genetic data (Kahn and others, 1999; Oyler-McCance and others, 1999) revealed patterns consistent with a lack of gene flow between sage-grouse in southwestern Colorado-southeastern Utah and northern Colorado, which supported the idea that this group of sage-grouse was a different species. In 2000, the American Ornithologists' Union recognized the formal description of this group of sage-grouse as a new species, named Gunnison Sage-Grouse (*C. minimus*; Young and others, 2000). All other sage-grouse were subsequently renamed Greater Sage-Grouse (*C. urophasianus*).

This reassessment of sage-grouse taxonomy spurred a reexamination of the subspecies classification of the sage-grouse. The geographic delineation separating the eastern and western subspecies is ambiguous and has changed through time (Aldrich, 1946; Aldrich and Duvall, 1955; American Ornithologists' Union, 1957; Aldrich, 1963). Morphological comparisons by Schroeder (2008) revealed slight variations among individuals and some populations, yet the magnitude of the differences were not sufficient to be recognized as distinct subspecies using current taxonomic standards, and the patterns of variation were not consistent with geographically described subspecies. Schroeder (2008) and Taylor and Young (2006) both examined strutting behavior and did find some regional differences, but those differences were inconclusive in distinguishing the purported eastern and western subspecies. Genetic data (using both mitochondrial and nuclear genetic markers) collected from individuals across the range were not differentiated at the subspecies boundary (Benedict and others, 2003; Oyler-McCance and others, 2005b), yet a population that spans the border between California and Nevada (Bi-State population) was found to be unique genetically. This Bi-State population, although genetically unique, does not appear to have obvious morphological or behavioral differences as was seen in the Gunnison Sage-Grouse (Taylor, 2006; Schroeder, 2008). Though the taxonomic status of the Bi-State population has been widely debated, no formal taxonomic change regarding this population has been made. Additionally, the U.S. Fish and Wildlife Service no longer considers listing consideration at the subspecies level based on the multiple lines of evidence that do not support the eastern and western subspecies delineation in sage-grouse.

Population Distribution and Trends—Including Subpopulations and Management Zones

The current range of sage-grouse includes 11 U.S. States and 2 Canadian provinces (fig. 1) and is thought to be a reduction of 44 percent from the pre-settlement range (Connelly and Braun, 1997; Schroeder and others, 2004). Although specific reasons for population decline differ across the range, the underlying cause is the loss, degradation, and fragmentation of suitable sagebrush habitat (Connelly and Braun, 1997; Leonard and others, 2000; Aldridge and others, 2008). As sagebrush habitats increasingly overlap with natural resources (for example, oil, gas, wind, minerals, agriculture, and recreation areas) and face increased landscape-level changes caused by invasive plants, fire, and conifer encroachment (Connelly and others, 2004), populations have declined substantially raising conservation concern for the species.

The broad distribution of sage-grouse encompasses a diverse collection of environments with an equally varied assortment of ecological pressures. Therefore, management practices and conservation strategies are often quite dissimilar in different portions of the range (Stiver and others, 2006a). To facilitate development of management and conservation actions that are more consistent within ecological regions, instead of political boundaries, the sage-grouse range was divided into seven sage-grouse Management Zones based on similarities in geography, climate, topography, and floristics (West, 1983; Miller and Eddleman, 2000; Connelly and others, 2004; Stiver and others, 2006a; fig. 2).

Sage-grouse MZ I includes seven sage-grouse populations on the northwestern Great Plains (Connelly and others, 2004) in parts of Montana, Wyoming, North Dakota, South Dakota, Saskatchewan, and Alberta (fig. 3 and table 1). Three of these populations are considered large and are loosely connected to adjacent populations (Connelly and others, 2004). The Wyoming Basin (MZ II) consists of 13 populations covering parts of Montana, Wyoming, Colorado, Idaho and Utah. Three populations are considered to be large and connected to adjacent populations (Connelly and others, 2004), and the Wyoming Basin proper includes five subpopulations that are perceived to be well connected. Management Zone III represents the Southern Great Basin and consists of 13 populations in parts of California, Nevada, and Utah. Only two of these populations have been described as large (table 1; Connelly and others, 2004). The Mono Lake (Bi-State Local Planning) population is included in MZ III; however, that Distinct Population is being addressed through a separate planning process involving California and Nevada working groups. The Snake River Plain and associated drainage basins characterize MZ IV; this region includes 14 sage-grouse populations in Oregon, Montana, Idaho, Nevada, and Utah, and two of these populations are considered to be large (Connelly and others, 2004). Management Zone V consists of five populations in the Northern Great Basin. These populations are found in Oregon, California, and Nevada. The Lake Area (Oregon, California, and Nevada) population is the only one described as large and loosely connected (Connelly and others, 2004). Washington is the only State with populations of sage-grouse in the Columbia Basin (MZ VI). Only two populations exist in this entire MZ (Moses Coulee and Yakima, Wash.), and both populations are isolated and far removed from the rest of the sage-grouse range (Connelly and others, 2004). These populations are not covered by this report, although similarities and information overlap may exist. The Colorado Plateau (MZ VII) is made up of six populations of sage-grouse in Utah and Colorado. All populations are considered to be small and isolated (Connelly and others, 2004). This MZ also includes populations of *Gunnison* Sage-Grouse. One population (living near Gunnison, Utah) is a *Greater* Sage-Grouse population that was translocated into the range of Gunnison Sage-Grouse. The MZ VII populations are summarized along with populations in MZ II for this report because of the limited area and similar attributes of the few populations living in northwestern Colorado and northeastern Utah.

The highest densities of strutting male sage-grouse occur in MZs I, II, IV, and V (fig. 4; Doherty and others, 2010c). Management Zone III includes lower densities, and MZ VI represents dispersed birds in the Columbia Basin. In the Colorado Plateau (MZ VII), the Gunnison Sage-Grouse persist in the south, whereas small populations of Greater Sage-Grouse persist in the north (fig. 4).

Forty-one discrete populations of sage-grouse (described in reference to MZs above) were defined by Connelly and others (2004; fig. 5). Some of these populations cross MZ boundaries and are thus divided into subpopulations for management purposes. Detailed descriptions of populations and subpopulations and justification for their definitions were provided in the WAFWA Conservation Assessment (Connelly and others, 2004), and a summary of that information is provided here (fig. 5). The most isolated populations occur in Colorado, Utah, Nevada, California, and Washington. Of the seven MZs, the most populations occur in MZs III and IV.

The species' range and total population size have declined dramatically from historical levels (Hornaday, 1916; Crawford, 1982; Drut, 1994; Braun, 1998; Schroeder and others, 1999). Analysis of rangewide decline between 1965 and 2003 revealed an average of 2-percent decline per year with the earlier years (1965–1985) declining at a greater rate, 3.5 percent, than the later years when the rate slowed to 0.37 percent (Connelly and others, 2004). Two additional analyses found similar rates of decline using different statistical techniques and additional years of data (Western Association of Fish and Wildlife Agencies, 2008; Garton and others, 2011). Connelly and others (2004) also estimated that sage-grouse numbers in the 1960s and 1970s were double or triple current numbers, an analysis that was corroborated by Garton and others (2011). Three analyses of sage-grouse population trends within MZs showed long-term population declines in most MZs (Connelly and others, 2004; Western Association of Fish and Wildlife Agencies, 2008; Garton and others, 2011). Only one MZ (VII) has recently demonstrated population trend estimates that were not negative. Estimated trends in populations are summarized (table 2) by MZ for each of the three studies (U.S. Fish and Wildlife Service, 2010b). Declines in male population estimates (table 3) were considerably larger than effect sizes for the total population (table 2). The minimum number of male sage-grouse in 2007 was estimated (Garton and others, 2011b), along with the percent change in number of males per lek and percent change in active leks between 1965 and 2007. The most male sage-grouse occur in MZ II, and the least are in MZ VII. The highest percent change (decline) in number of males per lek and the largest percent change in active leks both occurred in MZ VI.

Genetic Diversity, Population Structure, and Sustainability

The spatial organization of populations across a species' range is an important factor influencing its long-term viability. Species that have multiple interconnected populations are more likely to persist because the risk of extirpation caused by regional events is confined to local populations; connectivity among populations ensures that re-colonization can occur following local extirpation assuming that sufficient suitable habitat remains (Gilpin and Hanski, 1991; Hanski and Thomas, 1994; Hanski, 1998). Thus, movement by individuals within this spatial network is expressed through gene flow, one of the most critical, yet least understood, processes governing species persistence. For several grouse species, patches of unsuitable/poor habitat above a particular size threshold have been

Table 1. Recognized populations and subpopulations of sage-grouse included in this analysis.

Management Zones	Population Subpopulation	Approximate Separation from Adjacent Populations (km)	Brief Description
	Dakota (Mont./N. Dakota/S. Dakota)	30–40	Isolated population, fragmented
	Fall River S. Dakota/ Eastern Wyoming	10–20	Small population, fragmented
	Alberta/ Southwest Saskatchewan/ Montana	20, narrow corridor	Isolated population
1	North Central Montana	20	Large population, isolated by river
	South Central Saskatchewan/ Montana	20–40	Fragmented
	Central Mont.	N.A.	Large population, isolated by river
	Eastern Interior Mont./Northeastern Wyoming	10–20	Large population, loosely connected
	Eastern Tavaputs Plateau, Utah	50	Small population, isolated
	Eagle/ Southern Routt, Colorado	20–30 and mountains	Small population, isolated
	Garfield, Colorado	40	Small population, isolated
	Jackson Hole, Wyoming	50	Small population, isolated
	Laramie, Wyoming	30 and mountains	Small population, isolated
	Middle Park, Colorado	20–30 and mountains	Isolated
2	Northeastern-Interior, Utah	30–50	Isolated, natural fragmentation
	Summit/Morgan, Utah	20–40 and mountains	Small population, isolated
	Dinosaur, Utah/ Colorado	10–20, narrow corridors	Isolated
	North Park Colorado/ Wyoming	10, narrow corridor	Isolated, loosely connected
	South Central Mont./North Central Wyoming	10–40	Large population, loosely connected
	South Central, Wyoming/North Central, Colorado	N.A.	Large population, loosely connected
	Southwestern Wyoming/ Northwestern Colorado/ Northeastern Utah/ Southeastern Idaho	N.A.	Large population, loosely connected
	Central Nevada	N.A.	Large population, natural fragmentation
	Southeastern Nevada/ Southwestern Utah	N.A.	Large population, natural fragmentation
	Gunnison Range, Utah	200	Small, translocated population, isolated
	No. Mono Lake California / Nevada *	20–40 and mountains	Isolated
	Northwestern Interior Nevada	20–30	Dispersed and isolated sub-populations
	Pine Nut, Nevada	50–60 and valleys	Small population, isolated
3	Quinn Canyon Range, Nevada	50–80 and valleys	Small population, isolated
	S Mono Lake, California *	20–50 and mountains	Small population, isolated
	S White River, Utah	40–50	Small population, isolated
	Sanpete/Emery, Utah	50–60	Small population, isolated
	S-Central, Utah	50–70 and mountains	Small population, isolated
	Tooele/Juab, Utah	40	Small population, isolated
	White Mountains, Nevada/ California *	50 and mountains	Small population, isolated

Table 1. Recognized populations and subpopulations of sage-grouse included in this analysis.—Continued

Management Zones	Population Subpopulation	Approximate Separation from Adjacent Populations (km)	Brief Description
4	Baker, Oregon	30	Small population, isolated
	Bannack, Mont.	30–50 and Continental Divide	Small population, isolated
	Belt Mountains, Mont.	70, narrow corridor	Small population, isolated
	E-Central, Idaho	30–50	Isolated
	Red Rock, Mont.	20–40 and mountains	Small population, isolated, natural fragmentation
	Sawtooth, Idaho	70–80	Small population, isolated
	Big Lost, Idaho	10, narrow corridors	Loosely connected
	Lemhi-Birch, Idaho	20 and topography	Isolated
	Little Lost, Idaho	20 and narrow corridors	Loosely connected
	N Side Snake	10–30	Large population, loosely connected
	Upper Snake	20–40 and mountains	Isolated
	Twin Bridges, Montana	60	Small population, isolated
	Weiser, Idaho	20	Small population, isolated
	Wisdom, Montana	4–60	Small population, isolated
5	E-Central Oregon	10–30	Loosely connected
	Lake Area Oregon/ Northeastern California/ Northwestern Nevada	20–50	Large population, loosely connected
	South Central Oregon/North Central Nevada	20–30	Several connected subpopulations
	Northeastern Nevada/South Central Idaho/Northwestern Utah	10–20	Large population, loosely connected
	North Central Nevada/ Southeastern Oregon/ Southwestern Idaho	10–20	Several connected subpopulations
	Central Oregon	30	Isolated and fragmented
	Klamath, Oregon/ California	50	Small population, fragmented
	Warm Springs Valley, Nevada	30–60 and valleys	Small population, isolated, fragmented
6 *	Moses Coulee, Washington *	50 and Columbia R.	Isolated
	Yakima, Washington *	50 and Columbia R.	Isolated
7 (2)	Piceance, Colorado	30–40	Small population, isolated
	White River, Colorado	30–40 and mountains	Small population, isolated

*Recognized populations which are not part of this assessment.

(Adapted from Connelly and others, 2004.)

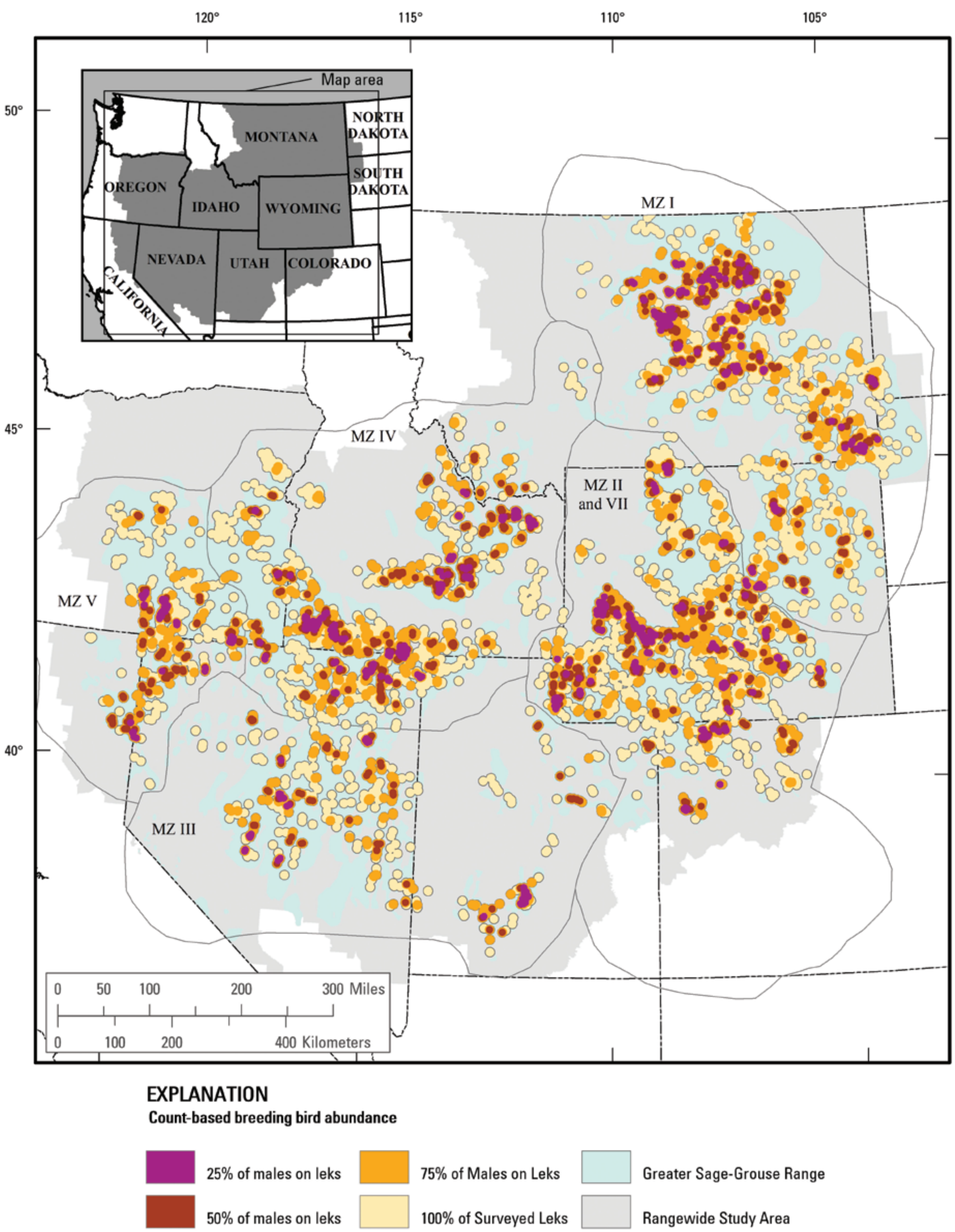


Figure 4. Concentrations of strutting males at leks, an indication of the distribution of individuals, populations, and reproductive effort across Management Zones (MZ).

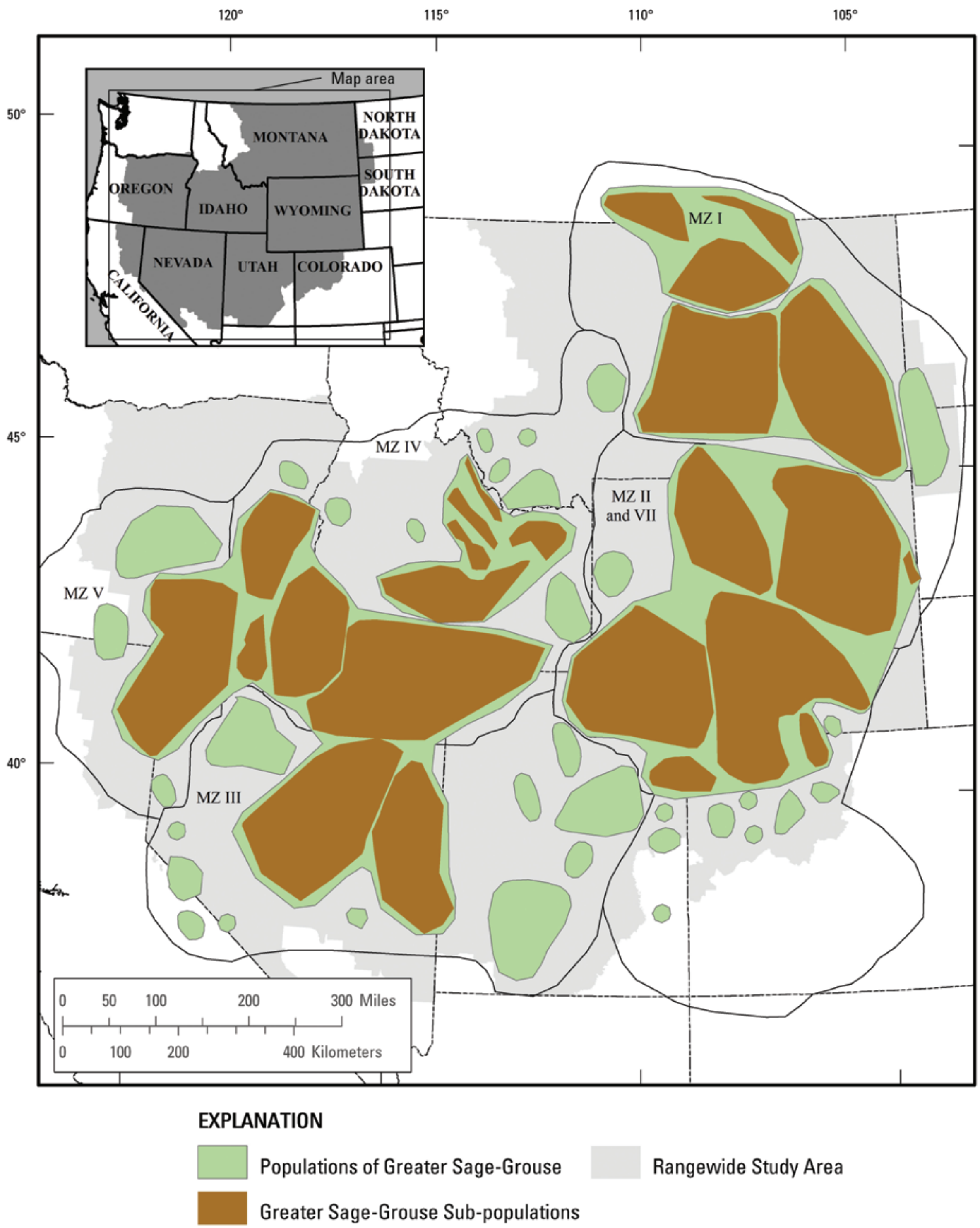


Figure 5. Greater Sage-Grouse populations and subpopulations. MZ, Management Zone.

Table 2. Estimated trends in population size for each sagebrush Management Zone (MZ).

MZ	State and Provinces Included	Population Trend Estimates 1965–2003* (Connelly and others, 2004)	Population Trend Estimates Based on Annual Rates of Change (%) 1965–2007 (WAFWA 2008)	Population Trend Estimates Based on Annual Rates of Change (%) 1965–2007 (Garton and others, 2011)
I	MT, WY, ND, SD, SK, AL	Long-term decline	–2.9	–2.9
II	ID, WY, UT, CO	Long-term decline	–2.7	–3.5
III	UT, NV, CA	Long-term decline	–2.2	–10**
IV	ID, UT, NV, OR	Long-term decline	–3.8	–4**
V	OR, CA, NV	Change statistically undetectable	–3.3	–2**
VI	WA	Long-term decline	–5.1	–6.5
VII	CO, UT	Change statistically undetectable	No detectable trend	+34**

*Average annual rate of change was not reported.

**Due to sample inadequacies for the statistical analyses used, only data from 1995 to 2007 could be used.

(Adapted from USFWS, 2010, table 5.)

Table 3. Male sage-grouse minimum population estimates (2007), percent change in number of males per lek, and percent change in number of active leks 1965–2007 by Management Zone (MZ).

MZ	Minimum Population Estimate in 2007 (number of males)	Percent Change in Number of Males per Lek (1965–2007)	Percent Change of Active Leks (1965–2007)
I	14,814	–17	–22
II	42,429	–30	–7
III	6,851	–24	–16 ***
IV	15,761	–54	–11***
V	6,925	–17**	–21**
VI	315	–76	–57
VII	241	–13	–39*

*1995 to 2007—due to sample sizes, only data from this time period were used.

**1985 to 2007—due to sample sizes, only data from this time period were used.

***1975 to 2007—due to sample sizes, only data from this time period were used.

(Adapted from Garton and others, 2011.)

shown to prevent successful movement of individuals between populations (Piertney and others, 1998; Oyler-McCance and others, 2005a; Fedy and others, 2008).

The rangewide extent of almost all species, including sage-grouse, is orders of magnitude larger than the dispersal distance of any single individual. In addition, heterogeneity in habitat quantity, configuration, and quality creates spatial discontinuities in population densities. Consequently, species distributions do not consist of a single panmictic population but instead can be best described by a meta-population structure having hierarchical levels of connectivity (Weins and others, 1993). At larger ecological scales, less frequent but longer movements by individuals between populations influence rangewide connectivity and are essential for population persistence. The probability that an individual will move from one population to another is influenced by the species' life-history strategies, relative densities among populations, and the cost to movement. At smaller ecological scales, short dispersals characteristic of most individuals result in the majority of breeding occurring within a relatively distinct and confined area characterized by extensive internal connectivity. Importantly, sage-grouse have demonstrated strong site fidelity suggesting resistance of individuals to adjust to changing habitat conditions (Berry and Eng, 1985; Fischer and others, 1993; Schroeder and Robb, 2003; Holloran and Anderson, 2005; Moynahan and others, 2007; Baxter and others, 2008; Doherty and others, 2010a; Holloran and others, 2010). Identification of these demographically independent populations and defining their boundaries is a fundamental component to managing any wildlife species.

In addition to population connectivity, maintaining sufficient levels of genetic diversity is also important for population viability and persistence. Observations of inbreeding depression in captive (Lacy and others, 1996) and field populations (Jimenez and others, 1994; Keller and others, 1994; Keller and Waller, 2002) and studies of heterozygosity-fitness relations (Reed and Frankham, 2003) have led to the realization that loss of genetic variation could affect population viability (Gilpin and Soule, 1986; Lacy, 1997). Furthermore, observations of wildlife populations that have experienced loss of genetic variation due to bottlenecks also support the conclusion that such losses can affect population productivity, particularly in lek-breeding birds (Bouzat and others, 1998) such as sage-grouse. Practices that lead to reduced genetic variation, such as establishing populations with only a few individuals or allowing populations to remain small and fragmented, might have serious consequences for population viability. Concerns about effects of inbreeding on demography relate to time scales that are relevant to management activities (Westemeier and others, 1998; Johnson and Dunn, 2006). On a longer time scale, managers must be concerned about loss of allelic variation that can affect the ability of populations to adapt to new environmental challenges (Allendorf and Leary, 1986; Frankham, 1995), including enhanced susceptibility to parasitic agents or infectious disease such as West Nile virus, which has been shown to be a significant threat for sage-grouse (Naugle and others, 2004).

Most conservation geneticists promote maintaining large effective sizes of well-connected populations to prevent loss of genetic variation and possible associated reductions in population viability. Recommendations concerning population sizes necessary to prevent adverse genetic consequences vary considerably; there is no general agreement on what appropriate minimum numbers are acceptable for long-term management goals (Gilpin and Soule, 1986; Simberloff, 1988; Hedrick and Kalinowski, 2000; Reed and Bryant, 2000). Most published recommendations of minimum population size are in terms of minimum effective size, and these recommendations indicate that the number of breeding-age individuals in most populations should be at least two to four times larger than the minimum effective size. This is particularly relevant for sage-grouse whose effective population size may be much less than census size due to their highly skewed mating system.

Sage-grouse need vast expanses of sagebrush habitat to meet their seasonal habitat needs (Connelly and others, 2004; Connelly and others, 2011d). Fundamental to developing conservation objectives for sage-grouse is to identify and subsequently design strategies to maintain a set of viable and connected populations. Therefore, it is important to know (1) the spatial delineation of breeding populations of sage-grouse, (2) how primary populations are interconnected across regions of lower population densities and less suitable habitat, and (3) the spatial scale and relative importance of landscape features that influence gene flow. Currently, an understanding of how populations are spatially structured for sage-grouse is somewhat limited. The characteristics of gene flow within and among populations and what landscape features represent barriers to sage-grouse dispersal that are significant enough to fragment or isolate populations are largely unknown. Distance, topography, or large blocks of unsuitable habitat all potentially influence dispersal at local and regional scales. Few studies using conventional radio-telemetry techniques or recaptures of marked individuals have documented either dispersal distances or landscape features that influence dispersal patterns. Considerable money and effort has been spent tracking the movement of animals using radio-telemetry and band recoveries for sage-grouse. Although these methods are effective, they are limited in the spatial and temporal scale of the questions they can address.

A recent model of the rangewide spatial structure of sage-grouse based on the mapped distribution of leks delineated numerous small populations interspersed between a few large populations and around the periphery of the range by clustering leks interconnected within an 18 km (11 mi) dispersal distance (fig. 6; Knick and Hanser, 2011). Concern over the degree of isolation of the small populations is warranted. Current sagebrush habitats were relatively intact within the large populations. Nonetheless, additional habitat loss caused by natural or human disturbance could fragment and divide these large populations as well as further isolate small

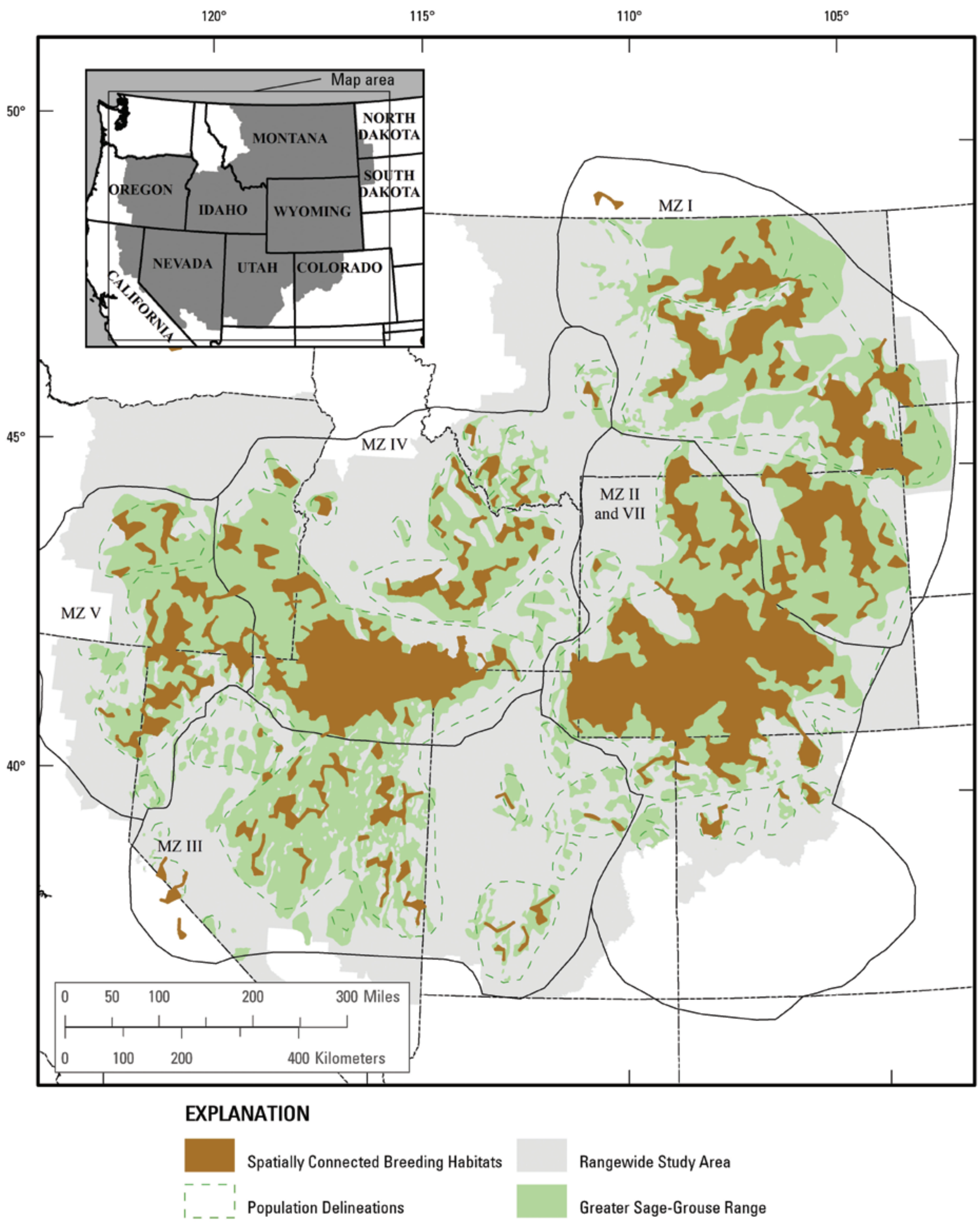


Figure 6. Spatial connectivity within sage-grouse population structure across the current species' range. MZ, Management Zone.

populations whose viability may depend on dispersal from neighboring populations.

A complementary approach to understanding population boundaries and movement among populations uses genetic methods that allow for assessment over broad spatial extents and the measurement of the actual breeding consequences of animal movement. In addition to defining populations and measuring connectivity, genetic approaches also address many other relevant questions including the conservation of genetic diversity, the impacts of inbreeding, and the association between habitats and genetics. Previous genetic work has provided a coarse-scale examination of the distribution of genetic variation across the entire range of sage-grouse using both mitochondrial DNA (mtDNA) sequence data and data from nuclear microsatellites (Oyler-McCance and others, 2005b). In this study, 1,080 samples were collected from 46 populations from all U.S. States with populations of sage-grouse and one Canadian province (Alberta) spanning the entire range of the species (Oyler-McCance and others, 2005b). Overall, Oyler-McCance and others (2005b) found the distribution of genetic variation showed a gradual shift across the range in both mitochondrial and nuclear datasets. This pattern suggests localized gene flow with isolation by distance, for example movements common among neighboring populations yet highly unlikely across distant portions of the range. A genetic-clustering analysis (fig. 7; Oyler-McCance and others, 2005b) revealed that unique genetic clusters were comprised of populations geographically adjacent to one another, and though most genetic clusters consisted of many populations, the smaller, more fragmented populations on the periphery of the range (in Colorado, Utah, Bi-State in Nevada/California, and Washington) comprised their own clusters, suggesting lower amounts of gene flow in these areas (peripheral isolates). These data are consistent with previous research on dispersal (Dunn and Braun, 1985), suggesting that gene flow is likely limited to the movement of individuals between neighboring populations and not likely the result of long-distance movements of individuals (across large portions of the range). Their data suggest linkages among neighboring populations and differences among distant populations. This raises the possibility that local adaptations may exist, and therefore, translocations involving neighboring populations rather than geographically distant populations are more likely to succeed.

In addition to estimating levels of connectivity among populations, genetic analysis can compare levels of genetic diversity and document genetically unique populations. Similar to previous findings, (Benedict and others, 2003), recent analyses by Oyler-McCance and others (2005b) revealed that the least amount of genetic diversity occurred in the two Washington populations (MZ VI), which was likely caused by prior habitat loss, isolation and subsequent population decline. One population sampled in Utah, Strawberry Valley, was also found to have low genetic diversity, likely due to a severe genetic bottleneck caused by unnaturally high predation. The Bi-State population (MZ III) was found to be genetically unique compared to all other populations, and the difference was striking. Most individuals (93 percent) in the Bi-State population contained novel mtDNA haplotypes not found elsewhere across the range. The genetic diversity present in the Bi-State population, however, was comparable to (if not higher than) most other populations, suggesting the differences were not due to a genetic bottleneck or founder event. Nuclear data corroborated these data as the Bi-State population was significantly different from all other populations and was the only population forming its own unique genetic cluster (fig. 7).

Under the National Greater Sage-Grouse Land Use Planning Strategy, BLM and USFS are designing management actions for sage-grouse based on identifying priority areas containing the highest densities of breeding birds and their seasonal and annual habitats. This approach is intended to reduce threats to priority habitat and focus limited conservation resources in regions that have the greatest potential to benefit the largest proportion of sage-grouse (Doherty and others, 2011c). Complementary to the priority areas, general habitat areas will also be identified with objectives related to maintaining connectivity, movement, and genetic diversity (Bureau of Land Management, 2011a). As a trade-off, energy and other development may be proposed within general habitat under less restrictive stipulations. However, meeting the overall goals for sage-grouse in this approach will rely on avoiding the unintended consequence of isolating sage-grouse populations within priority areas. Therefore, it is important to understand how sage-grouse populations are structured, the relation of breeding populations to delineated core areas, and how landscape features influence dispersal among core areas.

The concepts of structural and functional connectivity are critical components for guiding conservation actions emphasizing priority areas coupled with identifying and maintaining corridors to facilitate gene flow through general habitat. Structural connectivity, the spatial arrangement of habitat and environmental variables, is an important first step and is the foundation for delineating priority areas. Recent rangewide assessments (Connelly and others, 2004; Rowland and others, 2006; Knick and Connelly, 2011b) have provided extensive spatial information on habitats, threats, and conservation actions that is necessary for understanding the structural connectivity of habitats (Tischendorf and Fahrig, 2000). These data help delineate the spatial patterns of important ecological components for sage-grouse. Ongoing genetic studies that incorporate landscape data are attempting to better understand functional connectivity, which is based on interpreting the spatial arrangement of habitats from a species' perspective (Wiens, 2002). Functional connectivity is far more challenging to study than structural connectivity, but it provides information on the processes underlying the patterns. State and Federal agencies have the opportunity to influence the future form and function of sagebrush landscapes across broad regions through resource planning, and sage-grouse population and habitat connectivity are an important consideration for this process. Landscape-genetics concepts provide keys to developing conservation strategies by identifying population strongholds, habitat connectivity, and movement corridors that

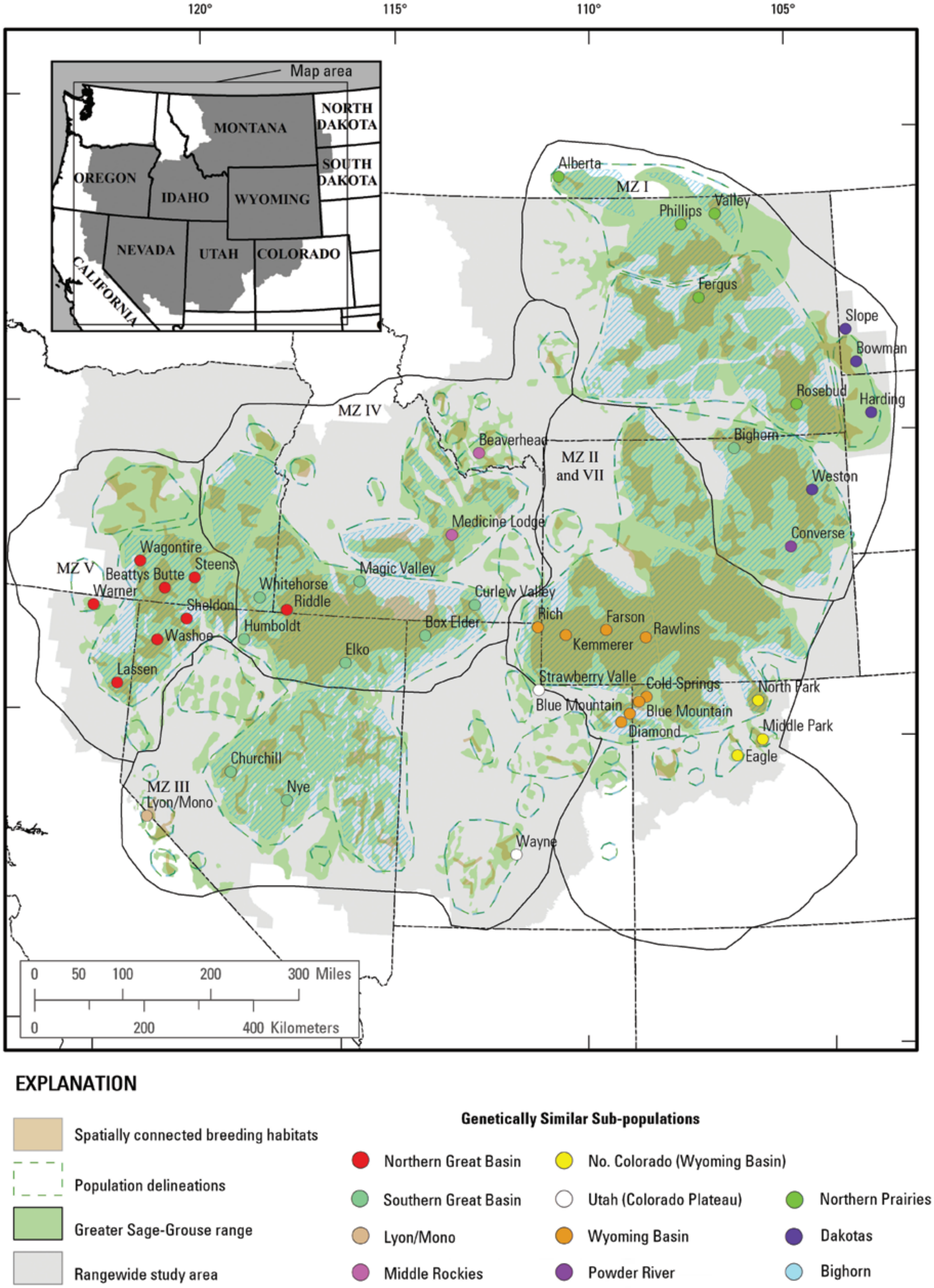


Figure 7. Map of sampling sites for the microsatellite analysis assigned by 'Structure' analysis; genetic similarity is implied for subpopulations with similar color coding. MZ, Management Zone.

facilitate dispersal and gene flow and are, therefore, important to sustain population viability.

Habitat Characteristics and Ecosystem Associations

Sage-grouse is a sagebrush-obligate species that relies on a variety of sagebrush dominated communities to meet various needs throughout their life cycle (Patterson, 1952; Braun and others, 1976; Connelly and others, 2004; Connelly, 2005; Miller and others, 2011). Sage-grouse are closely tied to sagebrush communities and the range of sage-grouse includes at least eleven species, or subspecies (as many as 20 identified in some States), of sagebrush (*Artemisia* spp.) that differ in their associated plant communities, productivity, resilience, and ability to resist disturbance (Miller and Eddleman, 2000; West and Young, 2000; Connelly and others, 2004; Knick and Connelly, 2011a). Sagebrush communities comprise diverse plant communities that include perennial grasses and forb species with composition, structure, and productivity influenced by abiotic conditions such as topography, elevation, precipitation, and soil (Miller and Eddleman, 2000; Connelly and others, 2004). The species of sagebrush most commonly associated with sage-grouse include *Artemisia tridentata* ssp. *wyomingensis* (Wyoming big sagebrush), *A. t.* ssp. *vaseyana* (mountain big sagebrush), *A.t. tridentata* (basin big sagebrush), *A. arbuscula* (low sagebrush), *A. nova* (black sagebrush), *A. frigida* (fringed sagebrush), and *A. cana* (silver sagebrush; Schroeder and others, 1999; Connelly and others, 2004). The distribution of sage-grouse is highly correlated with the distribution of sagebrush across its distribution in North America (Schroeder and others, 2004).

In the spring, during the breeding season, sage-grouse males seek out lek sites that are open areas of bare soil, short grass steppe, windswept ridges, or exposed knolls in which to gather and perform their ritualized mating displays (Patterson, 1952; Connelly and others, 2004) in order to attract females for breeding. The location of active leks is generally known, and this information has been used to define MZs, planning units, and research designs as discussed throughout this report. The timing of lek attendance varies considerably depending on snow depth, elevation, weather, and geographic region with first attendance ranging from the end of February to early April and ending in late May or early June (Eng, 1963; Schroeder and others, 1999; Aldridge, 2000; Hausleitner, 2003; Connelly and others, 2004). Such lek sites are typically open areas (low-shrub cover) located in the midst of denser shrub stands, which together provide the necessary combination of visibility, protection, food, and thermal regulation (Connelly and others, 1981; Connelly and others, 2000b; Connelly and others, 2011b). Females visit leks for copulation and then can travel more than 20 km (12.5 mi) for nesting afterward (Connelly and others, 2000c), yet distances from the lek to nesting areas are highly variable. Five studies that included 301 nest locations revealed that the distance from lek of capture to nesting areas averaged from 3.4 km to 7.8 km (2.1–4.8 mi; Schroeder and others, 1999). Nesting areas tend to be surrounded by sagebrush with an understory of native grasses and forbs with ample vertical and horizontal structure to support a diversity of insect prey, provide cover, as well as herbaceous forage for pre-laying and nesting hens (Gregg, 1991; Schroeder and others, 1999; Connelly and others, 2000b; Connelly and others, 2004; Connelly and others, 2011b). Vegetation characteristics of successful nesting areas have been described with details not provided here (Connelly and others, 2000c).

Egg laying and incubation typically occur 3–4 weeks after peak lek attendance followed by brood-rearing in late spring and early summer (Schroeder, 1997; Aldridge and Brigham, 2003b; Hausleitner, 2003; Connelly and others, 2004). Broods are typically found in areas near nest sites for the first 2–3 weeks after hatching (Connelly and others, 2004). Such habitat needs to provide adequate cover and areas with sufficient forbs and insects to ensure chick survival in this life stage (Connelly and others, 2004). As the chicks get older, sage-grouse tend to move into more moist areas (streambeds or wet meadows) because as herbaceous vegetation dries out, wetter areas provide more forbs and insects for hens and their chicks (Schroeder and others, 1999; Connelly and others, 2000a). Hens without broods and male sage-grouse use wetter areas that are close to sagebrush cover in late summer (Connelly and others, 2004).

Beginning at the end of summer, and extending into fall and winter, the diet of sage-grouse shifts to one comprised solely of sagebrush (Schroeder and others, 1999). During this time, sage-grouse also depend on sagebrush for cover. Habitat selection at the sagebrush-stand level during winter months is driven by the depth of snow (Patterson, 1952; Hupp, 1989), the availability of sagebrush above the snow (Connelly and others, 2004), and topographic patterns (Beck, 1977; Crawford and others, 2004) that create localized habitats providing cover and forage. Because use and availability of these seasonal habitats are spread across a given landscape, sage-grouse require vast areas of contiguous sagebrush to meet their needs on an annual basis (Patterson, 1952; Connelly and others, 2004; Connelly and others, 2011d; Wisdom and others, 2011).

Sagebrush-vegetation types are strongly determined by environmental limitations and gradients driven primarily by temperature and precipitation patterns (Miller and others, 2011). The sagebrush-steppe occurs in the northern portion of the range of sage-grouse from British Columbia and the Columbian Basin in the northwest; south through the northern Great Basin and Snake River Plain; and east into southwestern Montana, the Wyoming Basin, and northern Colorado Plateau (fig. 8). In this type, sagebrush typically co-dominates with perennial bunchgrasses (Miller and others, 2011). The second major type, Great Basin sagebrush, is found south (and west) below the polar-front gradient where the herbaceous component contributes a smaller portion of the total plant cover (Miller and Eddleman, 2000) due to hydrologic patterns. Thus, in this type, sagebrush is frequently the canopy dominant with little understory (Miller and others, 2011). The Great Basin

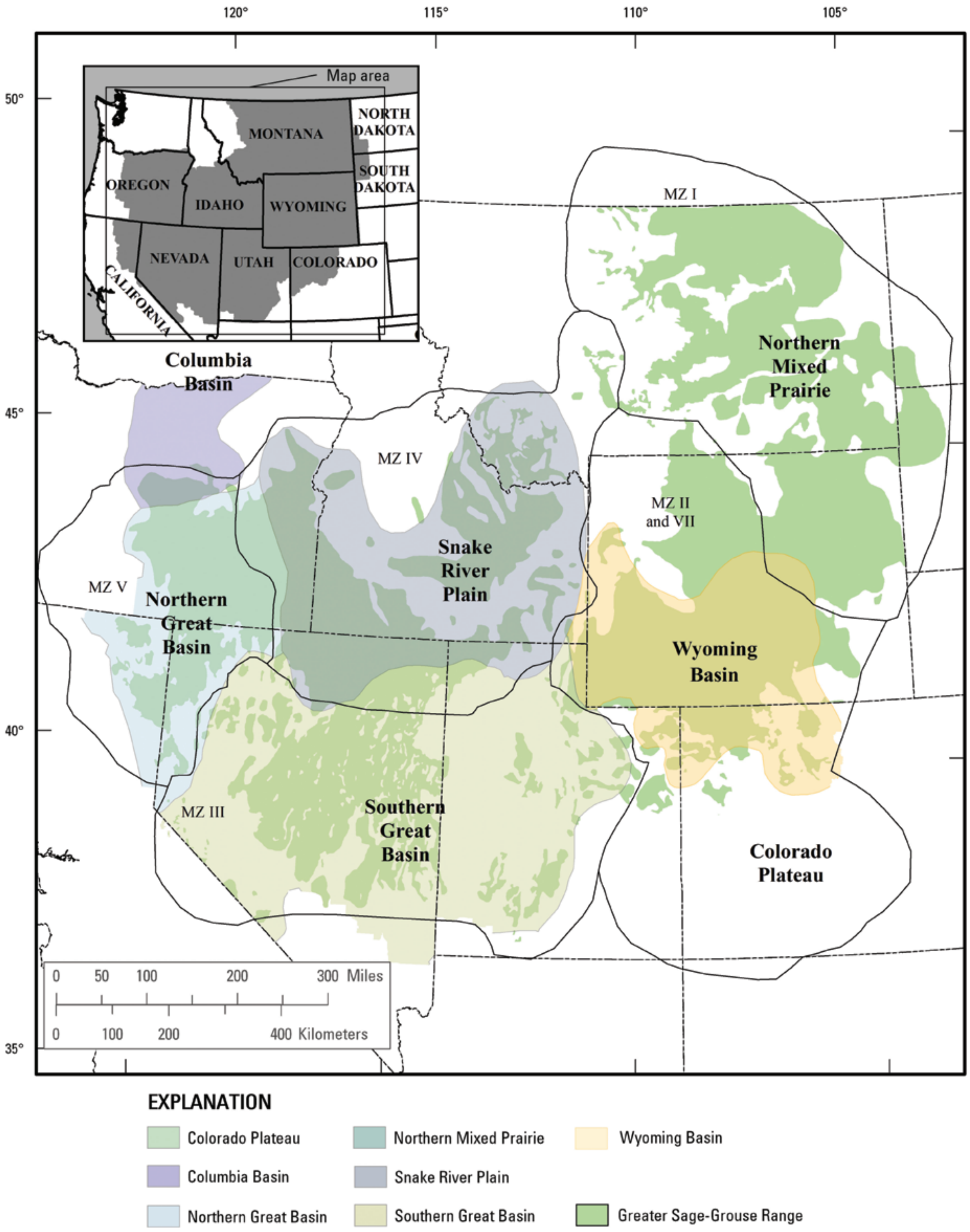


Figure 8. Seven major sagebrush biomes, including the southern Great Basin types (Southern, Northern, and Colorado Plateau), northern sagebrush-steppe (Snake River Plain, Wyoming Basin, and Columbia Basin) and northern mixed prairies. MZ, Management Zone.

sagebrush community type extends from the Colorado Plateau west across Nevada and Utah and into California (Miller and others, 2011). A third major sagebrush-vegetation type, the mixed shrubland, occurs in the Bighorn Basin in north-central Wyoming. A fourth type includes the mixed big sagebrush and silver sagebrush-grasslands (including portions of the Northern Prairies) that are found in eastern Montana and Wyoming (Miller and others, 2011); these support sage-grouse populations primarily within *A. cana* and *A. filifolia* associations.

Multiscale Habitat Selection

Sage-grouse are currently estimated to occupy 165 million acres (668,000 km^2) across the Western United States and Canada (Knick and Connelly, 2011a), and this range encompasses tremendous variability in habitat conditions, anthropogenic activities, and grouse populations. Development of comprehensive monitoring approaches lead to formal recognition that habitat selection assessments are needed to utilize approaches that address multiple spatial scales to represent selection processes of the animals (Connelly and others, 2003b; Connelly and others, 2011d; Stiver and others, 2010). The first-order (1) is the geographic range and defines the sage-grouse population of interest, and within this geographic range (2) characterization of the second-order hinges on large, relatively intact regions of habitat identified using subpopulation distributions (for example, geographic connections among leks or regional population connectivity using genetics) to link habitats to use. The third-order (3) requires refinement from broad habitat delineations by specifying seasonal habitats (for example, nesting habitat), patch selection, and migration habitats. Finally, assessment can be made of fourth-order selection (for example, daily site selection and behavioral observations) by (4) quantifying food and cover attributes and foraging behavior at particular sites. In practice, selection of food items is nested within selection of feeding site because selection of a particular site determines the array of food items available to be selected; importantly, habitat value and use will best be determined using a combination of these characteristics (not one alone). To accurately characterize sage-grouse habitat selection for a given population at the first- and second-orders, or landscape spatial scales, the migratory nature (seasonal movements) of the population must be well understood (see Connelly and others, 2000), and this may include very large areas on an annual basis. It has been suggested that migratory populations may range across hundreds of square miles (Connelly and others, 2003b) with individual movements up to 145 km (90 mi; Smith 2012).

The relative importance of a particular seasonal habitat may be dictated by *quantity* (for example, critical winter habitat may represent a small proportion of the available sagebrush habitats in the area), *quality* (this may be realized when *potential* early brood-rearing habitats are widespread, for example, but suboptimal herbaceous cover reduces value and use of some areas), and *juxtaposition* (as an indication of the necessary proximity of suitable early brood-rearing sites and suitable nesting sites), which together describe relevant local-scale spatial heterogeneity within broadly suitable and available habitats. It is also likely that movement corridors between seasonal sites have particular value for sage-grouse as seasonal habitats (distinct from origination and destination habitats), especially for migratory populations moving long distances between seasons (Connelly and others, 2003). Although the optimal proportions of distinct seasonal habitats required on a landscape for productive sage-grouse populations are unknown, sage-grouse productivity is generally increased if individuals are able to space themselves widely across the available landscape allowing them full advantage of variations in land and habitat to satisfy their cover, forage, solitude, and migratory needs (Holloran and Anderson, 2005).

III. Characterization of Important Threats and Issues

The USFWS 12-month finding, in agreement with recent reviews, research, and analyses provided by the science and management communities (Federal Register 50 CFR Part 17; FWS-R6-ES-2010-0018; Connelly and others, 2004; Knick and Connelly, 2011b), recognized a range of important influences on sage-grouse populations and their successful conservation. These common threats and issues fall into five main categories, which were recognized by USFWS in the published findings—habitat change (Factor A), over-utilization (Factor B), disease and predation (Factor C), chemical poisoning (Factor E), and policy and land use (Factor D)—which may vary in relative importance among MZs but are inclusive and representative of the suite of threats and issues across the species' range. (Factors A-E were originally characterized in the USFWS findings report; we reorganized our treatment of these topics [Factors A, B, C, E, then D] to consolidate conceptually related topics. The organization in this document does not exactly parallel the USFWS Federal Register document, but all topics in the findings report are addressed here.) Each of these topics are addressed in the following pages, with particular attention paid to issues identified by USFWS and others that contribute to direct or indirect impacts on sage-grouse populations. With this broad outlook, it is important to recognize that though over-utilization, disease and predation, and chemical poisoning are recognized as having direct effects (such as mortality) on sage-grouse populations—and the effects of these factors may be the principal cause of population declines in local areas during specific years, for example West Nile virus outbreaks—the impact of these factors on rangewide population sustainability are considered relatively small compared to indirect effects on populations via habitat degradation, policy limitations, and competing land uses. Habitat change (Factor A), which represents a suite of changes in both local conditions (implications for forage, cover and nest quality, for example) as well as regional landscape patterns (implications for habitat availability, connectivity, and isolation, for example), includes the bulk of factors identified in previous research and litigation as affecting sage-grouse populations. Despite research and expertise that address the role of these factors in habitat condition and function of the sagebrush ecosystem, causal connections that precisely relate these factors to population responses are not known in many cases (and likely cannot be consistently and accurately translated as simple causal mechanisms); this is often the case with complicated relations. Thus, many of the following sections outline connections between activities, patterns, and processes recognized as threats to the condition (measured, theoretical, and desired) of the sagebrush ecosystem and the likely, or expected, response of local sage-grouse populations to these influences, as presented in the literature. These discussions and diagnoses may recognize local population details; however, detailed local distinctions are largely beyond the scope of this effort. The broad-scale patterns and associations occurring rangewide and regionally, which are summarized here, will benefit from incorporation with detailed knowledge of local managers, including unpublished reports and similar locally explicit references, when translating these regional patterns into local conservation planning. Therefore, this summary and spatial analysis will inform and enhance local understanding by providing broad-scale data summary and interpretation helping to put local conditions and issues into context and thereby informing the process of developing complete and comprehensive land and resource management planning.

This distinction (local detail versus regional perspective) is consistent with the multiple-scale approach to management and conservation being applied here. This report is focused on providing “global” (first order) and “regional” perspectives (second order); much of the information provided herein is summarized from research on individuals and populations (third and fourth order). Local data, and associated local decisions, are critically important to conservation and management success, but they cannot be accurately represented here (without expanding the scope and effort); local perspectives and decisions need to be informed by local professionals. Information on sage-grouse has been accumulated from many different populations residing in different habitats, and current knowledge is based on combining these disparate sources and extrapolating understanding derived from specific populations and circumstances to establish rangewide consistencies (Crawford and others, 2004). Confounding factors across all populations and analytical units include different causes of mortality in different areas, differences between migratory and resident populations, temporal and spatial differences in habitat conditions, nuances and variability in population estimates, and differences in cycling rates and current position relative to long-term and short-term trends (Fedy and Doherty, 2011).

Recent developments in wildlife conservation have included a shift from project-level to landscape-level perspectives in conservation planning. However, effective management of a species of wildlife under this paradigm typically requires the consideration of several scales. Sage-grouse are a wide-ranging species, and large landscapes need conservation to maintain the species (Connelly and others, 2004; Connelly and others, 2011d). However, habitat degradation—one of the overriding mechanistic factors resulting in population declines—will have to be handled at much smaller scales to restore the condition and function of rangelands.

Factor A: Habitat Change

Sage-grouse populations typically occupy habitats with a diversity of species and subspecies of sagebrush interspersed with a variety of other habitats (riparian meadows, agricultural lands, grasslands, and sagebrush habitats with some conifer or deciduous trees); these habitats are usually intermixed in a sagebrush-dominated landscape and are often used by sage-grouse during certain times of the year (seasonally) or during certain years, for example, a winter with above-normal snowpack (Connelly and others, 2011d). The natural variation in vegetation, the dynamic nature of sagebrush habitats, and the variation in the habitats selected by sage-grouse across a landscape imply that characterizing habitats using a single value or narrow range of values, for example, 15- to 25-percent sagebrush-canopy cover in breeding habitat (Connelly and others, 2000c), is insufficient to describe sage-grouse habitat requirements. The differing seasonal habitat requirements of sage-grouse dictate that multiple vegetation attributes, across the landscape *and* in particular sites, are important, reinforcing emphasis that combinations of shrub overstory and herbaceous understory, which are both important as habitat components during different seasons, are important in combination and across scales (Connelly and others, 2011d). Although animals may have different requirements and selection behaviors in different seasons, seasonal habitats may overlap; for example, winter habitat may also provide brood-rearing habitat in some populations, whereas others may travel great distances between seasonal habitats. Interspersion and juxtaposition of the differing cover types used by sage-grouse on an annual basis within the range of a local population will greatly influence the effectiveness of the landscape to provide quality sage-grouse habitat (Connelly and others, 2011d).

Human alterations, uses, and impacts coupled with natural variability (for example, drought) have changed the extent, condition, and distribution of sagebrush-steppe and the ecosystem services this biome provides (Meinke and others, 2009). Current sage-grouse range is estimated to be 56 percent of historic (pre-European settlement) distribution (Stiver and others, 2006a). Disrupted disturbance regimes, degraded or depressed native species, and dominance by introduced noxious plants have moved many of these systems toward, or beyond, critical thresholds from which restoration is difficult or excessively time-consuming and expensive (Meinke and others, 2009). Three of the fundamental characteristics of the sagebrush biome that have been altered from presettlement conditions include (1) the total area of sagebrush shrubland has been reduced; (2) the composition and structure of the vegetation and soils in sagebrush communities have been changed, including increased abundance and performance of invasive species and decreased abundance and performance of native species; (3) fragmentation created by roads, power lines, fences, energy developments, urbanization, and other anthropogenic features isolate populations by restricting movements or degrading habitat (Connelly and others, 2004). For example, 75 percent of the shrub steppe growing on deep soils has been converted to agricultural croplands (Connelly and others, 2004), and intense historic land use (especially livestock grazing) in the late 19th and early 20th centuries reduced the dominance of native grasses, trampled microbiotic crusts, and encouraged expansion of Eurasian grasses (Anderson and Inouye, 2001; Ponzetti and others, 2007; Root and McCune, 2012). Therefore, long-term conservation of the species as well as sagebrush habitats may, simply stated, hinge on adaptation, reclamation, and recovery of native ecosystems from historic land uses and former practices.

The combination of natural variability (for example, drought) and a legacy of multiple human land uses with various but widespread impacts has induced changes in the extent, condition, and distribution of sagebrush ecosystems and the biological services they provide. Currently, few intact sagebrush ecosystems are in the condition they were in historically (reference conditions), which influences habitat function, and consequentially, the distribution and health of wildlife in the region (Connelly and others, 2004). To better address cumulative effects of multiple (different) land uses, and to begin to account for indirect impacts (besides direct habitat removal, for example), a combination of factors may be combined to estimate a “human footprint” providing an index to assess and compare levels of use and potential impacts (Leu and Hanser, 2011). The human-footprint index considered here indicates the spatial accumulation of effects due to anthropogenic features—including human habitation, highways and roads, railroads, power lines, agricultural lands, campgrounds, rest stops, landfills, oil and gas developments, and human-induced fires—on a landscape expressed on a 1 to 10 scale (Johnson and others, 2011; Leu and Hanser, 2011). The human footprint is most intense at low elevations near valley floors and may have disproportionate effect on sage-grouse populations reliant on these habitats during critical portions of the year (Leu and Hanser, 2011). Across the sage-grouse range, lek count declines were measurable when human-footprint scores exceeded “2” at lek sites and when scores exceeded “3” within either 5 km or 18 km (3.1 or 11.2 mi) of a lek (Johnson and others, 2011). Notably, these values (2 and 3) are toward the low-intensity end of this distribution. In the following pages, six sections summarize information regarding contributions of the human footprint to sage-grouse habitat conditions: (A1) fragmentation and connectivity, (A2) agricultural conversion, (A3) urbanization and human habitation, (A4) general infrastructure, including highways and improved surface roads, railroads, transmission lines and power lines, communication towers, and fences, (A5) energy development and associated infrastructure, and (A6) fire.

A1. Habitat Fragmentation and Connectivity

Sage-grouse populations generally rely on large, interconnected expanses of sagebrush to accommodate local migrations and access to seasonal habitats distributed within their inhabited range (Connelly and others, 2004), and “fragmentation” represents the dissection of large expanses via various mechanisms. Conclusive, consistent data establishing minimum sizes of sagebrush-dominated landscapes necessary to support viable populations of sage-grouse are unavailable (Connelly and others, 2011d). However, some quantitative indications exist, for example sage-grouse populations in Idaho used an annual range of at least 683,000 acres (2,764 km^2; Leonard and others, 2000). Research in Wyoming and Montana suggested that a sagebrush-dominated landscape 77,600 acres (314 km^2) in size may provide the area necessary to maintain breeding habitat around a given lek (Doherty and others, 2008). The size of a landscape needed to support breeding habitats of an interspersed population (for example, an area with *multiple* leks spaced less than 6.2 miles [10km] apart) may exceed 247,000 acres (1,000 km^2; Doherty and others, 2008). Investigations from Idaho and Wyoming suggest that relatively large blocks of sagebrush habitat (>9,900 acres [4,000 ha]) are critical to successful reproduction and overwinter survival (Leonard and others, 2000; Walker and others, 2007a). Mean sagebrush patch size within an 18 km radius (250,000 acres [1,018 km^2]) was more than nine times as large in occupied versus extirpated sage-grouse range; sagebrush patch size in occupied range averaged 10,300 acres (4,173 ha; Wisdom and others, 2011). Based on natural geographic patterns, it has been suggested that sage-grouse may have adapted to a scale of natural fragmentation in sagebrush habitats organized at 2.8–5.6 mi (4.5 to 9 km; Leu and Hanser 2011); research on selection behavior indicated similar, emergent patterns based on spacing between leks (nearest-neighbor distances of 0.36 mi [5.9 km]), mean lek to nest movements (3.2 mi [5.1 km]), and nest to summer range movements generally limited to less than 6.2 mi (10 km; Fedy and others, 2012), supporting this contention.

The scale of the landscape used by sage-grouse changes throughout seasons and may differ between populations based on available habitats. Strong site fidelity of sage-grouse for established nesting habitat (Fischer and others, 1993; Holloran and others, 2005; Thompson, 2012) and suggested for other seasonal habitats (Berry and Eng, 1985; Thompson, 2012) indicates that the “landscape” targeted by an individual female during different life-history stages may be relatively small. The overall landscape requirements for an individual would be the conglomeration of these seasonal habitats combined with the necessary migration corridors (the length of these corridors will be different between and within populations depending on the local landscape as much as on the birds). Thus, the landscape required by an individual is a combination of the seasonal habitat requirements on a relatively small scale, the spatial distribution of those seasonal habitats, and the habitats required to move between those seasonal ranges.

Distances between consecutive-year nests of 0.46 mi (740 m) on average suggest a female will nest (repeatedly) within a 425-acre (172-ha) area during its lifetime (Fischer and others, 1993; Holloran and others, 2005). Additionally, a high degree of fidelity of female offspring to their natal home ranges has been observed (for example, yearling females nesting close to their natal nest) suggesting that family groups of females may inhabit relatively distinct areas (Thompson, 2012). Based on cumulative mean daily movements of sage-grouse broods between hatch and 2-weeks post-hatch (Gregg, U.S. Fish and Wildlife Service, unpub. data, May 2000 – July 2003; received July 2010), early brood-rearing tends to occur within 2.9 mi (4.6 km) of the nest. Sage-grouse generally move ≤6.2 mi (10 km) from nests to summer range—but may travel as far as 50 mi (82 km; Fedy 2012)—and remain in relatively distinct locations upon reaching summer range (Connelly and others, 2011d). In contrast, a majority of sage-grouse move >6.2 mi (10 km) from summer to winter locations with movements of up to 90 mi (145 km) documented (Smith, 2013). Fidelity to a specific region does not appear to be as strong for sage-grouse during winter, and populations have been documented traveling up to 31 mi (50 km) in search of exposed sagebrush after severe storm events in Wyoming (Smith, 2013). Movements from spring to summer range and from summer to winter range generally occur along sagebrush-dominated habitats (Jensen, 2006; Connelly and others, 2011d; Smith, 2013); however, sage-grouse can traverse or circumvent unsuitable habitats between seasonal ranges (Bush, 2009).

In addition to the size of selected habitat patches, lek persistence is strongly related to lek connectivity, which is a measure of the relation between each lek with the maintenance of a regional population network with active dispersal and genetic mixing among subpopulations (Knick and Hanser, 2011). Centrally located, large lek sites have greater importance and metapopulation implications, whereas abandoned leks have lower connectivity importance (Knick and Hanser, 2011). Dispersal distances reported in the literature were compiled and combined to establish the connectivity scale; reported dispersal distances range from 4.6 to 6.6 mi (7.4-10.6 km) for males, 5.5 to 8.1 mi (8.8-13.1 km) for females, and distances of 17 mi (27.6 km) are within the range of variation (Knick and Hanser, 2011). Gene flow in sage-grouse populations is likely limited to the movement of individuals between neighboring populations and not likely the result of long-distance movements of individuals across large portions of the species' range (Oyler-McCance and others, 2005b). Thus, regional connectivity among leks represents a fundamental source of genetic re-combination and metapopulation structure that supports the long-term viability of the species.

Fragmentation in general results in a landscape that consists of remnant areas of native habitats surrounded by a matrix of non-native and typically unsuitable habitats, for example developed or cultivated lands. Fragmentation generally begins to have significant effects on wildlife when suitable habitat becomes less than 30 to 50 percent of the landscape; at lower levels of suitable habitat, the distances between remnant patches of native habitat increase exponentially, and spatial arrangement becomes the critical factor determining success of dispersers finding and using suitable areas (Connelly and others, 2004). Research on fragmented landscapes has focused primarily on the biogeographic consequences of the creation of habitat "islands," which provides little practical value to managers (Saunders and others, 1991). According to Saunders and others (1991), management of fragmented ecosystems has two basic components: (1) management of the internal dynamics of remnant habitats, or managing the natural system; and (2) management of the external influences of non-native areas on these remnant patches. Therefore, management of fragmented landscapes requires integration across land ownership with an approach that incorporates several remnant areas managed as an inclusive system to provide the habitats and resources needed by the sage-grouse population inhabiting the area.

A2. Conversion to Agriculture

One of the fundamental characteristics of western landscapes, which have been altered from pre-settlement conditions, includes a reduction in the total land area dominated by sagebrush (Connelly and others, 2004). Development of vegetation and soil using clearing, tillage, and irrigation (among other practices including seeding, application of fertilizers, pesticides, and herbicides) results in long-term conversion of native sage-grouse habitats to sustained human uses (obviously agriculture, but also subdivisions and exurban developments in portions of all MZs). Cultivated agriculture, primarily cropland, covers more than 56.8 million acres (230,000 km^2; 11 percent) of the total land area within the estimated, historic distribution of sage-grouse, including a 31 mi (50km) buffer (Knick and Connelly, 2011a). Agriculture is defined as predominantly cropland, or lands that have been converted for the production of foods and goods (Knick and Connelly, 2011a). The primary agricultural regions in the sagebrush biome include central Washington and northern Oregon, the Snake River Plains of southern Idaho, northern Utah, northern Montana, southern Alberta, southern Saskatchewan, and western North Dakota (Connelly and others, 2004). Thus, agricultural lands are widespread across the range of sage-grouse (table 4, fig. 9). Approximately 4.4 million acres 17,800 km^2; 3.04 percent) of designated sage-grouse habitat has been converted to crops throughout the range of the species, with approximately 261,400 acres (1,050 km^2; 2.25 percent) of priority habitats and 3.1 million acres (12,500 km^2; 8.90 percent) of general habitats converted in MZ I, the MZ most influenced by agriculture. Indirect effects to sage-grouse of crop lands (estimated as effects on sage-grouse populations due to habitat alterations rather than direct mortality) were assessed using the spatial foraging scale of sage-grouse avian predators, which may be attracted to agricultural lands (6.9 km [4.3 mi]; Boarman and Heinrich, 1999; Leu and others, 2008) to summarize the influence area. Based on this estimate, agricultural lands influence a majority (approximately 84.2

Table 4. Summary of the direct and indirect influences of agricultural lands* (crops, tillage, and similar, not open range) across Management Zones (MZs) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

	PPH					PGH				
Management Zone Entity	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2]
MZ I–GP	**11,636,400**	**261,400**	**11,558,300**	**2.25**	**99.33**	**34,663,000**	**3,084,100**	**34,619,100**	**8.90**	**99.87**
BLM	2,994,300	6,600	2,944,300	0.22	25	4,524,900	17,700	4,503,800	0.39	13
Forest Service	292,400	600	292,400	0.21	3	515,300	1,000	515,300	0.19	1
Tribal and Other Federal	219,700	1,300	219,700	0.59	2	2,427,700	534,900	2,427,800	22.03	7
Private	7,132,500	247,400	7,113,800	3.47	62	24,682,800	2,436,900	24,664,400	9.87	71
State	995,600	5,400	986,300	0.54	9	2,498,400	93,300	2,494,100	3.73	7
Other	1,900	0	1,900	0.00	0	13,900	300	13,900	2.16	0
MZ II and VII–WB & CP	**17,476,000**	**113,000**	**14,711,100**	**0.65**	**84.18**	**19,200,200**	**402,300**	**15,046,400**	**2.10**	**78.37**
BLM	9,021,200	2,100	7,091,200	0.02	48	9,012,500	3,200	6,324,600	0.04	42
Forest Service	162,000	0	124,100	0.00	1	452,500	300	407,400	0.07	3
Tribal and Other Federal	784,000	1,400	701,900	0.18	5	1,354,600	5,200	1,252,100	0.38	8
Private	6,233,900	106,100	5,627,900	1.70	38	7,394,800	385,900	6,194,900	5.22	41
State	1,244,800	3,300	1,135,900	0.27	8	979,800	7,700	861,400	0.79	6
Other	30,100	100	30,100	0.33	0	6,000	0	6,000	0.00	0
MZ III–SGB	**10,028,500**	**80,000**	**8,086,800**	**0.80**	**80.64**	**3,970,100**	**4,600**	**2,803,800**	**0.12**	**70.62**
BLM	6,309,400	3,800	4,679,000	0.06	58	3,199,800	1,000	2,191,500	0.03	78
Forest Service	1,236,200	400	1,065,000	0.03	13	356,200	0	243,300	0.00	9
Tribal and Other Federal	260,800	2,100	246,000	0.81	3	29,100	0	13,000	0.00	0
Private	1,836,200	72,900	1,720,100	3.97	21	384,800	3,500	355,700	0.91	13
State	385,900	800	376,500	0.21	5	200	0	200	0.00	0
MZ IV–SRP	**21,930,600**	**72,300**	**18,309,700**	**0.33**	**83.49**	**10,958,500**	**257,400**	**9,762,400**	**2.35**	**89.09**
BLM	13,710,700	14,800	10,960,600	0.11	60	4,928,200	14,500	4,227,900	0.29	43
Forest Service	1,613,800	900	1,452,800	0.06	8	1,113,500	1,800	1,009,300	0.16	10
Tribal and Other Federal	633,600	500	573,300	0.08	3	522,500	1,800	478,200	0.34	5
Private	4,890,200	55,200	4,404,300	1.13	24	3,516,742	233,600	3,272,000	6.64	34
State	1,019,373	800	855,800	0.08	5	846,200	4,400	743,600	0.52	8
Other	62,900	200	62,800	0.32	0	31,400	1,300	31,400	4.14	0

Table 4. Summary of the direct and indirect influences of agricultural lands* (crops, tillage, and similar, not open range) across Management Zones (MZs) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).—Continued

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

	PPH					PGH				
Management Zone Entity	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2]
MZ V–NGB	**7,097,200**	**6,300**	**4,711,300**	**0.09**	**66.38**	**5,808,000**	**58,300**	**4,948,800**	**1.00**	**85.21**
BLM	5,117,500	300	3,333,900	0.01	71	4,196,700	700	3,435,400	0.02	69
Forest Service	62,200	0	60,800	0.00	1	114,900	0	104,700	0.00	2
Tribal and Other Federal	717,100	0	223,400	0.00	5	101,800	300	76,900	0.29	2
Private	798,000	3,000	696,300	0.38	15	1,199,000	55,700	1,155,900	4.65	23
State	64,900	0	60,200	0.00	1	115,800	400	96,100	0.35	2
Other	337,500	2,900	336,700	0.86	7	79,800	1,200	79,800	1.50	2

*Data Source: National Agriculture Statistics Service Cropland Data Layer 2012.

[1]Direct footprint is the co-location of agricultural lands within the designated habitat boundaries, and indirect influence is inferred by applying an effect buffer to the features and estimating the area affected. Indirect influence distance derived from foraging distances of predators (Boarman and Heinrich, 1999; Leu and others, 2008).

[2]For each MZ, these were calculated as the percent of the particular sage-grouse habitat type influenced by the indirect impact of the threat. For management entities within a management zone; these were calculated as the percent of the total indirect impact in the management zone represented by that management entity; that is, the relative area of indirect influence among management entities. Small differences

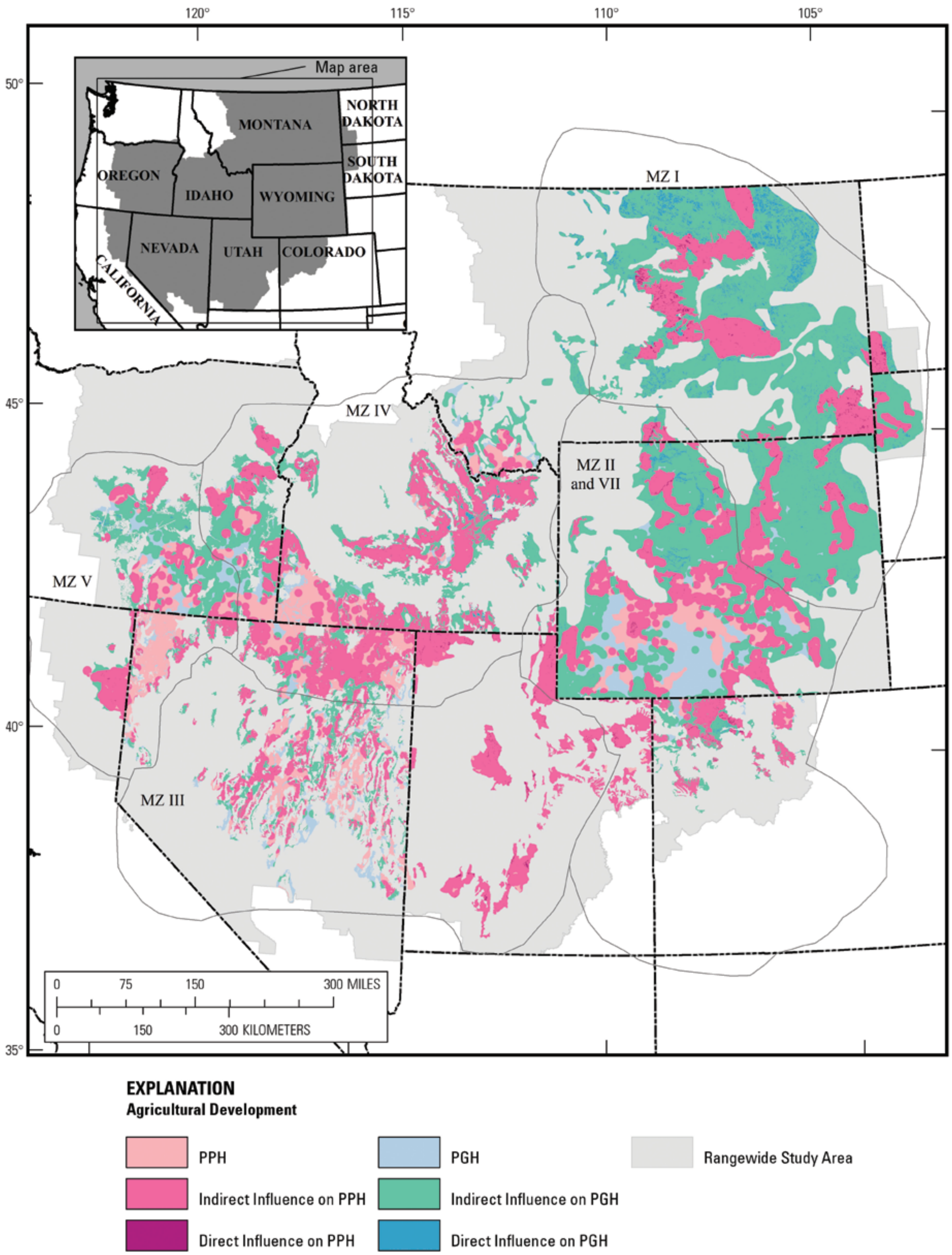


Figure 9. Overlap of agricultural land development, potential indirect effects of agriculture, and preliminary priority habitats (PPH) and preliminary general habitats (PGH) for sage-grouse. MZ, Management Zone.

percent) of priority habitats throughout the species' range. Although little BLM land has been directly converted, this approach suggests that BLM administers approximately 50 percent of the priority habitats influenced by agriculture. Areas converted to croplands are generally those with deeper, loamy soils that are able to be irrigated while sagebrush remains in arid areas where soils and topography are limiting to crops; agriculture has replaced 75 percent of the shrub steppe in deep soils but only 15 percent in shallow soils (Connelly and others, 2004). Summary analyses indicate that though agricultural conversion is widespread across and within MZs, current overlap with PPH and PGH designations vary among MZs, which will help differentiate priorities among management entities within each MZ (table 4).

Conversion of sagebrush to agriculture can influence the ability of sagebrush-dominated landscapes to support sage-grouse through habitat loss and fragmentation (Connelly and others, 2004). Isolation of shrub steppe habitats increased, mean patch size decreased, and number of patches increased with habitat conversion to agriculture in Washington (Connelly and others, 2004). Agricultural development can also influence sage-grouse by providing access to sagebrush habitats for predators such as domestic cats, red fox, and corvids (Connelly and others, 2004).

In a comparison of currently occupied versus unoccupied sage-grouse range (see Schroeder and others, 2004), estimates indicated that sage-grouse were extirpated from areas of their range when the proportion of a 735,000 acre (2,975 km^2) area in cropland exceeded 25 percent (Aldridge and others, 2008). A similar analysis of occupied versus unoccupied range reported areas where sagebrush cover was <27 percent (within a 251,500 acre [1,018 km^2] search area) had a high probability of sage-grouse extirpation. Areas with >50 percent sagebrush cover had high probabilities of sage-grouse persistence, and extirpated range contained approximately three times more area in agriculture compared to occupied range (Wisdom and others, 2011). In Idaho between 1975 and 1992, declines in the mean number of males per lek were strongly correlated to increases in the amount of land converted to agriculture, which increased 74 percent in the region during this period. The proportion of sagebrush habitat (positive effect) and the proportion of tillage agriculture (negative effect) within 4 mi (6.4 km) best explained lek persistence in northeastern Wyoming (Walker and others, 2007a). The percentage of cultivated land within 2.5 mi (4 km) of active leks in North Dakota was lower than that around inactive leks, and the proportion of cultivated land (area of cultivated/area of noncultivated) was greater within a region of the State historically occupied, but currently not occupied, compared to a region where sage-grouse still occurred (Smith and others, 2005).

A comparison of treatments in Wyoming, Montana, and Colorado found that eliminating ≥16 percent of the sagebrush-dominated area in a landscape closely associated with a group of leks either through plowing or herbicide spraying was correlated with a 50 to 100 percent reduction in the number of males occupying the leks (Swenson and others, 1987). A similar study suggested greater sensitivity with observed reduction in rangewide sage-grouse lek trends when agricultural land use exceeded 2.5 percent of the area within a 3.1 mi (5 km radius (or 1.5 percent of the area within an 11.2 mi [18 km] radius); trends in lek counts stabilized as the percent of agricultural land increased beyond these proportions, but few leks occurred in areas where the proportion of agricultural land exceeded 50 percent (Johnson and others, 2011). Conversion of 30 percent of the sagebrush-dominated winter habitats within a focused 50,000 acres (202 km^2) area in Montana by plowing and conversion to cropland resulted in a 73 percent decline in the number of breeding-male sage-grouse on leks in the area relative to controls (Swenson and others, 1987). In southern Canada, nesting sage-grouse avoided areas with a high proportion of anthropogenic-edge habitats (borders with a non-natural edge, such as cropland), and broods avoided areas close to cultivated cropland (Aldridge and Boyce, 2007).

The sage-grouse habitat management guidelines (Connelly and others, 2000c) recommend that a minimum of 80 percent of nesting, early brood-rearing, and winter habitats are dominated by a sagebrush overstory; for example, if 20 percent of the sagebrush habitats used by a population of sage-grouse are eliminated through a prescribed fire, these areas need to regrow and provide sagebrush cover useful for sage-grouse prior to additional treatments. The research presented here suggests that this guideline may be most appropriate for short-term habitat treatments (for example, vegetation and fuel treatments). Available research suggests (1) sage-grouse populations may become extirpated when the proportion of a landscape permanently converted from sagebrush to agriculture exceeds 25 to 27 percent, (2) substantial declines in lek counts may occur when this proportion exceeds 16 percent, and (3) lek-count declines may occur when the proportion is as low as 1.5 to 2.5 percent of the landscape.

A3. Urbanization

Low densities of indigenous peoples in western North America (estimated range from one person per 1,500 acres [6 km^2] to as low as one person per every 22,000 acres [90 km^2] in the Great Basin) probably limited their impact on the biophysical landscape, although their activities for hunting, gathering, and burning may have been significant locally (Connelly and others, 2004). Ultimately, settlement by Europeans in sagebrush habitats had a much greater effect on transforming or converting habitats and altering disturbance regimes and animal communities than behaviors exerted by the low densities of indigenous people (Connelly and others, 2004). Human populations have grown and expanded during the past century, primarily in the western portion of the sagebrush biome. Human populations in sagebrush habitats increased between 166 and 666 percent between 1920 and 2000 and between 19 and 31 percent between 1990 and 2000; the amount of uninhabited area (0 residents/km^2) within the Great Basin decreased from 22.2 million acres (90,000 km^2) in 1990 to <3 million acres (12,000 km^2) in 2004 (Knick and

Connelly, 2011a). Although urbanized areas occur throughout the range of sage-grouse, the direct footprint is relatively small with approximately 792,700 acres (3,200 km^2; 0.56 percent) of sage-grouse habitat directly converted to urbanized areas (table 5, fig. 10). Preliminary priority habitats in Utah in particular, and to a lesser degree priority habitat in MZs II and VII, have a higher urbanized footprint than the remainder of the species' range. Indirect impacts of urban areas—estimated as the spatial foraging scale of avian predators that may be attracted to urban areas (4.3 mi [6.9 km]; Boarman and Heinrich, 1999; Leu and others, 2008)—influence a relatively small percentage (approximately 5.7 percent) of priority habitats throughout the species' range suggesting localized potential impacts (versus widespread potential impacts such as with agriculture). BLM lands account for approximately 38 percent of the priority habitats influenced by urban areas, according to our estimates. Rural areas have also been developed throughout the sagebrush region, particularly around urban centers and major highways (Knick and Connelly, 2011a). Although many urban developments in rural areas continue to provide some sagebrush habitat in contrast to total urban conversion, habitat fragmentation and disturbance from human dwellings and activities probably render much of the area inhospitable to sage-grouse (Connelly and others, 2004). Comparison of currently occupied to historically occupied (presumed extirpated) sage-grouse range determined that mean human density (circa 1950 and 2000) was up to 26 times lower in currently occupied range (Aldridge and others, 2008; Wisdom and others, 2011).

There is little information directly assessing the response of sage-grouse to urbanization. Research in Canada revealed that brood-rearing females avoided habitats associated with a high density of urban developments (Aldridge and Boyce, 2007). Urban areas by themselves remove habitat and present inhospitable environments for sage-grouse, but the physical boundaries of cities are small relative to the total sagebrush area. The roads, railways, power lines and communications corridors connecting urban centers may exert a greater influence on sagebrush habitats than that exerted by the actual city (Connelly and others, 2004). Additionally, recreation, including hiking, hunting and fishing, and OHV use in areas surrounding urban centers can negatively influence sage-grouse through habitat loss and fragmentation, facilitation of exotic plant spread, animal displacement or avoidance, establishment of population barriers, or increased human-wildlife encounters that increase wildlife mortality (Connelly and others, 2004). Recreation on lands managed by the BLM remains a significant land use with potential impacts to range conditions and sage-grouse populations (Connelly and others, 2004; also see Section III. A12. Other Land Uses). The cumulative nature of changes to the sagebrush biome as a result of human encroachment needs to be considered when managing sage-grouse. Potential synergistic effects of the components of urbanization—including the stresses in habitats surrounding urban centers—may influence sage-grouse habitat use and demography making growth and mitigation of urban areas and effects an important consideration in many MZs. For example, the development of an energy field (discussed at length below) involves more than the infrastructure required to extract the resource. Urban centers near the developing field will expand with the increased human population in the area, communication towers and power lines will be erected, traffic on highways will increase, recreational use of areas surrounding urban centers will increase, and all these factors individually and in combination may influence sage-grouse populations (Johnson and others, 2011).

A4. Infrastructure

Interstates and major highways are ubiquitous throughout the range of sage-grouse directly influencing 1,338,200 acres (5,400 km^2; 2 percent) of sage-grouse PPH habitat and more than 3 million acres (12,100 km^2) of PPH and PGH combined, with indirect influences (impacts beyond habitat loss and immediate threats of mortality such as via collision) estimated on more than 139 million acres (565,800 km^2) across the range of the species (table 6, fig. 11). Secondary paved roads exist in most sagebrush regions in densities >1.25 mi/100acres (≈5 km/km^2), less than 5 percent of the sage-grouse range is more than 1.5 mi (2.5 km) from a paved road, and almost no area of sagebrush is more than 4.3 mi (6.9 km) from a paved road (Knick and Connelly, 2011a). Indirect influences such as aversions to noise and activities were assessed using 4.6 mi (7.5 km) buffers for interstates and 1.9 mi (3 km) buffers for highways, primary, and secondary routes. Based on indirect effects estimates, interstates and major highways potentially affect the habitat quality of more than 95 percent of priority habitats throughout the range of the species. A large proportion of these roads exist as rights-of-way on public lands, including 55 percent of BLM-managed PPH and 5 percent of USFS-managed PPH (52 percent and 5 percent of PGH, respectively; table 6). In contrast to roads, major railroads are not as widespread throughout the range of sage-grouse and directly influence (including abandoned rail-lines) only 32,500 acres (132 km^2; 0.02 percent) of sage-grouse habitat (PPH and PGH) across the range of the species (table 7, fig. 12). Railroads are slightly more widespread in MZ I and in Wyoming portions of MZs II and VII; additionally, railroads may have a relatively important influence in some priority habitats in central Utah. Indirect effects of non-abandoned railroads (similarly to roads, indirect effects are considered impacts besides immediate habitat loss or mortality due to collision) were assessed using estimated contributions to spread of exotic plant species (1.9 mi [3 km]), which potentially influence approximately 4 percent of priority sage-grouse habitats across the range.

Transmission lines and local distribution lines (collectively power lines) are widespread throughout the range of sage-grouse and are especially prevalent in MZ II and in priority habitats in portions of MZs III and IV (table 8, fig. 13*A*). Major power lines directly influence approximately 3,896,400 acres (276,000 km^2; 2.7 percent) of sage-grouse habitats throughout the range of the species, including approximately

Table 5. Summary of the direct and indirect influences of urban areas* across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

	PPH					PGH				
Management Zone Entity	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)
MZ I–GP	**11,636,400**	**5,000**	**436,600**	**0.04**	**3.75**	**34,663,000**	**130,100**	**2,733,300**	**0.38**	**7.89**
BLM	2,994,300	100	34,600	0.00	8	4,524,900	9,300	190,300	0.21	7
Forest Service	292,400	100	9,600	0.03	2	515,300	0	32,400	0.00	1
Tribal and Other Federal	219,700	0	400	0.00	0	2,427,700	200	100,700	0.01	4
Private	7,132,500	4,100	331,800	0.06	76	24,682,800	113,200	2,188,300	0.46	80
State	995,600	800	59,800	0.08	14	2,498,400	7,300	219,000	0.29	8
Other	1,900	0	300	0.00	0	13,900	0	2,600	0.00	0
MZ II and VII–WB & CP	**17,476,000**	**155,700**	**1,875,000**	**0.89**	**10.73**	**19,200,200**	**353,400**	**3,841,800**	**1.84**	**20.01**
BLM	9,021,200	37,400	820,900	0.41	44	9,012,500	106,200	1,431,100	1.18	37
Forest Service	162,000	0	3,500	0.00	0	452,500	24,600	80,500	5.44	2
Tribal and Other Federal	784,000	32,400	86,000	4.13	5	1,354,600	2,500	145,000	0.18	4
Private	6,233,900	79,100	833,600	1.27	44	7,394,800	209,300	2,008,500	2.83	52
State	1,244,800	6,800	126,300	0.55	7	979,800	10,900	175,800	1.11	5
Other	30,100	0	4,700	0.00	0	6,000	0	800	0.00	0
MZ III–SGB	**10,028,500**	**57,200**	**909,800**	**0.57**	**9.07**	**3,970,100**	**14,500**	**144,900**	**0.37**	**3.65**
BLM	6,309,400	4,100	226,500	0.06	25	3,199,800	2,200	81,000	0.07	56
Forest Service	1,236,200	0	50,400	0.00	6	356,200	0	2,400	0.00	2
Tribal and Other Federal	260,800	100	50,400	0.04	6	29,100	0	3,700	0.00	3
Private	1,836,200	51,500	527,500	2.80	58	384,800	12,300	57,700	3.20	40
State	385,900	1,500	54,900	0.39	6	200	0	100	0.00	0
MZ IV–SRP	**21,930,600**	**5,200**	**635,900**	**0.02**	**2.90**	**10,958,500**	**66,700**	**937,800**	**0.61**	**8.56**
BLM	13,710,700	1,100	386,600	0.01	61	4,928,200	19,700	277,700	0.40	30
Forest Service	1,613,800	0	48,000	0.00	8	1,113,500	700	39,200	0.06	4
Tribal and Other Federal	633,600	4,100	20,700	0.65	3	522,500	100	28,200	0.02	3
Private	4,890,200	0	153,400	0.00	24	3,516,742	43,400	535,500	1.23	57
State	1,019,373	0	26,900	0.00	4	846,200	2,800	56,800	0.33	6
Other	62,900	0	400	0.00	0	31,400	0	300	0.00	0

Table 5. Summary of the direct and indirect influences of urban areas* across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).—Continued

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

	PPH					PGH				
Management Zone Entity	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)
MZ V–NGB	**7,097,200**	**300**	**17,000**	**0.00**	**0.24**	**5,808,000**	**4,600**	**92,200**	**0.08**	**1.59**
BLM	5,117,500	0	3,900	0.00	23	4,196,700	0	19,700	0.00	21
Forest Service	62,200	0	0	0.00	0	114,900	0	1,800	0.00	2
Tribal and Other Federal	717,100	0	0	0.00	0	101,800	100	400	0.10	0
Private	798,000	300	13,000	0.04	76	1,199,000	4,500	65,300	0.38	71
State	64,900	0	0	0.00	0	115,800	0	0	0.00	0
Other	337,500	0	0	0.00	0	79,800	0	5,000	0.00	5

*Data Source: Tele Atlas ESRI Street Map Premium for ArcGIS v 9.0, 2008

[1]Direct footprint is the co-location of urban areas within the designated habitat boundaries, and indirect influence is inferred by applying an effect buffer to the features and estimating the area affected. Indirect influence distance derived from foraging distances of predators (Boarman and Heinrich, 1999; Leu and others, 2008).

[2]For each MZ these were calculated as the percent of the particular sage-grouse habitat type influenced by the indirect impact of the threat. For management entities within a management zone, these were calculated as the percent of the total indirect impact in the management zone represented by that management entity, that is, the relative area of indirect influence among management entities. Small differences between individual entity totals and MZ summary values may exist due to rounding of acre estimates during calculations.

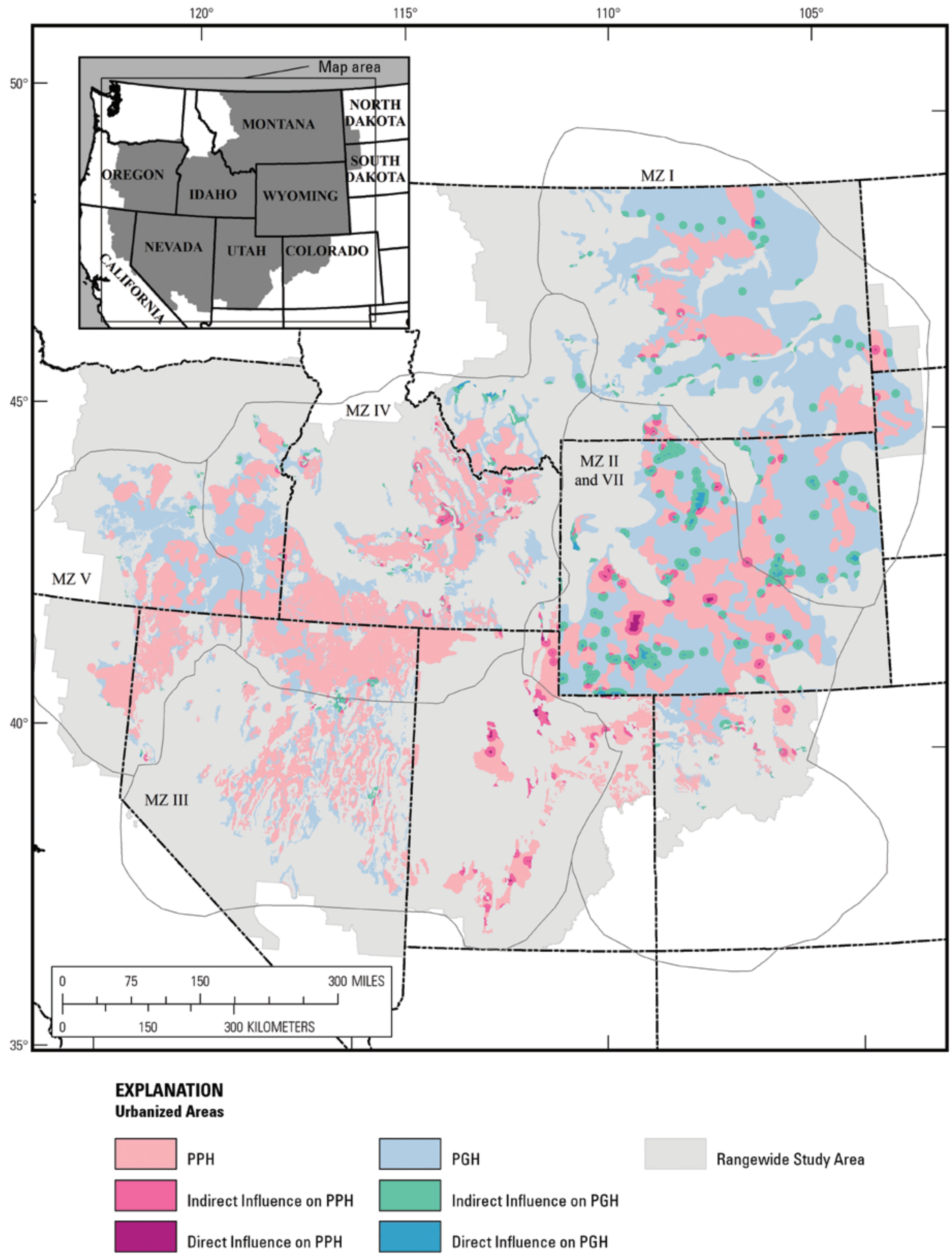


Figure 10. Overlap of urbanized areas, potential indirect influences of urbanization, and sage-grouse preliminary priority and general habitats (PPH and PGH, respectively).

Table 6. Summary of the direct and indirect influences of roads* across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH SG Habitat (acres)	PPH Direct Footprint[1] (acres)	PPH Indirect Influence[1] (acres)	PPH Direct Footprint[1] (%)	PPH Relative Influence[2] (%)	PGH SG Habitat (acres)	PGH Direct Footprint[1] (acres)	PGH Indirect Influence[1] (acres)	PGH Direct Footprint[1] (%)	PGH Relative Influence[2] (%)
MZ I–GP	**11,636,400**	**255,300**	**11,602,600**	**2.19**	**100**	**34,663,000**	**887,300**	**34,604,700**	**2.56**	**99.83**
BLM	2,994,300	48,200	2,971,300	1.61	26	4,524,900	79,600	4,511,000	1.76	13
Forest Service	292,400	7,200	292,400	2.46	3	515,300	12,300	515,100	2.39	1
Tribal and Other Federal	219,700	3,300	218,100	1.50	2	2,427,700	61,500	2,418,200	2.53	7
Private	7,132,500	176,200	7,127,900	2.47	61	24,682,800	675,000	24,653,700	2.73	71
State	995,600	20,300	991,200	2.04	9	2,498,400	58,600	2,492,700	2.35	7
Other	1,900	0	1,800	0.00	0	13,900	300	13,900	2.16	0
MZ II and VII–WB & CP	**17,476,000**	**431,400**	**17,395,000**	**2.47**	**100**	**19,200,200**	**483,200**	**19,062,400**	**2.52**	**99.28**
BLM	9,021,200	209,600	8,993,500	2.32	52	9,012,500	188,800	8,948,200	2.09	47
Forest Service	162,000	2,900	160,700	1.79	1	452,500	5,600	420,300	1.24	2
Tribal and Other Federal	784,000	17,100	769,100	2.18	4	1,354,600	28,600	1,341,700	2.11	7
Private	6,233,900	170,800	6,200,300	2.74	36	7,394,800	236,700	7,370,400	3.20	39
State	1,244,800	30,200	1,241,300	2.43	7	979,800	23,400	975,800	2.39	5
Other	30,100	900	30,100	2.99	0	6,000	200	6,000	3.33	0
MZ III–SGB	**10,028,500**	**211,700**	**9,599,100**	**2.11**	**96**	**3,970,100**	**71,700**	**3,772,500**	**1.81**	**95.02**
BLM	6,309,400	115,700	6,003,000	1.83	63	3,199,800	56,900	3,061,200	1.78	81
Forest Service	1,236,200	20,900	1,180,700	1.69	12	356,200	4,400	331,100	1.24	9
Tribal and Other Federal	260,800	8,800	260,600	3.37	3	29,100	600	28,000	2.06	1
Private	1,836,200	56,800	1,774,400	3.09	18	384,800	9,800	352,000	2.55	9
State	385,900	9,400	380,200	2.44	4	200	0	200	0.00	0
MZ IV–SRP	**21,930,600**	**351,700**	**20,890,500**	**1.60**	**95**	**10,958,500**	**187,900**	**10,638,900**	**1.71**	**97.08**
BLM	13,710,700	199,400	13,075,200	1.45	63	4,928,200	68,500	4,799,300	1.39	45
Forest Service	1,613,800	20,100	1,479,200	1.25	7	1,113,500	12,900	1,047,800	1.16	10
Tribal and Other Federal	633,600	11,200	628,200	1.77	3	522,500	8,000	449,300	1.53	4
Private	4,890,200	100,900	4,643,900	2.06	22	3,516,700	83,500	3,485,800	2.37	33
State	1,019,400	18,800	1,001,100	1.84	5	846,200	14,100	825,300	1.67	8
Other	62,900	1,200	62,900	1.91	0	31,400	800	31,400	2.55	0

Table 6. Summary of the direct and indirect influences of roads* across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).—Continued

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

	PPH					PGH				
Management Zone Entity	**SG Habitat (acres)**	**Direct Footprint[1] (acres)**	**Indirect Influence[1] (acres)**	**Direct Footprint[1] (%)**	**Relative Influence[2] (%)**	**SG Habitat (acres)**	**Direct Footprint[1] (acres)**	**Indirect Influence[1] (acres)**	**Direct Footprint[1] (%)**	**Relative Influence[2] (%)**
MZ V–NGB	**7,097,200**	**88,100**	**6,608,800**	**1.24**	**93**	**5,808,000**	**99,100**	**5,636,800**	**1.71**	**97.05**
BLM	5,117,500	54,300	4,724,400	1.06	71	4,196,700	59,900	4,034,200	1.43	72
Forest Service	62,200	2,000	62,200	3.22	1	114,900	3,600	114,900	3.13	2
Tribal and Other Federal	717,100	6,900	639,800	0.96	10	101,800	2,200	99,500	2.16	2
Private	798,000	17,400	788,600	2.18	12	1,199,000	29,400	1,194,600	2.45	21
State	64,900	1,300	64,200	2.00	1	115,800	2,100	115,600	1.81	2
Other	337,500	6,200	329,500	1.84	5	79,800	1,900	77,900	2.38	1

*Data Source: Tele Atlas ESRI StreetMap Premium for ArcGIS v 9.0, 2008

[1]Direct footprint is the co-location of roads within the designated habitat boundaries, and indirect influence is inferred by applying an effect buffer to the features and estimating the area affected. Indirect influence of roads was calculated using 7.5 km for interstates and 3km for highways, primary routes, and secondary routes. (Connelly and others, 2004, Holloran, 2005; Lyon, 2000).

[2]For each MZ, calculated as the percent of the particular sage-grouse habitat type influenced by the indirect impact of the threat. For management entities within a management zone, calculated as the percent of the total indirect impact in the management zone represented by that management entity; that is, the relative area of indirect influence among management entities. Small differences between individual entity totals and MZ summary values may exist due to rounding of acre estimates during calculations.

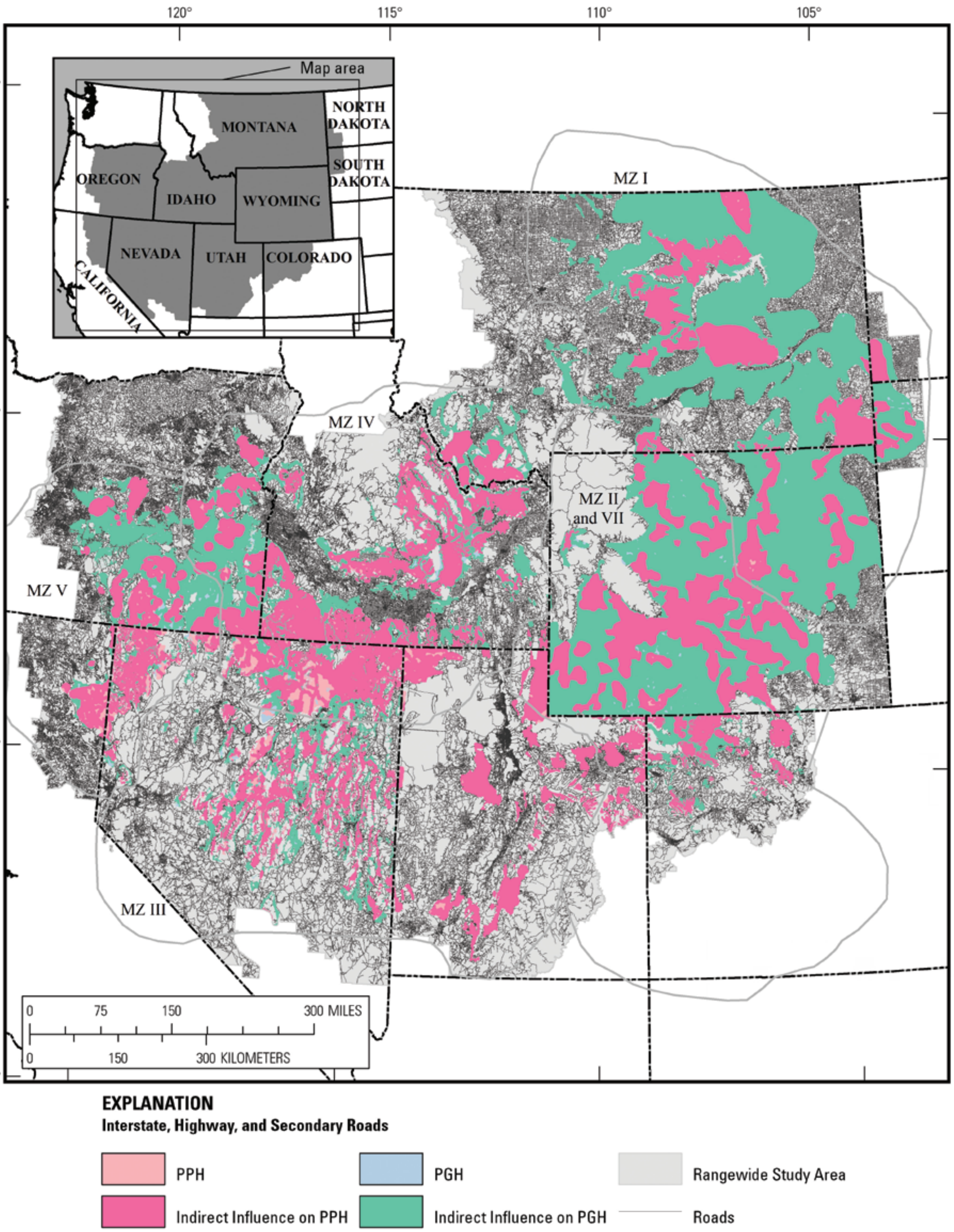


Figure 11. Overlap of roads and potential indirect influences of roads and sage-grouse preliminary priority and general habitats (PPH and PGH, respectively). MZ, Management Zone.

Table 7. Summary of the direct influences of abandoned and non-abandoned, railroads* and indirect influences of non-abandoned railroads across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

	PPH					PGH				
Management Zone Entity	SG Habitat (acres)	Direct Footprint[1] (acres)	3 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)	SG Habitat (acres)	Direct Footprint[1] (acres)	3 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)
MZ I–GP	**11,636,400**	**1,500**	**235,400**	**0.01**	**2.02**	**34,663,000**	**11,800**	**2,493,800**	**0.03**	**7.19**
BLM	2,994,300	100	14,300	0.00	6	4,524,900	400	130,500	0.01	5
Forest Service	292,400	0	3,000	0.00	1	515,300	200	63,900	0.04	3
Tribal and Other Federal	219,700	0	0	0.00	0	2,427,700	600	165,000	0.02	7
Private	7,132,500	1,300	200,100	0.02	85	24,682,800	9,900	1,983,500	0.04	80
State	995,600	100	17,900	0.01	8	2,498,400	700	149,500	0.03	6
Other	1,900	0	100	0.00	0	13,900	0	1,400	0.00	0
MZ II and VII–WB & CP	**17,476,000**	**3,100**	**586,500**	**0.02**	**3.36**	**19,200,200**	**7,800**	**1,718,200**	**0.04**	**8.95**
BLM	9,021,200	900	202,600	0.01	35	9,012,500	1,700	539,100	0.02	31
Forest Service	162,000	0	200	0.00	0	452,500	0	300	0.00	0
Tribal and Other Federal	784,000	100	6,800	0.01	1	1,354,600	300	69,900	0.02	4
Private	6,233,900	1,900	339,000	0.03	58	7,394,800	5,500	1,022,800	0.07	60
State	1,244,800	200	33,000	0.02	6	979,800	400	86,100	0.04	5
Other	30,100	0	5,000	0.00	1	6,000	0	0	0.00	0
MZ III–SGB	**10,028,500**	**2,300**	**408,700**	**0.02**	**4.08**	**3,970,100**	**200**	**61,000**	**0.01**	**1.54**
BLM	6,309,400	500	149,700	0.01	37	3,199,800	200	43,200	0.01	71
Forest Service	1,236,200	0	10,000	0.00	2	356,200	0	0	0.00	0
Tribal and Other Federal	260,800	400	37,000	0.15	9	29,100	0	0	0.00	0
Private	1,836,200	1,100	174,100	0.06	43	384,800	100	17,800	0.03	29
State	385,900	200	37,900	0.05	9	200	0	0	0.00	0
MZ IV–SRP	**21,930,600**	**2,100**	**316,600**	**0.01**	**1.44**	**10,958,500**	**3,000**	**436,300**	**0.03**	**3.98**
BLM	13,710,700	1,000	138,500	0.01	44	4,928,200	900	175,800	0.02	40
Forest Service	1,613,800	100	17,000	0.01	5	1,113,500	0	4,600	0.00	1
Tribal and Other Federal	633,600	100	36,500	0.02	12	522,500	100	10,400	0.02	2
Private	4,890,200	800	114,500	0.02	36	3,516,742	1,900	223,000	0.05	51
State	1,019,373	100	10,000	0.01	3	846,200	100	22,400	0.01	5
Other	62,900	0	100	0.00	0	31,400	0	100	0.00	0

Table 7. Summary of the direct influences of abandoned and non-abandoned, railroads* and indirect influences of non-abandoned railroads across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).—Continued

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

	PPH					PGH				
Management Zone Entity	SG Habitat (acres)	Direct Footprint[1] (acres)	3 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)	SG Habitat (acres)	Direct Footprint[1] (acres)	3 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)
MZ V–NGB	**7,097,200**	**500**	**6,800**	**0.01**	**0.10**	**5,808,000**	**200**	**14,000**	**0.00**	**0.24**
BLM	5,117,500	200	2,400	0.00	35	4,196,700	0	7,500	0.00	54
Forest Service	62,200	0	0	0.00	0	114,900	0	0	0.00	0
Tribal and Other Federal	717,100	0	4,100	0.00	60	101,800	0	100	0.00	1
Private	798,000	0	100	0.00	1	1,199,000	100	4,500	0.01	32
State	64,900	0	0	0.00	0	115,800	0	0	0.00	0
Other	337,500	200	300	0.06	4	79,800	0	1,900	0.00	14

*Data Source: Federal Railroad Administration (FRA) Rail Lines of the of the U.S.A., 2001.

[1]Direct footprint is the co-location of rail lines (abandoned and non-abandoned) within the designated habitat boundaries, and indirect influence is inferred by applying an effect buffer to the features and estimating the area affected. Indirect influence distance derived from estimated spread of exotic plants (Knick and others, 2011).

[2]For each MZ, these were calculated as the percent of the particular sage-grouse habitat type influenced by the indirect impact of the threat. For management entities within a management zone, these were calculated as the percent of the total indirect impact in the management zone represented by that management entity; that is, the relative area of indirect influence among management entities. Small differences between individual entity totals and MZ summary values may exist due to rounding of acre estimates during calculations.

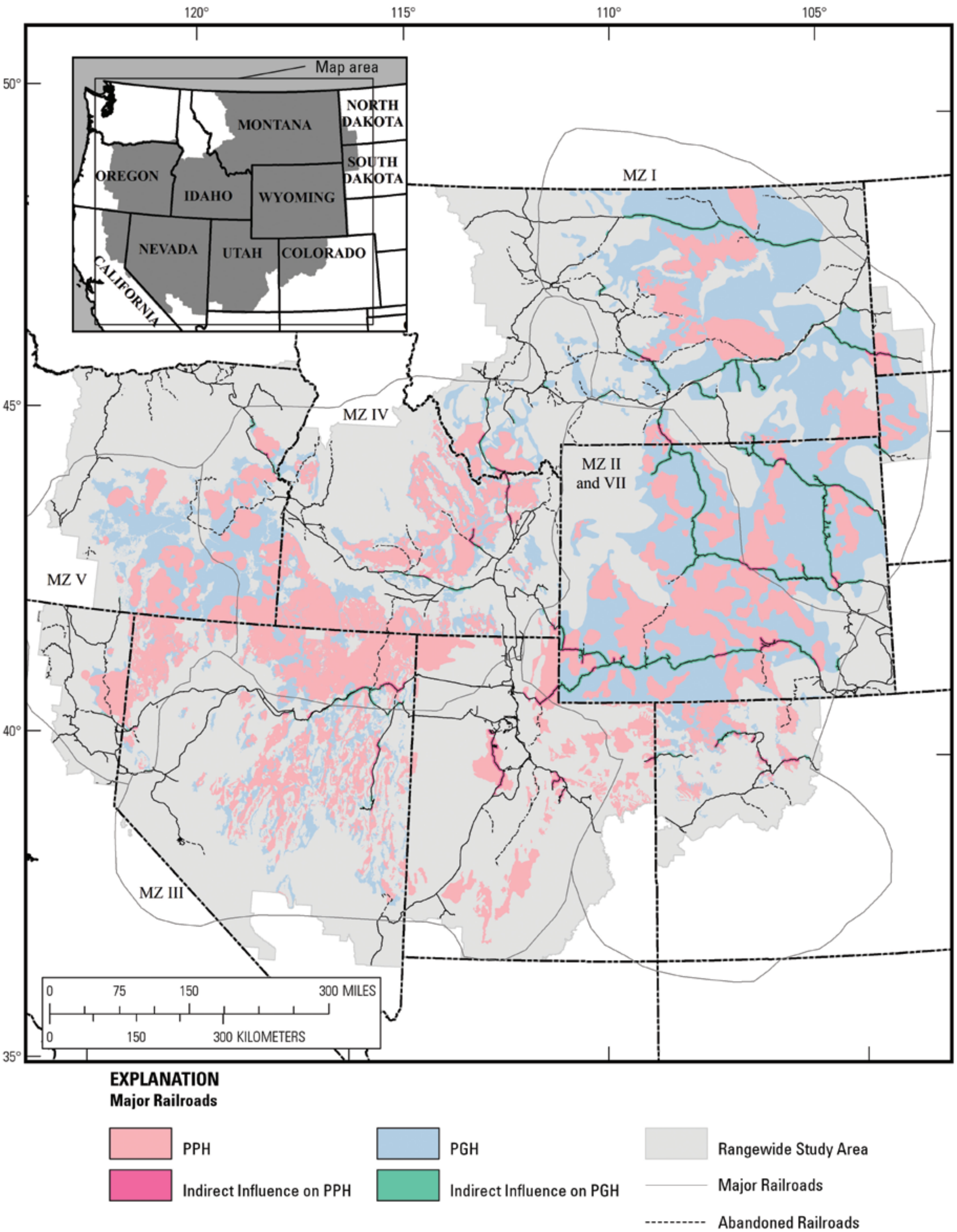


Figure 12. Overlap of abandoned and non-abandoned railroads, potential indirect influences of non-abandoned railroads, and sage-grouse preliminary priority and general habitats (PPH and PGH, respectively). MZ, Management Zone.

Table 8. Summary of the distribution of power transmission lines (>115 kilovolt)[*] across sage-grouse habitats (PPH and PGH) by Management Zone (MZ).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

	PPH					PGH				
Management Zone Entity	**SG Habitat (acres)**	**Direct Footprint[1] (acres)**	**6.9 km Indirect Influence[1] (acres)**	**Direct Footprint[1] (%)**	**Relative Influence[2] (%)**	**SG Habitat (acres)**	**Direct Footprint[1] (acres)**	**6.9 km Indirect Influence[1] (acres)**	**Direct Footprint[1] (%)**	**Relative Influence[2] (%)**
MZ I–GP	**11,636,400**	**128,700**	**3,348,700**	**1.11**	**28.78**	**34,663,000**	**1,082,400**	**16,029,400**	**3.12**	**46.24**
BLM	2,994,300	18,600	601,600	0.62	18	4,524,900	71,300	1,482,800	1.58	9
Forest Service	292,400	3,800	136,300	1.30	4	515,300	16,700	270,100	3.24	2
Tribal and Other Federal	219,700	1,000	34,600	0.46	1	2,427,700	90,600	1,459,500	3.73	9
Private	7,132,500	92,100	2,280,300	1.29	68	24,682,800	831,100	11,655,300	3.37	73
State	995,600	13,200	295,600	1.33	9	2,498,400	71,400	1,156,600	2.86	7
Other	1,900	0	300	0.00	0	13,900	1,300	5,000	9.35	0
MZ II and VII–WB & CP	**17,476,000**	**673,800**	**10,480,800**	**3.86**	**59.97**	**19,200,200**	**961,700**	**12,051,000**	**5.01**	**62.76**
BLM	9,021,200	320,500	5,286,400	3.55	50	9,012,500	392,800	5,430,900	4.36	45
Forest Service	162,000	5,300	91,900	3.27	1	452,500	7,100	137,400	1.57	1
Tribal and Other Federal	784,000	13,000	339,900	1.66	3	1,354,600	62,100	760,700	4.58	6
Private	6,233,900	284,400	4,033,300	4.56	38	7,394,800	454,900	5,120,900	6.15	42
State	1,244,800	48,100	711,200	3.86	7	979,800	44,700	597,900	4.56	5
Other	30,100	2,400	18,100	7.97	0	6,000	200	3,200	3.33	0
MZ III–SGB	**10,028,500**	**181,700**	**3,346,700**	**1.81**	**33.37**	**3,970,100**	**43,200**	**1,001,500**	**1.09**	**25.23**
BLM	6,309,400	84,500	1,775,800	1.34	53	3,199,800	36,900	801,500	1.15	80
Forest Service	1,236,200	5,500	211,700	0.44	6	356,200	800	46,500	0.22	5
Tribal and Other Federal	260,800	1,300	92,100	0.50	3	29,100	0	1,700	0.00	0
Private	1,836,200	80,100	1,074,900	4.36	32	384,800	5,500	151,600	1.43	15
State	385,900	10,200	192,100	2.64	6	200	0	200	0.00	0
MZ IV–SRP	**21,930,600**	**392,600**	**8,015,200**	**1.79**	**36.55**	**10,958,500**	**266,300**	**4,204,300**	**2.43**	**38.37**
BLM	13,710,700	234,900	4,973,200	1.71	62	4,928,200	112,200	1,795,300	2.28	43
Forest Service	1,613,800	13,000	400,700	0.81	5	1,113,500	7,900	313,000	0.71	7
Tribal and Other Federal	633,600	17,400	245,500	2.75	3	522,500	7,900	149,000	1.51	4
Private	4,890,200	106,700	2,035,600	2.18	25	3,516,742	116,200	1,619,700	3.30	39
State	1,019,373	15,900	301,900	1.56	4	846,200	20,500	302,300	2.42	7
Other	62,900	4,800	58,200	7.63	1	31,400	1,700	24,900	5.41	1

Table 8. Summary of the distribution of power transmission lines (>115 kilovolt)* across sage-grouse habitats (PPH and PGH) by Management Zone (MZ).—Continued

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

	PPH					PGH				
Management Zone Entity	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)
MZ V–NGB	**7,097,200**	**77,100**	**1,814,200**	**1.09**	**25.56**	**5,808,000**	**88,900**	**1,922,400**	**1.53**	**33.10**
BLM	5,117,500	59,500	1,403,800	1.16	77	4,196,700	60,000	1,237,000	1.43	64
Forest Service	62,200	200	15,400	0.32	1	114,900	2,100	45,800	1.83	2
Tribal and Other Federal	717,100	0	10,500	0.00	1	101,800	900	24,800	0.88	1
Private	798,000	12,600	238,700	1.58	13	1,199,000	21,500	521,300	1.79	27
State	64,900	300	31,700	0.46	2	115,800	3,200	67,600	2.76	4
Other	337,500	4,500	114,100	1.33	6	79,800	1,300	25,800	1.63	1

*Data Source: EV Energy Map, Platts/Global Energy, 2005 ICBEMP Existing Utility Corridors, 2003.

[1]Direct footprint is the co-location of power lines within the designated habitat boundaries, and indirect influence is inferred by applying an effect buffer to the features and estimating the area affected. Indirect influence distance derived from foraging distances of predators (Boarman and Heinrich, 1999; Leu and others, 2008).

[2]For each MZ, these were calculated as the percent of the particular sage-grouse habitat type influenced by the indirect impact of the threat. For management entities within a management zone, calculated as the percent of the total indirect impact in the management zone represented by that management entity; that is, the relative area of indirect influence among management entities. Small differences between individual entity totals and MZ summary values may exist due to rounding of acre estimates during calculations.

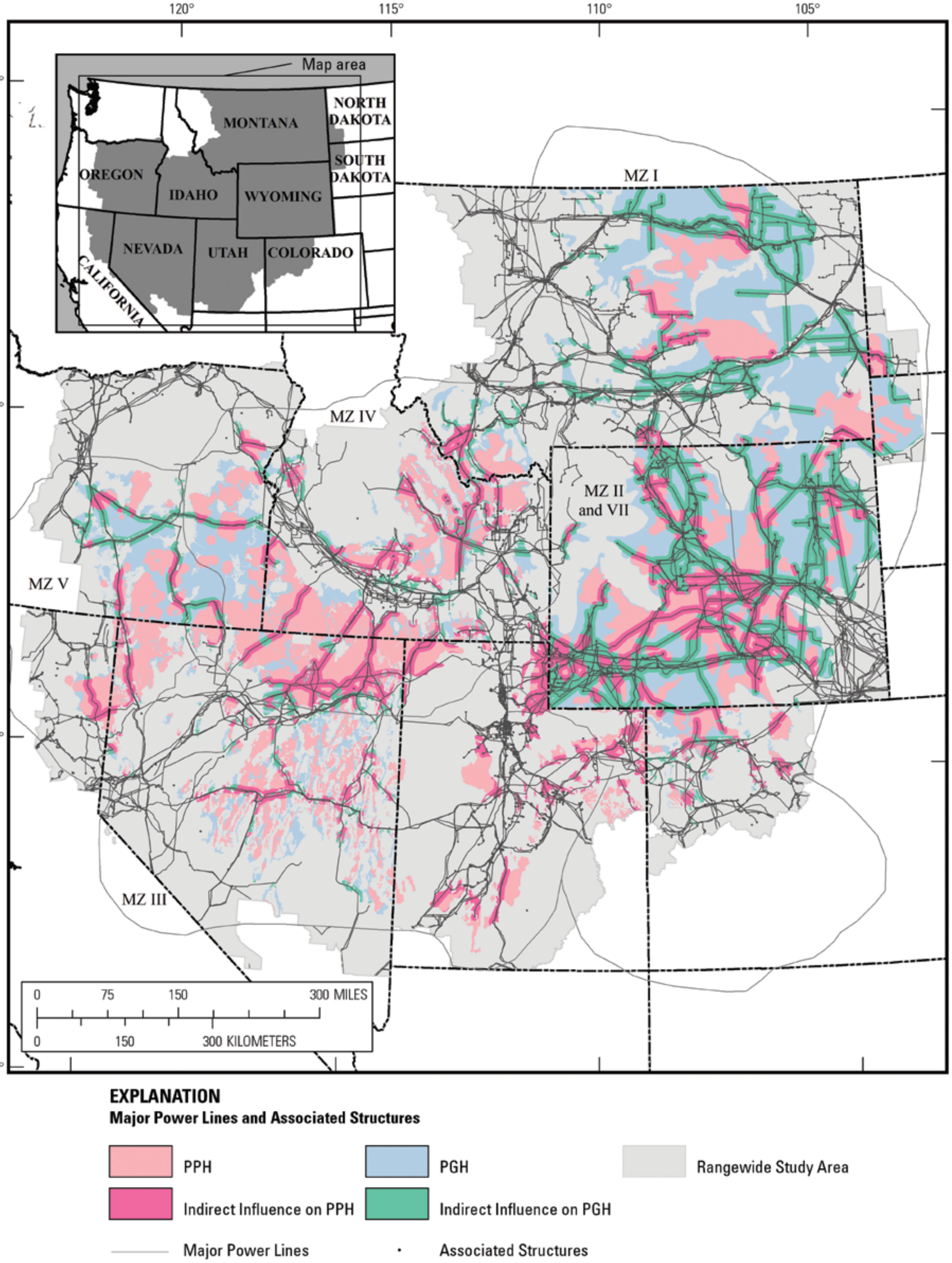


Figure 13*A*. Overlap of major power lines and associated infrastructure, indirect influences of these structures, and preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

673,800 acres (2,725 km^2; 3.9 percent) of priority habitats and 961,700 acres (3,900 km^2; 5.0 percent) of general habitats directly influenced in MZs II and VII—the largest among MZs. Indirect impacts of power lines—estimated using the spatial foraging scale of avian predators, which may be attracted to power lines (4.3 mi [6.9 km])—are estimated to influence approximately 44 percent of priority and general habitats throughout the species' range, and approximately 60 percent of priority habitats in MZs II and VII. Collectively, BLM lands account for approximately 48 percent of the priority habitats indirectly influenced by major power lines.

Nonwind-power-related vertical structures are widespread and directly influence approximately 15,200 acres (61 km^2; 0.01 percent) of sage-grouse habitat throughout the range of the species (table 9; fig. 13*B*). A minimum of 10,182 communication towers exist in or within 50 km (30 mi) of current sage-grouse range (Knick and Connelly, 2011a). Indirect effects of vertical structures—similarly, estimated using the spatial-foraging scale of sage-grouse avian predators, which may be attracted to these structures (6.9 km [4.3 mi]; Boarman and Heinrich, 1999; Leu and others, 2008)—influence approximately 33.4 percent of priority habitats throughout the range of the species, so the potential indirect effects of vertical structures are not insignificant (table 9, fig. 13*B*). BLM lands account for approximately 45 percent of the priority habitats indirectly influenced by vertical structures. Fences are ubiquitous throughout sage-grouse range (fig. 13*C*), with areas having fence densities exceeding 4 mi/1,000 acres (1.5 km/km^2) in all MZs except western portions of MZ III (Knick and Connelly, 2011a). Approximately 167,700 mi (270,000 km) of fence are present within BLM- and USFS-managed allotment and pasture boundaries on sage-grouse habitats, with approximately 78,300 mi (126,000 km) of fence present on these public lands, in priority habitats (table 10; fig. 13*C*). These estimates of fence densities across the range of the species are approximately 0.75 miles per section (one section equals one square mile) and exceed 1 mi/section (1.2 km/2.6 km^2) in priority habitats in MZ I, without accounting for similar fencing on private lands.

Compared to occupied range, extirpated sage-grouse range was 60 percent closer to highways and had 25 percent higher densities of roads compared to occupied range (Wisdom and others, 2011). Mean distance to transmission lines was more than two times farther in occupied range than in extirpated range, and the distance to communication towers averaged almost two times as far in occupied versus extirpated range (Wisdom and others, 2011). Although relatively few leks across the range of the species had interstate highways nearby, declines in the numbers of males on leks closer to interstates were slightly less than those farther from interstates; nonetheless, there was a consistent downward trend in sage-grouse numbers as the length of interstate within 3.1 mi (5 km) increased (Johnson and others, 2011). Similarly, despite low numbers of communication towers across the sagebrush biome, sage-grouse lek trends across the range of the species generally increased with distance from nearest tower and generally decreased with increasing numbers of towers within 5 km (3.1 mi) and 18 km (11.2 mi) of leks (Johnson and others, 2011). Sage-grouse population response to a human footprint metric (see Section III.A) indicated that sage-grouse generally respond negatively to increased anthropogenic infrastructures located in sagebrush habitats. Roads and power lines are especially widespread throughout the range of the species, and communication towers are becoming increasingly prevalent. Although the response of sage-grouse to communication towers may be correlated with human development in general (towers are often concentrated along major roadways and around urban centers; Johnson and others, 2011), an extensive rural network exists, and with potential for an increase in these types of structures throughout the sagebrush biome with ongoing development (for example, meteorological towers at proposed wind developments), the accumulation of factors (traffic, predator accessibility, and invasive species) is likely to have effects on sage-grouse habitat quality.

Lekking and nesting sage-grouse appear to avoid road infrastructure and related activities (especially traffic). Along Interstate 80 in Wyoming and Utah between 1970 and 2003, observers found no leks within 2 km (1.25 mi) of the interstate and fewer birds on leks within 7.5 km (4.7 mi) than within 7.5–15 km (4.7–9.3 mi) beyond the interstate (Connelly and others, 2004). Additionally, there were higher rates of decline in lek counts within 7.5 km than beyond 7.5 km of the interstate. Negative relations between the length of road segments within 3.2 km (2 mi) of leks and the probability of lek occurrence were found in Montana and southern Canada with the impacts of increasing road lengths (implying larger roads) being greatest for larger leks (>25 males); the probability of occurrence of a large lek approached 0 percent as the length of road segments within 3.2 km (2 mi) of a lek exceeded 100 km (62 mi; Tack 2009).

Generally, road-effect distances (the distance from a road at which a population density decrease is detected) are positively correlated with increased traffic density and speed (Forman and Alexander, 1998). The upgrade of haul roads associated with surface coal mining activity in Colorado resulted in increased traffic levels and was correlated with declines in the number of displaying males on sage-grouse leks situated within 2 km (1.25 mi) of the road (Remington and Braun, 1991). Rates of decline in sage-grouse male lek attendance increased as traffic volumes on roads near leks increased, and vehicle activity on roads during the daily strutting period (that is, early morning) had a greater influence on male lek attendance compared to roads with no vehicle activity during early morning in southwestern Wyoming (Holloran, 2005). In central Wyoming, peak male attendance (that is, abundance) at leks experimentally treated with noise recorded at roads in a gas field decreased 73 percent relative to paired controls (Blickley, 2012).

Sage-grouse avoided nesting and summering near major roads (for example, paved secondary highways) in south-central Wyoming (LeBeau, 2012), and traffic disturbance (1 to 12 vehicles/day) within 3 km (1.9 mi) of leks during the

Table 9. Summary of the direct and indirect influences of communication towers and other (non-wind) vertical structures* across preliminary priority and preliminary general habitat.

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

	PPH					PGH				
Management Zone Entity	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)
MZ I–GP	**11,636,400**	**400**	**3,969,600**	**0.00**	**34**	**34,663,000**	**5,700**	**19,294,600**	**0.02**	**55.66**
BLM	2,994,300	0	665,300	0.00	17	4,524,900	200	1,891,000	0.00	10
Forest Service	292,400	0	104,500	0.00	3	515,300	100	279,300	0.02	1
Tribal and Other Federal	219,700	0	18,800	0.00	0	2,427,700	400	1,596,300	0.02	8
Private	7,132,500	300	2,881,200	0.00	73	24,682,800	4,700	14,125,500	0.02	73
State	995,600	0	299,300	0.00	8	2,498,400	200	1,397,000	0.01	7
Other	1,900	0	400	0.00	0	13,900	0	5,300	0.00	0
MZ II and VII–WB & CP	**17,476,000**	**1,500**	**7,395,100**	**0.01**	**42**	**19,200,200**	**4,600**	**10,775,800**	**0.02**	**56.12**
BLM	9,021,200	500	3,309,100	0.01	45	9,012,500	1,100	4,540,700	0.01	42
Forest Service	162,000	0	67,400	0.00	1	452,500	0	177,700	0.00	2
Tribal and Other Federal	784,000	100	322,200	0.01	4	1,354,600	100	685,500	0.01	6
Private	6,233,900	700	3,176,100	0.01	43	7,394,800	3,100	4,828,200	0.04	45
State	1,244,800	100	507,100	0.01	7	979,800	200	541,600	0.02	5
Other	30,100	0	13,100	0.00	0	6,000	0	2,200	0.00	0
MZ III–SGB	**10,028,500**	**800**	**3,420,700**	**0.01**	**34**	**3,970,100**	**200**	**1,073,500**	**0.01**	**27.04**
BLM	6,309,400	200	1,595,600	0.00	47	3,199,800	100	756,000	0.00	70
Forest Service	1,236,200	100	377,500	0.01	11	356,200	0	68,900	0.00	6
Tribal and Other Federal	260,800	0	121,300	0.00	4	29,100	0	9,800	0.00	1
Private	1,836,200	500	1,154,200	0.03	34	384,800	100	238,600	0.03	22
State	385,900	0	172,000	0.00	5	200	0	200	0.00	0
MZ IV–SRP	**21,930,600**	**800**	**6,818,700**	**0.00**	**31**	**10,958,500**	**900**	**4,544,900**	**0.01**	**41.47**
BLM	13,710,700	400	3,876,700	0.00	57	4,928,200	300	1,551,000	0.01	34
Forest Service	1,613,800	0	460,400	0.00	7	1,113,500	100	359,500	0.01	8
Tribal and Other Federal	633,600	0	280,400	0.00	4	522,500	100	153,000	0.02	3
Private	4,890,200	300	1,859,100	0.01	27	3,516,742	400	2,078,800	0.01	46
State	1,019,373	0	326,300	0.00	5	846,200	100	385,100	0.01	8
Other	62,900	0	15,800	0.00	0	31,400	0	17,500	0.00	0

Table 9. Summary of the direct and indirect influences of communication towers and other (non-wind) vertical structures* across Management Zones (MZ) by acres of PPH and PGH.—Continued

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

	PPH					PGH				
Management Zone Entity	**SG Habitat (acres)**	**Direct Footprint[1] (acres)**	**6.9 km Indirect Influence[1] (acres)**	**Direct Footprint[1] (%)**	**Relative Influence[2] (%)**	**SG Habitat (acres)**	**Direct Footprint[1] (acres)**	**6.9 km Indirect Influence[1] (acres)**	**Direct Footprint[1] (%)**	**Relative Influence[2] (%)**
MZ V–NGB	**7,097,200**	**100**	**1,164,400**	**0.00**	**16**	**5,808,000**	**200**	**1,224,900**	**0.00**	**21.09**
BLM	5,117,500	100	727,000	0.00	62	4,196,700	100	705,100	0.00	58
Forest Service	62,200	0	6,800	0.00	1	114,900	0	46,100	0.00	4
Tribal and Other Federal	717,100	0	45,800	0.00	4	101,800	0	17,600	0.00	1
Private	798,000	0	217,300	0.00	19	1,199,000	100	412,000	0.01	34
State	64,900	0	11,600	0.00	1	115,800	0	10,700	0.00	1
Other	337,500	0	155,900	0.00	13	79,800	0	33,400	0.00	3

*Data Source: Federal Communications Commission, 2009; Federal Aviation Administration Digital Obstacles File, 2011.

[1]Direct footprint is the co-location of communication towers within the designated habitat boundaries, and indirect influence is inferred by applying an effect buffer to the features and estimating the area affected. Indirect influence distance derived from foraging distances of predators (Boarman and Heinrich, 1999; Leu and others, 2008).

[2]For each MZ, calculated as the percent of the particular sage-grouse habitat type influenced by the indirect impact of the threat. For management entities within a management zone, these were calculated as the percent of the total indirect impact in the management zone represented by that management entity; that is, the relative area of indirect influence among management entities. Small differences between individual entity totals and MZ summary values may exist due to rounding of acre estimates during calculations.

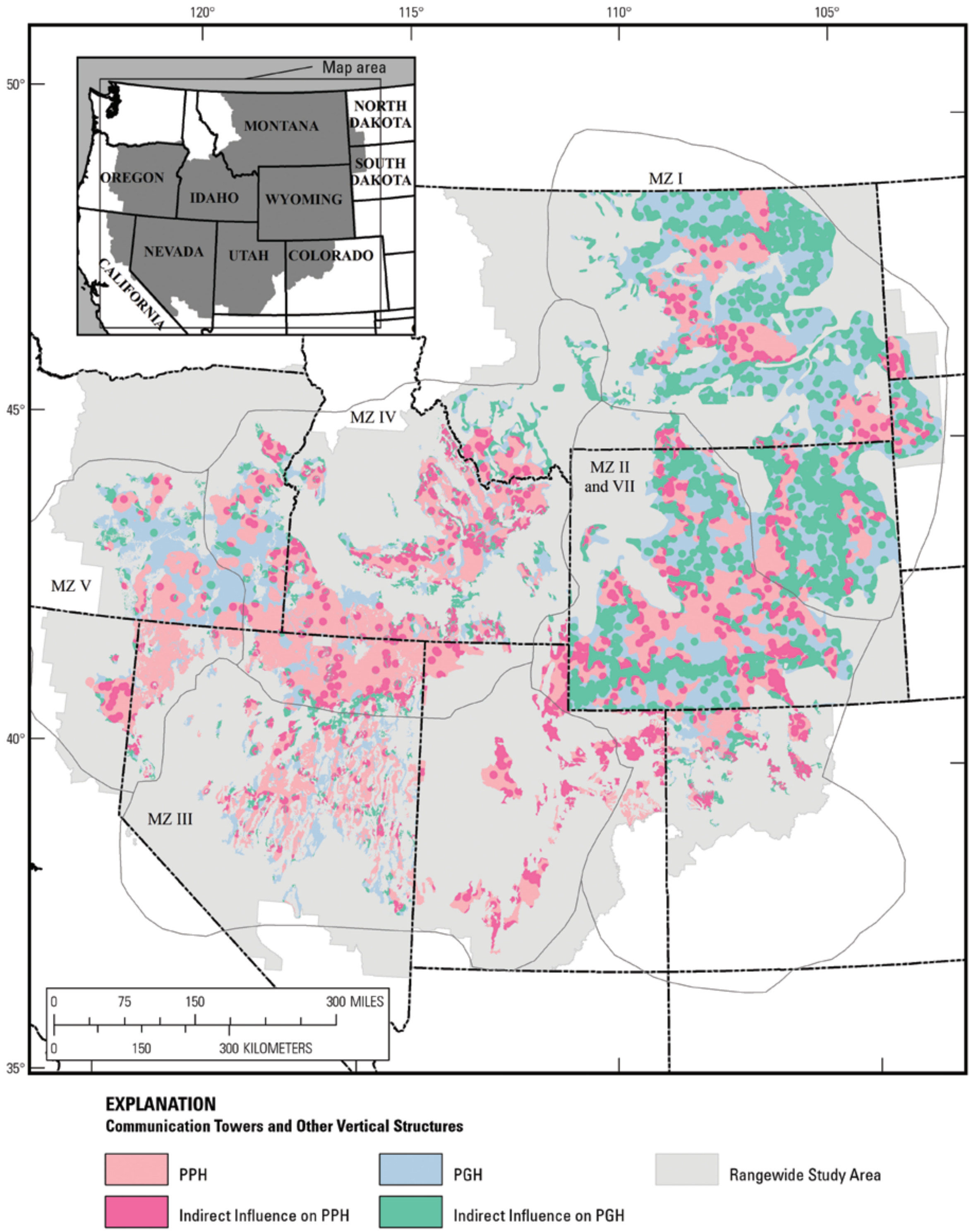


Figure 13*B*. Overlap of communication towers and other vertical structures (non-wind), potential indirect influences of these structures, and sage-grouse preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

Table 10. Summary of the influence of fences* across Management Zones (MZ) by miles within preliminary priority and preliminary general habitats (PPH and PGH, respectively) using Bureau of Land Management and U.S. Forest Service allotment and pasture boundaries as a surrogate for fence locations.

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH			PGH		
	SG Habitat (acres)	Direct Footprint (miles)	Average miles per section	SG Habitat (acres)	Direct Footprint (miles)	Average miles per section
MZ I–GP	**11,636,400**	**18,700**	**1.03**	**34,663,000**	**48,200**	**0.89**
BLM	2,994,300	6,100	1.30	4,524,900	11,300	1.60
Forest Service	292,400	500	1.09	515,300	900	1.12
Tribal and Other Federal	219,700	100	0.29	2,427,700	500	0.13
Private	7,132,500	10,700	0.96	24,682,800	32,100	0.83
State	995,600	1,400	0.90	2,498,400	3,300	0.85
Other	1,900	0	0.00	13,900	0	0.00
MZ II and VII–WB & CP	**17,476,000**	**18,300**	**0.67**	**19,200,200**	**18,900**	**0.63**
BLM	9,021,200	9,300	0.66	9,012,500	8,800	0.62
Forest Service	162,000	500	1.98	452,500	1,100	1.56
Tribal and Other Federal	784,000	400	0.33	1,354,600	500	0.24
Private	6,233,900	6,700	0.69	7,394,800	7,400	0.64
State	1,244,800	1,300	0.67	979,800	1,100	0.72
Other	30,100	0	0.00	6,000	0	0.00
MZ III–SGB	**10,028,500**	**7,800**	**0.50**	**3,970,100**	**3,000**	**0.48**
BLM	6,309,400	4,700	0.48	3,199,800	2,000	0.40
Forest Service	1,236,200	1,700	0.88	356,200	600	1.08
Tribal and Other Federal	260,800	100	0.25	29,100	0	0.00
Private	1,836,200	1,100	0.38	384,800	300	0.50
State	385,900	300	0.50	200	0	0.00
MZ IV–SRP	**21,930,600**	**27,900**	**0.81**	**10,958,500**	**13,900**	**0.81**
BLM	13,710,700	16,100	0.75	4,928,200	7,200	0.94
Forest Service	1,613,800	2,800	1.11	1,113,500	1,900	1.09
Tribal and Other Federal	633,600	400	0.40	522,500	400	0.49
Private	4,890,200	7,400	0.97	3,516,742	3,900	0.71
State	1,019,373	1,200	0.75	846,200	500	0.38
Other	62,900	0	0.00	31,400	0	0.00
MZ V–NGB	**7,097,200**	**5,600**	**0.50**	**5,808,000**	**5,400**	0.60
BLM	5,117,500	4,000	0.50	4,196,700	3,600	0.55
Forest Service	62,200	100	1.03	114,900	200	1.11
Tribal and Other Federal	717,100	100	0.09	101,800	100	0.63
Private	798,000	1,000	0.80	1,199,000	1,400	0.75
State	64,900	100	0.99	115,800	100	0.55
Other	337,500	300	0.57	79,800	100	0.80

*Data Source: BLM GSSP grazing allotments and pastures, 2012; USFS Enterprise Data Warehouse, 2012. Small differences between individual entity totals and MZ summary values may exist due to rounding of acre estimates during calculations.

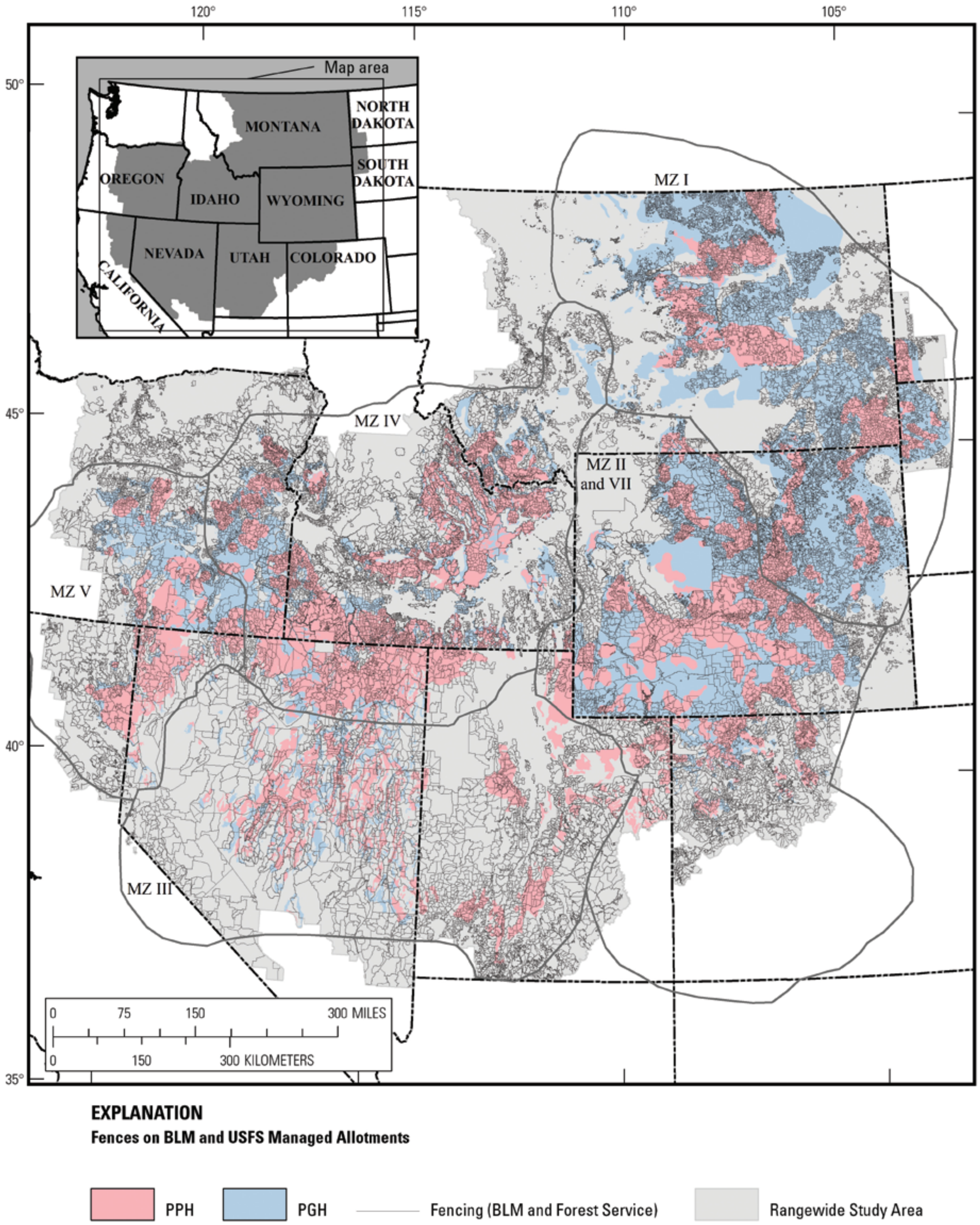


Figure 13*C*. Distribution of fences associated with Federally managed allotments across the sage-grouse study area, estimated from Bureau of Land Management and U.S. Forest Service pasture and allotment boundaries.

breeding season reduced nest-initiation rates and increased distances moved from leks during nest-site selection of female sage-grouse in southwestern Wyoming (Lyon and Anderson, 2003). Nesting propensity (that is, nest initiation rates) was 24 percent lower for females breeding on road-disturbed leks compared to undisturbed females. Fifty-six (56) percent of females breeding on disturbed leks initiated nests in consecutive years compared to 82 percent of females breeding on undisturbed leks; and females moved twice as far from leks to nest locations if breeding on disturbed leks (Lyon and Anderson 2003). Roads within 3 km (1.9 mi) of leks also negatively influence female habitat selection and fecundity. In summary, research suggests that roads within 7.5 km (4.7 mi) of leks negatively influence male lek attendance. Increased size of road, increased traffic levels on roads, and traffic activity during the early morning on roads within approximately 3 km (1.9 mi) of leks negatively influence male lek attendance as well as female behavior, nest-initiation, and nest success. Although minimal traffic volumes (<12 vehicles/day) on these roads negatively influence sage-grouse, higher traffic volumes appear to have a greater effect. The intermittent noise characteristic of traffic has been connected to declines in male lek attendance; however, details of causal relations have not been experimentally examined.

Transmission- and distribution-line construction (power lines) may result in substantial indirect habitat loss (that is, avoidance) due to sage-grouse avoidance of vertical structures, potentially because of changes in raptor concentrations and raptor species' composition relative to perches on flat landscapes. Additionally, the tendency of sage-grouse to fly relatively low, and in low light or when harried, may put them at a particularly high risk of collision with lines. Transmission lines generally refer to the high-voltage lines transferring electricity to substations, whereas distribution lines refer to lower voltage, smaller lines carrying electricity to consumers (we use "power lines" to refer to them collectively). The erection of a transmission line located within 650 ft (200 m) of an active sage-grouse lek, and between the lek and day-use areas, in northeastern Utah resulted in a 72 percent decline in the mean number of displaying males and an alteration in daily dispersal patterns during the breeding season within 2 years (Ellis, 1985). This project also reported that the frequency of raptor–sage-grouse interactions during the breeding season increased 65 percent and golden eagle interactions alone increased 47 percent between pre- and post-transmission line comparisons (Ellis, 1985). Negative effects of power lines on lek persistence were documented in northeastern Wyoming; the probability of lek persistence decreased with proximity to power lines and with increasing proportion of power lines within a 4 mi (6.4 km) window around leks (Walker and others, 2007a). Braun (1998b) reported that use of areas near transmission lines by sage-grouse increased as distance from transmission lines increased up to 1970 ft (600 m). Sage-grouse avoided brood-rearing habitats within 2.9 mi (4.7 km) of transmission lines in south-central Wyoming (LeBeau, 2012). Power line collisions accounted for 33 percent of juvenile (1st winter) mortality in low-elevation areas in Idaho (Beck and others, 2006). In general, it appears sage-grouse may avoid habitats within 0.4–2.9 mi (0.6–4.7 km) of a transmission line, and erection of a transmission line close to a lek will negatively influence sage-grouse lek attendance and breeding-season behavior. Additionally, higher densities of power lines within 4 mi (6.4 km) of a lek may negatively influence lek persistence. Power lines may be locally significant causes of mortality due to collisions. Potentially more important, poles and towers associated with transmission lines have been shown to influence raptor and corvid distributions and hunting efficiency resulting in increased predation on sage-grouse (Steenhof and others, 1993; Connelly and others, 2004). Foraging distances of avian, sage-grouse predators have been estimated at 4.3 mi (6.9 km; Knick and Connelly, 2011a), suggesting that transmission and power lines may influence sage-grouse at large spatial scales (Connelly and others, 2004; Cresswell and others, 2010). Based on these data, the direct footprint within any given MZ is relatively small (1.1–5.0 percent; table 8), but the area of relative influence is more extensive (25.2–62.8 percent PGH; table 8). Whereas theoretical effects are clear and logical, information relating sage-grouse response to transmission lines and distribution lines, or the effects of these lines on sage-grouse demographics, is not extensive.

Fences represent potential movement barriers (especially woven-wire fences), predator perches, or travel corridors and are a potential cause of direct mortality to sage-grouse (Braun, 1998). Theoretically, not every fence is a problem, and those that tend to cause problems typically include one or more of the following characteristics: (1) constructed with steel t-posts, (2) constructed near leks, (3) bisect winter concentration areas, or (4) border riparian areas (Christiansen, 2009). Areas of greater topographic relief (roughness) appear to have lower incidence of collisions apparently because the birds have to fly higher to avoid the ground (Christiansen, 2009). At broad spatial scales during the breeding season, fence collision risk was lower in areas with high topographic ruggedness, higher in areas with increased fence density on the landscape, decreased with increasing distance to nearest lek (impacts detected within approximately 2 km [1.25 mi] of leks), and increased with increasing lek size (Stevens and others, 2011; Stevens and others, 2012). Visibility of fences also influences collision rates, with greater rates associated with less visible fences, for example, those constructed using only steel t-posts (without wooden posts) and wider segment widths (more than 4 m (13 ft)) between posts (Stevens and others, 2011). Marking both sides of the top fence strand at 1 m intervals with reflective materials reduced collision frequency between 61 and 83 percent (Christiansen, 2009; Stevens and others, 2012). Decisions on the best design or treatment to mitigate collision risk must consider tradeoffs; for example, although wooden posts are more visible, they may provide better raptor perches than t-posts.

A5. Energy Development

Oil and gas development in habitats used by sage-grouse and construction of accompanying power lines, roads, and pipelines began in the late 1800s with the discovery of oil in the Interior West (Connelly and others, 2004). Since the 1960s, development of natural gas resources in this region has dominated the industry (Connelly and others, 2004). The United States National Energy Policy projects an increase in oil consumption by 33 percent, in natural gas consumption by >50 percent, and in electricity by 45 percent by 2025 (Connelly and others, 2004). Development of oil and gas resources requires construction (well pads, access roads, and ancillary infrastructure including flow lines, other roads, compressor stations, pumping stations, and electrical facilities), drilling and extraction, and transport of oil and gas (Connelly and others, 2004). The expected economic production life of coal bed methane wells is 12–18 years and of oil and deep-seam gas wells is 20–100 years with advanced technology (Connelly and others, 2004). Gas and oil wells are widespread throughout priority and general habitats with concentrated development areas exceeding 10 wells/section (1 mi^2 [2.6 km^2]) common throughout MZs I and II and the far eastern portions of MZ III (table 11, fig. 14), whereas current oil shale developments are concentrated solely in MZ VII (see Oil Shale Section, below). Despite significant closures of public lands to oil and gas leasing within PPH and PGH (table 12, fig. 15), current leases, including those leased but not yet developed, are substantial across sage-grouse ranges in MZs I and II (table 13, fig. 16*A*). Locations of geologic fields for traditional oil and gas (Copeland and others, 2011; fig. 16*B*) suggest potential development across eastern portions of the range (MZs I, II, VII, and eastern parts III); the potential for oil shale development is concentrated in MZs II and VII (see Oil Shale Section, below). It has been predicted that currently proposed and existing energy developments could affect more than 41 million hectares (24 percent) of shrubland habitats in the Western United States and Canada (Copeland and others, 2011). This may be a conservative estimate of impact for species sensitive to anthropogenic activity where the development of energy resources results in large-scale indirect habitat loss.

Notably, most research on the effects of energy development on sage-grouse has been focused in MZs I and II (Wyoming, Montana, Dakotas, and southern Canada) where development is concentrated. The relative consistency of distance and density effects of the infrastructure of gas and oil developments on sage-grouse across different development types—including shallow coal bed methane and deep gas and oil development (Naugle and others, 2011)—suggests results from these studies should be applicable elsewhere in the range. In 2011, fourteen studies were conducted investigating impacts of energy development on sage-grouse; all reported negative effects, whereas none reported a positive influence of development on populations or habitats (Naugle and others, 2011). Studies consistently reported that breeding populations of sage-grouse were negatively impacted at conventional well-pad densities of four and eight well pads/2.6 km^2 (1-mi^2 section), with declines in lek attendance by male sage-grouse ranging from 13 to 79 percent associated with these well densities (Harju and others, 2010; Naugle and others, 2011). Lek attendance declines have consistently been reported when well-pad densities exceed 1 pad/section (2.6 km^2 [1 mi^2]) within approximately 3.2 km (2 mi) of a lek (Naugle and others, 2011). Well-pad densities exceeding approximately 0.4 pads/section within 18 km (11 mi) of leks negatively influenced lek trends rangewide (Johnson and others, 2011), and larger leks (>25 males) did not occur in areas where well-pad densities exceeded 2.5 pads/section within 12.3 km (7.6 mi) of a lek (Tack, 2009). A recent study reported that the probability of lek persistence (that is, leks remaining active) approached 0 percent when well-pad densities exceeded approximately 6.5 pads/section (Hess and Beck, 2012).

A recent summary of studies investigating sage-grouse response to natural gas development reported that impacts to leks were most severe when infrastructure occurred near leks and were discernible out to distances of 6.2–6.4 km (3.8–4 mi; Naugle and others, 2011). However, negative impacts to male counts were observed as far as 12.3 km (7.6 mi) on large leks (>25 males) with additional impacts as far as 11 mi (18 km; the largest scale evaluated in literature, Naugle and others, 2011). Government imposed stipulations often restricted surface occupancy within 0.4 km (0.25 mi) of a lek during the time most studies were conducted, and leks that had ≥1 pad within this radius had 35 to 92 percent fewer attending males than did leks with zero wells within this distance (Harju and others, 2010; Naugle and others, 2011). It is also notable that a 1-km (0.6-mi) restricted-surface-occupancy buffer is currently applied during development of many energy fields. However excluding infrastructure within a 0.6-mi buffer may be ineffective for successful conservation because a negative response is still estimated with this density of development. These patterns were apparent when comparing developed areas in Wyoming, whereby gas and oil infrastructure encircling leks within smaller radii (≤1.6–2 km [1–1.25 mi]) had fewer sage-grouse compared to leks at which no infrastructure occurred within this distance (Harju and others, 2010). Additionally, there was a strong negative effect of natural gas development within 0.8–3.2 km (0.5–2 mi) on lek persistence in northwestern Wyoming (Walker and others, 2007a). Rates of decline in numbers of males occupying leks increased on leks located relatively centrally within a developing gas field—that is, leks surrounded by producing wells in three or more directions (Holloran, 2005). Peak male attendance (a surrogate for abundance) at leks experimentally treated with noise from natural gas drilling decreased 29 percent relative to paired controls (Blickley and others, 2012). Additionally, changes in the number of males occupying leks situated downwind of drilling rigs were more negative than those witnessed on leks upwind of drilling rigs, supporting evidence that increased noise intensity negatively influences male lek attendance (Holloran, 2005). A time lag—or a delay between activity associated with energy development and its measurable effects

Table 11. Summary of the direct influence of active and abandoned well sites and indirect influence of active oil and natural gas development-related wells* across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

	PPH					PGH				
Management Zone Entity	SG Habitat (acres)	Direct Footprint[1] (acres)	19 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)	SG Habitat (acres)	Direct Footprint[1] (acres)	19 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)
MZ I–GP	**11,636,400**	**11,100**	**6,939,400**	**0.10**	**59.64**	**34,663,000**	**119,500**	**20,621,100**	**0.34**	**59.49**
BLM	2,994,300	2,000	1,528,400	0.07	22	4,524,900	18,200	2,402,800	0.40	12
Forest Service	292,400	400	276,600	0.14	4	515,300	1,000	370,200	0.19	2
Tribal and Other Federal	219,700	0	58,400	0.00	1	2,427,700	2,700	1,442,900	0.11	7
Private	7,132,500	8,000	4,479,200	0.11	65	24,682,800	88,800	14,874,800	0.36	72
State	995,600	600	595,800	0.06	9	2,498,400	8,800	1,521,100	0.35	7
Other	1,900	0	1,000	0.00	0	13,900	0	9,300	0.00	0
MZ II and VII–WB & CP	**17,476,000**	**10,800**	**13,558,000**	**0.06**	**77.58**	**19,200,200**	**53,700**	**16,072,400**	**0.28**	**83.71**
BLM	9,021,200	6,300	7,375,300	0.07	54	9,012,500	32,000	8,079,600	0.36	50
Forest Service	162,000	0	41,400	0.00	0	452,500	100	143,100	0.02	1
Tribal and Other Federal	784,000	800	670,200	0.10	5	1,354,600	2,000	1,093,900	0.15	7
Private	6,233,900	3,100	4,493,600	0.05	33	7,394,800	16,500	5,974,300	0.22	37
State	1,244,800	700	952,600	0.06	7	979,800	3,100	775,600	0.32	5
Other	30,100	0	25,000	0.00	0	6,000	0	6,000	0.00	0
MZ III–SGB	**10,028,500**	**2,000**	**1,764,600**	**0.02**	**17.60**	**3,970,100**	**0**	**316,400**	**0.00**	**7.97**
BLM	6,309,400	500	663,800	0.01	38	3,199,800	0	252,700	0.00	80
Forest Service	1,236,200	0	209,400	0.00	12	356,200	0	7,800	0.00	2
Tribal and Other Federal	260,800	300	139,300	0.12	8	29,100	0	600	0.00	0
Private	1,836,200	900	697,600	0.05	40	384,800	0	55,200	0.00	17
State	385,900	300	54,500	0.08	3	200	0	100	0.00	0
MZ IV–SRP	**21,930,600**	**0**	**222,100**	**0.00**	**1.01**	**10,958,500**	**0**	**32,700**	**0.00**	**0.30**
BLM	13,710,700	0	123,000	0.00	55	4,928,200	0	14,800	0.00	45
Forest Service	1,613,800	0	0	0.00	0	1,113,500	0	0	0.00	0
Tribal and Other Federal	633,600	0	0	0.00	0	522,500	0	0	0.00	0
Private	4,890,200	0	99,100	0.00	45	3,516,700	0	17,900	0.00	55
State	1,019,400	0	0	0.00	0	846,200	0	0	0.00	0
Other	62,900	0	0	0.00	0	31,400	0	0	0.00	0

Table 11. Summary of the direct influence of active and abandoned well sites and indirect influence of active oil and natural gas development-related wells* across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).—Continued

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

	PPH					PGH				
Management Zone Entity	SG Habitat (acres)	Direct Footprint[1] (acres)	19 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)	SG Habitat (acres)	Direct Footprint[1] (acres)	19 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)
MZ V–NGB	**7,097,200**	**0**	**0**	**0.00**	**0.00**	**5,808,000**	**0**	**0**	**0.00**	**0.00**
BLM	5,117,500	0	0	0.00	0	4,196,700	0	0	0.00	0
Forest Service	62,200	0	0	0.00	0	114,900	0	0	0.00	0
Tribal and Other Federal	717,100	0	0	0.00	0	101,800	0	0	0.00	0
Private	798,000	0	0	0.00	0	1,199,000	0	0	0.00	0
State	64,900	0	0	0.00	0	115,800	0	0	0.00	0
Other	337,500	0	0	0.00	0	79,800	0	0	0.00	0

*Data Source: BLM Automated Fluid Minerals Support System (AFMSS) Database, 2011, Enerdeq IHS database 2011. Direct and indirect impacts are calculated for the surface management entity; however, subsurface mineral rights may be severed from surface rights.

[1]Direct footprint is the co-location of active or plugged and abandoned oil and natural gas wells within the designated habitat boundaries, and indirect influence is inferred by applying an effect buffer to the active features and estimating the area affected. Indirect influence of active (non-abandoned) wells was estimated using the identified area of demographic impact (Johnson and others, 2011; Taylor and others, 2012).

[2]For each MZ, calculated as the percent of the particular sage-grouse habitat type influenced by the indirect impact of the threat. For management entities within a management zone, calculated as the percent of the total indirect impact in the management zone represented by that management entity; that is, the relative area of indirect influence among management entities. Small differences between individual entity totals and MZ summary values may exist due to rounding of acre estimates during calculations.

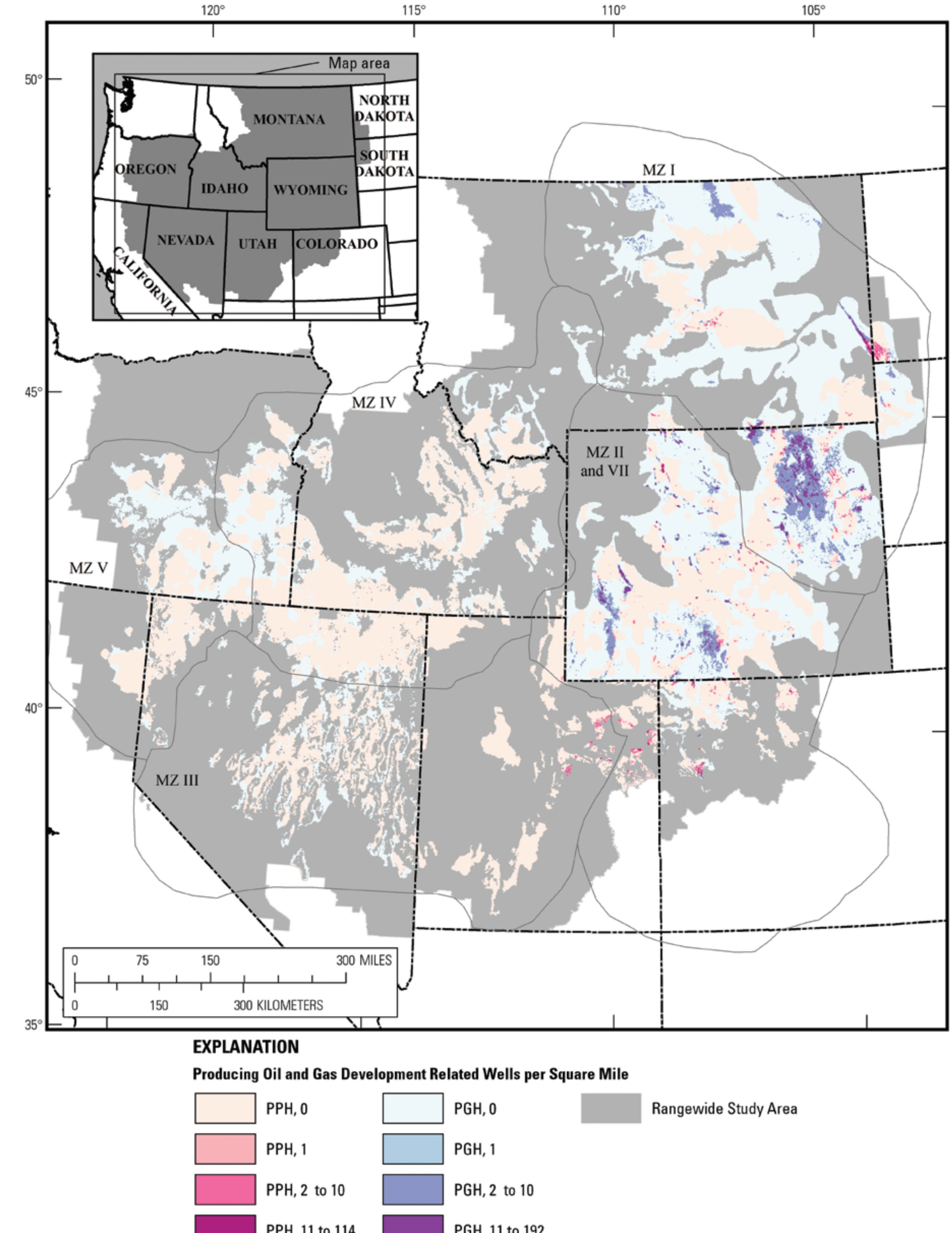


Figure 14. Density of active wells related to oil and gas development within preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

Table 12. Summary of the areas closed to Federal oil and gas development across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats implicated (PPH and PGH, respectively).*

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone	PPH			PGH		
	SG Habitat (acres)	Federal Closed Areas (acres)	Federal Closed Areas (%)	SG Habitat (acres)	Federal Closed Areas (acres)	Federal Closed Areas (%)
MZ I–GP	11,636,400	170,900	1.47	34,663,000	668,300	1.93
MZ II and VII–WB & CP	17,476,000	1,302,400	7.45	19,200,200	1,242,400	6.47
MZ III–SGB	10,028,500	329,700	3.29	3,970,100	241,300	6.08
MZ IV–SRP	21,930,600	1,709,200	7.79	10,958,500	727,400	6.64
MZ V–NGB	7,097,200	744,000	10.48	5,808,000	82,400	1.42

*Data Source: Aggregated from individual Bureau of Land Management State Office Submissions in 2011 and 2012. Leased areas are calculated based on Federal subsurface management; however, subsurface mineral rights may be severed from surface rights. Small differences between individual entity totals and MZ summary values may exist due to rounding of estimates during calculations.

Table 13. Summary of existing Federal oil and gas leases (currently held by production or undeveloped) across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).*

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH			PGH		
	SG Habitat (acres)	Federal Leases (acres)	Federal Leases (% habitat type)	SG Habitat (acres)	Federal Leases (acres)	Federal Leases (% habitat type)
MZ I–GP	**11,636,400**	**1,304,600**	**11.21**	**34,663,000**	**5,016,800**	**14.47**
Leased–Held By Production		388,400	3.34		2,607,900	7.52
Leased–Undeveloped		916,200	7.87		2,408,900	6.95
MZ II and VII–WB & CP	**17,476,000**	**3,161,000**	**18.09**	**19,200,200**	**4,620,200**	**24.06**
Leased–Held By Production		680,500	3.89		2,134,600	11.12
Leased–Undeveloped		2,480,500	14.19		2,485,600	12.95
MZ III – SGB	**10,028,500**	**1,300,600**	**12.97**	**3,970,100**	**513,300**	**12.93**
Leased–Held By Production		39,000	0.39		1,300	0.03
Leased–Undeveloped		1,261,600	12.58		512,000	12.90
MZ IV – SRP	**21,930,600**	**245,900**	**1.12**	**10,958,500**	**100,200**	**0.91**
Leased–Held By Production		0	0.00		0	0.00
Leased–Undeveloped		245,900	1.12		100,200	0.91
MZ V – NGB	**7,097,200**	**0**	**0.00**	**5,808,000**	**0**	**0.00**

*Data Source: Aggregated from individual Bureau of Land Management State Office Submissions in 2011 and 2012. Leased areas are calculated based on Federal subsurface management; however, subsurface mineral rights may be severed from surface rights. Small differences between individual entity totals and MZ summary values may exist due to rounding of estimates during calculations.

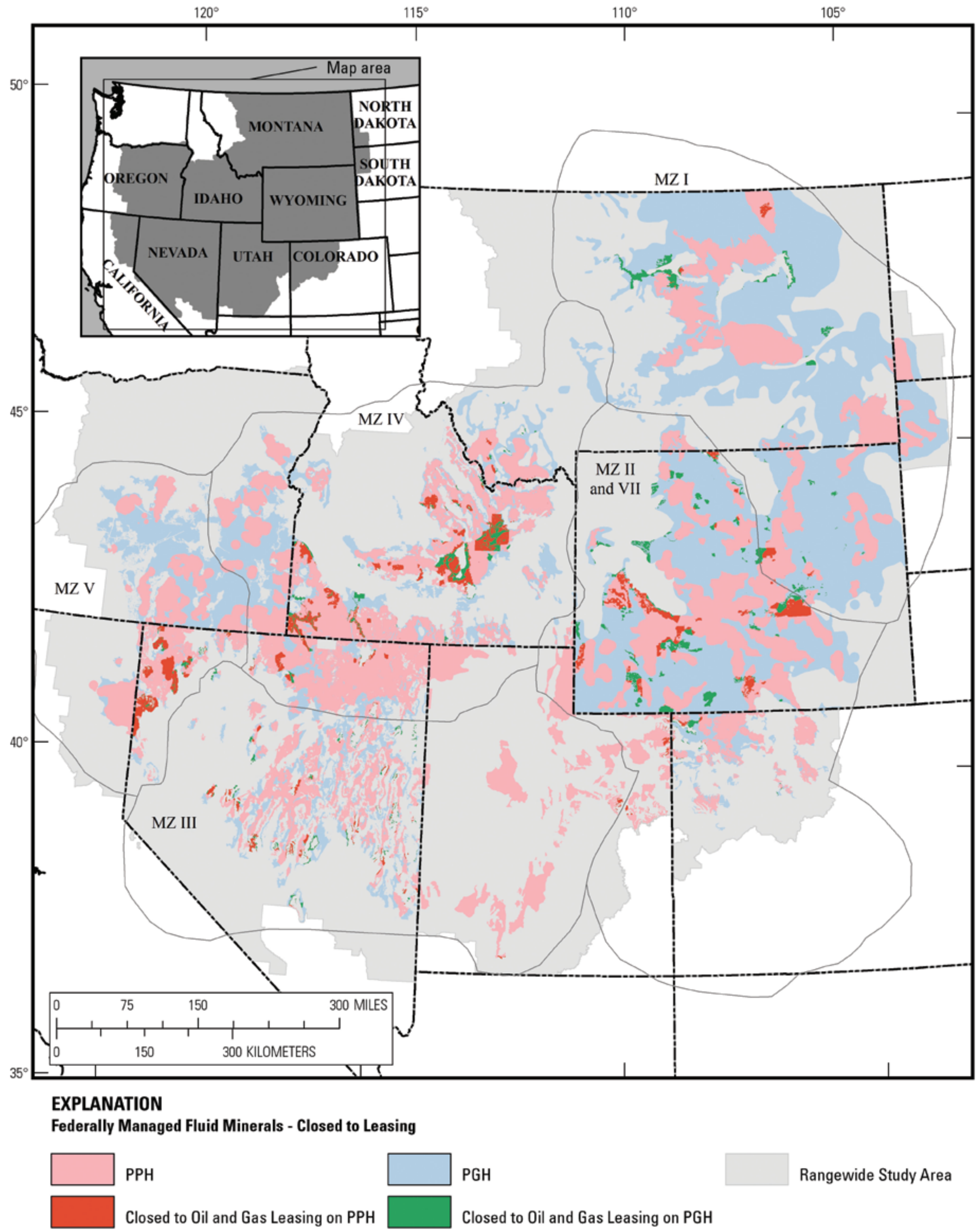


Figure 15. Overlap of Federally managed, subsurface acres closed to oil and gas leasing and sage-grouse preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

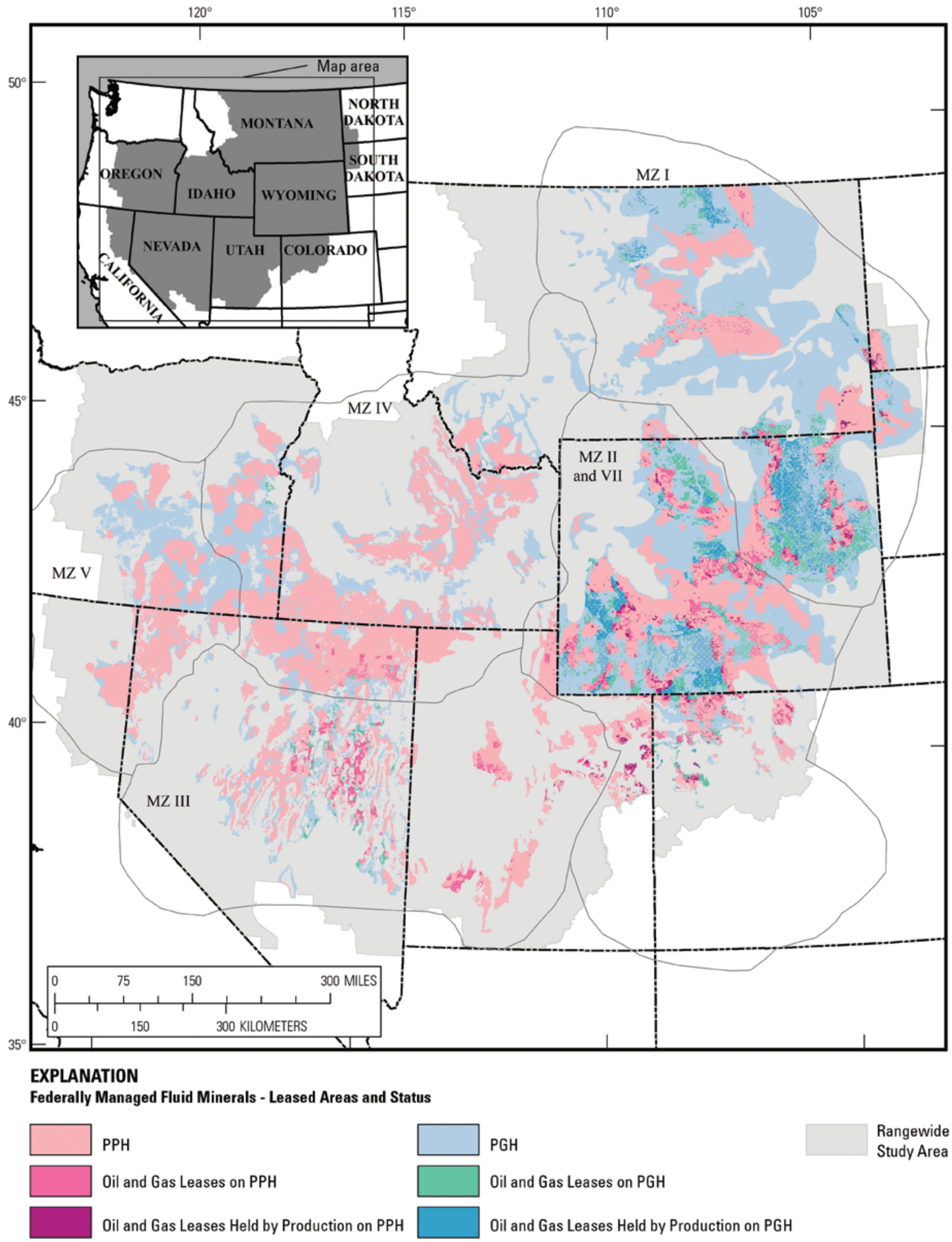


Figure 16*A*. Overlap of Federally managed, subsurface acres (held by production and developed leases) and sage-grouse preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

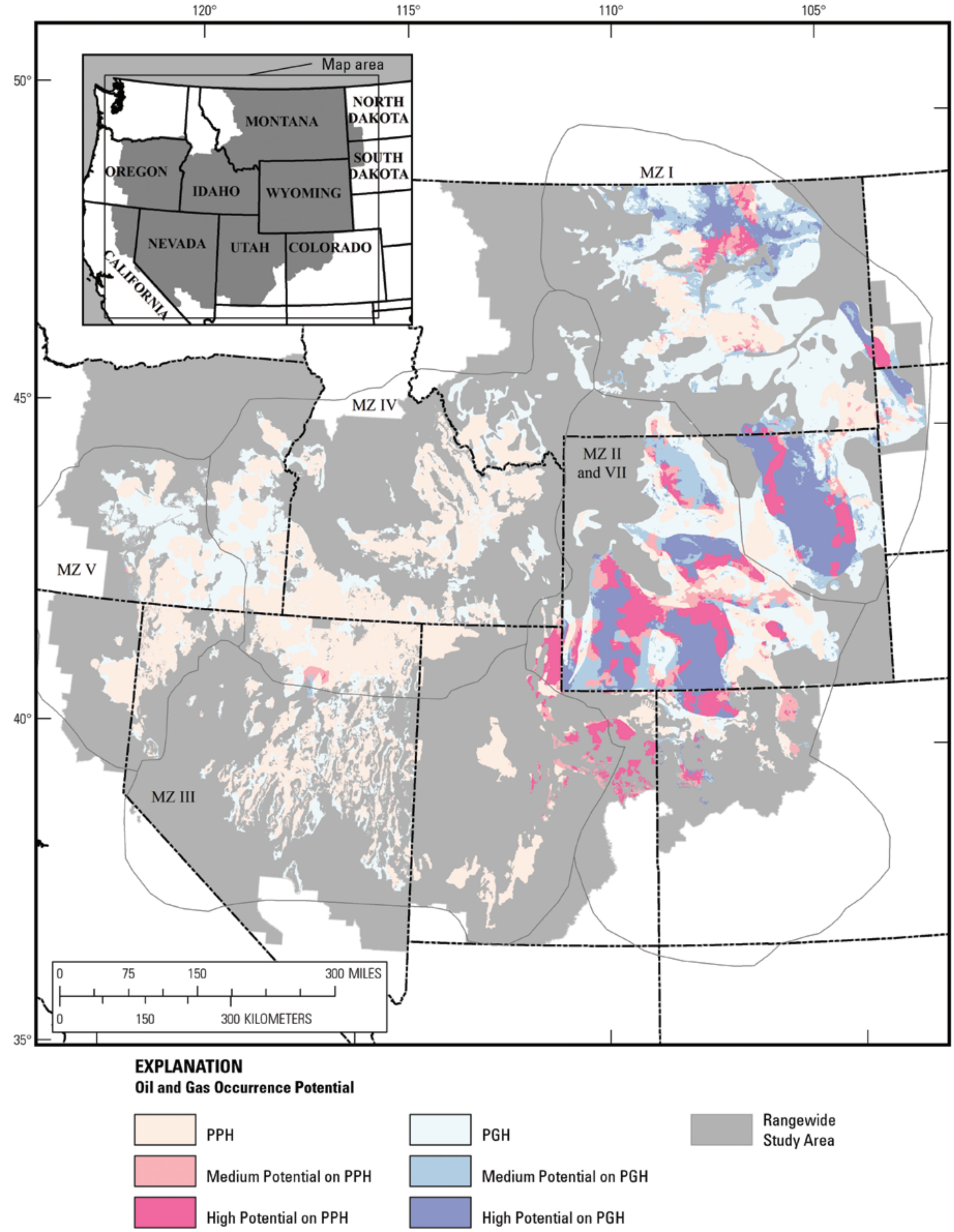


Figure 16*B*. Overlap of oil and gas resource occurrence potential and sage-grouse preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

on lek attendance—of 3 to 4 years between the time infrastructure is placed and lek abandonment has been consistently documented (Naugle and others, 2011) making short-term observations potentially misleading. Time lags in response to infrastructure have been documented as short as 2 years, or as long as 10 years (Harju and others, 2010).

In general, the research suggests that sage-grouse are negatively affected when well-pad densities within approximately 3.2 km (2 mi) of a lek exceed 1 pad/section and when leks become surrounded by infrastructure. Energy development as far as 6.4 km (4 mi) to a lek may negatively influence lek attendance. Anthropogenic noise is a component of energy developments causing declines in male lek attendance; however, all potential causes of declines resulting from energy developments have not been examined empirically. Negative effects of energy development to sage-grouse may occur at distances approaching 18 km (11 mi), and the ultimate effects of infrastructure may not become apparent for up to 10 years following the addition of infrastructure to the landscape.

Sage-grouse population declines resulted from avoidance of infrastructure during one or more seasons, reduced productivity, and (or) reduced survival (Naugle and others, 2011). A meta-analysis of grouse populations in general (including sage-grouse, prairie chickens, sharp-tailed grouse, and black grouse) suggested moderate to large displacement effects and small to moderate demographic effects of the infrastructure of energy developments; the displacement effect varied by feature type with power lines and roads having the largest effects (Hagen, 2010). Yearling female sage-grouse avoided nesting within 950 m (0.5 mi) of the infrastructure of natural gas fields (Holloran and others, 2010), and visible wells within a 1 km^2 (247 acres) area negatively influenced female selection of nesting habitats (Kirol, 2012). Female early brood-rearing (early June to early July) locations were negatively correlated with the number of visible wells within a 1 km^2 area, and late brood-rearing females (early July through late August) avoided habitats when a surface disturbance (well pads and improved roads, for example) threshold of approximately 8 percent of a 5 km^2 (1,200 acres) area was surpassed (Kirol, 2012). Sage-grouse were 1.3 times more likely to occupy winter habitats within a 4 km^2 (990 acre) area that had not been fully developed for energy (eight pads/section) and avoided habitats within 1.9 km (1.2 mi) of infrastructure during winter (Naugle and others, 2011).

Decline in sage-grouse population growth (21 percent) between pre- and post-development was primarily attributed to decreased nest success and adult female annual survival; treatment effect (proximity to gas field infrastructure) was especially noticeable on annual survival of nesting adult females (Holloran and others, 2005). Annual survival of individuals reared near gas field infrastructure (yearling females and males) was significantly lower than control individuals that were not reared near infrastructure (Holloran and others, 2010). The probability that males reared near gas fields established a breeding territory was half that of control males (Holloran and others, 2010). Fewer females from impacted leks (that is, leks within 3 km [1.9 mi] of gas field infrastructure) initiated nests compared to females from non-impacted leks (Lyon and Anderson, 2003). The closer a nest was to a natural gas well (that existed or was installed in the previous year), the more likely it was to fail (Dzialak and others, 2011). When a surface disturbance (such as well pads and improved roads) threshold of approximately 4 percent of a 1 km^2 (247 acre) area was surpassed, risk of daily brood loss increased, and risk of chick mortality was 1.5 times greater for each additional well site visible within 1 km (0.6 mi) of brood locations (Naugle and others, 2011; Kirol, 2012).

Only one study has empirically examined the response of sage-grouse to explicit changes in conventional natural gas development protocols. In southwestern Wyoming, differences in reactions of wintering sage-grouse to conventional well pads (liquid by-products stored and collected on-site) and well pads equipped with liquid gathering systems (liquid by-products piped off-site eliminating the need for tanker trucks to visit the pad) with reduced daily traffic volumes to individual pads from eight to three vehicles/day on average were examined (Holloran and others, in press). Sage-grouse avoided suitable winter habitats with high well-pad densities regardless of differences in activity levels associated with well pads. However, there was consistent suggestion across analyses that the distance-effect on sage-grouse of well pads equipped with liquid gathering systems may be less than that of conventional well pads. There was a strong positive relation between distance to drilling rig and average hours spent in an area.

In general, females selecting habitats near infrastructure have demonstrated lower annual survival (resulting in population-level declines in response to development), and females influenced by development activity within 3 km (1.8 mi) of the lek are less likely to initiate a nest. Nesting females avoid areas within approximately 1 km (0.6 mi) of infrastructure, and nests closer to infrastructure are at a higher risk of nest failure. Brood-rearing females avoid areas within approximately 0.5 km (0.3 mi) of infrastructure, broods reared within 1 km of infrastructure are less likely to be successful, and yearling male and female survival and yearling male fecundity (the probability of establishing a breeding territory) are lower for individuals reared near infrastructure. It is worth noting that a meta-analysis of sage-grouse demographic rates collected rangewide during a 73-year period suggested that female survival, chick survival, and nest success were demographics that had the greatest influence on sage-grouse population growth (Taylor and others, 2012). Sage-grouse during the winter avoid habitats with high well-pad densities and avoid areas within 1.9 km (1.2 mi) of a well pad; reduced anthropogenic activity levels at well pads may reduce the range of indirect (nonmortality effects) effects on sage-grouse on winter habitats (for example, reduction of avoidance).

Wind Energy Developments

Federal lands in the Western United States have significant potential to produce energy from wind power (Connelly and others, 2004). Few wind turbines currently exist within the range of sage-grouse, which makes assessment of this threat challenging; approximately 1,800 acres (0.001 percent) of sage-grouse habitat are directly influenced by wind turbines throughout the range of the species (table 14, fig. 17). Indirect effects to sage-grouse from wind energy developments were also assessed using the spatial foraging behaviors of avian predators that have an estimated range of 4.3 mi (6.9 km) from perching locations. This estimate suggests that current wind energy developments influence approximately 0.31 percent of priority habitats throughout the species' range. Private lands account for most (approximately 72 percent) of the priority habitats indirectly influenced by wind turbines; BLM lands account for approximately 21 percent of these habitats indirectly influenced by turbines. Though largely unspecified (most Federal lands are not currently leased or developed), the coincidence of wind potential (for energy production) and sage-grouse habitats, including PPH and PGH, is high across sage-grouse range, and is especially widespread in MZs I and II (fig. 18*A*). Estimating development potential also includes location and proximity of transmission infrastructure and markets as well as market trends (energy prices); therefore, wind potential is only one of several indications of potential and all are not considered here. However, current development is greatest where rights of way leases have been issued, suggesting wind energy development potential in the near future will increase if in close proximity to available transmission. Thus areas with suboptimal wind speeds may be developed before those with better resources if near available transmission. For example, although wind potential for energy production is not high in MZ IV, significant wind energy transmission Rights of Way overlap PPH in MZ IV suggesting habitats in this MZ may be developed (fig. 18*B*). Concerns surrounding wind energy development and sage-grouse include noise produced by the rotor blades, sage-grouse avoidance of structure, and mortality to sage-grouse flying into rotors; however, the greater influence on sagebrush ecosystems will likely result from the roads and power lines that are necessary to construct and maintain sites used for wind energy (Connelly and others, 2004). These effects are discussed at length in the previous section (also see Section III. A4. Infrastructure). The only study on specific effects of wind development on sage-grouse was recently completed in south-central Wyoming (LeBeau, 2012). The relative probabilities of a sage-grouse nest and brood failing (all chicks lost between hatch and 35-days post-hatch) increased with proximity to nearest wind turbine. Notably, this study investigated the short-term response of sage-grouse to a wind energy facility; the impacts of a facility may not be realized within 2 to 4 years of the addition of wind turbines due to the time lags associated with responses of sage-grouse breeding populations to infrastructure.

In Situ Uranium

According to the World Nuclear Association (London, United Kingdom; *www.world-nuclear.org*), in situ recovery (ISR) of uranium in North America involves recovering the minerals from an ore body by injecting solution to dissolve the uranium, pumping the pregnant solution to the surface, and removing the uranium from solution at a processing plant. Several projects are currently licensed to operate in the United States including several producing and proposed mines in Wyoming; most of the operating mines date from the 1990s. Uranium deposits are found predominantly in southeastern portions of MZ I (Powder River Basin), throughout MZ II, and in eastern MZ III and western MZ VII (Finch, 1996). The design of ISR-well fields varies depending on local conditions such as permeability, sand thickness, deposit type, ore grade, and ore distribution. However, whatever the well-field design used, there is a mixture of injection wells (to introduce the leach solution to the ore body) and extraction wells with submersible pumps used to deliver pregnant solution via pipeline to the processing plant. Wells with a common purpose (injection or extraction) are generally spaced 65 to 200 ft (20 to 60 m) apart. Wells are typically the same size as water-well bores, and the processing plant is generally situated on-site creating basic infrastructure of wells, pipelines, and a processing plant within a geologically defined area.

The largest environmental risk with an ISR uranium facility is the potential impacts to groundwater resulting from (1) residual constituent concentrations in excess of baseline concentrations after the restoration of the production aquifer, (2) a migration of production liquids from the production aquifer to the surrounding aquifers during operation, (3) a mechanical failure of the subsurface-well materials releasing production fluids into the overlying aquifers, (4) movement of constituents to groundwater outside the licensed area, and (5) excessive consumption of groundwater (School of Energy Resources, University of Wyoming, Laramie, Wyo.; *www.uwyo.edu/ser/*). A detailed description of surface disturbance associated with an in situ uranium mine could not be found; however, based on pictures provided by Ur-Energy (Littleton, Colo.), a company developing in situ uranium mines in Wyoming, surface disturbance most closely aligns with that found in a coal bed natural gas field at a localized scale (for example, wells not distributed across a large landscape but focused on discrete ore deposits) without overhead utilities and substantial water discharge. Beyond potential impacts of water contamination, potential disturbance to sage-grouse could occur during drilling phases of development, from the processing plant, and from traffic on roads accessing well fields (an intensively developed region) and the processing plant. Minimal surface disturbance appears to occur within the well field.

Oil Shale and Tar Sands

Oil shale (also referred to as tar sands) is fine-grained sedimentary rock that contains relatively large amounts of kerogen, which can be converted into liquid and gaseous hydrocarbons (petroleum liquids, natural gas liquids, and methane) by heating the rock. According to the U.S. Energy Information Administration (*www.eia.gov*), the richest U.S.

Table 14. Summary of the direct and indirect influences of wind turbines* across Management Zones (MZ) by acres of preliminary priority and preliminary general sage-grouse habitats (PPH and PGH, respectively).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH					PGH				
	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Innfluence[2] (%)	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)
MZ I–GP	**11,636,400**	**100**	**122,100**	**0.00**	**1.05**	**34,663,000**	**800**	**243,600**	**0.00**	**0.70**
BLM	2,994,300	0	25,800	0.00	21	4,524,900	0	14,900	0.00	6
Forest Service	292,400	0	100	0.00	0	515,300	0	0	0.00	0
Tribal and Other Federal	219,700	0	0	0.00	0	2,427,700	0	0	0.00	0
Private	7,132,500	100	88,100	0.00	72	24,682,800	700	211,100	0.00	87
State	995,600	0	8,100	0.00	7	2,498,400	0	17,600	0.00	7
Other	1,900	0	0	0.00	0	13,900	0	0	0.00	0
MZ II and VII–WB & CP	**17,476,000**	**0**	**75,900**	**0.00**	**0.43**	**19,200,200**	**700**	**306,700**	**0.00**	**1.60**
BLM	9,021,200	0	16,500	0.00	22	9,012,500	0	65,700	0.00	21
Forest Service	162,000	0	0	0.00	0	452,500	0	0	0.00	0
Tribal and Other Federal	784,000	0	0	0.00	0	1,354,600	0	0	0.00	0
Private	6,233,900	0	52,900	0.00	70	7,394,800	600	223,000	0.01	73
State	1,244,800	0	6,600	0.00	9	979,800	100	18,000	0.01	6
Other	30,100	0	0	0.00	0	6,000	0	0	0.00	0
MZ III–SGB	**10,028,500**	**0**	**0**	**0.00**	**0.00**	**3,970,100**	**0**	**0**	**0.00**	**0.00**
MZ IV–SRP	**21,930,600**	**0**	**11,500**	**0.00**	**0.05**	**10,958,500**	**200**	**93,800**	**0.00**	**0.86**
BLM	13,710,700	0	2,000	0.00	17	4,928,200	0	29,900	0.00	32
Forest Service	1,613,800	0	0	0.00	0	1,113,500	0	0	0.00	0
Tribal and Other Federal	633,600	0	0	0.00	0	522,500	0	2,900	0.00	3
Private	4,890,200	0	9,400	0.00	82	3,516,742	200	57,900	0.01	62
State	1,019,373	0	100	0.00	1	846,200	0	3,100	0.00	3
Other	62,900	0	0	0.00	0	31,400	0	0	0.00	0

Table 14. Summary of the direct and indirect influences of wind turbines* across Management Zones (MZ) by acres of preliminary priority and preliminary general sage-grouse habitats (PPH and PGH, respectively).—Continued

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH					PGH				
	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Innfluence[2] (%)	SG Habitat (acres)	Direct Footprint[1] (acres)	6.9 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)
MZ V–NGB	**7,097,200**	**0**	**0**	**0.00**	**0.00**	**5,808,000**	**0**	**0**	**0.00**	**0.00**

*Data Source: Federal Aviation Administration Digital Obstacles File, 2011

[1]Direct footprint is the co-location of existing wind turbines within the designated habitat boundaries, and indirect influence is inferred by applying an effect buffer to the features and estimating the area affected. Indirect influence distance derived from foraging distances of predators (Boarman and Heinrich, 1999; Leu and others, 2008).

[2]For MZ calculated as the percent of the particular sage-grouse habitat type influenced by the indirect impact of the threat. For management entities within a management zone calculated as the percent of the total indirect impact in the management zone represented by that management entity; that is, the relative area of indirect influence among management entities. Small differences between individual entity totals and MZ summary values may exist due to rounding of estimates during calculations.

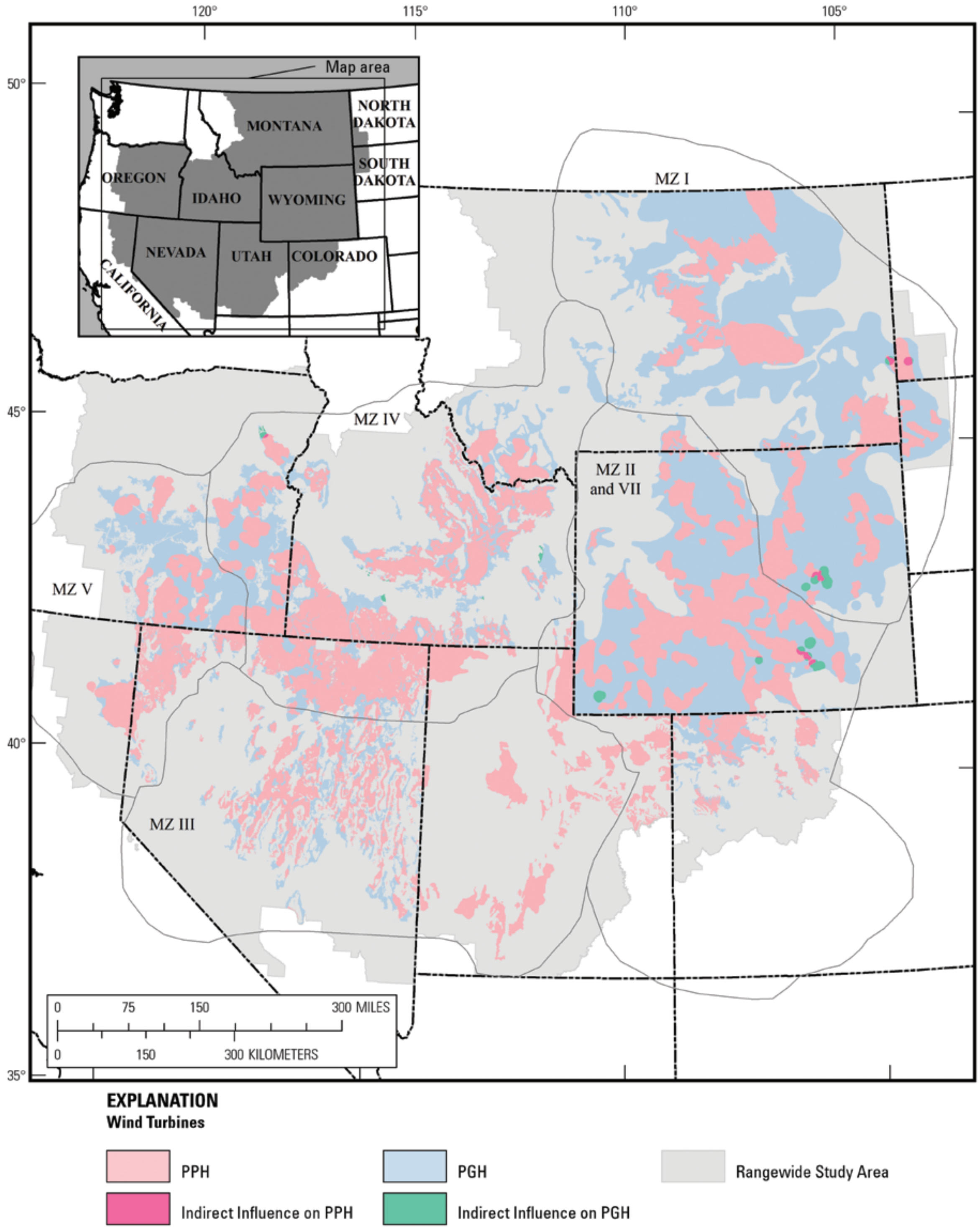


Figure 17. Overlap of wind turbines, potential indirect influences of wind turbines, and preliminary priority and preliminary general habitats (PPH and PGH, respectively) across Management Zones (MZ).

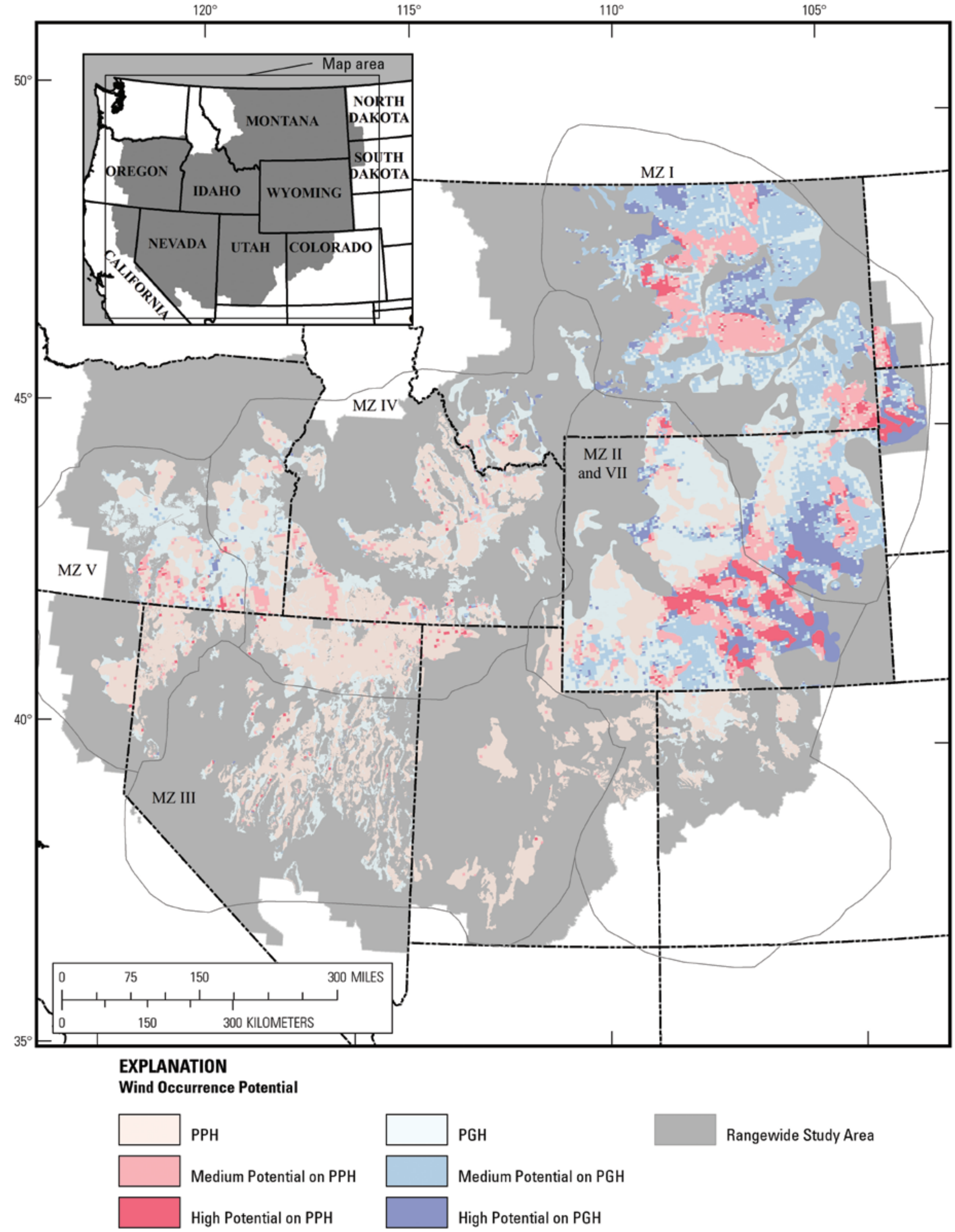


Figure 18*A*. Distribution of wind occurrence potential (based on mean wind speeds) within preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

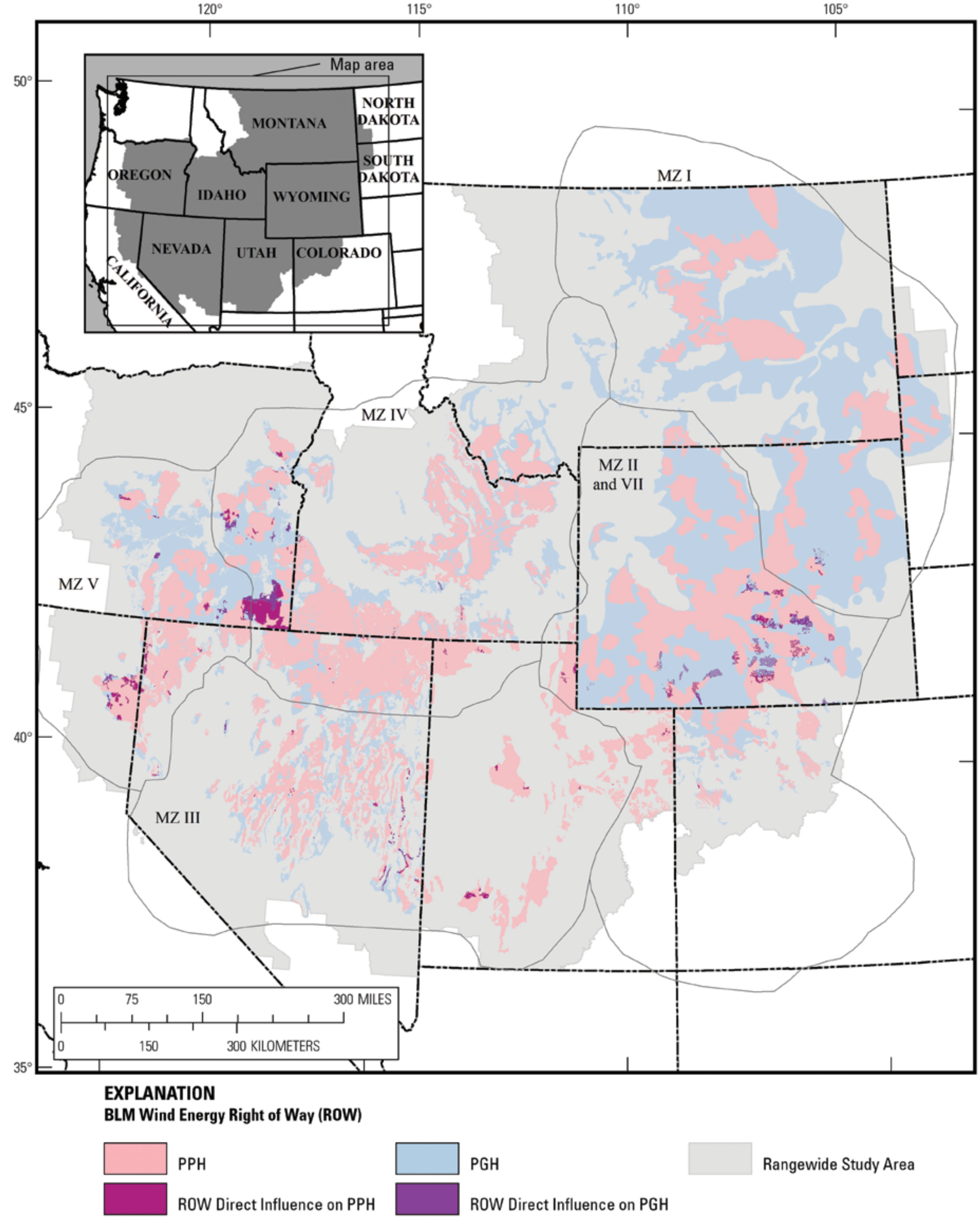


Figure 18*B*. Overlap of Federal wind energy right-of-way leases with preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

oil shale deposits are located in northwest Colorado, northeast Utah, and southwest Wyoming, and deposits in these regions are currently the focus of petroleum industry research and potential future production. Current Federal leases for oil shale resources within sage-grouse range are limited to 331 km^2 (81,800 acres) within MZs II and VII (fig. 19*A*); a majority of these developments are on BLM managed lands (surface) with the remaining portion split between private and State lands. Development potential extends beyond the current footprint with the richest deposits in northwest Colorado overlapping sage-grouse populations in MZ VII (fig. 19*B*) and has been subjected to a programmatic analysis considering resource potential, technology, and resource management issues (BLM, 2012b). Given support of technology and market forces, these fields may ultimately produce more than 1 million barrels of oil equivalent per one acre (2.6 km^2; deposits in Alberta are expected to produce about 100,000 barrels per acre [2.6 km^2]) suggesting that this may be an important factor in sage-grouse habitat conservation in the future.

Techniques for extracting resources from oil shale can be generally categorized as direct or indirect recovery: (1) direct recovery involves the removal of the oil shale from its formation for ex situ processing and (2) indirect or in situ recovery involves some degree of processing of the oil shale while it is still in its natural depositional setting, leading ultimately to the extraction of just the desired organic fraction. The key steps in processing are retorting and pyrolysis. Retorting is a process that causes thermal decomposition of the organic fraction of the oil shale (kerogen); the recovered organic fraction is then distilled, or pyrolyzed, to produce three products: crude shale oil, flammable gases (including hydrogen, methane, and natural gas), and char (deposited on spent shale). Surface mining techniques (strip mining and or pit mining) as well as subsurface mining techniques (room-and-pillar mining, longwall mining, and other derivatives) have been successfully employed in the recovery of oil shale; however, the BLM considers the potential of surface mining in the future low. Indirect recovery techniques generally cause decomposition of kerogen to liquid and gaseous organic fractions that have sufficient mobility to “flow” through the formation for removal by conventional oil and gas recovery techniques. Surface disturbance most closely aligns with that found in a natural gas field, although well densities may be higher due to the requirement of injection (heat) and recovery wells in relative close proximity. Therefore, sage-grouse will likely respond to in situ oil shale development similarly to conventional natural gas development.

In situ recovery processes currently being researched are regarded by the U.S. Department of Energy as a promising technology. Although the technical feasibility of in situ retorting has been proven, considerable technological development and testing are needed before any commitment can be made to a large-scale commercial project. Confirmation of the technical feasibility of the processes hinges on the resolution of two major technical issues: controlling groundwater during production and preventing subsurface environmental problems, including groundwater impacts. Of special concern in the arid Western United States is the large amount of water required for oil shale processing; currently, oil shale extraction and processing require several barrels of water for each barrel of oil produced. The Energy Information Administration estimates that the earliest date for initiating construction of a commercial in situ oil shale project is 2017 with the first commercial production occurring probably no sooner than 2023. The information presented in this paragraph as well as a detailed discussion of the technology required for the recovery (that is, mining), processing (that is, retorting and pyrolysis of the hydrocarbon fraction), and upgrading of oil shale resources can be found in the Draft Programmatic Environmental Impact Statement and Possible Land Use Plan Amendments for Allocation of Oil Shale and Tar Sands Resources on Lands Administered by the Bureau of Land Management in Colorado, Utah, and Wyoming (BLM, 2012b).

Solar

Solar power generation facilities that are likely to be developed for utility-scale capture of solar energy (that is, ≥20 MW [megawatts] electricity that will be delivered into the electricity transmission grid) in the United States during the next 20 years include concentrating solar power—which includes parabolic trough, power tower, and dish engine systems—and photovoltaic arrays. The main component that all these technologies have in common is a large solar field where solar collectors capture the sun’s energy. In the parabolic trough and power tower systems, the energy is concentrated in a heat transfer fluid and transferred to a power block where steam-powered turbine systems generate electricity using similar technology to that used in fossil-fuel-fired power plants. In contrast, the dish engine and photovoltaic systems are composed of many individual units or modules that generate electricity directly and whose output is combined; these systems do not use a central power block. Solar facilities are likely to have an operational lifetime of 30 years or more, representing long-term effects on habitats where they co-occur. Although no current facilities affect sage-grouse range measurably (the USFWS listing decision identified small developments in Wyoming and California), the southern portion of sage-grouse range includes higher yields per unit area of solar potential indicating that, given technological developments, transmission infrastructure, and market forces, many of these lands could be targeted for solar energy facilities in the future (fig. 20; BLM, 2012c).

The primary environmental concerns associated with solar power generation include the large land area required for solar facilities and water consumption. Concentrating solar power systems generally require 5–10 acres (2 ha–4 ha) to produce 1 MW, and photovoltaic systems require around 10 acres (4 ha) per MW. Additional impacts will include access roads and transmission lines. Although solar developments themselves are not similar to the infrastructure of energy developments discussed above, impacts to sage-grouse from

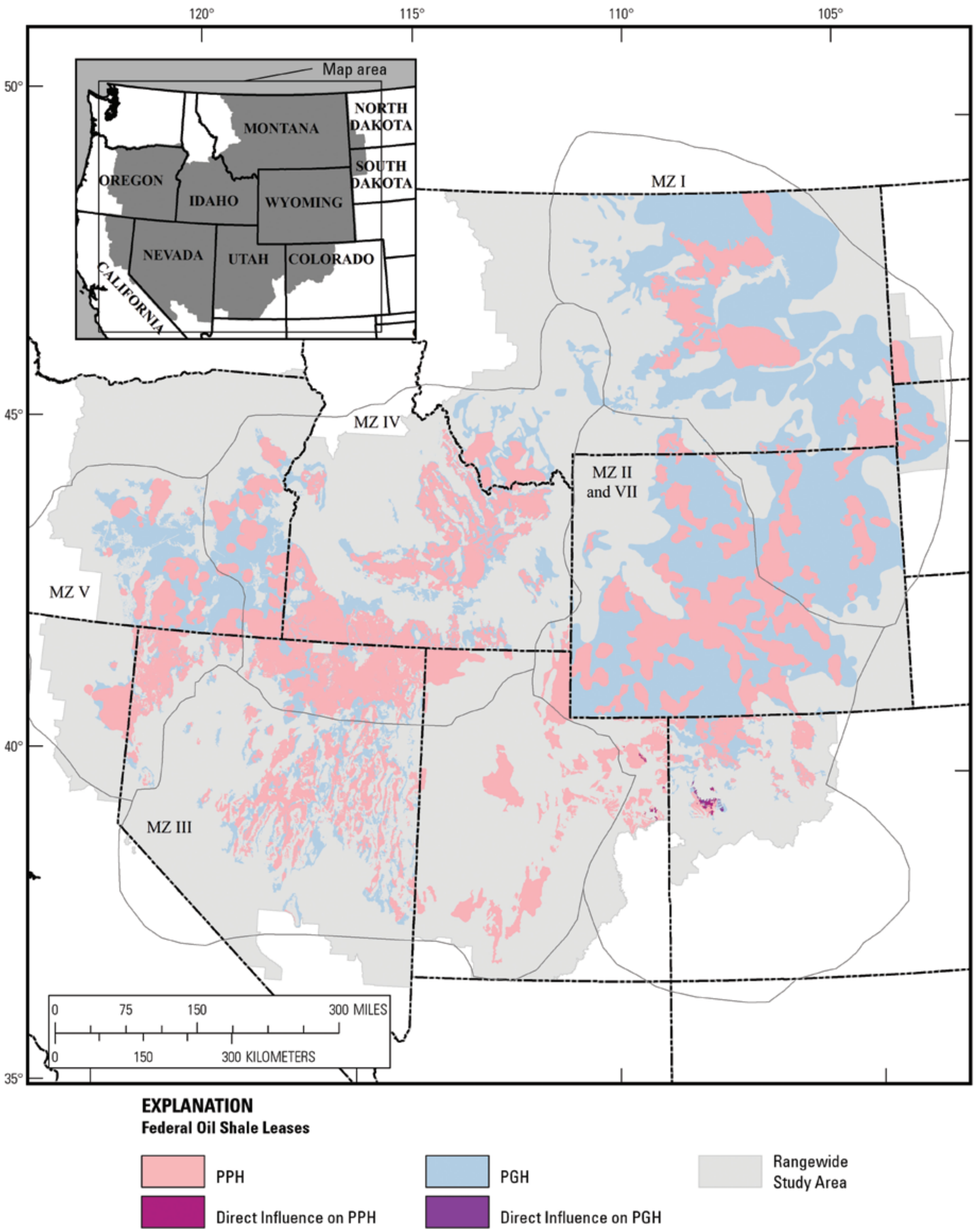


Figure 19*A*. Overlap of Federal oil shale leases and sage-grouse preliminary priority and preliminary general habitats (PPH and PGH). MZ, Management Zone.

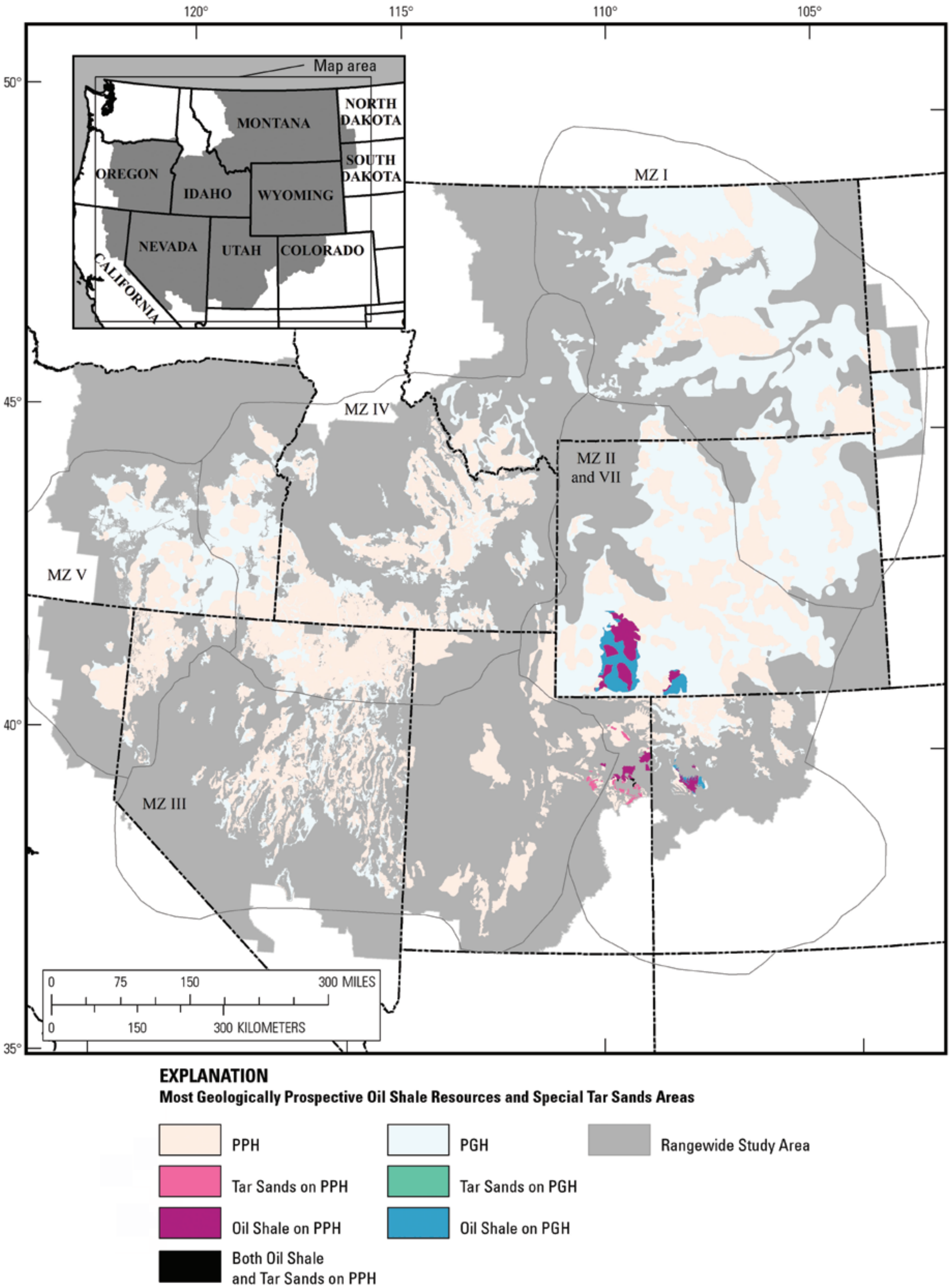


Figure 19*B*. Overlap of the most likely geological prospects for oil shale and tar sands development and sage-grouse preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

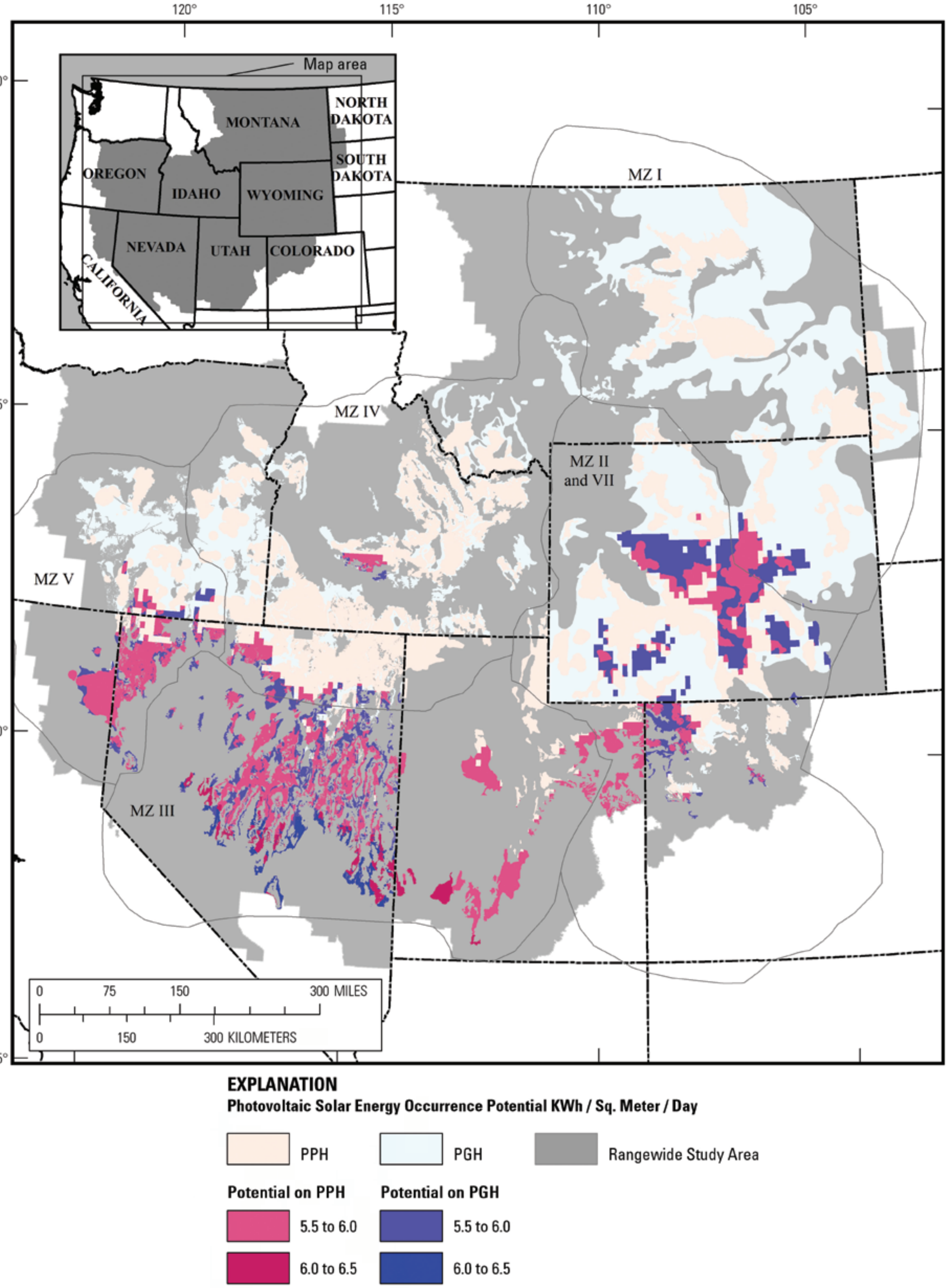


Figure 20. Overlap of photovoltaic-based estimates of solar power potential and sage-grouse preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone; KWh/M^2/day, kilowatt hours per square meter per day.

direct habitat loss, habitat fragmentation via roads and transmission lines, noise, and increased human presence (Connelly and others, 2004) may be similar to those discussed for nonrenewable energy development. The information presented in this section as well as a detailed discussion of the technology required for generation of solar-based electricity can be found in the Programmatic Environmental Impact Statement (PEIS) for Solar Energy Development in Six Southwestern States (BLM, 2012c).

Geothermal

According to the Geothermal Energy Association (see Web site at geo-energy.org), geothermal energy is defined as heat from the Earth; heat continuously flowing from the Earth's interior is estimated to be equivalent to 42 MW of power. Geothermal energy production within the range of sage-grouse is primarily within the Southern and Northern Great Basins MZs. As of 2011, approximately 2,000 km^2 (494,200 acres) of sagebrush habitat has been leased for this purpose and an additional 1,140 km^2 (281,700 acres) are pending (Knick and others, 2011). The only type of geothermal energy that has been widely developed, currently, is hydrothermal energy, which consists of trapped hot water or steam, however technologies are evolving such that these developments may become an important consideration in the near future.

Impacts to sage-grouse associated with geothermal energy development have not been assessed because the development has been too recent to identify any immediate or lag effects (Knick and others, 2011), but geothermal power plants are similar to fossil-fuel-fired power plants in that resources are exploited in a highly centralized fashion, thus surface impacts could include the footprint of the power plant itself, access roads, and transmission lines. Extraction of geothermal fluids (gases, steam, and water) for power generation generally requires many of the same infrastructure features for construction and operation as do traditional nonrenewable energy resources. As such, impacts of geothermal developments to sage-grouse from direct habitat loss, habitat fragmentation via roads and transmission lines, noise, and increased human presence (Connelly and others, 2004) may be similar to those discussed for nonrenewable energy development with comparable effects on local sage-grouse populations also anticipated.

Although geothermal development occurs throughout MZs III, IV, and V, the direct footprint is relatively small with approximately 141,800 acres (0.38 percent) of sage-grouse habitat directly impacted by geothermal leases in these MZs (table 15, fig. 21*A*). Geothermal developments are widespread in priority habitats in western portions of MZ III in particular. No geothermal development currently occurs in MZs I and II. However, geothermal development potential is distributed across a majority of priority and general habitats throughout the range of sage-grouse (fig. 21*B*).

Air and water pollution, disposal of hazardous waste, siting, and land subsidence are environmental concerns related to geothermal electricity generation; however, many of the air and water concerns are eliminated in closed-loop systems. In addition to these impacts, geothermal energy extraction may cause the release of toxic gases (carbon dioxide and hydrogen sulfide) and elements (arsenic) into the environment. The form, and subsequent effects, of these substances depends on the geological formation from which energy is being extracted. Large quantities of water may also be required for drilling and condenser cooling (Suter Ii, 1978), and if the water used for these purposes depletes the water resources of the surrounding habitat, riparian and brood-rearing habitats may be affected by water-table changes. On-site water storage may increase potential WNv (West Nile virus) exposure in the area (Friend, 2001; Zou and others, 2006; Walker and others, 2007a; Walker and Naugle, 2011).

Hydrothermal energy, based on trapped water or steam, is the only type of geothermal energy that has been widely developed at this time. However, new technologies are being developed to exploit hot dry rock (accessed by drilling deep into rock), geopressured resources (pressurized brine mixed with methane), and magma (see Union of Concerned Scientists Web site at *www.ucsusa.org*) making these developments potentially important considerations for the near future and making direct and indirect effects on sage-grouse anticipated and logical, but speculative.

Mining

Besides oil and natural gas development, the major mining activity within sage-grouse habitats has been for coal (Braun, 1998). However, mining for other substances—especially bentonite, trona, and gravel—occurs throughout the range of the species, and mining and exploration for rare minerals (such as, gold, silver, and copper) has recently become more common and may influence sage-grouse habitats extensively in some regions. Coal mines are widespread, but discretely located in sage-grouse habitats MZ I and southern portions of MZs II and VII, and Federal leases developed through surface extraction directly influence approximately 22,100 acres (89 km^2; <0.1 percent) of these MZs (table 16, fig. 22). There is potential for additional coal mining in large portions of priority and general habitats in MZs I, II, and VII (fig. 23). Indirect effects of surface coal mines with Federal leases were estimated using a 19-km (11.8-mi) effects buffer based on observations of industrial infrastructure effects on sage-grouse, which suggests influence over approximately 8 percent of priority sage-grouse habitats across the range of the species and approximately 5 percent of priority habitats in MZs I, II, and VII. Approximately 36 percent of priority habitats that are indirectly influenced by coal mines across the species' range are managed by BLM. Surface mining accounts for about 67 percent of production in the United States; large opencast mines can cover an area of many square kilometers. Coal mining and the use of coal to produce electricity raises a number of environmental challenges including soil erosion, dust, noise, water pollution, acid-mine drainage, and

Table 15. Summary of geothermal leases* across Management Zones (MZ) by acres of sage-grouse preliminary priority and preliminary general habitats (PPH and PGH, respectively).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH			PGH		
	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)
MZ I–GP	11,636,400	0	0.00	34,663,000	0	0.00
MZ II and VII–WB & CP	17,476,000	0	0.00	19,200,200	0	0.00
MZ III–SGB	10,028,500	72,900	0.73	3,970,100	52,700	1.33
MZ IV–SRP	21,930,600	58,000	0.26	10,958,500	17,900	0.16
MZ V–NGB	7,097,200	10,900	0.15	5,808,000	31,800	0.55

*Data Source: Aggregated from individual BLM State Office Submissions in 2011 and 2012.

air emissions in addition to impacts on local species. Burning coal releases oxides (especially of sulfur [SO_x] and nitrogen [NO_x]), trace elements (mercury, for example), and particulate matter into the atmosphere with potential effects on local, and global, habitat conditions.

Other forms of mining (for example, bentonite, gravel, potash, and trona) can also influence sage-grouse habitats. The magnitude of the impacts of mining activities on sage-grouse and sagebrush habitats is largely unknown (Braun, 1998), but mining of various Federal mineral resources (locatable and saleable) currently affects approximately 3.6 percent of potential sage-grouse habitat directly (across all MZs) with indirect effects potentially affecting large portions (5–32 percent) of some MZs (table 17*A*). In addition, existing leases for development of non-energy, leasable minerals represent a relatively small threat (spatially) but may ultimately be developed to their full, spatial extent based on existing agreements (table 17*B*).

Development of surface mines and associated infrastructure (such as, roads and power lines), noise, and human activity may negatively impact sage-grouse numbers in the short term (Braun, 1998), and a variety of mineral claims could result in industrial activities that would disrupt the habitat and life-cycle of sage-grouse (fig. 24). The number of displaying sage-grouse on 2 leks within 2 km (1.25 mi) of active mines in northern Colorado declined by approximately 94 percent during a 5-year period following an increase in mining activity (Remington and Braun, 1991). However, Braun (1998) reported recovery of populations in Montana, Wyoming, and Colorado may occur after initial development and subsequent reclamation of mine sites, although populations do not recover to pre-development sizes. Additionally, population re-establishment may take as long as 30 years (Braun, 1998).

A6. Fire

Although large fires play an important role in landscape ecology for most of the Western United States, fire is much less important in the function of sagebrush-bunchgrass ecosystems than most forested systems (Keane and others, 2008). Given the suite of contributing disturbances, fire currently has largely negative effects on sage-grouse by directly affecting the distribution and condition of available sagebrush habitats (Nelle and others, 2000; Beck and others, 2009; Rhodes and others, 2010; Baker, 2011). Sage-grouse require the cover and forage provided by mature sagebrush and healthy herbaceous communities, and habitat selection research indicates strong selection at multiple scales and increased nesting success in areas with greater cover (Sveum and others, 1998a; Connelly and others, 2000c; Holloran and others, 2005; Aldridge and Boyce, 2007; Hagen and others, 2007; Yost and others, 2008; Kolada and others, 2009; Atamian and others, 2010; Carpenter and others, 2010; Doherty and others, 2010b; Bruce and others, 2011; Doherty and others, 2011a; Hagen and others, 2011; Aldridge and others, 2012; Kirol and others, 2012; Tack and others, 2012). Wildfire and prescribed fires typically kill sagebrush thereby reducing cover and forage in the short term. However, fire is also associated with natural dynamics and spatial heterogeneity of many sagebrush ecosystems, suggesting that not all fires (wildfire or prescribed) in sagebrush communities have net-negative effects on sage-grouse populations and habitats. On the contrary, whereas vegetation and fuel management will likely preclude use of fire in some areas (for example, winter habitats or Wyoming big sagebrush habitats), the need to reduce tree cover (especially juniper) and fuel continuity (in mountain sagebrush communities of MZs II, IV, and V, for example) means that prescribed fire may be an important management option in other areas. If landscape-scale habitat patterns stabilize and local populations are not

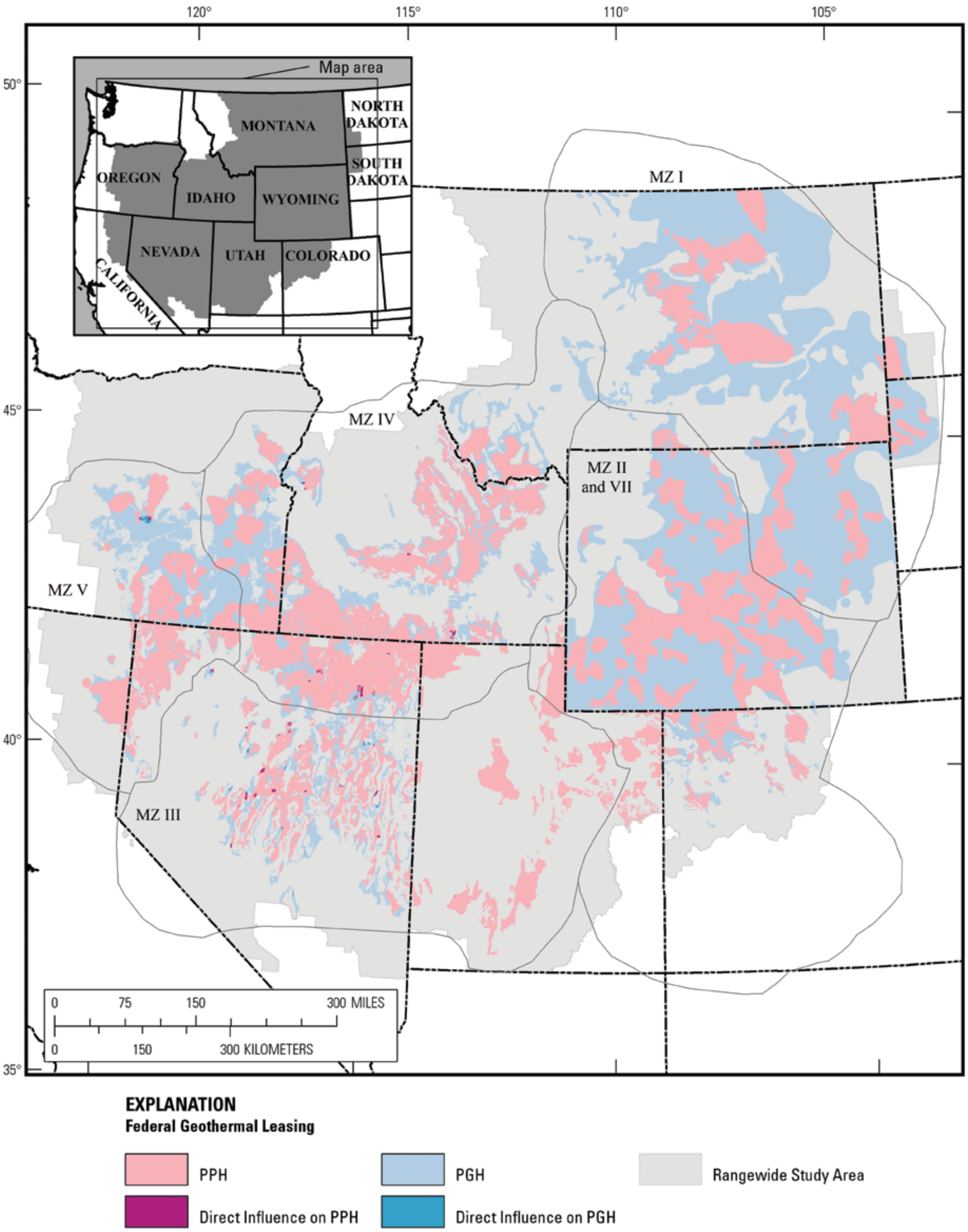


Figure 21*A*. Overlap of Federal geothermal leases with sage-grouse preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

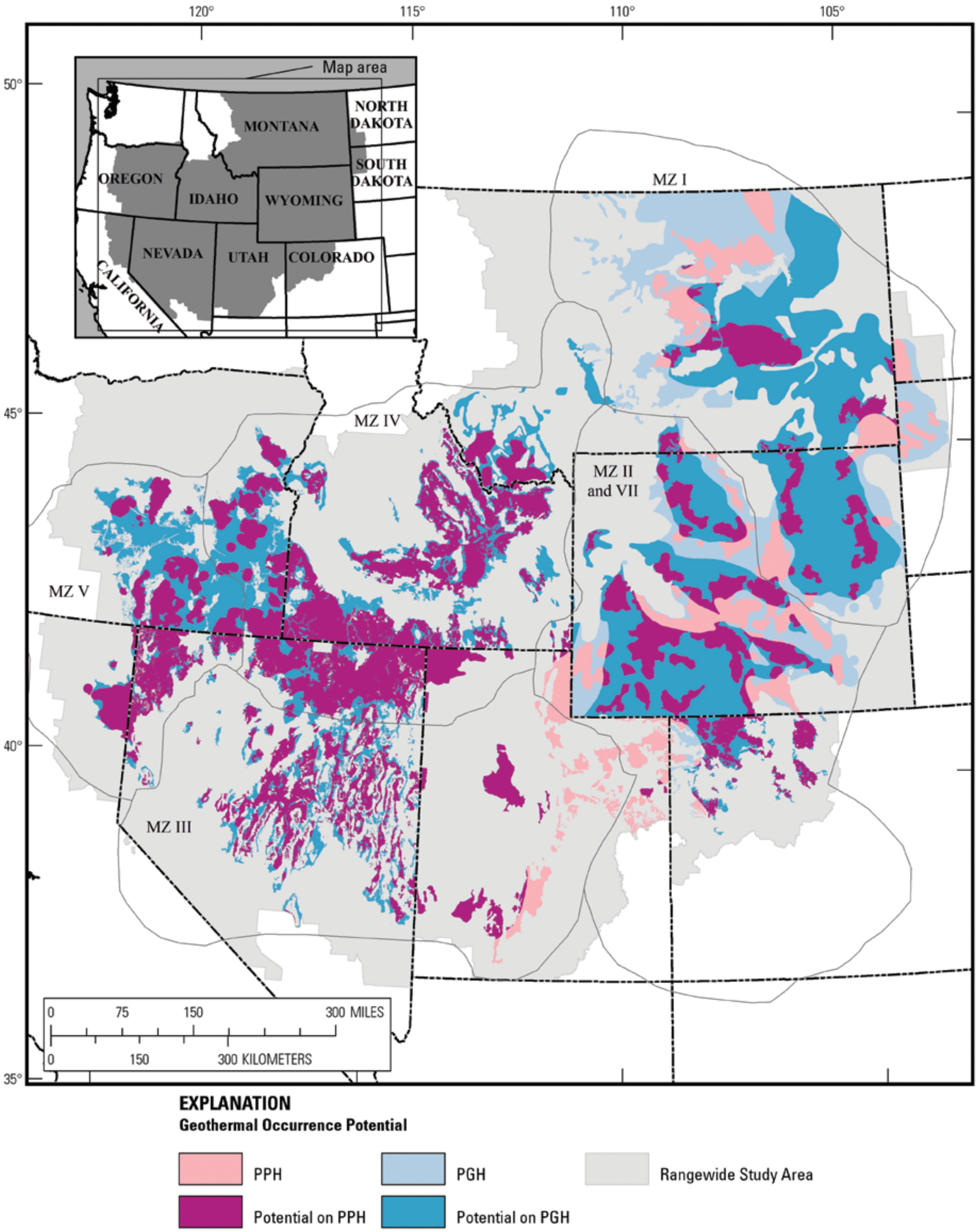


Figure 21*B*. Overlap of geothermal occurrence potential in sage-grouse preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

Table 16. Summary of the direct and indirect influences of Federal surface coal leases* across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH					PGH				
	SG Habitat (acres)	Direct Footprint[1] (acres)	19 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)	SG Habitat (acres)	Direct Footprint[1] (acres)	19 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)
MZ I–GP	**11,636,400**	**5,700**	**335,900**	**0.05**	**2.89**	**34,663,000**	**202,600**	**2,685,600**	**0.58**	**7.75**
BLM	2,994,300	600	28,200	0.02	8	4,524,900	2,600	104,400	0.06	4
Forest Service	292,400	0	53,800	0.00	16	515,300	32,900	189,000	6.38	7
Tribal and Other Federal	219,700	0	100	0.00	0	2,427,700	0	14,100	0.00	1
Private	7,132,500	5,100	229,800	0.07	68	24,682,800	164,500	2,203,400	0.67	82
State	995,600	0	24,000	0.00	7	2,498,400	2,500	172,000	0.10	6
Other	1,900	0	0	0.00	0	13,900	0	2,700	0.00	0
MZ II and VII–WB & CP	**17,476,000**	**16,400**	**1,325,000**	**0.09**	**7.58**	**19,200,200**	**35,700**	**1,873,200**	**0.19**	**9.76**
BLM	9,021,200	12,200	567,300	0.14	43	9,012,500	28,100	706,600	0.31	38
Forest Service	162,000	0	0	0.00	0	452,500	0	1,400	0.00	0
Tribal and Other Federal	784,000	2,400	31,000	0.31	2	1,354,600	0	5,700	0.00	0
Private	6,233,900	1,200	663,200	0.02	50	7,394,800	7,500	1,074,400	0.10	57
State	1,244,800	600	63,100	0.05	5	979,800	100	85,000	0.01	5
Other	30,100	0	300	0.00	0	6,000	0	100	0.00	0
MZ III–SGB	**10,028,500**	**1,500**	**63,300**	**0.01**	**0.63**	**3,970,100**	**0**	**0**	**0.00**	**0.00**
BLM	6,309,400	1,100	22,900	0.02	36	3,199,800	0	0	0.00	0
Forest Service	1,236,200	0	400	0.00	1	356,200	0	0	0.00	0
Tribal and Other Federal	260,800	0	0	0.00	0	29,100	0	0	0.00	0
Private	1,836,200	400	30,800	0.02	49	384,800	0	0	0.00	0
State	385,900	0	9,300	0.00	15	200	0	0	0.00	0
MZ IV–SRP	**21,930,600**	**0**	**0**	**0.00**	**0.00**	**10,958,500**	**0**	**0**	**0.00**	**0.00**
MZ V–NGB	**7,097,200**	**0**	**0**	**0.00**	**0.00**	**5,808,000**	**0**	**0**	**0.00**	**0.00**

*Data Source: Aggregated from individual BLM State Office Submissions in 2011 and 2012. Direct and indirect impacts are calculated for the surface management entity; however, subsurface mineral rights may be severed from surface rights.

[1]Direct footprint is the co-location of surface coal mines within the designated habitat boundaries, and indirect influence is inferred by applying an effect buffer to the features (where Federal coal leases may be fully developed) and estimating the area affected. Indirect influence distance derived from area of identified demographic impact (Johnson and others, 2011; Taylor and others, 2012).

[2]For each MZ, calculated as the percent of the particular sage-grouse habitat type influenced by the indirect impact of the threat. For management entities within each management zone, calculated as the percent of the total indirect impact in the management zone represented by that management entity, that is, the relative area of indirect influence among management entities. Small differences between individual entity totals and MZ summary values may exist due to rounding of estimates during calculations.

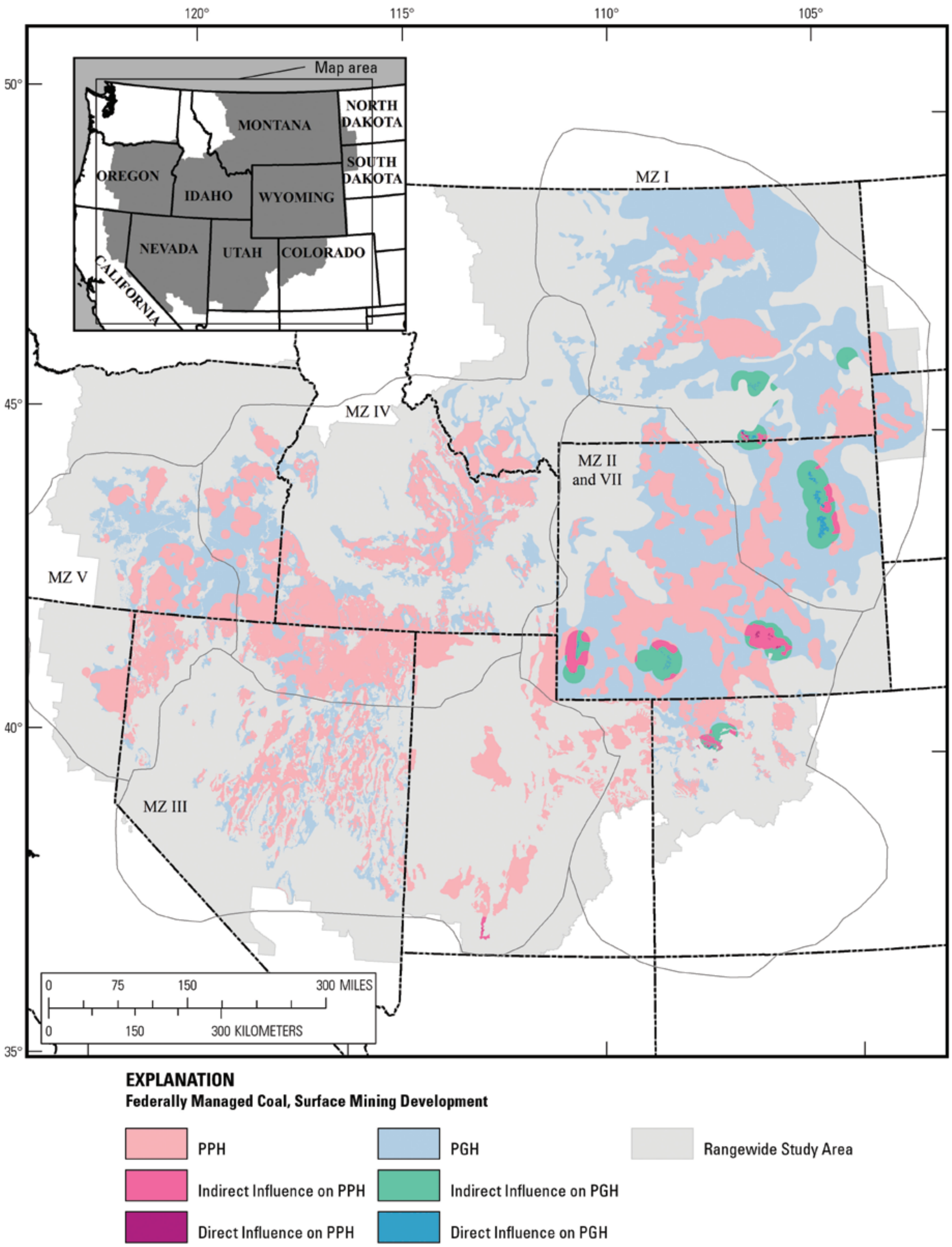


Figure 22. Overlap of Federally managed surface coal leases, potential indirect influences of these leases, and preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

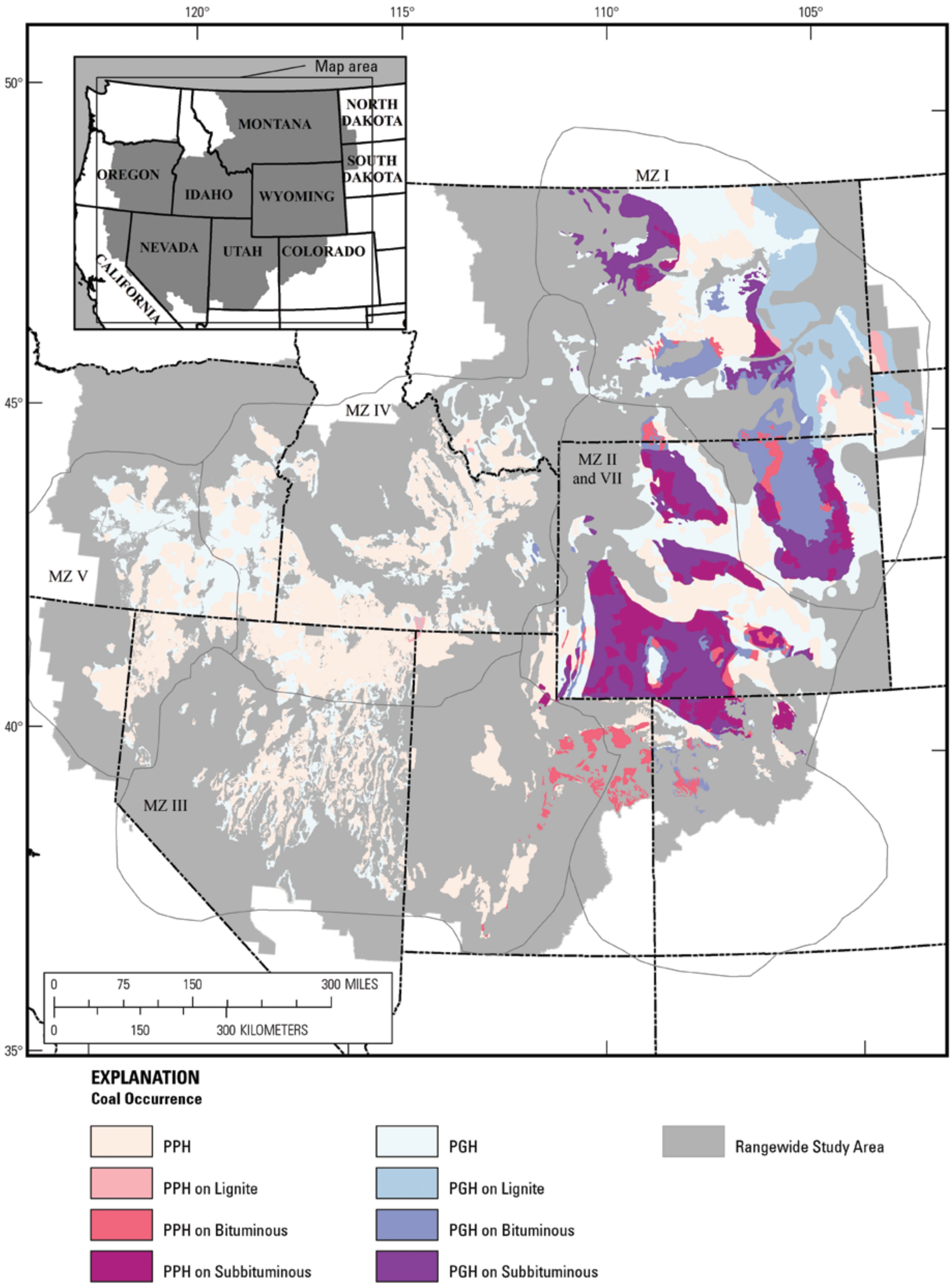


Figure 23. Overlap of coal occurrence and sage-grouse preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

Table 17*A*. Summary of the direct and indirect influences of mining and mineral materials disposal sites* (not including minerals mined as energy sources) across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH					PGH				
	SG Habitat (acres)	Direct Footprint[1] (acres)	2.5 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)	SG Habitat (acres)	Direct Footprint[1] (acres)	2.5 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)
MZ I–GP	**11,636,400**	**122,900**	**687,500**	**1.06**	**5.91**	**34,663,000**	**504,000**	**1,994,700**	**1.45**	**5.75**
BLM	2,994,300	65,000	261,000	2.17	38	4,524,900	64,500	226,200	1.43	11
Forest Service	292,400	0	300	0.00	0	515,3	1,200	17,300	0.23	1
Tribal and Other Federal	219,700	0	1,100	0.00	0	2,427,700	0	800	0.00	0
Private	7,132,500	49,000	364,100	0.69	53	24,682,800	430,500	1,602,600	1.74	80
State	995,600	8,900	61,100	0.89	9	2,498,400	7,800	147,800	0.31	7
Other	1,900	0	0	0.00	0	13,900	0	0	0.00	0
MZ II and VII–WB & CP	**17,476,000**	**582,100**	**2,947,000**	**3.33**	**16.86**	**19,200,200**	**445,400**	**2,177,700**	**2.32**	**11.34**
BLM	9,021,200	484,400	1,922,300	5.37	65	9,012,500	362,200	1,301,300	4.02	60
Forest Service	162,000	2,400	22,900	1.48	1	452,500	700	6,000	0.15	0
Tribal and Other Federal	784,000	0	7,200	0.00	0	1,354,600	2,200	43,200	0.16	2
Private	6,233,900	73,200	754,000	1.17	26	7,394,800	72,500	695,200	0.98	32
State	1,244,800	22,000	238,600	1.77	8	979,800	7,800	132,000	0.80	6
Other	30,100	100	2,000	0.33	0	6,000	0	0	0.00	0
MZ III–SGB	**10,028,500**	**914,800**	**3,263,700**	**9.12**	**32.54**	**3,970,100**	**478,800**	**1,620,600**	**12.06**	**40.82**
BLM	6,309,400	762,500	2,502,800	12.09	77	3,199,800	377,700	1,285,300	11.80	79
Forest Service	1,236,200	42,400	250,300	3.43	8	356,200	44,200	144,400	12.41	9
Tribal and Other Federal	260,800	100	14,000	0.04	0	29,100	0	6,100	0.00	0
Private	1,836,200	106,400	437,500	5.79	13	384,800	56,900	184,600	14.79	11
State	385,900	3,400	59,100	0.88	2	200	0	200	0.00	0
MZ IV–SRP	**21,930,600**	**719,100**	**4,320,800**	**3.28**	**19.70**	**10,958,500**	**330,500**	**1,872,400**	**3.02**	**17.09**
BLM	13,710,700	462,100	2,620,800	3.37	61	4,928,200	189,900	899,900	3.85	48
Forest Service	1,613,800	113,700	427,000	7.05	10	1,113,500	56,500	239,900	5.07	13
Tribal and Other Federal	633,600	500	27,900	0.08	1	522,500	400	11,700	0.08	1
Private	4,890,200	139,200	1,115,900	2.85	26	3,516,742	80,200	629,100	2.28	34
State	1,019,373	3,600	127,600	0.35	3	846,200	3,400	91,200	0.40	5
Other	62,900	0	1,500	0.00	0	31,400	0	600	0.00	0

Table 17A. Summary of the direct and indirect influences of mining and mineral materials disposal sites* (not including minerals mined as energy sources) across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).—Continued

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH					PGH				
	SG Habitat (acres)	Direct Footprint[1] (acres)	2.5 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)	SG Habitat (acres)	Direct Footprint[1] (acres)	2.5 km Indirect Influence[1] (acres)	Direct Footprint[1] (%)	Relative Influence[2] (%)
MZ V–NGB	**7,097,200**	**75,900**	**549,400**	**1.07**	**7.74**	**5,808,000**	**43,400**	**469,200**	**0.75**	**8.08**
BLM	5,117,500	71,500	452,800	1.40	82	4,196,700	39,900	348,100	0.95	74
Forest Service	62,200	0	900	0.00	0	114,900	0	800	0.00	0
Tribal and Other Federal	717,100	900	27,100	0.13	5	101,800	300	10,200	0.29	2
Private	798,000	3,500	44,600	0.44	8	1,199,000	3,000	93,600	0.25	20
State	64,900	0	2,600	0.00	0	115,800	100	7,300	0.09	2
Other	337,500	0	21,300	0.00	4	79,800	100	9,200	0.13	2

*Data Source: Aggregated from individual BLM State Office Submissions in 2011 and 2012. Direct and indirect impacts are calculated for the surface management entity; however, subsurface mineral rights may be severed from surface rights.

[1]Direct footprint is the co-location of surface mining activities within the designated habitat boundaries, and indirect influence is inferred by applying an effect buffer to the features and estimating the area affected. Indirect influence distance derived from estimated spread of exotic plants (Bradley and Mustard, 2006).

[2]For each MZ, calculated as the percent of the particular sage-grouse habitat type influenced by the indirect impact of the threat. For management entities within management zones, calculated as the percent of the total indirect impact in the management zone represented by that management entity, that is, the relative area of indirect influence among management entities.

Table 17*B*. Summary of existing Federal mineral prospecting permits for non-energy, leasable resources* within preliminary priority and preliminary general sage-grouse habitats (PPH and PGH, respectively) by Management Zone (MZ).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH			PGH		
	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)
MZ I–GP	11,636,400	10,400	0.09	34,663,000	28,200	0.08
MZ II and VII–WB & CP	17,476,000	378,400	2.17	19,200,200	557,100	2.90
MZ III–SGB	10,028,500	33,900	0.34	3,970,100	23,500	0.59
MZ IV–SRP	21,930,600	7,100	0.03	10,958,500	4,900	0.04
MZ V–NGB	7,097,200	0	0.00	5,808,000	0	0.00

*Aggregated from individual BLM State Office Submissions in 2011 and 2012. Overall acres for the valid existing right are reported for the MZ, however, note that subsurface mineral rights may be severed from surface rights.

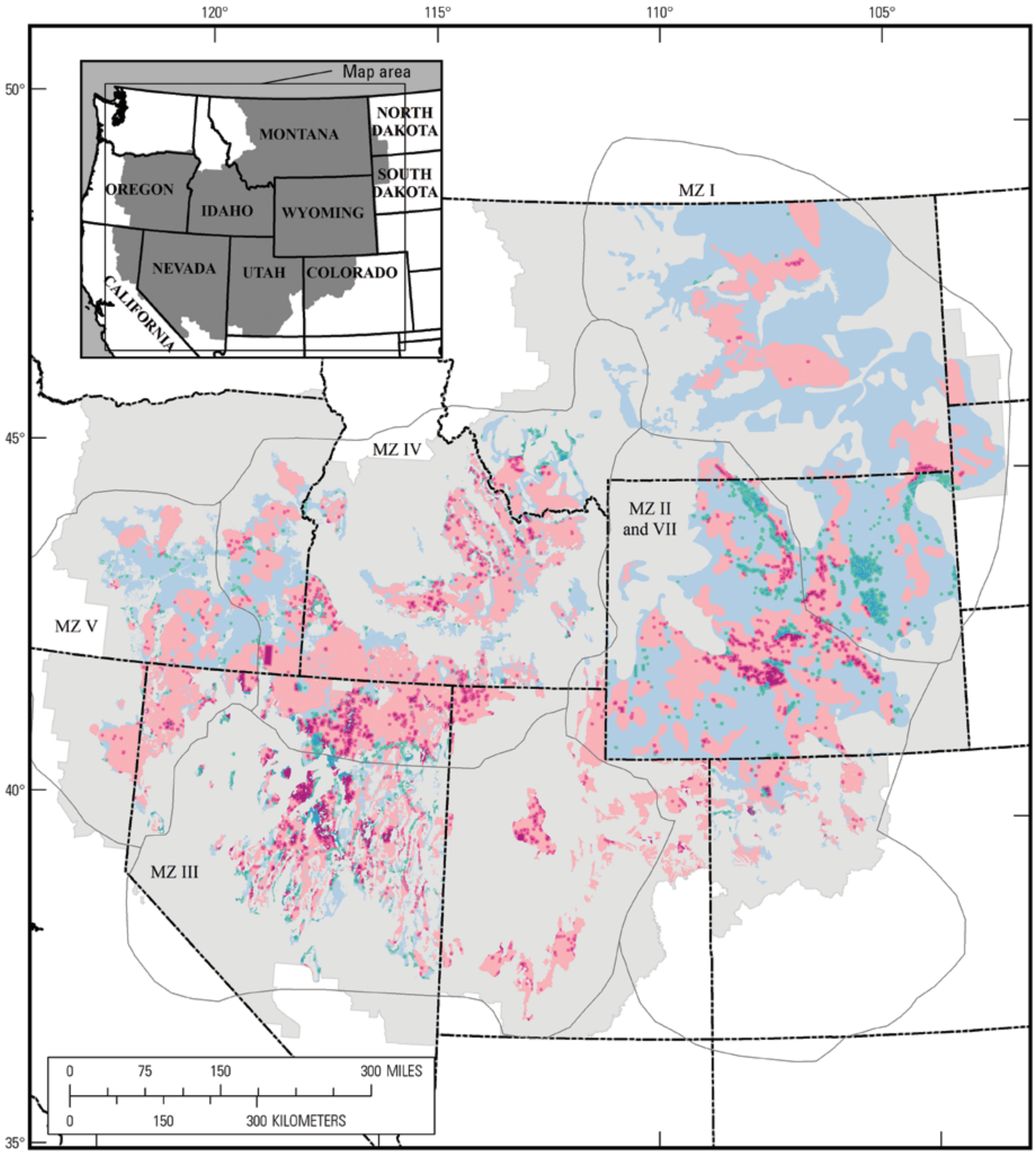
perceived to be under direct threat from habitat loss, the ecological role of fire in releasing canopy dominance of sagebrush and stimulating systemic regeneration may justify the use of fire for management.

The historical role of fire in sagebrush ecosystems has been difficult to estimate accurately, yet this information is important for guiding fuel and habitat treatments. Sagebrush generally does not provide direct evidence of previous fires (such as scarred wood on surviving individuals), so historic estimates were based on neighboring ecosystems and approximation. Early estimates indicated a range of possible return intervals ranging from as few as 13 to 100 years (Brown, 1982; Wrobleski and Kauffman, 2003; Connelly and others, 2004; Crawford and others, 2004), but broad estimates extrapolated from local perspectives hide the complexity of this process within the sagebrush ecosystem. Using a robust approach to consider landscape heterogeneity and biotic potential along with evidence of previous disturbances, Baker (2011) described 200–350 year fire-return intervals in Wyoming sagebrush (*Art. tri. wyomingensis*), 150–300 years in mountain big sagebrush (*Art. tri.* ssp. *vaseyana*), and more than 200 years for little sagebrush (*Art. tri. arbuscula*). These values capture differences among sagebrush types and provide approximate time frames that support the juxtaposition of disturbance (fire) and recovery (in this case, re-colonization by sagebrush); additional information on fire and fire-return intervals, especially relating to particular ecological types and (or) conditions, is available in the literature (Nelle and others, 2000; Miller, 2001; West and Yorks, 2002; Mensing and others, 2006; Lesica and others, 2007; Miller and Heyerdahl, 2008), and consideration of these and other local details may be necessary for comprehensive planning and mitigation.

Fire regimes are complex and vary tremendously across the sagebrush region and through time; furthermore, the ecological role of fire has changed dramatically since the European settlement era (circa 1850) due to changing fuel and habitat patterns (Crawford and others, 2004). Though the presence and distribution of suitable sagebrush habitats is limited at landscape scales, precluding the need for disturbances to intact sagebrush communities (Beck and others, 2009), maintenance of healthy sagebrush communities includes some localized disturbances in many regions. Because of the slow recovery time of most sagebrush species (none of the native big sagebrush species truly sprout, although reproduction by layering [akin to sprouting] from the root-crown has been described in the mountain variety, *Art. tri.* ssp. *vaseyana;* Winward, 2004), patterns of fire-free periods within a region are very important in determining landscape composition, habitat structure, and fire behavior. Three-tip (*Art. tripartita*) may increase after fire because it sprouts; however, three-tip is less preferred by nesting grouse (Lowe and others, 2009). In some higher elevation habitats, where mountain big-sagebrush is the canopy dominant, rapid regeneration due to site potential, seed production, and layering can produce 25 percent cover within 20 years (Winward, 2004).

Information on the variability of fire and fire-free periods across this landscape over time is limited, but the vast sea of sagebrush described by trappers, early European settlers, and official surveys would not have been possible under high-frequency fire regimes (Baker, 2011). There is little evidence that fire will enhance sage-grouse habitat in Wyoming big sagebrush communities, especially where there is already a balance of native shrubs, perennial grasses, and forbs (Crawford and others, 2004).There is a growing body of evidence that suggests that on the current landscape even prescribed fire designed to enhance brood-rearing habitat values does not have positive effect on herbaceous habitat conditions and can cause demonstrable decline in valuable sagebrush cover (Beck and others, 2009). Therefore, use of fire is not recommended strictly for sagebrush habitat enhancement (Baker, 2006; Beck and others, 2009).

Due to increased fuel potentials caused by annual grasses (*Bromus tectorum, Taenatherum asperum*) and landscape-scale decrease in intact sagebrush habitats (fragmentation), wildfire



EXPLANATION

Mining and Mineral Materials Disposal (Federal Minerals Only)

- PPH
- Indirect Influence on PPH
- Direct Influence on PPH
- PGH
- Indirect Influence on PGH
- Direct Influence on PGH
- Rangewide Study Area

Figure 24. Overlap of Federal mining- and mineral-material disposal sites, potential indirect influences of these areas, and sage-grouse preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

represents an important threat to habitat conservation and population stability (U.S. Fish and Wildlife Service, 2010b). Recent estimates indicate that the fire suppression era has had little effect on sagebrush ecosystem conditions due to the naturally long fire-return intervals (Baker, 2011); however, accumulation of fuels and volatile weather conditions may increase the importance of fuel breaks and related defense strategies for protecting priority habitats from wildfires. Current sage-grouse populations are limited by the distribution of suitable habitats, and near-term detrimental effects of fire on habitat suitability indicate a need to control fire in important sagebrush ecosystems. Ironically, the strategic use of fire to control fuels, as well as woodland expansion, may be warranted.

Assessment of fires reported to the National Interagency Fire Center (NIFC) occurring within designated habitats (PPH and PGH) from 2000–2012 (the years where reporting is considered to be mostly complete for fire perimeters rather than point locations for the study area) indicates that annual losses within most MZs have been minimal (2 percent or less); however, nearly 14 percent of PPH and 17 percent of PGH burned in MZ IV, 17 percent and 6 percent in MZ V (PPH and PGH, respectively), and 1.7 and 5.7 percent of MZ III (PPH and PGH, respectively) in recent years (2000–2012; table 18 and fig. 25). Wildfires in 2012 directly affected sagebrush habitats with sage-grouse populations in Nevada, California, Oregon, and Wyoming. Clearly, this time frame (one decade) is insufficient to assess the accumulation of fire and fire effects across the sagebrush landscape; however, this perspective is provided as a spatially consistent summary of recent fire occurrence that should be supplemented by additional data where available. Because the typical recovery time for sagebrush communities impacted by fire is several decades, the reporting period used here underrepresents some recent events that continue to affect habitat conditions, such as the large fires in the Great Basin during the late 1990s (BLM, 1999). Challenges related to fire and fuels management have become pronounced and sometimes extreme in the Great Basin (MZs III and V) and parts of the Snake River Plain (MZ IV) where cheatgrass has invaded, changed fuel profiles, and subsequently enhanced fire behavior by increasing surface intensity and decreasing return intervals (Knapp, 1996; Epanchin-Niell and others, 2009; Shinneman and Baker, 2009; Rowland and others, 2010; Baker, 2011; Condon and others, 2011). Minimizing disturbance within remnant sagebrush communities deemed important for sage-grouse conservation might include a combination of wildfire control as well as adjusting use standards (for example, grazing, energy development, and recreation) to avoid treatments and activities that remove sagebrush, degrade native herbaceous species, and (or) promote cheatgrass expansion. In areas with widespread loss of sagebrush and replacement with cheatgrass, active restoration may be required (see section III. A11. Habitat Treatments and Vegetation Management). Revegetation following fire is expensive compared to letting "natural regeneration processes" run their course, but the opportunity to reduce fire potential, increase forage quality, and increase habitat quality based on intensive revegetation efforts may justify these actions in some habitats (Epanchin-Niell and others, 2009). For example, stabilization of surface soils, prevention of noxious weed infestations, and re-establishment of native species are important vegetation management priorities, which may benefit from post-fire rehabilitation. Research and development of cheatgrass control strategies are ongoing, but management of the fire-return interval and fuel profile created by cheatgrass is recognized as a fundamental component of cheatgrass control efforts. Further, support and enhancement of deep-rooted, native, perennial plants may be important in the control of cheatgrass and post-disturbance response of the community (Balch and others, 2012).

Although precise occurrence of future fire is impossible to determine due to complicated interactions of weather, vegetation, and ignition, the distribution of fuel profiles have been used to estimate probability for development of large fires (see National Interagency Fire Center Geographic Area Coordination Centers Web site at *http://gacc.nifc.gov/rmcc/predictive/firedngr.htm*). Fuel models indicate vast acreages in all MZs, which are susceptible to fire with the most dramatic numbers occurring in MZs III, IV and V (63 percent, 84 percent, and 68 percent of PPH, and 60 percent, 76 percent, and 64 percent of PGH, respectively; table 19 and fig. 26)

In contrast, lack of fire at higher elevations, where moisture and productivity are greater than neighboring communities at lower elevations, has contributed to an increase in juniper cover (Miller and Rose, 1995; Miller and others, 2000; Miller and Heyerdahl, 2008; Sankey and Germino, 2008; Shinneman and others, 2008; Bradley, 2010). In these areas, active restoration using fire or "fire-mimic" (mechanical) treatments may be needed to maintain sage-grouse habitats by reducing juniper cover (Bradley, 2010; Rowland and others, 2010). Importantly, all sites do not have equal restoration potential, with the greatest potential being in the least altered locations where vegetation and soils can readily recover (Shinneman and others, 2008), but recovery processes may be supported and enhanced through methods and timing of application (Bates and others, 2011; Rau and others, 2011).

Because of the important value of sagebrush canopies and tall grasses for nesting cover (Holloran and others, 2005; Beck and others, 2009), wildfires and prescribed fires (and treatments with similar effects on vegetation) that reduce these values are likely detrimental for sage-grouse. On the other hand, fire control and mitigation represents an important component of modern habitat management due to the recently perceived (circa 50 years) threat of wildfire in many areas, including sage-grouse habitats (fig. 26). Particular caution and concern is warranted when noxious invasive species (notably, but not limited to, cheatgrass) are present in the pre-disturbance community because these species may have lasting, detrimental effects on post-disturbance habitat conditions. The threat of large wildfires in priority habitats, potentially resulting in removal of large stands of mature sagebrush, remains one of the most important and difficult to control obstacles to sage-grouse conservation.

Table 18. Summary of fires reported* to National Interagency Fire Center between 2000–2012, across Management Zones (MZ) by acres within preliminary priority and preliminary general habitats (PPH and PGH, respectively).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH						PGH					
	SG Habitat (acres)	Yearly Max Area Burned (acres)	Yearly Min Area Burned	Average Area Burned (acres/yr)	Area Burned 2000–2012 (%)	Relative Influence[1] (%)	SG Habitat (acres)	Yearly Max Area Burned (acres)	Yearly Min Area Burned	Average Area Burned (acres/yr)	Area Burned 2000–2012 (%)	Relative Influ-ence[1] (%)
MZ I–GP	**11,636,400**	**70,900**	**100**	**14,329**	**1.6**		**34,663,000**	**279,700**	**100**	**66,223**	**2.5**	
BLM	2,994,300	10,800	0	2,212	1.0	15	4,524,900	24,600	0	7,389	2.1	11
Forest Service	292,400	1,000	0	136	0.6	1	515,300	34,600	0	3,148	7.9	5
Tribal and Other Federal	219,700	22,100	0	1,702	10.1	12	2,427,700	29,500	0	3,673	2.0	6
Private	7,132,500	55,500	0	8,990	1.6	63	24,682,800	189,300	0	47,778	2.5	72
State	995,600	6,100	0	1,289	1.7	9	2,498,400	19,400	0	4,235	2.2	6
Other	1,900	0	0	0	0.0	0	13,900	0	0	0	0.0	0
MZ II and VII–WB & CP	**17,476,000**	**27,100**	**200**	**7,661**	**0.6**		**19,200,200**	**161,100**	**400**	**24,046**	**1.6**	
BLM	9,021,200	8,100	0	2,943	0.4	38	9,012,500	25,500	200	4,989	0.7	21
Forest Service	162,000	8,800	0	966	7.7	13	452,500	6,800	0	913	2.6	4
Tribal and Other Federal	784,000	13,600	0	1,388	2.3	18	1,354,600	126,000	0	10,062	9.7	42
Private	6,233,900	4,500	100	1,411	0.3	18	7,394,800	34,200	100	7,019	1.2	29
State	1,244,800	8,100	0	953	1.0	12	979,800	4,800	0	1,062	1.4	4
Other	30,100	0	0	0	0.0	0	6,000	0	0	0	0.0	0
MZ III–SGB	**10,028,500**	**55,900**	**0**	**13,500**	**1.8**		**3,970,100**	**55,000**	**0**	**17,577**	**5.8**	
BLM	6,309,400	44,700	0	9,397	1.9	70	3,199,800	30,900	0	9,394	3.8	53
Forest Service	1,236,200	3,100	0	527	0.6	4	356,200	4,600	0	468	1.7	3
Tribal and Other Federal	260,800	1,100	0	129	0.6	1	29,100	900	0	68	3.1	0
Private	1,836,200	9,300	0	2,559	1.8	19	384,800	26,800	0	7,646	25.8	43
State	385,900	4,300	0	888	3.0	7	200	0	0	0	0.0	0

Table 18. Summary of fires reported* to National Interagency Fire Center between 2000–2012, across Management Zones (MZ) by acres within preliminary priority and preliminary general habitats (PPH and PGH, respectively).—Continued

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH						PGH					
	SG Habitat (acres)	Yearly Max Area Burned (acres)	Yearly Min Area Burned	Average Area Burned (acres/yr)	Area Burned 2000–2012 (%)	Relative Influence[1] (%)	SG Habitat (acres)	Yearly Max Area Burned (acres)	Yearly Min Area Burned	Average Area Burned (acres/yr)	Area Burned 2000–2012 (%)	Relative Influ-ence[1] (%)
MZ IV–SRP	**21,930,600**	**1,030,400**	**0**	**239,769**	**14.2**		**10,958,500**	**442,900**	**0**	**144,147**	**17.1**	
BLM	13,710,700	790,600	0	181,646	17.2	76	4,928,200	361,000	0	101,975	26.9	71
Forest Service	1,613,800	89,700	0	9,509	7.7	4	1,113,500	117,500	0	14,015	16.4	10
Tribal and Other Federal	633,600	53,000	0	5,407	11.1	2	522,500	64,200	0	8,876	22.1	6
Private	4,890,200	189,000	0	37,313	9.9	16	3,516,742	69,400	0	16,024	5.9	11
State	1,019,373	30,500	0	4,954	6.3	2	846,200	12,600	0	3,147	4.8	2
Other	62,900	11,500	0	940	19.4	0	31,400	1,400	0	110	4.6	0
MZ V–NGB	**7,097,200**	**950,500**	**0**	**95,441**	**17.5**		**5,808,000**	**136,000**	**0**	**25,900**	**5.8**	
BLM	5,117,500	877,700	0	83,677	21.3	88	4,196,700	124,300	0	21,670	6.7	84
Forest Service	62,200	2,000	0	199	4.2	0	114,900	7,700	0	1,086	12.3	4
Tribal and Other Federal	717,100	7,500	0	1,082	2.0	1	101,800	800	0	111	1.4	0
Private	798,000	45,600	0	7,091	11.6	7	1,199,000	9,700	0	2,750	3.0	11
State	64,900	4,100	0	411	8.2	0	115,800	2,500	0	213	2.4	1
Other	337,500	22,900	0	2,981	11.5	3	79,800	900	0	70	1.1	0

*Data Source: Geospatial Multi-Agency Coordination (GeoMAC) Group, 2012.

[1]For management entities within a Management Zone, calculated as the percent of the total acres burned during the time period within the management zone represented by that management entity, that is, the relative area of direct influence among management entities. Small differences between individual entity totals and MZ summary values may exist due to rounding of estimates during calculations; regional averages were calculated independently from entity estimates; therefore, items in columns with averages may not sum equivalently.

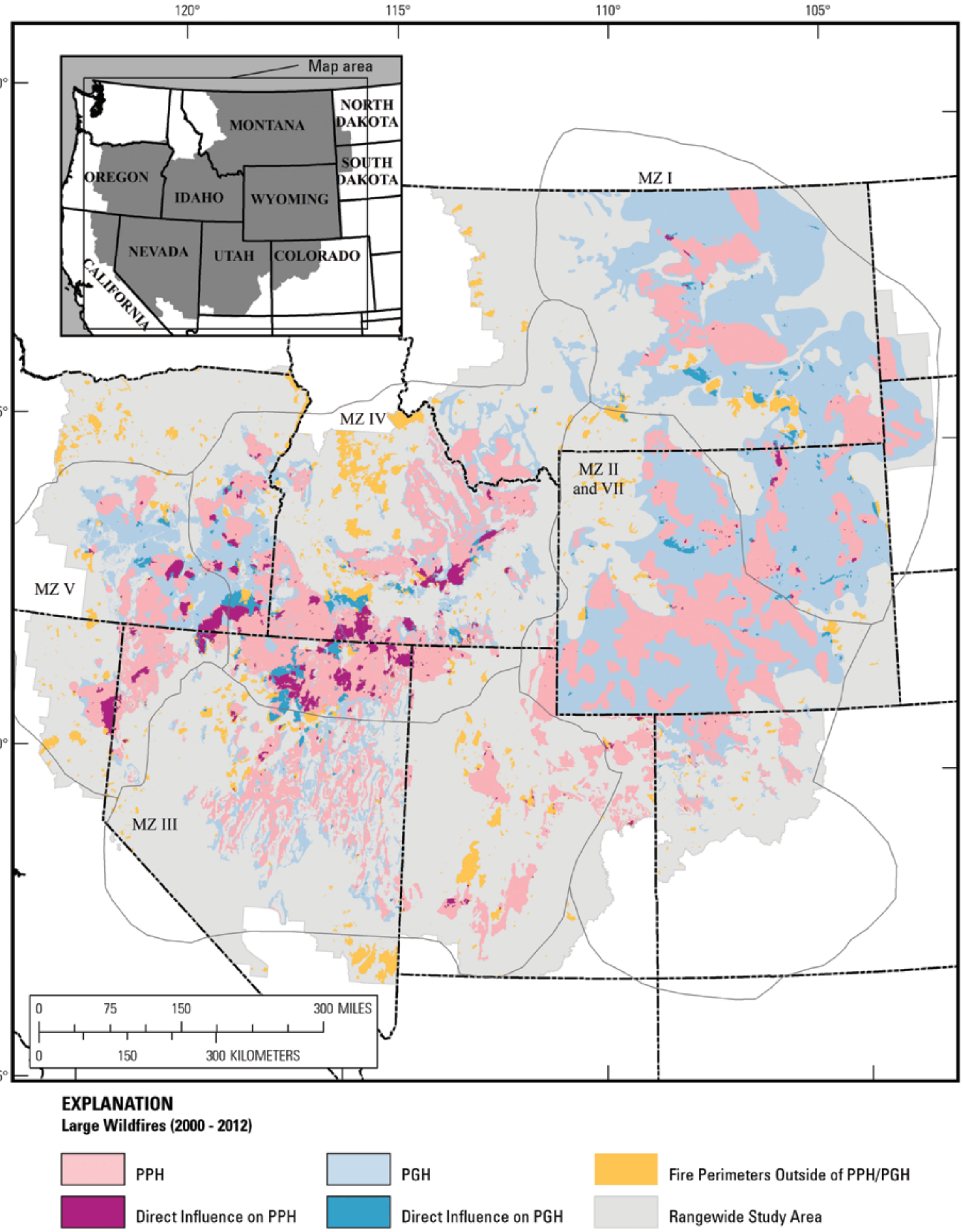


Figure 25. Overlap of fires reported to National Interagency Fire Center between 2000–2012 and preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

Table 19. Summary of areas with fuel models[*] that project a high probability of developing large fires across each management Zone (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH				PGH			
	SG Habitat (acres)	High Burn Probability (acres)	High Burn Probability (%)	Relative Influence[1] (%)	SG Habitat (acres)	High Burn Probability (acres)	High Burn Probability (%)	Relative Influence[1] (%)
MZ I–GP	**11,636,400**	**1,921,000**	**16.5**		**34,663,000**	**6,140,700**	**17.7**	
BLM	2,994,300	299,200	10.0	16	4,524,900	718,800	15.9	12
Forest Service	292,400	124,900	42.7	7	515,300	208,800	40.5	3
Tribal and Other Federal	219,700	39,600	18.0	2	2,427,700	67,800	2.8	1
Private	7,132,500	1,271,600	17.8	66	24,682,800	4,621,600	18.7	75
State	995,600	185,800	18.7	10	2,498,400	523,700	21.0	9
Other	1,900	0	0.0	0	13,900	0	0.0	0
MZ II and VII–WB & CP	**17,476,000**	**2,104,300**	**12.0**		**19,200,200**	**1,678,400**	**8.7**	
BLM	9,021,200	862,000	9.6	41	9,012,500	402,600	4.5	24
Forest Service	162,000	31,100	19.2	1	452,500	182,700	40.4	11
Tribal and Other Federal	784,000	180,100	23.0	9	1,354,600	435,900	32.2	26
Private	6,233,900	871,200	14.0	41	7,394,800	593,300	8.0	35
State	1,244,800	151,600	12.2	7	979,800	62,700	6.4	4
Other	30,100	8,400	27.9	0	6,000	1,300	21.7	0
MZ III–SGB	**10,028,500**	**6,312,300**	**62.9**		**3,970,100**	**2,391,600**	**60.2**	
BLM	6,309,400	4,583,100	72.6	73	3,199,800	1,990,900	62.2	83
Forest Service	1,236,200	280,500	22.7	4	356,200	78,900	22.2	3
Tribal and Other Federal	260,800	120,000	46.0	2	29,100	6,500	22.3	0
Private	1,836,200	1,137,600	62.0	18	384,800	315,200	81.9	13
State	385,900	191,000	49.5	3	200	100	50.0	0
MZ IV–SRP	**21,930,600**	**18,423,300**	**84.0**		**10,958,500**	**8,305,700**	**75.8**	
BLM	13,710,700	11,904,200	86.8	65	4,928,200	4,438,100	90.1	53
Forest Service	1,613,800	1,163,200	72.1	6	1,113,500	621,400	55.8	7
Tribal and Other Federal	633,600	487,200	76.9	3	522,500	301,900	57.8	4
Private	4,890,200	4,068,100	83.2	22	3,516,742	2,268,400	64.5	27
State	1,019,373	738,700	72.5	4	846,200	649,700	76.8	8
Other	62,900	62,000	98.6	0	31,400	26,300	83.8	0

Table 19. Summary of areas with fuel models* that project a high probability of developing large fires across each Management Zone (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).—Continued

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH				PGH			
	SG Habitat (acres)	High Burn Probability (acres)	High Burn Probability (%)	Relative Influence[1] (%)	SG Habitat (acres)	High Burn Probability (acres)	High Burn Probability (%)	Relative Influence[1] (%)
MZ V–NGB	**7,097,200**	**4,858,900**	**68.5**		**5,808,000**	**3,729,300**	**64.2**	
BLM	5,117,500	3,545,800	69.3	73	4,196,700	2,801,300	66.8	75
Forest Service	62,200	29,900	48.1	1	114,900	40,300	35.1	1
Tribal and Other Federal	717,100	351,100	49.0	7	101,800	77,000	75.6	2
Private	798,000	589,400	73.9	12	1,199,000	689,500	57.5	18
State	64,900	49,300	76.0	1	115,800	74,200	64.1	2
Other	337,500	293,200	86.9	6	79,800	47,100	59.0	1

*Data Source: National Interagency Fire Center (NIFC) 2012, Geographic Area Coordination Centers, available at *http://gacc.nifc.gov/rmcc/predictive/firedngr.htm*.

[1]For management entities within a Management Zone, calculated as the percent of the total direct impact in the management zone represented by that management entity that is, the relative area of direct influence among management entities. Small differences between individual entity totals and MZ summary values may exist due to rounding of estimates during calculations.

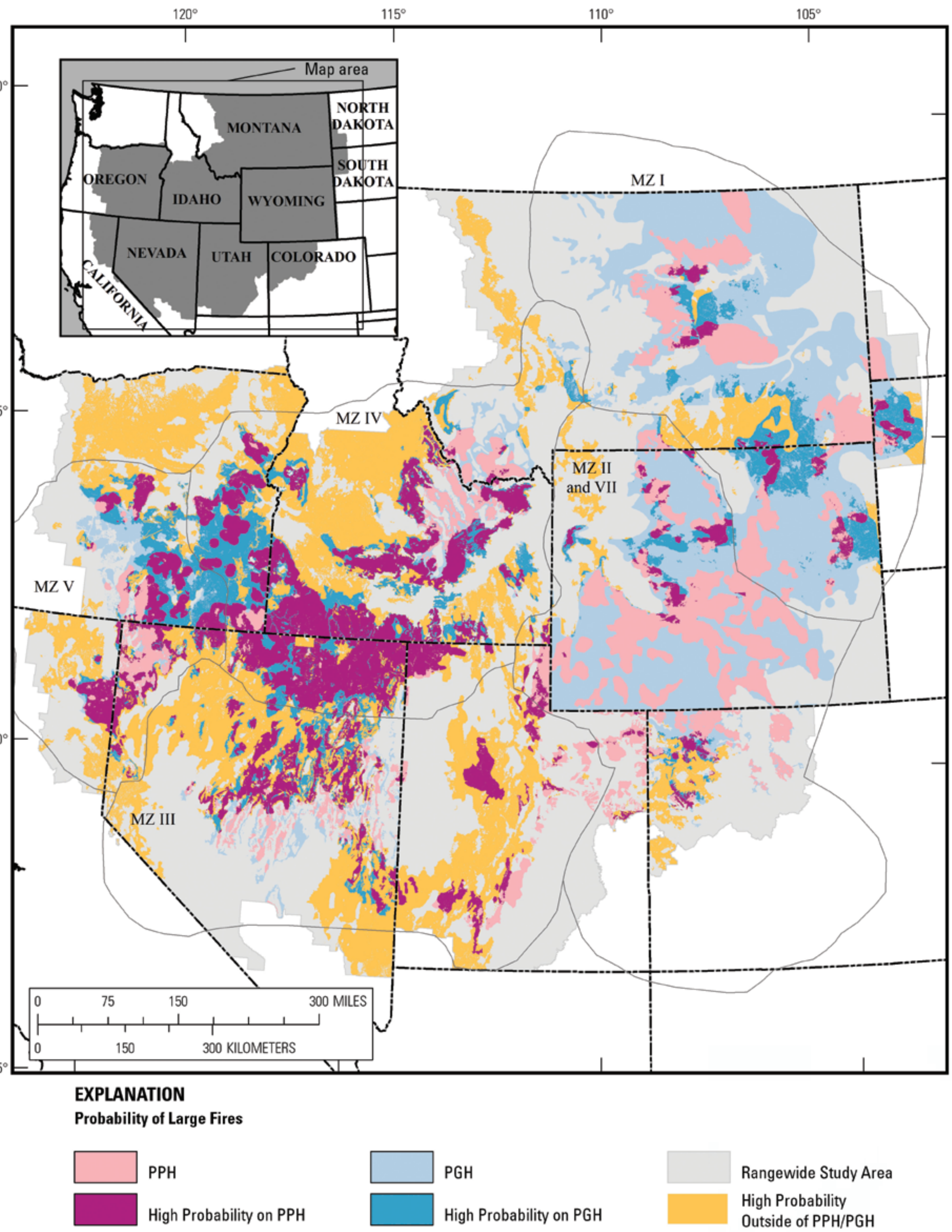


Figure 26. Overlap of areas modeled with a high probability for occurrence of large fires and preliminary priority and preliminary general habitats (PPH and PGH, respectively). MZ, Management Zone.

A7. Invasive Plants

Because of the strong interactions between disturbance, niche availability, and the "colonist" nature of most invasive species, presence of invasive species is a mechanism whereby a disturbance holds the potential for a strong, negative effect on habitat quality due to the post-disturbance response (Crawford and others, 2004). In Wyoming big sagebrush types, especially in the Great Basin (all or part of MZs III, IV, and V), the invasion by exotic annuals has resulted in dramatic increases in number and frequency of fires with widespread, detrimental effects on habitat conditions (Young and Evans, 1978; West and Young, 2000; West and Yorks, 2002; Connelly and others, 2004). For example, big sagebrush communities invaded by cheatgrass have estimated mean fire-return intervals of less than 10 years in many areas (Connelly and others, 2004), whereas the natural regime is estimated (conservatively) to be 10 to 20 times longer. Increased fire frequency or intense fire behavior typically results in removal of the sagebrush canopy in affected areas and often with replacement by annual species that provide little, to no, habitat value (Knapp, 1996; Epanchin-Niell and others, 2009; Rowland and others, 2010; Baker, 2011; Condon and others, 2011). Presumably cheatgrass (*Bromus tectorum*) was able to thrive in this region, in part because there was no pre-existing (native) dominant annual plant species. As this optimal colonist species established, chronic grazing by cattle, sheep, and horses combined with drought and fire to increase the distribution and frequency of disturbance and further optimize this region for dominance by an annual grass (Knapp, 1996). Importantly, research in sagebrush ecosystems has revealed an inverse relation between cheatgrass dominance and native perennial herbs, especially grasses (West and Yorks, 2002). Further, the post-disturbance response of sagebrush communities to fire and similar disturbances is strongly affected by the condition and composition before disturbance, the presence of propagules, and sprouting of native species (West and Yorks, 2002; Beck and others, 2009; Epanchin-Niell and others, 2009; Condon and others, 2011). Cheatgrass competes with native grasses and forbs that are important components of sage-grouse habitat. Cheatgrass abundance is negatively correlated with habitat selection by sage-grouse (Kirol and others, 2012) indicating that changes in composition and structure associated with cheatgrass specifically degrade sage-grouse habitat. Invasion by Medusahead (*Taeniatherum caput-medusae*), which can replace cheatgrass in some circumstances, may be even worse as it also reduces perennial productivity, degrades wildlife habitat, supports high-frequency fire-return intervals, and requires intensive treatment for restoration (Davies, 2010). Infestation of these species, and others, cause direct degradation of sagebrush habitats resulting in (indirect) effects on local sage-grouse populations by affecting forage and cover quality with potential to cause complete avoidance (funtional habitat loss).

In southern habitats (MZs III, IV, V, and VII), cheatgrass is found primarily at elevations between 5250 and 6550 ft (1,600–2,000 m), compared to 1950 to 5900 ft (600–1,800 m) in the sagebrush-steppe of Idaho and has been expanding in habitats below to 3900 ft (1,200 m; Connelly and others, 2004). Large-scale restoration is needed in many areas, making minimally invaded areas highly valuable for habitat conservation. In the sagebrush-steppe of northern habitats (all or parts of MZs I, II, IV, V, and VI), cheatgrass is less ubiquitous but demonstrates increased dominance, productivity, and elevation range on south-facing slopes (Connelly and others, 2004), which indicates the need for careful local considerations and best-practices that minimize disturbance in areas with a threat (presence) of cheatgrass expansion. Potential for cheatgrass occurrence has been modeled in the Great Basin region based on environmental correlations, which can help discern locations and habitats that have the greatest risk, either because cheatgrass is already on those landscapes (some of the risk has been realized) or the conditions are right to support cheatgrass (fig. 27*A*). Summary data indicate that invasion potential is widespread and similar among assessed MZs (table 20). Although the distribution of cheatgrass, and other annual invaders such as Japanese brome (*Bromus arvensis*), has been documented across shrub and grasslands of Colorado, Wyoming, and Montana, the currently available model was only parameterized for the Great Basin, therefore only MZs III, IV and V are described here (table 20, fig. 27*A*). Similar information is being developed rangewide, as well as with subregional details. Due to the emerging nature of invasive plants, especially cheatgrass, information and rapid changes in species' distributions, details of invasion, control, and risks will be best provided by local information and subregional to regional-scale models. Data presented here demonstrate the potential risk to priority habitats within the Great Basin and Snake River Plain based on a spatial model developed using field observations and geographic information system (GIS) representation of dominant environmental patterns (that predict and [or] restrict the distribution of the species). Model results suggest the most serious risk of cheatgrass invasion (in these analytical units) lies in the Snake River Plain where more than 50 percent of PPH and PGH are projected to be at risk of cheatgrass invasion (table 20). Assessment of regional habitat management issues by Wisdom and others (2005) highlighted concerns regarding expansion risk for cheatgrass and further specified the need for active restoration methods to improve sagebrush habitat conditions where fire and invasive species represent an interactive threat. The northern Great Basin follows this pattern closely with nearly 50 percent of preliminary priority habitats (PPH) and 36 percent of preliminary general habitats (PGH) threatened according to this independent, non-overlapping estimate, and similarly 31 percent and 43 percent of PPH and PGH, respectively, of the southern Great Basin MZ III is projected to share this level of risk. Importantly, most (more than 50 percent) of the affected lands in each MZ are managed by BLM and < 2% of the affected areas are USFS managed shrublands according to these data (table 20).

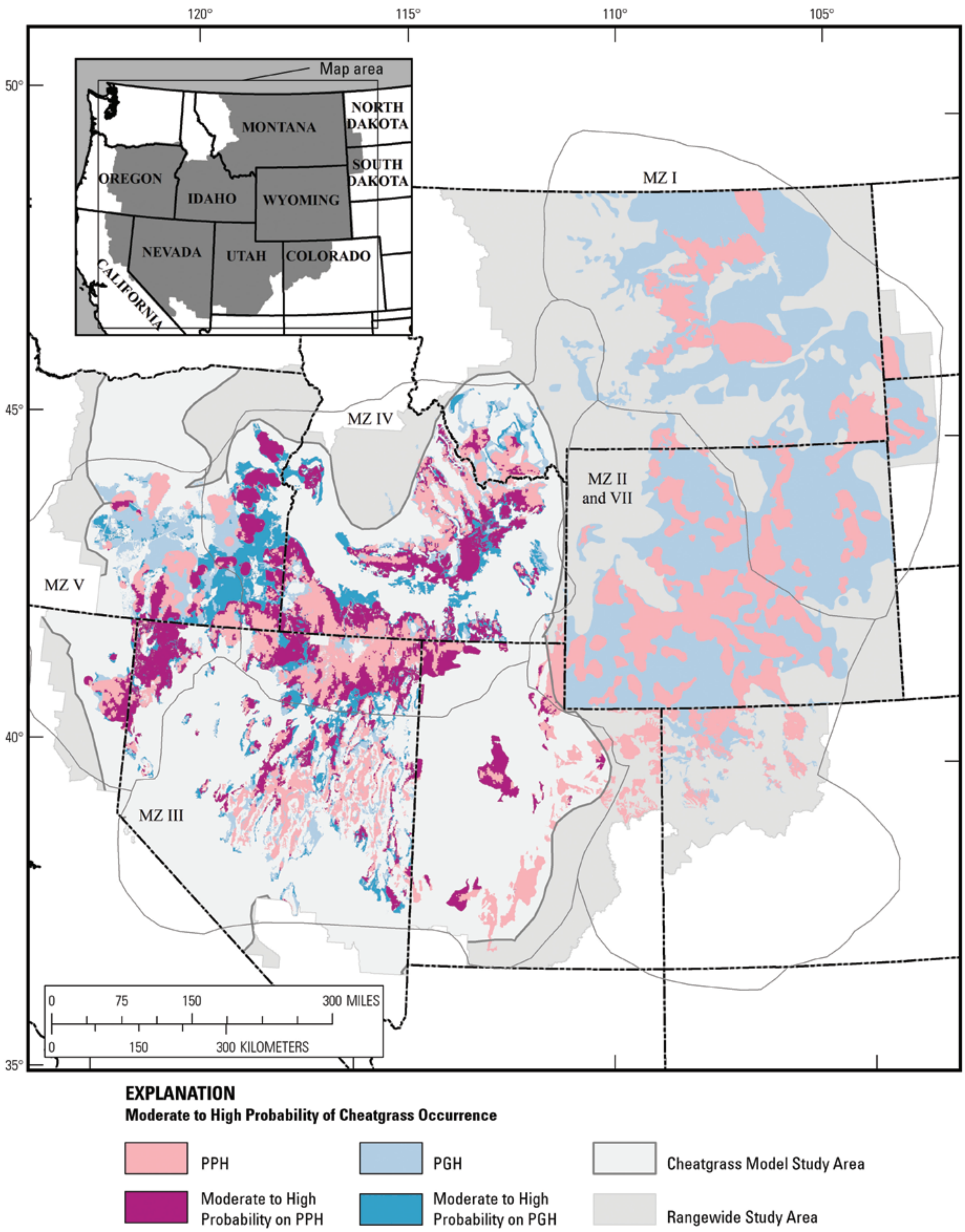


Figure 27*A*. Overlap of moderate to high probability of cheatgrass occurrence and preliminary priority and preliminary general habitats (PPH and PGH, respectively) in Management Zones III, IV and V (Great Basin) from logistic regression models. MZ, Management Zone.

Table 20. Summary of lands with moderate to high probability for cheatgrass occurrence* across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH				PGH			
	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)	Relative Influence[1] (%)	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)	Relative Influence[1] (%)
MZ I–GP	**11,636,400**	**n/a**	**n/a**	**n/a**	**34,663,000**	**n/a**	**n/a**	**n/a**
MZ II and VII–WB & CP	**17,476,000**	**n/a**	**n/a**	**n/a**	**19,200,200**	**n/a**	**n/a**	**n/a**
MZ III – SGB	**10,028,500**	**3,143,000**	**31.3**		**3,970,100**	**1,716,800**	**43.2**	
BLM	6,309,400	2,154,300	34.1	69	3,199,800	1,400,200	43.8	82
Forest Service	1,236,200	72,500	5.9	2	356,200	33,900	9.5	2
Tribal and Other Federal	260,800	90,500	34.7	3	29,100	8,800	30.2	1
Private	1,836,200	723,600	39.4	23	384,800	273,900	71.2	16
State	385,900	102,000	26.4	3	200	0	0.0	0
MZ IV–SRP	**21,930,600**	**11,657,100**	**53.2**		**10,958,500**	**6,401,100**	**58.4**	
BLM	13,710,700	7,796,700	56.9	67	4,928,200	3,542,300	71.9	55
Forest Service	1,613,800	176,000	10.9	2	1,113,500	140,800	12.6	2
Tribal and Other Federal	633,600	458,900	72.4	4	522,500	304,900	58.4	5
Private	4,890,200	2,732,800	55.9	23	3,516,742	1,909,500	54.3	30
State	1,019,373	459,700	45.1	4	846,200	474,100	56.0	7
Other	62,900	33,000	52.5	0	31,400	29,500	93.9	0
MZ V–NGB	**7,097,200**	**3,521,300**	**49.6**		**5,808,000**	**2,096,700**	**36.1**	
BLM	5,117,500	2,590,200	50.6	74	4,196,700	1,483,600	35.4	71
Forest Service	62,200	23,200	37.3	1	114,900	11,700	10.2	1
Tribal and Other Federal	717,100	625,900	87.3	18	101,800	40,100	39.4	2
Private	798,000	176,100	22.1	5	1,199,000	502,100	41.9	24
State	64,900	17,700	27.3	1	115,800	33,600	29.0	2
Other	337,500	88,200	26.1	3	79,800	25,500	32.0	1

*Data Source: Meinke, C.W., S.T. Knick, and D.A. Pyke (2009). A spatial model to prioritize sagebrush landscapes in the intermountain west (U.S.A.) for restoration. Restoration Ecology 17:652–659.

[1]For management entities within a Management Zone, these were calculated as the percent of the total direct impact in the management zone represented by that management entity, that is, the relative area of direct influence among management entities. Small differences between individual entity totals and MZ summary values may exist due to rounding of estimates during calculations.

Because of ecological and morphological characteristics, cheatgrass can often out-compete native perennial plants and promote rapid fire-return intervals (Klemmedson and Smith, 1964; Connelly and others, 2004). The positive feedback cycle connecting fire, sagebrush loss, and cheatgrass dominance has resulted in entire landscapes being converted to annual grasslands (D'Antonio and others, 2009), and these areas typically require active restoration, including costs and effort, associated with eradication of weeds and reseeding of native species, if local priorities indicate important potential habitat value for restored lands. Based on the scale of such efforts, locally planned and implemented sagebrush restoration efforts will likely benefit from planning and perspectives provided by regional scales to strategically combat the spread and dominance of invasive annuals in priority habitats and connected areas.

Invasive plants are thought to alter plant community structure and composition, productivity, nutrient cycling, and hydrology (Vitousek, 1990) and may competitively exclude native plant populations (Mooney and Cleland, 2001). In particular, invasive plants can reduce and eliminate vegetation that sage-grouse use for food and cover resulting in habitat loss and fragmentation. An assortment of nonnative annuals and perennials and native conifers are currently invading sagebrush ecosystems. Many areas throughout the range of sage-grouse are at high risk from invasive plants, yet the most concentrated areas of risk include the Intermountain West and Great Basin (MZs III, IV, V, and VI). Much of the Great Basin is at risk for invasion by cheatgrass or pinyon-juniper encroachment within the next 30 years (Wisdom and others, 2005; Leu and others, 2008; Doherty and others, 2008), and where cheatgrass has invaded, there has typically been an increase in fire frequency resulting in further degradation of sage-grouse habitats by removing and excluding sagebrush (Knapp, 1996; Epanchin-Niell and others, 2009; Rowland and others, 2010; Baker, 2011; Condon and others, 2011). Regions that are currently invaded or predicted by distribution models to be highly susceptible may benefit from explicit guidance and practices that avoid, eliminate, or mitigate feedbacks in this cycle, including natural disturbances, over-grazing, treatments, new roads, and industrial developments that disrupt native vegetation cover and destabilize soils. Disrupting the processes that generate chronic disturbance and thereby facilitate dominance of annual plants is a necessary first step in the restoration and conservation process. Even at low levels, invasive plants can decrease forage quality and compete with native species that provide high-quality habitat values for sage-grouse and productive agricultural systems for people. This decline can be expected to cause a decrease in secondary productivity (in this case, sage-grouse), but potential for infestation, upon disturbance, with more significant implications for conditions must be an important consideration when problem species are present. In cases of severe infestation, system phenology (timing of green-up), cover and forage quality, and fire regimes are often altered with widespread, severe, and detrimental effects on sage-grouse habitat conditions. The relation between cheatgrass and fire in degrading sagebrush habitats is well documented, and this interaction continues to challenge management and restoration efforts—considerable research and development effort is needed to reduce this threat (Wisdom and others, 2005).

A8. Conifer Woodland Expansion and Encroachment

Expansion of conifer woodlands, especially juniper (*Juniperus* spp.) present a threat to sage-grouse because they do not provide suitable habitat, and further, mature trees displace shrubs, grasses and forbs through direct competition for resources that are important components of sage-grouse habitat; juniper expansion is associated with increased bare ground and an increased potential for erosion (Petersen and others, 2009). Mature trees may offer perch sites for raptors, thereby, woodland expansion may also represent expansion of raptor predation threat, similar to perches on power lines, poles and other structures (also see Section III. C. Predation). Although the prolonged drought at the beginning of the 21st century (2002–2004) caused significant (55 percent) mortality of mature pinyon pine (Clifford and others, 2011), reducing the threat attributed to this species in some areas, increased pinyon-juniper forest density and distribution continue to be documented following the drought period and are recognized as a threat to the sagebrush ecosystem in other areas (Romme and others, 2009; Bradley, 2010; Rowland and others, 2010). Intensive grazing in the late 1800s and early 1900s, coupled with climate and fire, have been associated with invasion of annual grasses at lower elevations and expansion of juniper and pinyon pine at higher elevations (Burkhardt and Tisdale, 1976; Miller and others, 1994; Provencher and others, 2007; Miller and others, 2011). Precipitation and fire are thought to drive long-term trends in cover (Clifford and others, 2011; Miller and others, 2011), and disturbance-free periods coupled with grazing that reduced competition and precipitation that supplied moisture for seedlings increased success of tree establishment and woodland expansion during the 20th century (Miller and Rose, 1995; Strand and others, 2007; Miller and others, 2011). In some areas (best documented in MZs III, IV, and V, and VI), conifer encroachment is connected to reduced habitat quality in important seasonal ranges when woodland development is sufficient to restrict shrub and herbaceous production (Connelly and others, 2004). Though widespread, this problem affects specific sagebrush habitats and sage-grouse populations because of local juniper and pinyon-juniper woodland expansions; notably, USFS research indicated more than 55 percent of Great Basin sagebrush ecosystems (MZs III and V) are at risk of cheatgrass invasion, whereas approximately 40 percent of this same landscape was at risk of displacement by juniper expansion. The encroachment problem is likely exacerbated by adjacent land uses and cheatgrass invasions that have decreased the habitat values in nearby, lower elevation big sagebrush communities, thereby increasing the importance of remaining habitats. Thus it may be important to consider surrounding land use when prioritizing habitats for treatment to insure that the net result is more usable (for example, accessible to local populations) sage-grouse habitat across the local and regional landscape. Further, whereas juniper may have negative implications for sage-grouse habitat quality, these areas can provide important winter range for ungulates (Anderson and others, 2012) indicating potential interactions among multiple species and habitat functions at the sagebrush-forest ecotone. These locations can be mapped with reasonable accuracy; therefore, encroachment within priority habitats may be specifically targeted. Regional modeling efforts suggested that locations within 3280 ft (1,000 m) of current pinyon-juniper woodlands have the greatest (20 percent) juniper-expansion risk and locations beyond this distance, 3280 to 6550 ft (1,000–2,000 m), experience one-half of this potential (Bradley, 2010). Based on a simple proximity modeling approach, whereby sagebrush habitats in close proximity (820 ft [250 m]) to an existing conifer woodland (especially juniper and pinyon pine, but also ponderosa pine and Douglas-fir) are recognized as having increased invasion risk due to proximity of the seed source, we estimate that 6 to 13 percent of sage-grouse habitat within all MZs may be at risk of conifer expansion. The most pronounced risks are, again, across the Great Basin where an estimated 13 percent (both PPH and PGH; southern Great Basin) and 10 to 12 percent (PGH and PPH, respectively; northern Great Basin) are predicted to be at risk (table 21, fig. 27*B*). Though substantial, the estimated risks in the Snake River Plain (7 to 8 percent PPH and PGH, respectively) and Wyoming Basin (6 to 7 percent PPH and PGH, respectively) are perceived to be smaller (that is, less area projected to be affected). Importantly, the acreage of predicted woodland expansion is one-half of the area projected for cheatgrass risk, and not all of these areas will be invaded uniformly or completely. In addition, acreage projected to be a “high fire risk” is 2 to 10 times greater (depending on MZ) than the area of projected conifer expansion. Although the precise probability and realization of woodland expansion will likely vary (from these model results) within zones identified, based on local environmental conditions, for example, this risk assessment identified large portions of sage-grouse habitat in MZs III, IV, and V as at risk of tree invasion based on proximity to seed sources (table 21) making this a potentially important consideration for managing habitats in those regions.

Prescribed fire is often used as an affordable and seminatural means to control woody invasion and restore invaded communities (Pyke, 2011). However, it is not clear that prescribed fire is the best management option in many cases (Rhodes and others, 2010). The best results reported were attained using manual treatments that retained cover of woody and herbaceous litter post-treatment (Baughman and others, 2010). A review of the impacts of treatments and grazing on grouse (Beck and Mitchell, 2000) suggested that fire be applied cautiously because optimal patterns of burned-unburned habitat and the ideal size(s) for burned patches are unknown, suggesting that small treatment areas coupled with monitoring of subsequent habitat and use patterns may improve restoration success. Research focused on treatment effectiveness (Brockway and others, 2002) indicated that mechanical tree thinning increased native understory biomass by 200 percent; typically, this type of response represents improvement of sage-grouse habitat. Additionally, mechanical operations followed by seeding have been used successfully to restore shrub- and tree-dominant states, however these are typically the most expensive management actions (Provencher and others, 2007). Previous efforts indicate that the success of native plant recovery increases with less pinyon and juniper cover and increases with improved condition of the pre-treatment community (Pyke, 2011). Gradients of condition and potential, estimated locally and applied during the planning process, coupled with local habitat and restoration priorities, may be a useful combination for guiding specific actions (see Section III. A11. Habitat Treatment and Vegetation Management).

A9. Grazing

The effect of livestock grazing on range condition is one of the most contentious issues underlying the management and use of sagebrush habitats (Crawford and others, 2004). However, livestock grazing is the most widespread land use across the sagebrush biome (Connelly and others, 2004), making discussion of its role in sagebrush ecosystems and specifically sage-grouse population conservation a necessary consideration. Although isolated areas exist that have not been grazed by domestic livestock (for example, the kipukas in the Great Rift lava fields of southern Idaho), most sagebrush habitats have been grazed in the past century (Knick and Connelly, 2011b). Livestock grazing has been described as a diffuse form of biotic disturbance that exerts repeated pressure over many years on a system; unlike point-sources of disturbance (for example, fires that have acute perturbations from well-defined origins), livestock grazing is characterized as a “press” form of disturbance because it exerts *repeated* pressure across the landscape (Knick and Connelly, 2011b). Thus, effects of grazing are not likely to be detected as disruptions—except in extreme cases as around water sources or mineral-nutrient blocks—but rather as differences in the processes and functioning of the sagebrush system (Knick and Connelly, 2011b). Importantly, effects of grazing are not distributed evenly, because historic practices, management plans and agreements, and animal behavior all dictate differential use and therefore different effects.

Historically, the numbers of livestock and the area grazed increased between 1880 to 1905 and combined with the drought that followed in the 1920s and 1930s severely altered the condition of western landscapes (Connelly and others, 2004). Numbers of livestock increased from 4.1 million cattle and 4.8 million sheep in 1870 to 19.6 million cattle and 25.1 million sheep in 1900 (Knick and Connelly, 2011b). Native perennial grasses and forbs that were not adapted to heavy

Table 21. Summary of spatial model describing pinyon pine, juniper, and other conifer encroachment risk* across Management Zones by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH				PGH			
	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)	Relative Influence[1] (%)	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)	Relative Influence[1] (%)
MZ I–GP	**11,636,400**	**130,600**	**1.12**		**34,663,000**	**894,500**	**2.58**	
BLM	2,994,300	33,100	1.11	25	4,524,900	180,800	4.00	20
MZ II and VII–WB & CP	292,400	1,100	0.38	1	515,300	20,300	3.94	2
BLM	219,700	1,700	0.77	1	2,427,700	25,400	1.05	3
MZ III–SGB	7,132,500	82,800	1.16	63	24,682,800	604,800	2.45	68
BLM	995,600	12,000	1.21	9	2,498,400	63,100	2.53	7
MZ IV – SRP	1,900	0	0.00	0	13,900	0	0.00	0
MZ II and VII–WB & CP	**17,476,000**	**1,076,300**	**6.16**		**19,200,200**	**1,390,500**	**7.24**	
BLM	9,021,200	499,700	5.54	46	9,012,500	595,500	6.61	43
Forest Service	162,000	18,200	11.23	2	452,500	62,300	13.77	4
Tribal and Other Federal	784,000	77,100	9.83	7	1,354,600	88,400	6.53	6
Private	6,233,900	373,000	5.98	35	7,394,800	545,800	7.38	39
State	1,244,800	106,600	8.56	10	979,800	97,800	9.98	7
Other	30,100	1,700	5.65	0	6,000	700	11.67	0
MZ III–SGB	**10,028,500**	**1,292,400**	**12.89**		**3,970,100**	**517,400**	**13.03**	
BLM	6,309,400	751,400	11.91	58	3,199,800	394,000	12.31	76
Forest Service	1,236,200	247,000	19.98	19	356,200	86,800	24.37	17
Tribal and Other Federal	260,800	29,400	11.27	2	29,100	4,600	15.81	1
Private	1,836,200	217,400	11.84	17	384,800	32,000	8.32	6
State	385,900	47,100	12.21	4	200	0	0.00	0
MZ IV–SRP	**21,930,600**	**1,698,500**	**7.74**		**10,958,500**	**918,100**	**8.38**	
BLM	13,710,700	938,700	6.85	55	4,928,200	311,300	6.32	34
Forest Service	1,613,800	248,200	15.38	15	1,113,500	228,100	20.48	25
Tribal and Other Federal	633,600	10,000	1.58	1	522,500	11,100	2.12	1
Private	4,890,200	427,500	8.74	25	3,516,742	295,200	8.39	32
State	1,019,373	67,700	6.64	4	846,200	69,600	8.23	8
Other	62,900	6,400	10.17	0	31,400	2,900	9.24	0

Table 21. Summary of spatial model describing pinyon pine, juniper, and other conifer encroachment risk* across Management Zones by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).—Continued

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH				PGH			
	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)	Relative Influence[1] (%)	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)	Relative Influence[1] (%)
MZ V–NGB	**7,097,200**	**823,500**	**11.60**		**5,808,000**	**533,700**	**9.19**	
BLM	5,117,500	597,500	11.68	73	4,196,700	346,600	8.26	65
Forest Service	62,200	11,300	18.17	1	114,900	29,200	25.41	5
Tribal and Other Federal	717,100	44,000	6.14	5	101,800	8,100	7.96	2
Private	798,000	106,800	13.38	13	1,199,000	132,300	11.03	25
State	64,900	2,700	4.16	0	115,800	7,300	6.30	1
Other	337,500	61,200	18.13	7	79,800	10,100	12.66	2

*Data Source: Modeled from National GAP/ReGAP Landcover, National GAP Analysis Program, 2010. Based on occurrence of sagebrush within 120 m of a conifer vegetation type.

[1]For management entities within a management zone calculated as the percent of the total direct impact in the Management Zone represented by that management entity, that is, the relative area of direct influence among management entities. Small differences between individual entity totals and MZ summary values may exist due to rounding of estimates during calculations.

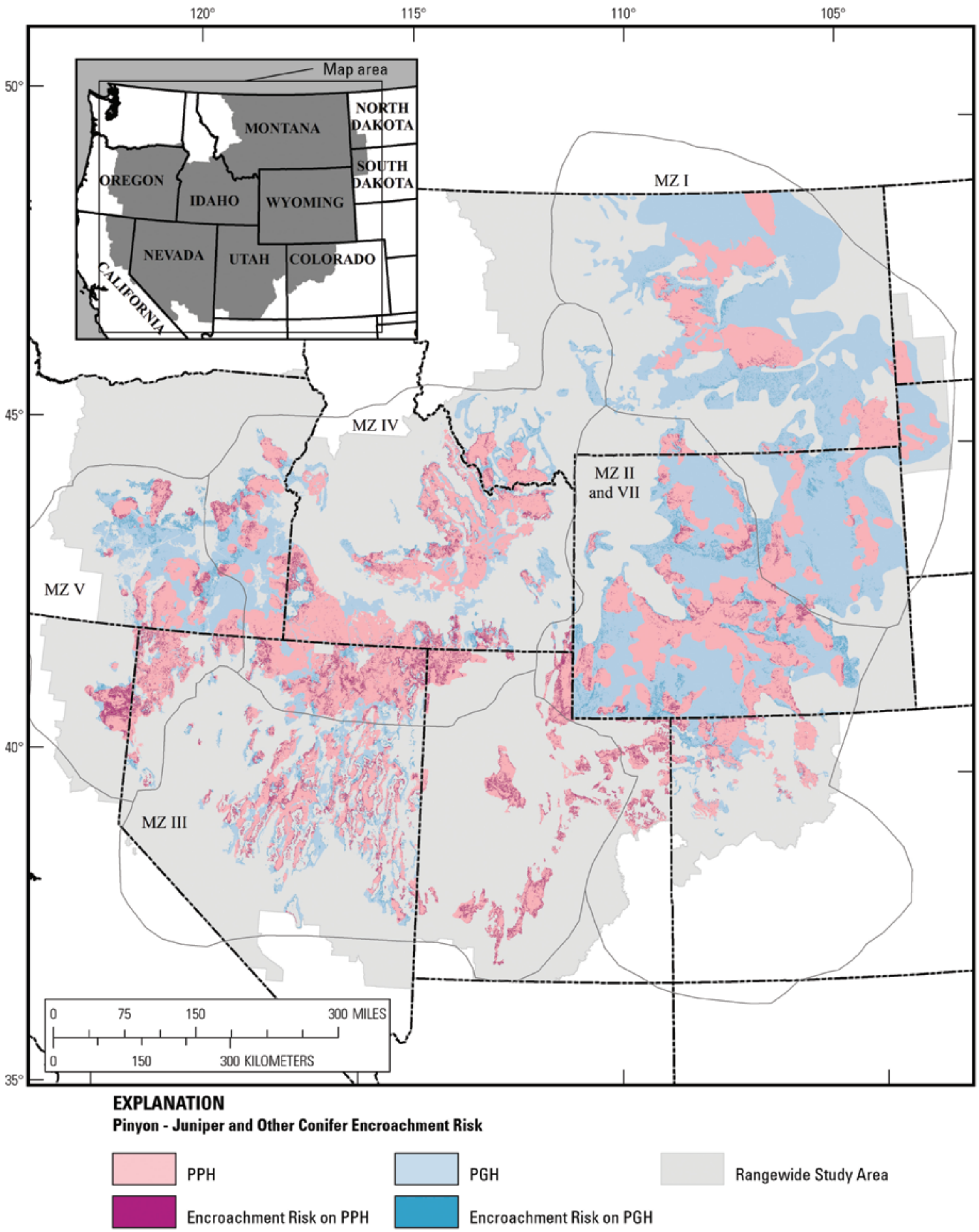


Figure 27*B*. Overlap of pinyon pine, juniper, and other conifer encroachment risk and preliminary priority and preliminary general habitats (PPH and PGH, respectively) in Management Zones (MZ) III, IV, and V (Great Basin).

grazing pressure were depleted from the vegetative community and replaced in much of the Great Basin, Snake River Plain, and surrounding intermountain regions by grazing-tolerant grass species, exotic annual grasses, or both. Loss of protective vegetation cover in some communities resulted in extensive soil disturbance and erosion, and shrub density increased (although the total distribution of shrubs across the region likely remained similar). Research revealed that the decline of palatable forage species and increases in plant species of low palatability took only 10 to 15 years at any given site under heavy uncontrolled grazing (Knick and Connelly, 2011b). Forage production for livestock dropped to an estimated 10 percent of site potential following depletion of the vegetation community in some regions. The area required to support an animal unit month (AUM; the amount of forage required to feed one 1,000-pound cow and her calf, one horse, five sheep, or five goats for one month) was estimated at 3 acres (1.2 ha) prior to European settlement, 9 acres (3.7 ha) in the 1930s, and 8 acres (3.2 ha) in the 1970s (Knick and Connelly, 2011b). Implied in this estimate is the assumed relation that 3 times the area per AUM is required because current primary production is approximately one-third of what it was during the first interval, years after severe overgrazing and droughts of the early 1900s ended. Current-use patterns vary based on local and regional plans and conditions, and grazing allotments and pastures on public lands (management units) represent the typical planning, leasing, and evaluation units used in grazing management across sage-grouse range. Grazing, assessed using Field Office records of grazing allotments, suggested that allotments "not meeting wildlife land health standards due to livestock grazing" influence sage-grouse habitats throughout MZ IV and western portions of MZ III, although BLM lands not meeting wildlife land health standards (due to livestock) can be found throughout the range of sage-grouse (table 22, fig. 28). Importantly, assessments for some lands were not available (some Federal and all State, private, and tribal lands), and conditions have changed since the data were gathered (assembled in 2008 using available data), so regional-scale comparisons may be misleading (contemporary, local data should supersede this information in most cases). Approximately 6.6 million acres (26,700 km^2; 10.42 percent) of BLM controlled sage-grouse range did not meet land health standards, and 17.9 percent of priority habitats in MZs III and IV did not meet these standards.

Livestock grazing can affect soils, vegetation, water, and nutrient availability by consuming or altering vegetation, redistributing nutrients and plant seeds, trampling soils and vegetation, and disrupting microbiotic crusts (Connelly and others, 2004). At *unsustainable* levels of grazing, these impacts can lead to loss of vegetative cover, reduced water infiltration rates, decreased plant litter on soil surface, increased bare ground, reduced nutrient cycling, decreased water quality, increased soil erosion, and reduced overall habitat quality for wildlife including sage-grouse (Wisdom and others, 2002; Knick and others, 2011). Ultimately, livestock function as keystone species; domestic grazing does not preclude native wildlife and vegetation, but it influences ecological pathways and can influence which plant and animal species persist (Knick and others, 2011). Thus there are two important influences of detrimental grazing on sage-grouse habitat: the influence on annual conditions in the near-term and the accumulation of selective pressure resulting in altered vegetation dominance over time. Prolonged selective pressure can affect condition of individual plants, abundance of species, inter-specific competition, and ultimately, community composition (Miller and others, 1994; Beck and Mitchell, 2000; Wisdom and others, 2002; Erichsen-Arychuk and others, 2002; Holechek and others, 2003; Connelly and others, 2004; and Pyke, 2011). Although specific effects and conditions are localized in most cases, the cumulative effect of these transitions across the species' range may affect the regional condition of sage-grouse habitats.

There is little scientific data directly linking grazing practices to sage-grouse population levels (Knick and others, 2011). Direct positive and negative effects of livestock grazing on sage-grouse reported in the literature include (1) light to moderate rest-rotation cattle grazing in mesic upland meadows promoted forb growth and availability and sage-grouse use, (2) sage-grouse used sheep salting grounds as leks, (3) heavy grazing in wet meadows deteriorated hydrology and reduced the extent of habitats suitable for summer—these sites were avoided by sage-grouse, and (4) sheep and cattle trampled nests and caused nest desertions (Beck and Mitchell, 2000). To help make the connection between the effects of livestock grazing on plant community dynamics in sagebrush ecosystems, the context of state and transition theory (states being discrete, observable communities or conditions, and transitions represent the influence of drivers of change that move the community among alternative states) has been used to describe the observed range of variation of plant communities (Pyke, 2011) and frame a discussion of grazing effects on vegetation and habitat conditions, habitat treatments, wild horse and burro herds, and water developments. Though differences in tolerance and resilience may exist among different communities within the sagebrush ecosystem (for example, eastern versus western, northern versus southern), multiple lines of evidence indicate the presence of thresholds in the response of grasses and other native vegetation, including sagebrush, to variations in grazing pressure, which, in turn, have important implications for sage-grouse habitat quality in multiple-use environments (Beck and Mitchell, 2000; Erichsen-Arychuk and others, 2002; Holechek and others, 2003; Connelly and others, 2004; Pyke, 2011).

Sage-grouse population persistence has been linked to the availability and condition of sagebrush habitat; the dependence of the species on sagebrush through all seasonal periods has been well documented and cannot be overemphasized (Connelly and others, 2004). Nesting sage-grouse consistently select areas with more sagebrush canopy cover and taller grasses compared to available habitats (Hagen and others, 2007); tall, dense herbaceous cover—including residual grasses—in selected dense sagebrush stands

Table 22. Summary of grazing allotments not meeting Land Health Standards for wildlife habitat with grazing as the causal factor* by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).

Management Zone Entity	PPH			PGH		
	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)
MZ I–GP						
BLM	2,994,300	82,500	2.76	4,524,900	52,100	1.15
MZ II and VII–WB & CP						
BLM	9,021,200	286,900	3.18	9,012,500	366,000	4.06
MZ III–SGB						
BLM	6,309,400	965,400	15.30	3,199,800	654,600	20.46
MZ IV – SRP						
BLM	13,710,700	2,617,200	19.09	4,928,200	968,900	19.66
MZ V–NGB						
BLM	5,117,500	417,000	8.15	4,196,700	158,700	3.78

*Data Source: (Veblen and others, 2011; Assal and others, 2012). Only BLM-managed portions of allotments were evaluated. Data assembled in 2008 from available records.

increases the probability of a successful hatch. Thermal cover, predator protection, and food availability are important for chick survival during the early brood-rearing period with tall (>30cm) grasses and sagebrush creating this habitat structure. Grazing intensity—including stocking rate, duration, and frequency—has consistently been identified as having impacts on ecosystem and rangeland health (Vallentine, 1990; Briske and others, 2008; Veblen and others, 2011) including the structure required by sage-grouse. Similarly, the timing of grazing relative to plant phenology in particular can influence the sustainability of grazing (Briske and Hendrickson, 1998; Briske and others, 2003; Veblen and others, 2011) and compatibility with wildlife requirements. Resting pastures from livestock grazing during periods of fastest growth of dominant grasses and forbs in intermountain sagebrush-steppe generally enhances herbaceous plant growth and reproduction and increases culm height, long-term tiller production, and flower and seed production (Pyke, 2011) improving range conditions and habitat. Repeated grazing during this time tends to favor sagebrush growth (Pyke, 2011) through reduced competitive ability of grasses. Seasonal monitoring of range conditions could enable removal of livestock when stubble heights required to protect nests and broods are reached; however, this information is difficult to attain accurately in a timely way across large regions; therefore, surrogate measures or indices of condition would likely benefit this effort.

Heavy fall utilization of sagebrush habitats by livestock has been deemed detrimental to sagebrush overstories and thus may negatively influence sage-grouse habitat suitability (Wright, 1970; Owens and Norton, 1990; Angell, 1997; Beck and Mitchell, 2000). Trampling by livestock under short-duration or season-long grazing may kill sagebrush, particularly seedlings growing in interstitial spaces (Beck and Mitchell, 2000). Domestic sheep browsing in fall and winter can reduce the density and vigor of sagebrush, especially where sagebrush densities are low (Beck and Mitchell, 2000) and may require avoidance (rest, removal) in important sage-grouse habitats with limited sagebrush cover. Spring grazing may benefit sage-grouse winter range because grass reductions can increase sagebrush densities (Wright, 1970; Owens and Norton, 1990; Angell, 1997; Beck and Mitchell, 2000) suggesting an opportunity for adaptation of grazing systems to graze winter habitats in spring when brood-rearing habitats would be avoided, and vice versa.

A study (Van Poolen and Lacey, 1979), compiling results from 18 western grazing-system studies reported that adjustments in livestock numbers resulted in increased herbage production of approximately 35 percent and 28 percent when grazing-use levels were reduced from heavy (60–80 percent) to moderate (40–60 percent) and from moderate to light (20–40 percent), respectively. The authors concluded that livestock stocking intensity was more important than grazing system for herbage production (Van Poolen and Lacey, 1979), a key habitat feature associated with hatching success of sage-grouse nests and chick survival during early brood-rearing. In contrast, others found season of use to influence production: grazing heavily during the spring or during spring and fall was detrimental to herbaceous understories (Mueggler, 1950; Laycock, 1978; Owens and Norton, 1990). Insect diversity and density were positively correlated with herbaceous density and diversity (Hull and others, 1996; Jamison and others, 2002); thus, spring or spring-fall grazing could negatively impact nesting sage-grouse and young chick survival during early brood-rearing, and avoidance through rotation or rest may benefit nesting or brood-rearing success. Grazing during the fall had minor effects on herbaceous understories (Mueggler,

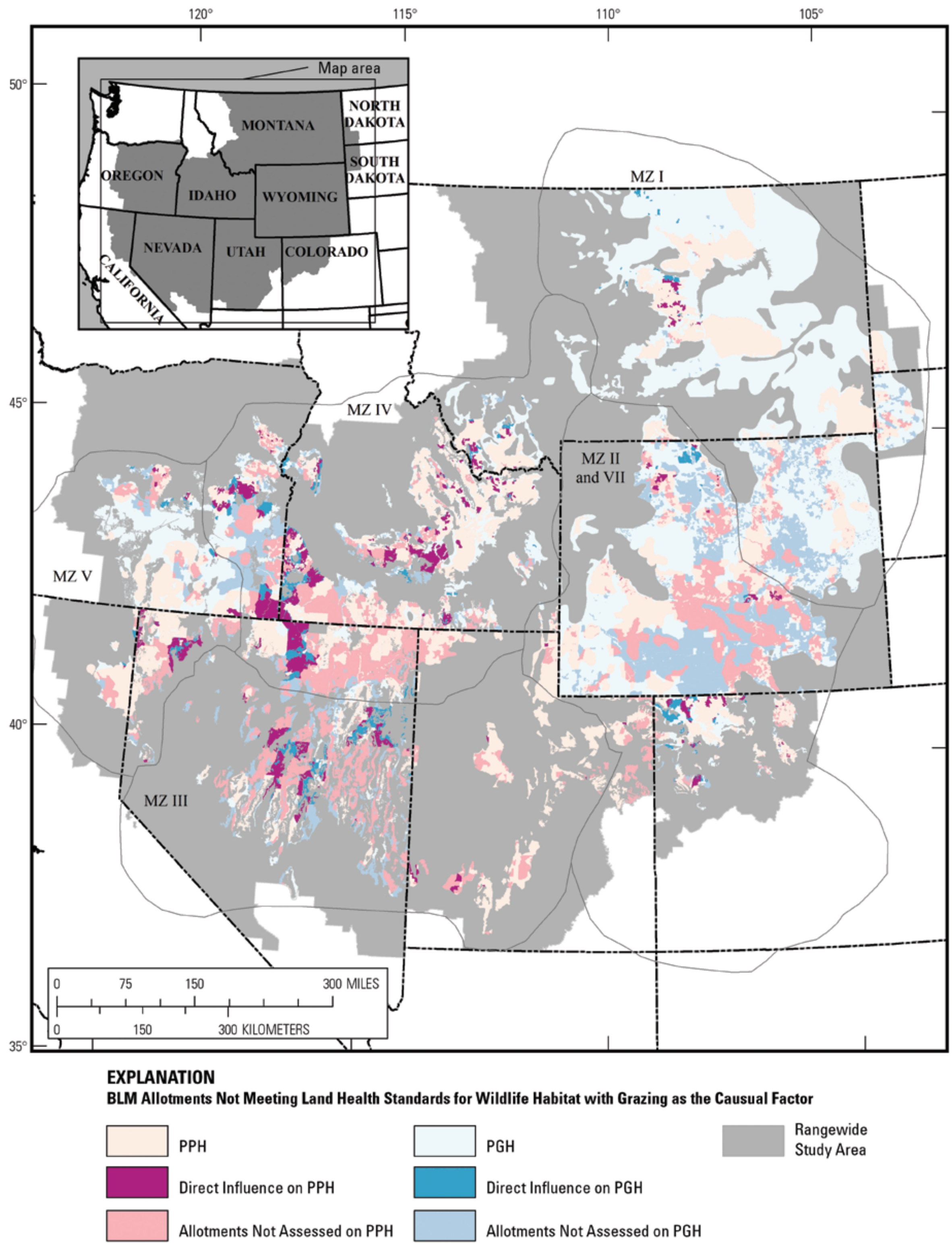


Figure 28. Overlap of grazing allotments not meeting Land Health Standards for wildlife habitat with grazing as the causal factor and preliminary priority and preliminary general habitats (PPH and PGH, respectively). Bureau of Land Management (BLM) lands only, assembled in 2008. MZ, Management Zone.

1950; Laycock, 1978; Owens and Norton, 1990). However, grazing during the dormant season (late summer through winter) may influence residual-grass-stubble height (Pyke, 2011), which could influence nesting habitat quality for sage-grouse the following spring.

A study conducted in central Wyoming compared vegetative conditions in grazed pastures to conditions selected by sage-grouse in the area and found that reduced forage utilization, extended periods of rest, and reduced spring grazing provided conditions most suitable for sage-grouse nesting and early brood-rearing, even during a drought (precipitation 68 percent of normal during study, Kuipers, 2004). Grazing system (based on rotation period) was less important relative to stocking rates and season of use in this study. Long-term removal of livestock generated a steady increase in the richness of shrubs, perennial grasses and forbs, and vegetative heterogeneity through 45-years post-removal of livestock in southwestern Idaho (Anderson and Inouye, 2001). Comparing grazed to un-grazed (not grazed for 25 to 40 years) big sagebrush communities in Utah and Idaho, researchers reported increased sagebrush canopy cover of 13 to 54 percent (Beck and Mitchell, 2000). In contrast, no increases in total herbaceous standing crop after removal of livestock for 13 years were reported in Utah (Beck and Mitchell, 2000). Studies tracking changes in vegetation after removal of livestock in sagebrush systems report that initial proportions of the different growth forms were retained, and that a minimum of 10 to 15 years was required for seed production, seedling establishment, and growth to occur (Connelly and others, 2004; Pyke, 2011). Thus, well-prescribed livestock management may positively influence sage-grouse habitat suitability especially during nesting (spring), early brood-rearing (early summer), and winter, but extended rest may be required for areas that are currently degraded.

Livestock distribution patterns are directly linked with water availability, and this bias has also had relevant, measureable impacts to riparian habitats, which are of primary importance for sage-grouse as late brood-rearing and summer habitats. The most direct effect of livestock on riparian vegetation is removal of the lower vegetation layers; livestock exclusion from riparian habitats resulted in increased sedge cover, forb cover, foliage-height diversity, and water-table depth along with expansion of riparian vegetation laterally from stream channels (Dobkin and others, 1998). High stocking rates in areas with limited water availability were particularly detrimental to forage productivity on lands immediately surrounding water sources (Hall and Bryant, 1995; Dobkin and others, 1998). Similarly, summer grazing on riparian habitats concentrated livestock on riparian corridors resulting in decreased low-vegetative growth (typically the forb communities essential in sage-grouse summer diets) and reduced lateral extent of succulent vegetation associated with the riparian corridor due to a reduction in the hyporheic zone (that is, the region beneath and alongside a *water* body where there is mixing of *groundwater* and *surface water*). However, sage-grouse preferred grazed to ungrazed wet meadows where protective cover conditions were otherwise equal, and rest-rotation grazing provided the best effects on sage-grouse summer habitat through moderate stocking levels and rest of a minimum of every 3 years (Neel, 1980)

Most sagebrush grasslands are in winter-dominated precipitation regions, and cool-season plants generally dominate the herbaceous layers (Pyke, 2011). Exceptions are the Colorado Plateau in southern Utah, eastern Utah, northeastern Colorado, eastern Wyoming, and eastern Montana (eastern portions of both MZ I and MZ III) where monsoon moisture creates a second peak of predictable moisture in late summer; warm-season plants co-dominate with cool-season plants in the herbaceous layers of these regions (Pyke, 2011). Therefore, the most significant long-term influence of grazing on sage-grouse habitat is the potential for transition from an ecological state dominated by sagebrush and early (cool) season grasses to a site dominated by sagebrush, grazing-tolerant grasses (increasers), invasive annual grasses and forbs, or woodlands (Pyke, 2011) driven by persistent, selective herbivory that can affect composition, dominance, and community structure (Manier and Hobbs, 2007). Importantly, not all sagebrush communities are identical. Sagebrush-steppe is one of the most widespread and characteristic vegetation types in the intermountain west, and it comprises the northern portion of the sage-grouse distribution (West, 1988). In these communities, co-dominance of perennial bunchgrasses along with one or more of the 12 different species of sagebrush creates a variety of types and conditions that supported moderate species diversity and historically some limited populations of large herbivores (West, 1988). On eastern portions of the species' range, where the sagebrush-steppe gradates with mixed-grass prairie species, rhizomatous grasses often play a prominent role in community composition with important implications for grazing management (especially in MZ I). Great Basin sagebrush characterizes sagebrush communities in the southern and southwestern portions of the sage-grouse range (MZs III, IV, V, and VII) , and though there are similarities in composition and structure, these systems have significantly lower diversity, productivity, and resilience to disturbance owing to greater aridity across these regions (West, 1988). Thus, though the northern sagebrush-steppe has proven similar in response to disturbance and management to semiarid grasslands, Great Basin types are more similar to deserts with islands of fertility surrounding shrubs, increased potential for erosion due to limited cover (soil exposure), and seasonal drought and precipitation patterns (West, 1988). Thus, it is probable that the impacts of overgrazing are more severe in these arid regions compared to northern wetter regions. Further impacts of drought and prolonged shifts in precipitation patterns may trigger shifts in systemic condition, productivity, and resilience in areas that were previously more robust, and this may cause significant differences in effects of local grazing practices.

Sage-grouse generally initiate nesting in April, prior to production of new herbaceous cover; thus, residual grasses left from the previous year represent the initial cover available for nesting sage-grouse (Hausleitner and others, 2005;

Holloran and others, 2005). With few exceptions, ensuring adequate residual herbaceous cover through the nesting season (through June in most areas) will provide for long-term resilience with plant communities that include healthy bunchgrass understories and adequate residual grass cover and height to support annual objectives (Pyke, 2011). The potential exists to successfully manage for good sagebrush community condition but fail to achieve sage-grouse habitat objectives if *annual* management for sufficient residual vegetation (standing crop) is not considered. According to research conducted in sagebrush-steppe, adherence to light-utilization standards is the most dependable way to ensure a healthy plant community (Cagney and others, 2010). Conclusions from a review of the effects of herbivory on bluebunch wheatgrass (*Pseudoroegneria spicata*), an important sagebrush associate, indicated (1) utilization levels of 30 to 40 percent under deferred grazing systems is a recommended maximum use-level if maintaining the community is desirable; (2) onetime growing season utilization levels of more than 50 percent have long-term (up to a decade) impacts on plant vigor and productivity (even if followed by complete protection); and (3) grazing following the growing season has little effect, although yield reductions the following year may occur if grazed to 2-inch stubble height (Anderson, 1991). Annual and seasonal monitoring of production and standing crop, with subsequent removal of livestock as range utilization reaches capacity (Holechek and others, 1989; Thurow and Taylor, 1999) is important for providing for habitat quality rangewide and would be facilitated by development within local monitoring, planning, and adaptive management cycles.

Even though livestock numbers have been considerably lower since the implementation of the Taylor Grazing Act in 1934, and grazing management across the West has steadily improved, acres continue to transition away from reference (historic, potential, and [or] desired) conditions (Cagney and others, 2010). Because of lasting historic impacts (late 1800s–early 1900s), the reduced numbers of livestock in the modern era often do not simply represent reduced grazing effects (Knick and others, 2011), but rather, a slower rate of accumulation of effects. Importantly, environmental patterns, historic and current uses vary tremendously in space and time, and though some generalizations may be made, local conditions and appropriate solutions will be based on local understanding and adaptations. Thus in some areas, grazing on sage-grouse habitat may be a component of both long-term management to promote resilient, desirable plant communities and annual management of the standing crop to provide residual cover for sage-grouse (Cagney and others, 2010; Pyke, 2011). However, if the desired vegetative components are not present in a priority site, additional manipulations may be required such as addition of desired species through active restoration (Pyke, 2011), and because these treatments may be expensive, prioritization based on habitat value and site potential may be warranted.

Interactions between grazing and recent disturbances can have lasting effects on recovery of sage-grouse habitat values in the post-disturbance environment. Deferring grazing for two growing seasons after disturbance has been recommended because it allows the cool season bunchgrasses—which are especially vulnerable to grazing after treatment—to capitalize on resource availability created by the disturbance (Knick and others, 2011). However, reintroduction of livestock to a disturbed area prior to the native or reseeded plant community becoming established, regardless of the number of years of rest afforded the site, can result in failed rehabilitation efforts and increased levels of exotic grasses (Knick and others, 2011). Although rest is often prescribed, timing, intensity, and duration of grazing of treated rangelands may be more important than a specific period of rest after fire (Bates and others, 2009). Moderate grazing after perennial grass dormancy (that is, late season) in the first two summers after fire is not likely to reduce the recovery ability of herbaceous communities in sagebrush-steppe (Bates and others, 2009) when rest during the growing season is permitted. Differences in herbaceous cover among burn-ungrazed and burn-grazed areas were not observed during the first 6 years after fire, but between 7 and 18 years post-fire, perennial grass cover in grazed areas was less than cover in ungrazed areas (West and Yorks, 2002), so long-term post-treatment monitoring may be important. Treated areas may draw grazing pressure from all herbivores; thus, treatment designs that consider the possibility of an unplanned escalation of use by wild horses or elk (Cagney and others, 2010) when significant populations of these species are present have better chances of meeting productivity and habitat targets.

Wild Horses

Free-roaming horses (*Equus caballus*) and burros (*E. asinus*) have been a component in the dynamics of sagebrush and other semiarid communities since they were brought to North America at the end of the 16th century (Connelly and others, 2004). Approximately 40,000 free-roaming horses currently live in ten Western U.S. States; areas managed for horses and (or) burros from 1971 to 2007 constitute approximately 18 percent of currently occupied sage-grouse range predominantly in Nevada, southwest Wyoming, and southeast Oregon (Connelly and others, 2004; Beever and Aldridge, 2011). Because of physiological differences, a horse consumes 20 to 65 percent more forage than would a cow of equivalent body mass (Connelly and others, 2004). Comparing horse-removed sites to horse-occupied sites, researchers have documented the following equid-induced changes to sagebrush communities: (1) reduced total vegetative and grass abundance and cover, (2) lower sagebrush canopy cover, (3) increased fragmentation of shrub canopies, (4) lower species richness, (5) increased compaction in surface soil horizons (Bartmann and others, 1987), and (6) increased dominance of unpalatable forbs (Beever and Aldridge, 2011). Additionally, because horses separate themselves from cattle by using higher elevations and steeper slopes, horse occupancy of a sagebrush ecosystem reduces the occurrence of ungrazed areas (Connelly and others, 2004). Areas managed Federally as wild horse and burro range constitute approximately 14.6 million acres (5.9 million hectares; 10.24 percent) of sage-grouse habitats across the range of the species (table 23, fig. 29*A*). Wild horse and burrow range coincides with sage-grouse habitat predominantly in Nevada, southwest Wyoming, and southeast Oregon; in these MZs (III and V and II and VII), 19.9 percent of priority habitats are negatively influenced.

Water Developments

Open water has been suggested as a limiting factor for summering sage-grouse. Although water availability may influence the species' summer distribution (Patterson, 1952; Autrienth, 1981), movements to summer range are probably in response to lack of succulent forbs in an area rather than a lack of free water (Connelly and Doughty, 1989). Existing research suggests that sage-grouse do *not* regularly use water developments even during relatively dry years but obtain required moisture from consuming succulent vegetation in the vicinity (Connelly, 1982; Connelly and Doughty, 1989; Connelly and others, 2004). More than 56,500 water development projects have been implemented on lands managed by the BLM within the current distribution of sage-grouse plus a 50 km (31 mi) buffer around this distribution (Connelly and others, 2004; fig. 29*B*). Water developments are generally intended to provide water for livestock or wildlife but may also be designed to provide succulent vegetation surrounding the water.

Artificial water sources may facilitate the spread of West Nile virus (WNv) within sage-grouse habitats because these water developments support abundant populations of the mosquito (*Culex tarsalis*) longer than natural, ephemeral water sources thereby providing habitat for the vector responsible for the majority of WNv infections (Walker and Naugle, 2011). Additionally, projects that create mesic zones around water developments to promote the growth of succulent vegetation may inadvertently contribute to the proliferation of WNv as *Culex tarsalis* regularly breed in water-filled hoofprints in these areas (Walker and Naugle, 2011). Water developments tend to attract other animals and thus may serve as predator sinks for sage-grouse (Connelly and Doughty, 1989). Additionally, water developments have substantially influenced the movements and distribution of livestock in arid western habitats and have increased the amount of sagebrush area available for livestock (Connelly and others, 2004), which—although these practices may benefit riparian conditions (sage-grouse summer habitats)—may increase the effect of livestock across the landscape, expanding impacts to upland areas important for sage-grouse during nesting, early brood-rearing, and winter seasons.

A10. Climate Dynamics

Climate change is a complex process in which interactions among natural and anthropogenic drivers affect atmospheric characteristics leading to long-term changes in temperature and precipitation (IPCC, 2007; Miller and others, 2011). Notably, the climate has always been understood as a highly dynamic system, and although it has been possible to develop understanding and theories using persistent patterns (in space and time), the climate has always been changing. Modern issues and concerns over climate change are generally focused on rapid warming and associated circulation feedbacks that have been linked to human industrial activities. Although imprecise, plausible global climate change models predict higher temperatures, drier soils in summer with high variability, severe weather events (drought and storms), and changing moisture regimes across mid-latitude, semiarid regions of the American West (Finch, 2012; Friggens and others, 2012).

Sage-grouse population dynamics were strongly related to multiple climatic conditions as measured between 2003 and 2010 in central Nevada (Blomberg and others, 2012). Precipitation (annual rainfall, annual precipitation, and average winter snow depth) was positively related to annual recruitment (higher recruitment in years with high precipitation); the positive relation was strongest with total annual rainfall. Additionally, annual rainfall and mean monthly winter snowpack were positively related to sage-grouse population growth. Annual adult male survival was negatively related to maximum summertime temperatures (high survival in years with low maximum temperature). Results from this study suggest a direct link between sage-grouse population dynamics and several ecological processes expected to be influenced by climate change in southern portions of the species' range (for example, decreased precipitation amounts and increased temperatures); projected changes to climate are likely to negatively influence sage-grouse population dynamics if they decrease the productivity of the sagebrush ecosystem (Blomberg and others, 2012).

Changing climate conditions may render some locations less suitable for sagebrush than for other species, creating potential shifts in ecosystem distributions (Bradley, 2010). Increased temperatures, the trend for decreased snowpack, earlier onset and warmer spring periods, and reduced summer water flows in the Western United States could exert stresses on sagebrush; sagebrush seedling recruitment may be particularly susceptible to these changes in climate (Miller and others, 2011). A substantial increase in temperature could impart a competitive advantage to woodland vegetation currently dominating the Chihuahuan and Sonoran Deserts, and these woodlands may expand northward and displace large areas of sagebrush (Miller and others, 2011). Increased levels of carbon dioxide may favor exotic annual grasses; in controlled laboratory tests, reproductive biomass of cheatgrass doubled and time to maturation decreased at elevated levels of carbon dioxide (Miller and others, 2011). Under current atmospheric carbon dioxide levels, cheatgrass competes successfully against native grasses because of earlier maturation, shallow root systems preempting water in soils, greater seed production, and the ability to respond quickly to disturbance (Miller and others, 2011). Thus, plausible scenarios suggest that an

Table 23. Summary of Federally managed Wild Horse and Burro Herd Management Areas and Territories[*] across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH				PGH			
	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)	Relative Influence[1] (%)	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)	Relative Influence[1] (%)
MZ I–GP	**11,636,400**	**0**	**0.00**		**34,663,000**	**0**	**0**	
MZ II and VII–WB & CP	**17,476,000**	**2,217,100**	**12.69**		**19,200,200**	**2,734,700**	**14.24**	
BLM	9,021,200	1,792,900	19.87	81	9,012,500	2,007,200	22.27	73
Forest Service	162,000	0	0.00	0	452,500	0	0.00	0
Tribal and Other Federal	784,000	69,800	8.90	3	1,354,600	50,700	3.74	2
Private	6,233,900	271,200	4.35	12	7,394,800	602,400	8.15	22
State	1,244,800	83,200	6.68	4	979,800	74,300	7.58	3
Other	30,100	0	0.00	0	6,000	0	0.00	0
MZ III–SGB	**10,028,500**	**2,479,800**	**24.73**		**3,970,100**	**1,635,800**	**41.20**	
BLM	6,309,400	2,199,200	34.86	89	3,199,800	1,463,200	45.73	89
Forest Service	1,236,200	210,100	17.00	8	356,200	136,100	38.21	8
Tribal and Other Federal	260,800	11,700	4.49	0	29,100	14,700	50.52	1
Private	1,836,200	44,500	2.42	2	384,800	21,800	5.67	1
State	385,900	14,300	3.71	1	200	0	0.00	0
MZ IV–SRP	**21,930,600**	**1,244,200**	**5.67**		**10,958,500**	**642,600**	**5.86**	
BLM	13,710,700	1,177,200	8.59	95	4,928,200	601,400	12.20	94
Forest Service	1,613,800	0	0.00	0	1,113,500	0	0.00	0
Tribal and Other Federal	633,600	0	0.00	0	522,500	7,200	1.38	1
Private	4,890,200	51,900	1.06	4	3,516,742	29,100	0.83	5
State	1,019,373	15,000	1.47	1	846,200	4,800	0.57	1
Other	62,900	0	0.00	0	31,400	0	0.00	0

Table 23. Summary of Federally managed Wild Horse and Burro Herd Management Areas and Territories* across Management Zones (MZ) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).—Continued

Abbreviations: SG, sage-grouse; GP, Northern Great Plains, WB, Wyoming Basin; CP, Colorado Plateau; SGB, Southern Great Basin; SRP, Snake River Plain; NGB, Northern Great Basin.

Management Zone Entity	PPH				PGH			
	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)	Relative Influence[1] (%)	SG Habitat (acres)	Direct Footprint (acres)	Direct Footprint (%)	Relative Influence[1] (%)
MZ V–NGB	**7,097,200**	**2,190,000**	**30.86**		**5,808,000**	**1,476,300**	**25.42**	
BLM	5,117,500	2,002,900	39.14	91	4,196,700	1,399,600	33.35	95
Forest Service	62,200	0	0.00	0	114,900	0	0.00	0
Tribal and Other Federal	717,100	4,300	0.60	0	101,800	700	0.69	0
Private	798,000	73,400	9.20	3	1,199,000	75,000	6.26	5
State	64,900	5,600	8.63	0	115,800	400	0.35	0
Other	337,500	103,800	30.76	5	79,800	600	0.75	0

*Data Source: BLM (2012), USFS Enterprise Data Warehouse, 2012. Nonfederal lands fall within these areas and the presence of wild horses and burros on those lands is dependent on local management practices, such as, fencing or tolerance of trespass.

[1]For management entities within a Management Zone, these were calculated as the percent of the total direct impact in the Management Zone represented by that management entity, that is, the relative area of direct influence among management entities. Small differences between individual entity totals and MZ summary values may exist due to rounding of estimates during calculations.

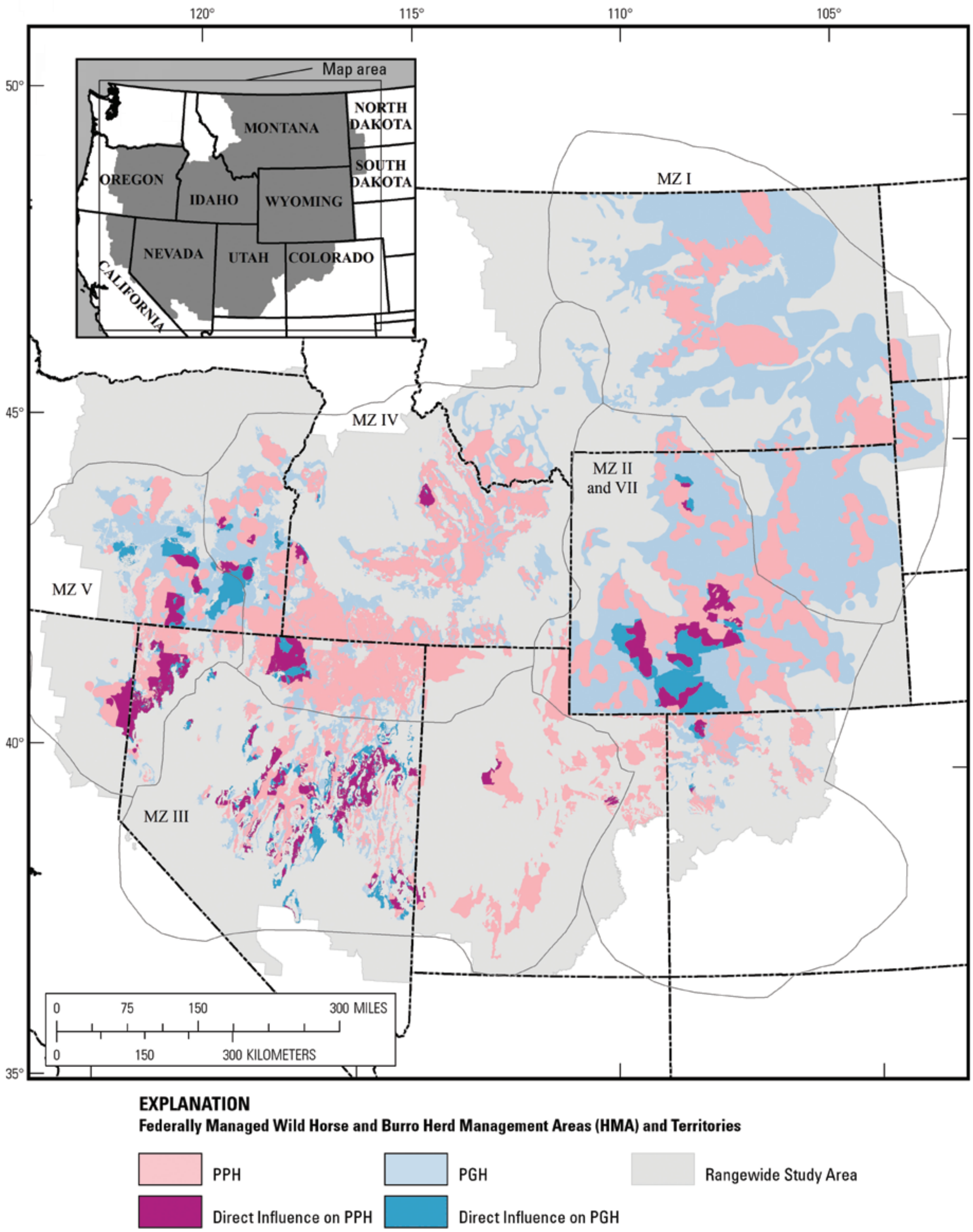


Figure 29*A*. Overlap of Federally managed Wild Horse and Burro Herd Management Areas and Territories and sage-grouse preliminary priority and preliminary general habitats (PPH and PGH, respectively) within each Management Zone (MZ).

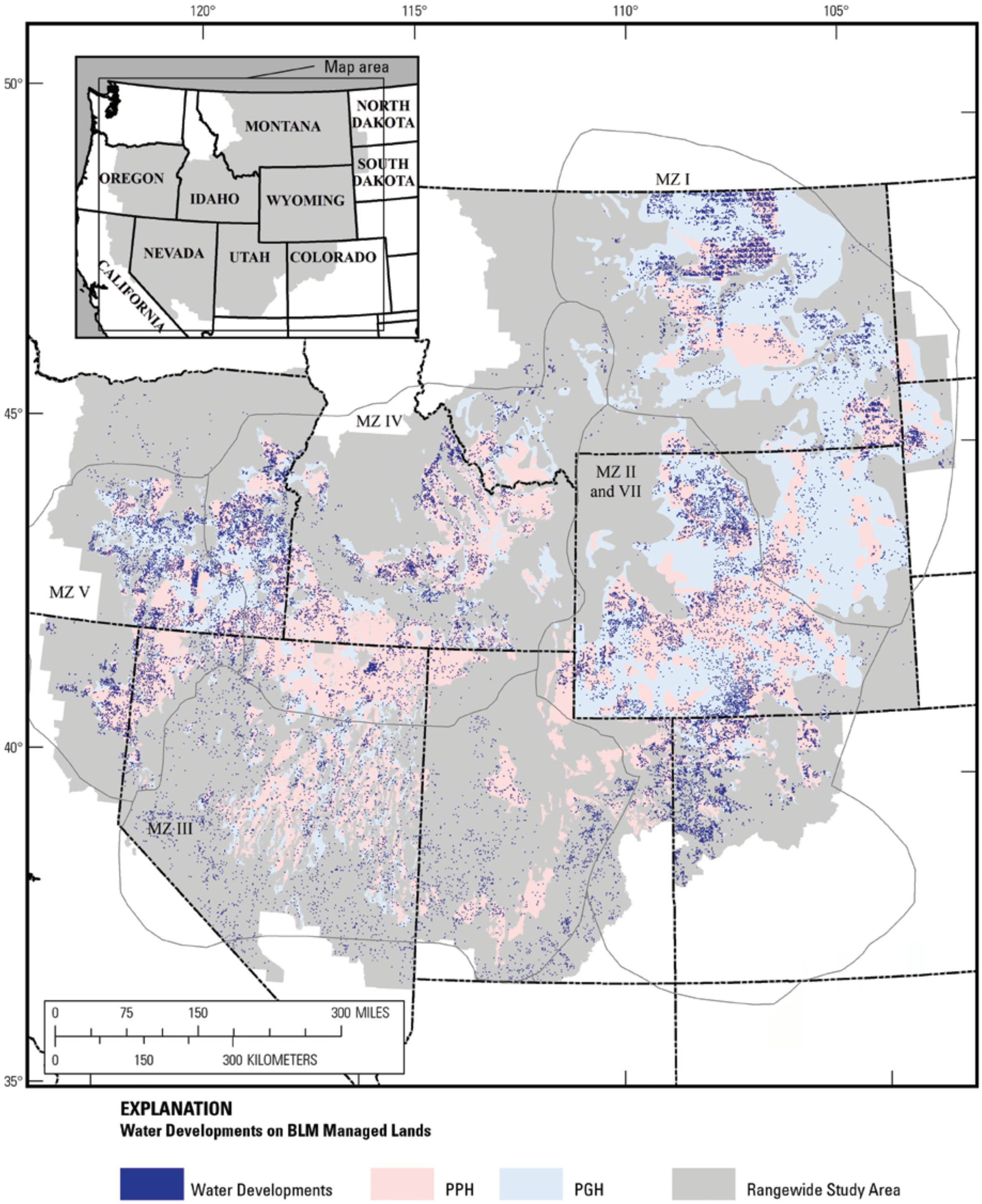


Figure 29*B*. Distribution of water developments on Bureau of Land Management lands overlapping sage-grouse preliminary priority and preliminary general habitats (PPH and PGH, respectively) across each Management Zone (MZ).

increase in the competitive advantage of cheatgrass may facilitate the species' spread, exacerbating the cycle of fire and cheatgrass-dominance already eliminating substantial acreages of sagebrush annually (Miller and others, 2011).

In central Nevada, recruitment of male sage-grouse to leks was consistently low in areas with substantial exotic grasslands interspersed in the landscape surrounding a lek, even during years when climatic conditions resulted in substantial recruitment to leks in the region (Blomberg and others, 2012). The interactive relation between climate and exotic annuals suggests that pulses in the growth of a sage-grouse population in response to increased precipitation may be mediated by the presence of areas dominated by exotic annuals within key habitats (Blomberg and others, 2012). Therefore, changing precipitation patterns and competitive advantages cheatgrass has over native vegetation, such as rapid response to moisture availability, may act synergistically to negatively affect sagebrush ecosystem condition and associated sage-grouse population dynamics.

Summer precipitation and temperature are the best predictors of sagebrush regional distribution suggesting that changing summer conditions may have the most impact on long-term viability of sagebrush habitats (Bradley, 2010). Climate change risk to sagebrush due to changing summer conditions may be most pronounced in southern portions of the species' range where decreased precipitation and (or) rising temperatures may make current habitat climatically unsuitable in the future (Bradley, 2010). However, in an experimental study where rainout shelters excluded natural rainfall and seasonal distribution of precipitation was controlled, Bates and others (2006) found that Wyoming big sagebrush (*Art. tri. wyomingensis*) did not respond in terms of cover or density to shifts in the timing of precipitation from predominantly winter (for example, normal precipitation timing on-site of 75 percent occurring between October and April) to spring (80 percent of total water applied between April and July) in the short term (7 years), suggesting changes to the shrub overstory may take decades to materialize. Additionally, increasing summer temperatures have been related to increases in threetip sagebrush (*Art. tripartita*) population growth, a result driven by increased survival of this species (Dalgleish, 2011).

The loss of approximately 12 percent of the current distribution of sagebrush was predicted to occur with each 1°C increase in temperature, primarily to increasing distributions of other woody vegetation (Miller and others, 2011). However, most scenarios do not factor in the potential response of exotic annual grasses and the consequences these changes may have on the distribution of sagebrush habitats; therefore, estimates of range contraction may be low. The current distribution of sagebrush is predicted to decline by 80 percent under one of the most extreme global climate change scenarios of an increase of 6.6 °C (Miller and others, 2011). A general geographic pattern of future sagebrush occurrence is characterized by substantial decreases in southern parts of the species' range combined with some increases in the northern parts; models also forecast small increases in distribution at higher elevations, for example, at the interface with coniferous forest (Schlaepfer and others, 2012). Forecasts additionally suggest that sagebrush ecosystems may split into several large but disjoint areas: Washington, Sierra Nevada area, Oregon- northern Nevada, central Idaho, an area encompassing eastern Utah, Wyoming, Colorado, and eastern Montana-Saskatchewan (Schlaepfer and others, 2012).

Decreased annual precipitation negatively influenced needle-and-thread (*Hespirostipa comata*) population growth in sagebrush habitats, primarily by reducing survival of this grass species (Dalgleish, 2011). Herbaceous plants were detrimentally affected by a shift in precipitation timing in sagebrush habitats from predominantly winter (75 percent of total water occurring between October and April) to spring (80 percent of total water applied between April and July) as indicated by a pattern of lower herbaceous biomass, cover, and densities compared to the other treatments (Bates and others, 2006).

Importantly, the potential effects of climate change on sagebrush and sage-grouse outlined above are not supported—nor are they falsified—by empirical data. Projecting the potential consequences of global climate change requires scientists to extend correlational and mechanistic relations beyond observed data leading to uncertainty in results. Despite limitations, the potential effects of climate change may be reasonably factored into long-term conservation actions through recognition of risks and possibilities, but predicted responses of species and habitats to long-term, imprecise forecasts are unlikely to provide accurate details regarding future conditions. Projections of sage-grouse population trends and extinction probabilities used for management of the species generally extend 100 years into the future (see Garton, 2011), and during this period the projected changes to the climate and the effects these changes may have on sagebrush habitats may become sufficiently large to overwhelm any current trajectory of habitat loss and alteration (Miller and others, 2011). The empirical data presented suggests that potential effects of global climate change (such as prolonged drought) may influence the herbaceous understory in sagebrush habitats before effects on the shrub overstory become apparent.

A11. Habitat Treatments and Vegetation Management

Given the historic reduction and conversion of the most productive communities within the sagebrush ecosystem, less than half of the original distribution of sagebrush ecosystems currently exists (Knick and Connelly, 2011b; Pyke, 2011) making conservation of existing sagebrush habitats a priority. Consideration of modern habitat treatments in the context of historic treatments and disturbances, which can affect the regional distribution and condition of sagebrush at multiple scales, may be useful for planning, maintenance, and restoration of priority sagebrush habitats (albeit with different emphases depending on local conditions). Historic habitat treatments often focused on removal or reduction of sagebrush in favor of improved herbaceous cover and productivity (Knick and others, 2011), whereas modern-era treatments have focused on fire control and fuel mitigation, noxious species control, and surface (soil) stabilization. Between 1929 and 2004, more than 6,000 land and vegetation treatments (burning, mowing, chaining, cabling, chipping, logging, chemical application, furrowing, ripping, tillage, pitting, terracing, checks, scalping, and seeding) were conducted on BLM lands in Colorado, Idaho, Montana, Nevada, Oregon, and Wyoming[1] (BLM Range Improvement Project database, Knick and others, 2011), which represents a large and coordinated effort to manipulate vegetation composition and structure, increase productivity, improve forage-browse quality, rejuvenate old growth, remove noxious or poisonous species, and manage structure and composition to protect buildings and manage fuels (Knick and others, 2011).

Although rangewide compilation of precise acreage and locations of historic treatments does not exist, recent estimates suggest more than 4,000 km^2 (988,400 acres) were treated within these States between 1997 and 2006 (617,750 acres [2,500 km^2] of prescribed burns; 346,000 acres [1,400 km^2] of mechanical fuel treatments; and 154,700 acres [626 km^2] of mechanical habitat treatments). This results in an estimate of more than 8.15 million acres (33,000 km^2) treated (approaching 12 percent of sage-grouse habitat area based on mean values and a data-limited estimate of a highly variable activity). Vegetation manipulations were more prominent during the post-war (WWII) era, circa 1940–60, making this extrapolation based on modern treatment areas a conservative estimate.

Accumulation of habitat treatments across a targeted landscape may outpace natural disturbance (Manier and others, 2005), suggesting that natural and anthropogenic disturbance history could be considered together for a comprehensive perspective on disturbance patterns and processes (capturing spatial and temporal dynamics) that influence sage-grouse habitats. Although treatments may have varied post-treatment effects, management treatments are typically designed to mimic natural processes, such as stimulating post-disturbance regeneration and (or) creating post-disturbance hazard levels (Baughman and others, 2010), without negative effects on public safety (for example, due to wildfire). Treated areas often have lasting effects that accumulate across the landscape and can affect resource use patterns for many years (Miller, 2008; Hess and Beck, 2012; Beck and others, 2012; Chong and Anderson, 2010). Comprehensive (accurate and inclusive) records for historic treatments have not been compiled or published at this time (making accurate assessment of historic effects impossible, currently); however, local planning and management efforts may incorporate this information when available. Importantly, due to perceived threat of wildfire and strong similarities in the detrimental effects of prescribed fire, mechanical and chemical treatments on habitat value for sage-grouse, "an immediate and potentially long-term result [of treatments in sagebrush habitats] is the loss of habitat" (U.S. Fish and Wildlife Service, 2010b).

Current treatments and active vegetation management typically focus on vegetation composition and structure for fuels management, habitat management, and (or) productivity manipulation for improving the habitat and forage conditions for ungulates and other grazers, for example thinning sagebrush cover or treating invasive plants (Knick and others, 2011). Locally and cumulatively across a region, the distribution of these treatments can affect the distribution of sage-grouse and sagebrush habitats by affecting the distribution of suitable cover and forage. Therefore, regional land-use plans that consider the distribution, composition, and condition of sage-grouse habitat (and potential for restoration), along with economic and planning criteria, may be able to improve habitat conditions using spatial patterns, habitat conditions, and treatment methods.

In addition to landscapes with large, intact patches of sagebrush, sage-grouse require high-quality habitat conditions including a diversity of herbaceous species, vegetative and reproductive health of native grasses, as well as an abundance of sagebrush, making management for high-condition in seasonally important habitats a priority; recent and ongoing management activities have sought to address these values making current activities relevant as they assist natural processes to recover from past disturbances. Residual vegetation cover, especially grass and litter, has often been noted as essential for concealment during nesting and brood-rearing (Sveum and others, 1998a; Sveum and others, 1998b; Kirol and others, 2012), suggesting opportunities to improve herbaceous cover (without sacrificing safety of sagebrush cover) may benefit fecundity. For example, adjusting timing and duration of livestock use to support quality conditions during seasonal use (that is, reduce or eliminate spring grazing in nesting and brood-rearing areas). Passive restoration is typically the most affordable approach to restoration treatment because it does not require directed human activities but rather depends on adjustments in processes and management structure that can be imparted through revised use strategies (Connelly and others, 2004, p.320). "The greatest land-use adjustment within the sage-grouse region that might bring about passive restoration is to change livestock management, largely because of the prevalence of livestock grazing as a land use" (Pyke, 2011, p. 537). A previous review of literature discussed positive *and* negative impacts of grazing on sage-grouse habitats (Beck and Mitchell, 2000) and indicated that simple modifications (such as removing livestock) may not have the desired consequences for habitat conditions (also see Section III. A9. Grazing). They suggested that treatments (prescribed fire, mechanical, and herbicide) that eradicate large areas of sagebrush be ceased but also indicated that thinning dense sagebrush down to

[1] Not all of these treatments were in sagebrush habitats (but we are unable to separate them at this time) so for these States these values may overestimate treatments in sagebrush; however, Calif., N. Dak., N. Mex., S. Dak., and Utah were excluded from this calculation as these States have lower ratio of sage to other types on BLM lands (for example, grasslands and woodlands); thus, we underestimate contribution to rangewide assessment by excluding these States leading to some balance in this index. These values are clearly not precise, but help provide context.

approximately 15-percent cover can support herbaceous production as well as provide sufficient cover for sage-grouse in Wyoming sagebrush communities (Beck and Mitchell, 2000). Patchy applications are better than large, homogeneous burns, but the most xeric sites should be avoided; herbicide treatments and seeding of native species will be effective in many areas (Beck and Mitchell, 2000). If historic alteration of the habitat has not been too severe, then adjusting management practices (the grazing system or seasonal recreation closures, for example) has a reasonable chance of improving degraded or altered habitat conditions (Connelly and others, 2004). Though individual activities do not typically alter landscape-scale habitat patterns, treatment areas and effects can accumulate with regional effects; revised treatment approaches that consider landscape distribution of habitat and disturbances can help insure a controlled, positive effect of treatments on sage-grouse populations.

Because local priorities may include improved connectivity or increased habitat area, active restoration treatments may be warranted if target areas have transitioned into new vegetation states or other degradation of the site has occurred (Pyke, 2011). Site degradation may be severe in some locations such that critical soil-surface horizons have been reduced or lost, or establishment of “undesirable” species has been sufficient to displace native species, requiring direct manipulation and making passive management approaches unsuitable (Connelly and others, 2004). For example, if invasive species (for example, cheatgrass) or native species (for example, junipers, pinyon pines, and rabbitbrush) have replaced desirable dominant species, as is common in parts of the Great Basin, Snake River Plain (MZs III and IV) and elsewhere, then active removal of the invaders and seedings of native species may be required for successful restoration (Connelly and others, 2004). Importantly, given the limited distribution of suitable sagebrush habitats and the cost of habitat restoration treatments, management plans that strategically protect intact sagebrush and restore impacted areas to enhance existing habitats (for example, connectivity of intact sagebrush) have the best chance of increasing the amount and quality of sagebrush cover and creating management flexibility in the future. Recognition of the relative condition and potential value of habitats can help determine options and priorities among regional and adjacent treatment areas and support considerations of cost, benefit, and risk. A treatment and restoration matrix represents a basic set of conditions and associated restoration options to guide scoping and preliminary planning steps (table 24). Further, distinction of well-directed, designed, and located treatments from historic treatments (with alternate goals but similar names) is useful for clarity in assessment and planning.

A12. Other Land Uses

Recreation

Dispersed recreation activities (including but not limited to off-highway vehicles, camping, bicycling, and hunting), which utilize the extensive network of official and unofficial roads, have an extensive and difficult-to-measure impact on sagebrush and sage-grouse (also see Section III. A4. Infrastructure). Potential impacts include noise (Blickley and others, 2012), distribution of invasive plants, (With, 2004; Christen and Matlack, 2009; Bradley, 2010; Huebner, 2010), generation of fugitive dust (Gillies and others, 2005; Lee and others, 2007; Ouren and others, 2007; Padgett and others, 2008), and effects on predator and prey behavior (Gavin and Komers, 2006; Poulin and Villard, 2011; Whittington and others, 2011). Uninhabited areas within the Great Basin ecoregion (MZs III and V) decreased 90 percent (22.2 million acres [90,000 km^2]) to less than 3 million acres (12,000 km^2) with expansion driven by economic and recreation opportunities in the region (Knick and others, 2011); similarly, population densities have increased 19 percent in the Wyoming Basin region (MZ II) and 31 percent on the Colorado Plateau (MZ VII) since 1920 (Knick and others, 2011). With expanding populations comes greater human impacts (Leu and others, 2008), which is magnified by popular access to public lands (Hansen and others, 2005) and dispersed uses that expand the human footprint. Impacts of roads and motorized trails include mortality due to collisions, behavior modifications due to noise, activity and habitat loss, alteration of the physical environment, leaching of nutrients, erosion, spread of invasive plants, and increased use and noise due to accessibility (Knick and others, 2011). Closing unused and unnecessary roads in and around sagebrush habitats (for example, seasonal closure of specified sage-grouse habitats) may reduce the footprint and associated impacts to wildlife. Restricting access to important habitat areas based on seasonal use and coincident with sage-grouse activities (for example, lekking, nesting, brood-rearing, and wintering) may decrease the impacts associated with humans but will not eliminate other impacts such as spread of invasive plants, predator movements, loss of cover, and erosion. Although specific work addressing effects of roads, trails, and OHV use on sagebrush habitats and sage-grouse has not been conducted, research suggests common effects including habitat loss and fragmentation, invasive plant spread, induced displacement or avoidance behavior, creation of movement barriers, noise, and direct encounters (Knick and others, 2011) and reducing the extent and influence of roads and trails can be incorporated into near-term and long-term plans for consolidating, conserving, and improving priority habitat areas. Other human-dimensions approaches may also prove valuable whereby closures and restrictions may be avoided by adjusting user behaviors through education and voluntary behavior changes.

Training Facilities

There are 87 Department of Defense (DoD) managed facilities distributed across the Sage-grouse Conservation Area with various operations and intensity of use among and within those facilities. Obvious land-use impacts were evident on approximately 17 percent of those lands, leaving substantial

Table 24. Interpreting range condition for treatment and restoration: An adaptable and consistent decision matrix using vegetation and soil characteristics[*].

Level of implementation for restoration.[1]	Good to High Condition, little departure from reference conditions	Moderate to Good Condition, some departure from reference conditions but some important components remain	Poor Condition, Change in Dominance, full departure from reference conditions, typically associated with change of system state
	Description		
Differences may be ascribed to good range conditions reducing need, complicating environmental factors that reduce potential and (or) social-political-management factors that limit options.	*Structural and functional groups of vegetation are present—relative abundance and vigor of populations may vary; minor exotic/invasive species component may be part of pre-existing vegetation.*	*Functional or structural vegetation groups may be missing, under-represented, or in decline; invasive plants may be common but not dominant such that natives have been entirely displaced.*	*Sagebrush and tall grasses (usu. native) are missing or rare; invasive species dominate large areas; soil stability, water, and nutrient retention are likely altered; disturbance regimes may be altered.*
Low effort	Minimal actions: maintain status and protect intact shrub stands (for example, from wildfire), monitor and treat invasive species, monitor productivity and grazing intensities to reserve appropriate cover. Adjust management as necessary to maintain status.	Passive Restoration, including rest from grazing may be supplemented with localized (small areas) treatments or restoration actions. If habitat and range conditions are not improved consider increasing Active Restoration.	Active Restoration required. Prioritize based on regional habitat distribution and spatially explicit strategic planning; Potential for success with minimal (less) effort exists if soil quality and condition is good, invasive species control is possible and practical (not cost prohibitive).
Moderate effort	Minimal actions: maintain status and protect intact shrub stands (for example, from wildfire), monitor and treat invasive species, monitor productivity and grazing intensities to reserve appropriate cover. Increase effort and alter management if condition decline is documented or suspected.	Passive Restoration, including rest from grazing may be supplemented with localized (small areas) treatments or restoration actions. If habitat and range conditions are not improved consider increasing Active Restoration.	Active Restoration required. Prioritize based on regional habitat distribution and spatially explicit strategic planning; Potential for success with minimal (less) effort exists if soil quality and condition is good, invasive species control is possible and practical (for example, not cost prohibitive).
High effort	Minimal actions: monitor and treat invasive species, monitor productivity and grazing intensities to reserve appropriate cover, maintain status and protect intact shrub stands (for example, from wildfire). Implement Passive Restoration and consider further altering management if condition decline is documented.	Passive Restoration recommended unless significant funds and motivation exist (for example, industrial site reclamation) for conducting Active Restoration of soils and vegetation. No change in action (for example, grazing rotation) will be the best practice in many areas—to avoid a sudden change in disturbance regime and (or) exotic species invasion.	Unless significant funds and motivation exist (for example, industrial site reclamation) for conducting Active Restoration of soils and vegetation, inventory and reclassification is recommended. New management plans may be developed based on the new designation.

[*]Adapted from Pyke (2011).

[1]Field estimation and comparison of results to models and (or) reference conditions is required for accurate determination of position within this matrix.

portions of some facilities available for conservation and management of native species (Knick and others, 2011). However, only 26 percent (1.68 million acres [6,815 km^2]) of DoD facilities in the region are sagebrush dominated, and thus they represent only 0.01 percent of the currently estimated sage-grouse range (165.5 million acres [670,000 km^2] total area). Whereas the land-use and conservation activities of DoD may have important local effects on the distribution of sage-grouse habitats (including effects on disturbance regimes) as well as some populations (for example, the Saylor Creek Range in Idaho), they represent only a small portion of the species' range and therefore a small component of the conservation effort. Localized effects include woody plant eradication due to high-frequency fire returns (munitions testing and training) and fine-scale fragmentation due to concentrated, repeated vehicle maneuvers (Knick and others, 2011).

Factor B. Population Overutilization

In their review of threats to sage-grouse, USFWS recognized potential for "Overutilization for Commercial, Recreational, Scientific or Educational Purposes" as limited and not likely a factor (Valone and others, 2002) in the rangewide decline of sage-grouse. However, USFWS also recognized the ability of hunting to have significant effects on some populations, and further, the potential for interactive effects with indirect pressures from land-use development and other direct pressures, including predation and disease, makes close monitoring and annual adjustment of harvest rates a potentially important aspect of local population management. Importantly, sage-grouse are not currently commercially exploited anywhere in their range, and hunting of this species is prohibited in Canada and Washington. The other States within the species' range have direct management authority over hunting, which is exercised through Fish and Game Divisions (see Section IV. Factor D). Utilization of sage-grouse populations includes hunting, religious and traditional uses, and research and education; the number of animals affected by hunting far outweighs the number of mortalities associated with traditional, research, and educational activities, which have been considered and were deemed insignificant. Therefore, hunting practices and regulations are primarily discussed here.

To put hunting mortality in perspective, we recognize that sage-grouse, like other upland game birds, are exposed to a variety of predators including corvids (for example, common raven, *Corvus corax*), raptors (for example, golden eagle, *Aquila chrysaetos*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*), badger (*Taxidea taxus*), weasels (*Mustela* spp.), ground squirrels (*Spermophilus* spp.), bobcat (*Lynx rufus*), western rattlesnake (*Crotalus viridus*), and bull snake (*Pituophis catenifer*) (Connelly and others, 2011a). Most mortality of sage-grouse is caused by predators during spring, summer, and fall seasons with limited mortality observed during winter months. Despite these natural pressures, significant mortality can be associated with hunting (Connelly and others, 2000b; Connelly and others, 2011a, p.66; Gibson and others, 2011). Hunting is generally concentrated during short periods of time in the fall, but several indigenous American tribes occasionally harvest animals in spring months. Besides concerns over additive mortality effects, which account for direct reductions in population numbers, research has documented potential bias towards adult-female mortality due to hunting, in particular, with an estimated 42 percent of seasonal female mortality associated with harvest practices (compared to 15 percent in males) in Idaho; however, this differentiation was not observed in Montana and Wyoming (Connelly and others, 2011a). If widespread and consistent, adult female bias could have important effects by altering the reproductive capacity of populations (Connelly and others, 2000b); further research and monitoring are needed along with potential for adjustment to harvest regulations, if warranted. At this time, "[n]o studies have demonstrated that hunting [or any other direct utilization] is a primary cause of reduced numbers of Greater [S]age-[G]rouse" (Reese and Connelly, 2011, p.101), but evidence indicates significant variability in the abundance and distribution of birds through time and across landscape units, including decreased survival in October (hunting season) in some populations (Sedinger and others, 2011). Elucidation of connections between sage-grouse populations, habitat conditions, and mortality factors, including harvest, will require well-designed and implemented studies that can separate contributing factors.

B1. Hunting

In recent decades, as information about sage-grouse mortality, survival, and reproductive rates has improved, and paradigms regarding population management were adjusted as State wildlife management agencies responded to population dynamics and declining population numbers by reducing annual harvests. Wyoming, Utah, Idaho, Oregon, Montana, and California reduced harvests in recent years through various regulatory mechanisms; Washington no longer permits harvest of sage-grouse, and Colorado, Nevada, North Dakota, and South Dakota have retained fairly consistent regulations during the past decade (Reese and Connelly, 2011). Nevada has closed several counties and hunting units to sage-grouse hunting (including Bi-State population protections) in the past 20 years. Sage-grouse have not been commercially harvested since the 1930s; therefore, commercial hunting does not currently affect sage-grouse population dynamics (U.S. Fish and Wildlife Service, 2010b). Recent work comparing populations with consistently different harvest structures indicated that populations in areas closed to hunting had growing breeding populations, whereas areas open to hunting had declining population growth rates, even under moderate rates of harvest (Connelly and others, 2003a). Importantly, hunted populations within this study demonstrated both decreasing trends and increasing trends during the 6-year study, emphasizing the importance of *local* factors for determining harvest levels and the need to balance mortality within the tolerance of each population (Connelly and others, 2003a; Sedinger and others, 2010).

Approaches and concepts used in upland small game management were developed early in the 20th century (circa 1930s), and these early approaches employed little empirical evidence and a single universal paradigm to establish harvest rates (Strickland and others, 1994; Reese and Connelly, 2011). These early approaches assumed that all small game populations exhibited high reproductive rates and low year-to-year survival, thereby suggesting that hunting, even at high-harvest levels, was compensatory to over-wintering mortality (that is to say, winter survival rates account for greater mortality than hunting; therefore, there is no net effect on the population due to hunting). Based on this paradigm, harvest regulations have varied tremendously over time and from State-to-State during the past 100 years, including a population crash and subsequent recovery in the late 1800s (Reese and Connelly, 2011). As research and harvest data for sage-grouse began to increase, evidence indicated that in some situations, harvest *can* have an *additive* effect on mortality, and the in mid-1990s, revised estimation of sage-grouse vital rates (life-span, mortality, and survival) caused Idaho and Wyoming to reduce the number of harvested animals (Reese and Connelly, 2011) to avoid additive mortality effects. Recent estimates and comparison of mortality rates for two populations, in Colorado and Nevada, found no evidence for additive mortality due to existing hunting of those populations (Sedinger and others, 2010).

Monitoring of harvest demographics along with lek counts and targeted population research combined have contributed to understanding of the dynamics of sage-grouse populations at landscape scales, including calculation of sex and age ratios, nest and brood success rates, and seasonal mortality (Autrienth, 1981). Further, hunters and hunting associations represent important supporters of wildlife conservation efforts from a range of social and political backgrounds; this constituency can be important for species conservation (Reese and Connelly, 2011). Nonetheless, appropriate harvest rates have not been determined for sage-grouse populations region-wide; however, several studies have addressed this issue (Autrienth, 1981; Crawford, 1982; Braun and Beck, 1985; Connelly and others, 2000a). Since public interest, population data, and management funds are derived from harvest of sage-grouse, hunting might be a part of conservation management in the future, for instance, if population numbers exceed suitable habitat. However, because populations appear to respond positively when released from hunting pressure, relief from hunting may remain a useful management strategy for populations with multiple, interacting stressors.

B2. Religious and Traditional

Several indigenous American tribes harvest sage-grouse populations within their jurisdictions associated with ceremonial practices and subsistence. Annual hunting occurs on the Wind River Indian Reservation (Wyoming), the Shoshone-Bannock Reservation (Idaho), and formerly on the Duck Valley Indian Reservation (Idaho-Nevada) (U.S. Fish and Wildlife Service, 2010b). Harvest activities on the Duck Valley Indian Reservation were suspended after West Nile virus caused precipitous population declines, demonstrating the ability of local governance bodies to respond to population estimates and adjust harvest practices accordingly. Harvest on the Wind River Reservation was limited to males on leks through 2009, and was perceived to have little to no measureable effect on the local populations; and all hunting on the Reservation has been closed at the recommendation of USFWS, due to population declines (Hnilicka, USFWS, Lander, Wyo., oral commun. April 2013). There are no known harvests of sage-grouse by indigenous tribes in Colorado, Oregon, North Dakota, South Dakota, or Washington (U.S. Fish and Wildlife Service, 2010b).

B3. Science and Education

Dozens of scientific studies have been conducted on sage-grouse, including at least 50 that have directly handled birds. Based on 2005 estimates, the mortality rate due to capture, handling, or radio-tagging process was approximately 2.7 percent of capture rate (68 mortalities of 2,491 captured) (U.S. Fish and Wildlife Service, 2010b); there is no evidence that this level of mortality causes measureable impacts on sage-grouse populations. Efforts to re-establish populations in several U.S. States and British Columbia documented translocation of more than 7,000 birds (Reese and Connelly, 1997); however, only 5 percent of these were successful in producing sustained resident populations, thus indicating high mortality risks and limited benefits from these activities (Reese and Connelly, 1997). However at least one translocation effort (Strawberry Valley, Utah) demonstrated greater success with estimated 60-percent survival rates (Baxter and others, 2008). Based on the low number of translocated animals distributed across many years, and the low number of mortalities associated with research and restoration activities relative to population totals and other sources of mortality, USFWS indicated that research and education effects on source populations were minimal (U.S. Fish and Wildlife Service, 2010b).

Factor C: Population Disease and Predation

Disease

Although sage-grouse are host to a wide array of parasites and pathogens, including macroparasitic arthropods, helminthes, and microparasites (protozoa, bacteria, viruses, and fungi) (Thorne and others, 1982; Connelly and others, 2004; Christiansen, 2011), little effort was devoted to the monitoring of disease in sage-grouse prior to the emergence of West Nile virus (WNv). As such, few records exist to reveal the role disease may have played in population declines of sage-grouse (Connelly and others, 2004; Christiansen, 2011; Connelly and others, 2011c). Thorough reviews of disease impacts on sage-grouse can be found in Christiansen and Tate (Wyoming Executive Order) and Connelly and others (2004). Ectoparasites supported by sage-grouse include lice, ticks, and dipterans (Connelly and others, 2004; Christiansen, 2011; Connelly and others, 2011c). Most ectoparasites cannot produce disease but serve as vectors of transmission and can be detrimental if the bird is stressed (Thorne and others, 1982; Peterson, 2004). High louse concentrations have been shown to limit breeding opportunities of male sage-grouse due to female avoidance of affected males and may therefore potentially impact the genetic diversity of the species (Boyce, 1990; Deibert, 1995; Connelly and others, 2011c).

Two internal parasites have caused fatalities in sage-grouse: the disease coccidiosis is spread via protozoans *Eimeria spp.* (Connelly and others, 2004; Hagen and Bildfell, 2007) and possibly ixodid ticks (*Haimaphysalis cordeilishas*). A tularemia (*Francisella tularenis*) outbreak coincided with the mortalities attributed to an ixodid tick infestation (Parker and others, 1932; Christiansen, 2011). It is likely that the tularemia, in combination with the high number of ticks feeding on the birds, resulted in bird mortalities (Christiansen, 2011). This is the only reported case of tularemia in sage-grouse. Coccidiosis, though not common today, was once prevalent throughout sage-grouse range (Christiansen, 2011). This parasite causes decreased growth and significant mortality in young birds (Thorne and others, 1982; Connelly and others, 2004; Christiansen, 2011). Those birds that survive appear to develop immunity from subsequent infections (Thorne and others, 1982; Connelly and others, 2004). Outbreaks of coccidiosis have been clustered in areas where large numbers of birds gather causing the soil and water to become contaminated with fecal material (Scott, 1940; Honess, 1968; Connelly and others, 2004; Christiansen, 2011) and may regulate small, isolated populations of grouse (Peterson, 2004). Some researchers suggest that the decline in coccidiosis cases is directly related to the declining density of sage-grouse (Christiansen, 2011).

Bacteria and fungi can also occur in sage-grouse (Scott, 1940; Honess, 1968; Hausleitner, 2003; Connelly and others, 2004; Peterson, 2004; Hagen and Bildfell, 2007; Christiansen, 2011), but none currently play a role in limiting sage-grouse populations. This may change if environmental conditions result in greater concentrations of birds, leading to contamination of water supplies with fecal material (Christiansen, 2011). Prior to 2002, avian infectious bronchitis was the only identified virus infecting sage-grouse, and no clinical signs were noted (Peterson, 2004). West Nile virus (WNv) was introduced into North America in 1999 (Marra and others, 2004) and was first documented in sage-grouse in 2002 (Walker and Naugle, 2011). Although the disease is presently patchily distributed, it represents the only active disease that threatens sage-grouse populations with heavy mortality (U.S. Fish and Wildlife Service, 2010b). Sage-grouse are highly susceptible to WNv and suffer high rates of mortality (Clark and others, 2006; McLean, 2006). For example, data from four studies showed a 25 percent decline in sage-grouse numbers in July and August of 2003 (Naugle and others, 2004) and decline in male and female lek attendance in 2004 (Walker and others, 2004). Populations not exposed to WNv did not experience a similar decline. Deaths from WNv occur in mid-summer, a time when survival is typically high (Schroeder and others, 1999; Aldridge and Brigham, 2003a) making these losses additive and reducing annual survival (Naugle and others, 2005). These data suggest that WNv could contribute to local population extirpation (Walker and others, 2004; Naugle and others, 2005). Resistance to WNv is very low with exposure to the virus typically resulting in mortality of sage-grouse (Clark and others, 2006; Walker and Naugle, 2011). It is unknown if birds surviving exposure to WNv develop immunity to future exposure (Clark and others, 2006; Walker and Naugle, 2011) or if residual effects such as reduced productivity or overwinter survival occur (Walker and others, 2007b).

The distribution and probability of WNv outbreak in these rural semiarid environments is poorly understood; however, the WNv life-cycle provides applicable insights. The primary vector of WNv in sagebrush ecosystems is the mosquito *Culex tarsalis* (Naugle and others, 2004; Naugle and others, 2005; Walker and Naugle, 2011). WNv persists through a mosquito-bird-mosquito infection cycle (McLean, 2006), although bird-to-bird transmission has been observed (McLean, 2006; Walker and Naugle, 2011). The severity of WNv outbreaks and the transmission of the disease are primarily regulated by environmental factors including temperature, precipitation, and proximity to anthropogenic water sources, which support mosquito larvae (McLean, 2006; Reisen and others, 2006; Walker and Naugle, 2011). Mosquito activity and virus amplification is hindered by cold temperatures, restricting transmission to the summer months (Naugle and others, 2005; Zou and others, 2007). Cooler ambient temperatures at higher elevations and in more northerly locations may reduce the exposure risk of sage-grouse living in these areas (Naugle and others, 2004; Naugle and others, 2005; Walker and Naugle, 2011).

Although *C. tarsalis* is able to overwinter and individual mosquitos emerge as infected adults in the spring (Clark and others, 2006; Walker and Naugle, 2011), the species is dependent on the availability of warm pools of water for larval development. As such, the ongoing proliferation of anthropogenic surface-water features (stock ponds, coal bed methane discharge ponds, irrigated agricultural fields, and so forth) could help maintain or possibly increase the occurrence of WNv on the landscape (Friend, 2001; Zou and others, 2006; Walker and others, 2007b; Walker and Naugle, 2011). Mosquitoes are able to disperse up to 18 km (11.2 mi) from their larval pond (Clark and others, 2006; Walker and Naugle, 2011) implying that the entire sage-grouse range could potentially be exposed to the virus and that the prevalence of it will likely increase (U.S. Fish and Wildlife Service, 2010b). If minimizing the impact of WNv on sage-grouse is warranted due to local population dynamics, controlling the number of mosquitos emerging from anthropogenic water sources and reducing availability of these water features as habitat may be important options. Sage-grouse do not require standing water

(Schroeder and others, 1999; Connelly and others, 2004); therefore, the practice of placing water developments in arid landscapes for the benefit of sage-grouse may be reduced or eliminated (Clark and others, 2006; Walker and Naugle, 2011) without expectation of population impacts. Water sources may have specific value for managing some landscapes, but the threat of spreading WNv through anthropogenic water sources indicates consideration of control or mitigation to discourage breeding mosquitos either through construction, modification, or management (Doherty, 2007) may be warranted. The biting midge *Culicoides sonorensis* has also been identified as a possible vector of WNv (Schmidtmann, 2005); this species requires muddy banks to lay its eggs and therefore may particularly be a factor in areas with large numbers of stock ponds. *C. sonorensis* is an important vector of blue-tongue in ruminants, and though it is not known if they actively feed on avifauna, WNv was found in a midge sample from the Powder River Basin, Wyoming (Schmidtmann, 2005). Because of the large number of water sources and their widespread distribution, mitigation measures may be cost prohibitive (U.S. Fish and Wildlife Service, 2010b), but may be warranted when sage-grouse populations are small, isolated, or genetically limited (U.S. Fish and Wildlife Service, 2010b). Caution is warranted when employing mosquito control to ensure that benefit from reducing the occurrence of WNv is not overshadowed by cascading ecological effects (Marra and others, 2004). WNv fowl vaccines were tested in captive birds and were largely ineffective (Clark and others, 2006; Walker and Naugle, 2011). Development of a sage-grouse specific vaccine would require market incentive and would likely not be practical for large-scale deployment (U.S. Fish and Wildlife Service, 2010b).

Models suggest that the prevalence of WNv is likely to increase throughout the range of sage-grouse as the number of anthropogenic water sources and ambient temperatures increase (U.S. Fish and Wildlife Service, 2010b). Sage-grouse populations will respond differently to WNv infections depending on factors that affect exposure and susceptibility (Clark and others, 2006; Walker and Naugle, 2011). Though larger populations may be able to absorb losses from WNv as long as available habitat is sufficient (Clark and others, 2006; Walker and Naugle, 2011), a WNv outbreak in small, isolated, or genetically limited populations may be devastating and could reduce a population beyond a point where recovery is possible (Clark and others, 2006; Walker and Naugle, 2011).

Sage-grouse gather in mesic habitats during the mid-to late summer (Connelly and others, 2000c) making them potentially more vulnerable to all of the pathogens discussed. More dispersed populations in less arid habitats may not suffer the same threats. Historically, obvious morbidity and mortality in sage-grouse caused by the pathogens discussed above was tied to higher concentrations of sage-grouse localized near water sources during dry conditions (Scott, 1940; Honess, 1968; Connelly and others, 2004; Christiansen, 2011). "Likely" climate-change scenarios, according to the Intergovernmental Panel on Climate Change (IPCC, 2007), suggest the impacts of disease on sage-grouse could increase (Neilson and others, 2005) as habitat conditions become limiting due to increased temperatures and drought conditions predicted to occur across the sagebrush biome (IPCC, 2007). If realized, these conditions could particularly limit the availability of mesic areas, potentially leading to high densities of sage-grouse around these areas and other anthropogenic water sources. Past outbreaks of bacterial infections, coccidiosis and WNv, have been linked to such circumstances.

Predation

Typically sage-grouse live between 3 and 6 years, with individuals up to 9 years of age reported in the wild (Connelly and others, 2004). Predation is commonly identified as the primary cause of direct mortality for sage-grouse at all life stages (Schroeder and others, 1999; Connelly and others, 2000; Connelly and others, 2011), but there is little published support for predation being a limiting factor in sage-grouse populations (Connelly and others, 2004), particularly in areas where there is high-quality habitat (Hagen, 2011). Sage-grouse have co-evolved with a suite of predators, including coyotes (*Canis latrans*), badgers (*Taxidea taxus*), bobcats (*Felis rufus*), and red fox (*Vulpes vulpes*). Several raptor species are common predators of juvenile and adult sage-grouse (Patterson, 1952; Schroeder and others, 1999; Schroeder and Baydack, 2001), and coyote, badger, common raven (*Corvus corax*), and black-billed magpie (*Pica hudsonia*) are regular nest predators. Ground squirrels (*Spermophilus* spp.) were once thought to be major nest predators, but recent evidence indicates that the mandibles of some ground squirrel species are physically unable to puncture sage-grouse eggs (Holloran and Anderson, 2003; Coates, 2007). The degree and significance of snake predation on sage-grouse nests is unknown (Holloran and Anderson, 2003; Coates, 2007). Cryptic coloration, habitat selection, and behavioral patterns have allowed sage-grouse to persist throughout sagebrush habitats (Schroeder and others, 1999), co-existing with these predators. Although sage-grouse have a number of predators, none are known to focus on sage-grouse as a primary food source. Most predators of sage-grouse depend primarily on rodents and lagomorphs (Schroeder and others, 1999); however, alternate prey, such as sage-grouse, may still experience high-predation rates either because they are targeted when the primary prey become scarce or if predators kill indiscriminately as predator numbers increase (Norrdahl and Korpimaki, 2000).

Male sage-grouse have the greatest exposure to predation at leks (Schroeder and others, 1999; Schroeder and Baydack, 2001; Hagen, 2011) where they congregate and perform conspicuous mating displays. The concentration of birds present may attract a variety of predators and affect grouse-avoidance behavior (Aspbury and Gibson, 2004; Boyko and others, 2004). Because of the disproportionate predation on males during the breeding season, female sage-grouse have a longer life expectancy (Schroeder and others, 1999). Female sage-grouse are more susceptible to predators while nesting, but mortality rates are low as hens will abandon their nests when disturbed by predators (Hagen, 2011). Predation on sage-grouse outside of the lekking, nesting, and brood-rearing periods is rare (Connelly and others, 2000a; Moynahan and others, 2006; Hagen, 2011). The highly polygynous nature of sage-grouse suggests that sage-grouse populations are more sensitive to predation upon females (U.S. Fish and Wildlife Service, 2010b) because only a few males per lek breed each year. Predation of breeding hens and young chicks may negatively affect sage-grouse population numbers as these two cohorts are the most significant contributors to population productivity (Baxter and others, 2008; Connelly and others, 2011a).

Human encroachment into sagebrush habitats has affected the predator–sage-grouse dynamic. The act of altering the landscape can create an influx of predators into an area and lead to a decline in annual recruitment (Gregg and others, 1994; Delong and others, 1995; Braun, 1998; Schroeder and Baydack, 2001; Coates, 2007; Hagen, 2011). Predators that are closely associated with human development, red fox and corvids, have increased in abundance over the sagebrush landscape (Sovada and others, 1995). These species in particular have been shown to be efficient predators of nests and juvenile sage-grouse (Schroeder and others, 1999). As sage-grouse habitat is lost or fragmented due to energy development, agriculture, or exurban development, quality nesting and brood-rearing habitat becomes restricted (Bui, 2009). The higher density of grouse in lower quality habitat combined with potentially easier predator access along roads, fence rows, edges, and trails, may make foraging easier for predators (Connelly and others, 2004; Holloran, 2005; Holloran and others, 2005; Aldridge and Boyce, 2007; Bui, 2009). In addition to habitat loss and fragmentation, ranches, farms, and other housing developments have led to the introduction of domestic dogs (*Canis domesticus*) and cats (*Felis domesticus*) into sage-grouse habitats, both of which may prey upon grouse (Connelly and others, 2004; Holloran, 2005; Holloran and others, 2005; Aldridge and Boyce, 2007; Bui, 2009). Roads have been shown to be particularly efficient as mechanisms of distribution for predators throughout the sagebrush landscape. Some mammalian species (Forman and Alexander, 1998; Forman, 2000) and ravens (Knight and others, 1993; Connelly and others, 2004) have used these linear features to expand their distribution into previously unused regions, increasing the risk of predation to sage-grouse.

Nest predation has been linked to low herbaceous cover (Gregg and others, 1994; Delong and others, 1995; Braun, 1998; Schroeder and Baydack, 2001; Coates, 2007; Coates and others, 2008; Hagen, 2011). Sage-grouse select nesting sites specifically based on the amount of grass and forb cover (Hagen and others, 2007) because it is needed to conceal the nest from predators. Reduction of grass height due to livestock grazing below 4 in. (18 cm) has been shown to negatively affect nest survival (Gregg and others, 1994). However, abundant cover has also been shown to facilitate badger predation because it attracts small mammals, the primary prey of badgers (Coates, 2007). Adequate grass and forb cover provides valuable hiding cover for young chicks (Schroeder and Baydack, 2001), a life stage during which mortality due to predation has been estimated to be highest, at 82 percent (Gregg and others, 2007).

To support maintenance of suitable grass and forb cover and minimize associated predation risks, careful monitoring of grazing allotments within sage-grouse nesting habitat may be coupled with livestock management to ensure suitable grass and forb cover is reserved. In addition, pasture fencing creates perching sites for raptors and corvids and travel corridors for coyotes and foxes, increasing predation risk across many habitats (Call and Maser, 1985; Braun, 1998; Connelly and others, 2000b; Beck and others, 2003; Knick and others, 2003; Connelly and others, 2004) and leading to habitat avoidance by sage-grouse (Call and Maser, 1985; Braun, 1998; Connelly and others, 2000b,; Beck and others, 2003; Knick and others, 2003; Connelly and others, 2004).

Similarly, power poles, towers, and fence posts provide attractive hunting and roosting perches for corvids and raptors (Steenhof and others, 1993; Connelly and others, 2000b; Manville, 2002; Vander Haegen and others, 2002; Connelly and others, 2004). Power poles can increase a raptor's range of vision and allow for greater speed during attacks, increasing their hunting efficiency (Steenhof and others, 1993; Connelly and others, 2000b; Manville, 2002; Vander Haegen and others, 2002; Connelly and others, 2004). After the installation of transmission lines, densities of raptors and corvids increased markedly (Ellis, 1985; Steenhof and others, 1993) as did predation on sage-grouse (Ellis, 1985; Steenhof and others, 1993). Power lines may also cause changes in lek dynamics, with lower growth rates observed on leks within 0.25 mi (0.4 km) of new power lines in the Powder River Basin of Wyoming as compared to those farther from the lines. This was attributed to increased raptor predation (Braun and others, 2002). Raptors and corvids forage on average 3.1 to 4.3 mi (5 to 6.9 km) from perching sites, potentially impacting 32 to 40 percent of the sage-grouse conservation area (Connelly and others, 2004). Removing or reducing the number of perching structures and landfills in key nesting, brood rearing, and lekking habitats may reduce predation pressure on sage-grouse (Bui, 2009; Leu, 2011).

Predator Control

Although there is little published information supporting the notion that predation is a limiting factor on sage-grouse (Connelly and Braun, 1997; Connelly and others, 2000b; Schroeder and Baydack, 2001), arguments continue to be made supporting predator control as an important management action (Wambolt and others, 2002). Additionally, relatively high annual survival rates of adult sage-grouse (0.59–0.77 for females, 0.37–0.63 for males) (Zablan and others, 2003) accompanied by documented ineffectiveness of coyote control in affecting nest survival in one area in Wyoming (Slater, 2003), further reinforce the idea that predation is not a widespread factor acting to depress sage-grouse populations. Where predator removal has been used as a management tool, higher numbers of sage-grouse have sometimes been observed in the fall, but these gains have not carried over to spring breeding populations (Cote, 1997; Hagen, 2011; Leu, 2011). The removal of coyotes in some areas has resulted in an increase in the numbers of mesopredators, which may have greater impacts on grouse populations (Mezquida and others, 2006). Similarly, raven removal in northeastern Nevada resulted in only short-term reductions in raven numbers (Coates, 2007), and any benefits to sage-grouse populations were negated by an increase in badger predation (Coates, 2007). Predator removal may be warranted in areas with low habitat quality (that is, heavily fragmented or areas of high anthropogenic disturbance) supporting inflated numbers of synanthropic predators; however, predator numbers will rebound quickly without continual control (Hagen, 2011).

Factor E: Pesticides and Contaminants

Because of the overlap between current cropland distributions and historically high-quality sagebrush habitats (deep loamy and sandy loam soils, valley bottoms, and wet meadows) and fidelity of sage-grouse populations to these habitats (Berry and Eng, 1985; Dunn and Braun, 1985; Fischer and others, 1993; Holloran and Anderson, 2005; Holloran and others, 2010), there can be considerable summer use of agricultural lands by sage-grouse even though current sagebrush cover may be relatively low. With these overlapping uses comes risk of poisoning by pesticides (Blus and others, 1989; Connelly and Blus, 1991) and other chemicals used in vegetation and pest management. Many of these factors may have indirect effects on health and fitness, in addition to the obvious effects on survival (Connelly and others, 2004; table 25).

Pesticides

Sage-grouse typically avoid human developments and highly cultivated landscapes; however, because these lands often replaced historically important habitats and remain adjacent to remaining sagebrush habitats, use of these areas characterized by “low nest success” and “poor chick survival” (due to increased risks) remains common on some landscapes (Aldridge and Boyce, 2007). Nonetheless, irrigated crops, hay, and pastures represent an attractive source of foods including insects, especially during drought years and later in the brood-rearing season when native forbs become desiccated (Hagen, 2007; Connelly and others, 2011d; Knick and others, 2011). Research using collared animals found that 18 percent of marked sage-grouse in Idaho used croplands adjacent to sagebrush habitat that had been sprayed by dimethoate and methamidophos (Blus and others, 1989). Posthumous assessments indicated 5 percent mortality in the first year and 16 percent in the following year due to organophosphorus poisoning. This research was focused in an area with extensive agricultural development adjacent to sagebrush habitats; therefore, similar concentrations may be anticipated in similarly developed areas, but this level of mortality would extend rangewide only with similar applications.

In addition to direct impacts of pesticides through direct contact (Blus and others, 1989; Connelly and others, 2004), reduction of important seasonal foods such as forbs and insects can affect the forage base (Eng, 1952; Connelly and others, 2004); therefore, effects on sage-grouse seasonal habitat requirements may be an important consideration for pest and pesticide management. Insects are an important component of early brood-rearing habitat (Patterson, 1952; Klebenow and Gray, 1968; Johnson and Boyce, 1991). A complete assessment of early brood-rearing habitat includes an evaluation of insect abundance because they are an important part of seasonal diets. A depauperate or undependable invertebrate resource base is likely to depress growth rates and brood-rearing success (Connelly and others, 2004); however, vegetation alteration due to insect population peaks (outbreaks) may have negative effects on the forage base (Ritchie and Tilman, 1992; Scherber and others, 2010) suggesting need for future evaluation and management adaptation regarding population interactions with insect herbivores.

Herbicides

In addition to pesticides, several herbicides are commonly applied in and around the sagebrush ecosystem; alteration of desirable components of the habitat may be targeted or unintentional depending on the vegetation targets, for example, sagebrush or invasive species. Many enhancement and sagebrush restoration treatments involved alterations that include the removal of sagebrush (Carr and Glover, 1970; Klebenow, 1970; Connelly and others, 2004) to increase the cover and productivity of herbaceous species in the treatment areas. Although these treatments continue in many areas, decreased emphasis on sagebrush removal or reduction and increased emphasis on reducing invasive plant-species distributions mean that some chemicals may be applied on, or adjacent to, priority habitat areas. Most modern chemicals are applied at levels expected to decay quickly with minimal soil residuals. For example 2,4-D (2,4-Dichlorophenoxyacetic acid) degrades rapidly with half-life values estimated at 1–14 days (Gervais and others, 2008; table 25); however, detectable residues can persist for up to a year (Tu and others, 2001). Similarly, other commonly applied chemical herbicides, such as Imazapic (Plateau®, American Cyanamid Co.), Tebuthiuron (Spike80®, Dow AgroSciences LLC), and Glyphosphate (Round-up®, Rodeo®, Monsanto Co.) that interrupt cell chemistry had minimal effects on test animals and decay quickly in the environment. Tebuthiuron may cause mild skin irritation in mammals but is essentially nonirritating (tested on rabbits and guinea pigs); single-dose oral toxicity is moderate in mammals (LD50 for rats is 488mg/kg), but it is not a known carcinogen (Dow AgroSciences, 1999). Glyphosphate inhibits enzyme and amino acid formation in chloroplasts of most plant species; these organelles are not present in animal cells making transferred toxicity unlikely. Glyphosphate has an average half-life

Table 25. Insecticides and herbicides certified for application and commonly applied on and around sagebrush habitats.

Chemical	Use	Direct/Acute Effects	Indirect Effects
Dimethoate	Pesticide, forage, seed alfalfa	Very Toxic (Blus and others, 1989)	Reduced availability of insects for food
Methamidophos	Pesticide, seed alfalfa, potatoes; US registration cancelled 9/23/2009	Very Toxic (Blus and others, 1989)	Reduced availability of insects for food
Malathion	Pesticide, grasshoppers	Toxic	Reduced availability of insects for food
Carbaryl	Pesticide, grasshoppers	Low to Moderately Toxic	Reduced availability of insects for food
Dimilin	Pesticide, grasshoppers	Low Toxicity	Reduced availability of insects for food
2,4-D	Herbicide, sagebrush thinning	Low Toxicity	Reduced sagebrush cover; reduced forb availability
Plateau ® (Imazapic)[1]	Herbicide, cheatgrass	No more than slightly toxic	Reduced forb availability
Spike ® (Tebuthiuron) [1]	Herbicide, sagebrush thinning	Low to Moderately Toxic	Reduced sagebrush cover
Roundup ® (Glyphosphate) [1]	Herbicide	No more than slightly toxic	Reduced sagebrush cover; reduced forb availability

[1] Imazapic, Tebuthiuron, and Glyphosphate have chemical actions that target plant physiology; it is highly unlikely that they have a direct effect on sage-grouse at levels typically applied (according to manufacturer instructions).

of 47 days (Tu and others, 2001). According to the manufacturers, direct exposure to these chemicals may cause eye irritation, absorption through the skin, and inhalation toxicity effects. They are not known to bioaccumulate in animals and are rapidly excreted in urine and feces rendering them mostly nontoxic to a wide range of nontarget organisms including mammals, birds, fish, aquatic invertebrates, and insects (Tu and others, 2001). Direct assessment of toxicity effects on sage-grouse have not been conducted, but existing information indicates little concern for direct effects of certified herbicides on sage-grouse health.

IV. Factor D: Policies and Programs Affecting Sage-Grouse Conservation

In 2010, a lack of adequate regulatory mechanisms was determined by the USFWS to be a substantial threat to sage-grouse in its 12-Month Findings for Petitions to List the Greater Sage-Grouse (U.S. Fish and Wildlife Service, 2010b). In an effort to address sage-grouse conservation needs, many agreements and partnerships have been established across the sage-grouse range with various levels of commitment, jurisdiction, and participation. The national efforts of the BLM and USFS were outlined at the beginning of this report. To support continued facilitation and integrated management across administrative and political boundaries, this section documents existing and proposed conservation efforts directed at sage-grouse, including regulatory and nonregulatory approaches by Federal, State, and local agencies, as well as private lands and, where appropriate, the threats those efforts seek to address. This section aims to provide land managers and agency planners with an overview of those conservation activities, programs, and regulations across the range so that local and regional planning efforts may be recognized and continuing coordination across political and administrative boundaries encouraged.

One of the key challenges in implementing sage-grouse conservation efforts is the mixed pattern of surface-land ownership and jurisdiction across the species' range (Knick and Connelly, 2011b). This patchwork of land ownership is a result of historical public land policies that have guided disposition of public lands in the Western United States since their settlement (Knick and Connelly, 2011b). With such diverse ownership across a large range (table 26), regulatory actions and policies aimed at sage-grouse conservation require coordination across traditional geopolitical and landownership boundaries; a given population of sage-grouse can migrate between privately owned land and land administered by numerous Federal and State agencies (Stiver, 2011). Each class of surface ownership carries different management requirements and objectives. Notably, the BLM and USFS manage approximately 53 percent of the surface area across the region, with BLM jurisdiction over approximately 44 percent of the sage-grouse range and USFS administration of 4 percent of the range (estimated using PPH and PGH; table 26). Therefore, more than 50 percent of the surface area across the range is managed for multiple (often competing) uses including requirements to balance commodity production with wildlife (Knick and Connelly, 2011). The USFWS is the only Federal agency with an exclusive wildlife conservation mandate; however, it manages only one percent of the species' habitat (Knick, 2011). A large percent (31 percent) of surface area within the sage-grouse range remains in private ownership (Knick, 2011). States and other Federal agencies and departments manage the remainder of the surface area within the range (Knick, 2011).

Rangewide Conservation Efforts

The range of the sage-grouse includes habitat within the United States and Canada, with 99 percent of the current population found in the United States and the remaining 1 percent found in Canada (Stiver and others, 2006a). However, because the sage-grouse is not considered to be a migratory species, it is not afforded the protections of the Migratory Bird Treaty Act (16 U.S.C. § 703 *et seq*.; U.S. Fish and Wildlife Service, 2010b).

Though not regulatory mechanisms, a series of Memoranda of Understanding (MOUs) have been entered into by various State and Federal agencies that acknowledge the collaboration among the signatories. The partnerships formed by the MOUs have produced a rangewide conservation framework (Stiver, 2011). In 2004, the Western Association of Fish and Wildlife Agencies (WAFWA) in cooperation with the USFS, BLM, USFWS, and USGS (U.S. Geological Survey), published the Conservation Assessment of Greater Sage-Grouse and Sagebrush Habitats (Connelly and others, 2004), a comprehensive, ecologically focused analysis that documented the current status and potential factors influencing the long-term conservation of sage-grouse populations and sagebrush ecosystems. In 2006, WAFWA released the Greater Sage-Grouse Comprehensive Conservation Strategy (Stiver and others, 2006a), which includes seven substrategies to "maintain and enhance populations and distribution of sage-grouse by protecting and improving sagebrush habitats and ecosystems that sustain these populations." This strategy was itself a collaborative effort, reflecting the collective knowledge of local working groups, State and provincial conservation plans, Federal and State agencies, and a rangewide-issues forum (Stiver, 2011). In 2011, agency, academic, and private sector experts published a monograph on sage-grouse populations, sagebrush habitats, and the relations between land use and sage-grouse populations across the sage-grouse range (Knick and Connelly, 2011).

In the 2006 strategy, WAFWA recommended passage of the North American Sagebrush Ecosystem Conservation Act (NASECA, Stiver and others, 2006a). The NASECA is modeled after the North American Wetland Conservation Act, calls for leadership through the establishment of an NASECA Council, and proposes an initial five-year budget of $425 million to be administered by a fiduciary entity and dispersed across MZs, States, and provinces (Stiver and others, 2006a). The precise details of NASECA are to be determined by the Western Governors' Association, which along with WAFWA completed a draft version of the Act in 2009 (Stiver and others, 2006a; Western Governors' Association, 2011). In 2011, the Western Governors' Association requested Congress to pass the NASECA and appropriate the necessary funds for implementation (Western Governors' Association, 2011), and if approved, it will provide a rangewide funding mechanism to implement WAFWA's Comprehensive Conservation Strategy.

Canadian Conservation Efforts

The sage-grouse is a protected species in Canada under schedule 1 of the Species at Risk Act (SARA; Canada Gazette, 2002; U.S. Fish and Wildlife Service, 2010b). The Species at Risk Act, like its counterpart the Endangered Species Act, prohibits harming individuals within a protected species and allows for the protection of critical habitat (Aldridge and Brigham, 2003a).

Sage-grouse are also protected under the laws of the provinces of Alberta and Saskatchewan, neither of which allow harvesting of individual birds (Aldridge and Brigham, 2003a). In Saskatchewan, sage-grouse are listed as endangered under the Saskatchewan Wildlife Act, which restricts development within 1,640 ft (500 m) of leks and prohibits construction within 3,281 ft (1,000 m) of leks between March 15 and May 15 (Aldridge and Brigham, 2003a, p. 32). Additionally, under Saskatchewan's Wildlife Habitat Protection Act, sage-grouse habitat is afforded protection from transfer and cultivation (Aldridge and Brigham, 2003a). Alberta protects individual birds, but not sage-grouse habitat (Aldridge and Brigham, 2003a). USFWS has acknowledged these protections but concluded they are insufficient to assure conservation of the species (U.S. Fish and Wildlife Service 2010b).

United States Federal Agency Conservation Efforts

Natural Resources Conservation Service: Sage-Grouse Initiative

Launched in 2010, the USDA NRCS Sage-Grouse Initiative (SGI) supports work with private landowners in 11 Western States to improve habitat for sage-grouse while simultaneously improving working ranches (U.S. Natural Resources Conservation Service, 2012c). With approximately 31 percent of all sagebrush habitat across the range in private ownership (table 27; Stiver, 2011), a unique opportunity exists for NRCS to benefit sage-grouse and ensure the persistence of large and intact rangelands through implementation of the SGI (U.S. Fish and Wildlife Service, 2010a).

Table 26. Summary of management jurisdiction* across Management Zones (MZs) by acres of preliminary priority and preliminary general habitats (PPH and PGH, respectively).

		PPH		PGH	
Management Zone Entity	**Total Surface Area (acres)**	**SG Habitat (acres)**	**Area (%)**	**SG Habitat (acres)**	**Area (%)**
MZ I–GP	**84,110,800**	**11,636,400**	**13.8**	**34,663,000**	**41.2**
BLM	8,325,300	2,994,300	36.0	4,524,900	54.4
Forest Service	4,532,500	292,400	6.5	515,300	11.4
Tribal and Other Federal	5,458,500	219,700	4.0	2,427,700	44.5
Private	54,998,900	7,132,500	13.0	24,682,800	44.9
State	5,421,400	995,600	18.4	2,498,400	46.1
Other	5,374,100	1,900	0.0	13,900	0.3
MZ II and VII–WB & CP	**92,776,100**	**17,476,000**	**18.8**	**19,200,200**	**20.7**
BLM	30,295,000	9,021,200	29.8	9,012,500	29.7
Forest Service	23,558,800	162,000	0.7	452,500	1.9
Tribal and Other Federal	7,086,200	784,000	11.1	1,354,600	19.1
Private	27,405,400	6,233,900	22.7	7,394,800	27.0
State	4,053,900	1,244,800	30.7	979,800	24.2
Other	376,700	30,100	8.0	6,000	1.6
MZ III–SGB	**78,429,300**	**10,028,500**	**12.8**	**3,970,100**	**5.1**
BLM	45,097,500	6,309,400	14.0	3,199,800	7.1
Forest Service	12,377,600	1,236,200	10.0	356,200	2.9
Tribal and Other Federal	5,282,700	260,800	4.9	29,100	0.6
Private	12,251,400	1,836,200	15.0	384,800	3.1
State	3,101,900	385,900	12.4	200	0.0
MZ IV–SRP	**78,259,200**	**21,930,600**	**28.0**	**10,958,500**	**14.0**
BLM	26,220,300	13,710,700	52.3	4,928,200	18.8
Forest Service	22,291,600	1,613,800	7.2	1,113,500	5.0
Tribal and Other Federal	2,431,000	633,600	26.1	522,500	21.5
Private	23,150,400	4,890,200	21.1	3,516,700	15.2
State	3,681,000	1,019,400	27.7	846,200	23.0
Other	484,800	62,900	13.0	31,400	6.5
MZ V–NGB	**36,447,900**	**7,097,200**	**19.5**	**5,808,000**	**15.9**
BLM	14,179,800	5,117,500	36.1	4,196,700	29.6
Forest Service	10,136,000	62,200	0.6	114,900	1.1
Tribal and Other Federal	1,964,700	717,100	36.5	101,800	5.2
Private	6,299,000	798,000	12.7	1,199,000	19.0
State	473,600	64,900	13.7	115,800	24.5
Other	3,394,700	337,500	9.9	79,800	2.4

*Data Sources: BLM GSSP Surface Management Agency 2012; USFS Enterprise Data Warehouse 2012. Small differences between individual entity totals and MZ summary values may exist due to rounding of estimates during calculations.

Table 27. Sage-Grouse Initiative efforts by State (through 2011) with delineation of threats to sage-grouse targeted with mitigation.

State	Acres to be Treated with Improved Grazing Systems	"High Risk" Fence to be Marked or Removed (ft)	Acres of Pinyon-Juniper to be Removed	Habitat Loss Due to Fire or Conversion for Agriculture (total acres to be restored)	Brood Rearing Habitat Improvements (acres)	Conservation Easements (acres secured)
California	23,395	420,501	28,665	1,020	66	–
Colorado	18,817	9,676	555	3,661	4	5,017
Idaho	206,170	309,892	5,600	4,449	370	21,434
Montana	246,814	460,854	–	883	–	42,191
Nevada	4,571	81,637	7,423	3,732	5,883	3,695
N. Dakota	4,213	2,909	–	565	–	–
Oregon	8,488	5,280	54,626	–	–	–
S. Dakota	127,812	–	–	–	–	–
Utah	48,462	52,765	18,525	11,986	–	14,980
Wyoming	414,422	401,281	22	29	60	120,706
Totals	**1,103,164**	**1,744,795**	**115,416**	**26,325**	**6,383**	**208,023**

Participation in the SGI program is voluntary, but willing participants enter into binding contracts or easements to ensure that conservation practices that enhance sage-grouse habitat are implemented (U.S. Fish and Wildlife Service, 2010a). Though participation is voluntary, and thus not a traditional regulatory approach, participating landowners are bound by contract (usually three to five years in duration) to implement, in consultation with NRCS staff, conservation practices if they wish to receive the financial incentives offered by the SGI. These financial incentives generally take the form of payments to offset costs of implementing conservation practices and easement or rental payments for long-term conservation (U.S. Fish and Wildlife Service, 2010b). Demand to participate in the program has been strong; as of March 2012, 462 ranchers were enrolled in the SGI, covering 1.7 million acres (6,880 km^2; U.S. Natural Resources Conservation Service, 2012a). Funding for the SGI, through conservation programs provided for in the Food, Conservation, and Energy Act of 2008 (Farm Bill), has increased to meet the interest—from $21 million in fiscal year (FY) 2010 to more than $92 million in FY 2011 (U.S. Natural Resources Conservation Service, 2012c). In addition to the economic incentives offered by the SGI, participating landowners also have the benefit of knowing that if the sage-grouse is listed as threatened or endangered, their efforts under the SGI will comply with the ESA (though participation does not by itself offer permits for incidental take or protection similar to a Candidate Conservation Agreement with Assurances). Although potentially effective at conserving sage-grouse populations and habitat on private lands, incentive-based conservation programs that fund the SGI generally require reauthorization from Congress under subsequent Farm Bills, and therefore these funding streams are potentially variable as they are subject to the political process.

The NRCS is working to implement SGI conservation measures on private lands that address many of the threats to sage-grouse identified in the 2010 Listing Decision. Many of those threats, including fragmented landscapes and urban expansion, overgrazing, and conifer encroachment are also threats to sustainable ranching (U.S. Natural Resources Conservation Service, 2012c). Conversely, intact landscapes, an abundance of perennial grasses and forbs, invasive species management, and well-designed grazing plans benefit both sage-grouse and promote sustainable ranching (U.S. Natural Resources Conservation Service, 2012c).

Across the range, application of SGI conservation standards, including improved grazing systems, fence modification and removal, tree removal, and conservation easements vary from State to State. Grazing is the most widespread land use across the sagebrush biome (Connelly and others, 2004) and through the SGI, NRCS is working with landowners to implement grazing practices that, among other benefits to the species, increase cover in seasonal habitats (U.S. Natural Resources Conservation Service, 2012a). Nearly 415,000 acres (1,680 km^2) in Wyoming have (or are under contract to receive) some form of improved grazing system that could support increased hiding cover (U.S. Natural Resources Conservation Service, 2012a). A component of grazing management, pasture fencing, has created a variety of threats to sage-grouse, such as mortality from collisions, increased predation due to perch sites and corridors, and habitat fragmentation (Call and Maser, 1985; Braun, 1998; Oyler-McCance and others, 2001; Beck and others, 2003; Knick and others, 2003; Connelly and others, 2004). Nearly 625 miles (1006 km) of fences were constructed annually from 1996 to 2002 in the sage-grouse range with most being constructed in Montana, Nevada, Oregon, and Wyoming (Connelly and others, 2004). Through the SGI program, participants have agreed to remove or mark nearly 350 miles (563 km) of high-risk fence (U.S. Natural Resources Conservation Service, 2012a). In Idaho, a recent study demonstrated that fence marking can lead to reduced sage-grouse collisions (Stevens and others, 2011).

SGI has two particular approaches to restoring sagebrush habitats that have been degraded or modified. NRCS is working with landowners to remove juniper and other expanding conifers from valuable habitats. For example, 54,626 acres (405 km^2) of juniper and pine have already been treated in Oregon (MZs IV and V; table 27). Urbanization and conversion of habitat to agriculture, at the other end of the habitat change spectrum, have caused habitat loss and fragmentation across the Western United States, which has been determined to be a “key cause, if not the primary cause, of the decline of sage-grouse populations” (U.S. Fish and Wildlife Service, 2010b). Conservation easements are one important approach to creating and maintaining large, intact sagebrush communities (U.S. Natural Resources Conservation Service, 2012a). At this time, NRCS has secured conservation easements on 208,023 acres (840 km^2) across the sage-grouse range (U.S. Natural Resources Conservation Service, 2012a) with the largest percentage of easements occurring in Wyoming (120,706 acres [490 km^2]), Montana (42,191 acres [171 km^2]), and Idaho (21,434 acres [87 km^2]) (U.S. Natural Resources Conservation Service, 2012a).

Farm Service Agency: Conservation Reserve Program

Similar to the incentive-based programs that fund the SGI, the Conservation Reserve Program (CRP) is a program administered by the USDA Farm Service Agency (FSA, U.S. Farm Service Agency, 2010). CRP lands are generally taken out of agricultural production and planted with perennial vegetative cover. Generally, contracts under the CRP program run for 10–15 years (U.S. Farm Service Agency, 2010). Conversion of sagebrush to agriculture influences the ability of sagebrush-dominated landscapes to support sage-grouse through direct habitat loss and fragmentation (Connelly and others, 2004). CRP fields have provided valuable habitat in Washington (Schroeder and Vander Haegen, 2006), but the value of these lands to sage-grouse across its entire range has not been demonstrated (Stiver and others, 2006b). Launched in 2008, State Acres for Wildlife Enhancement (SAFE) is a program within CRP designed to “address state and regional high-priority wildlife objectives” (U.S. Farm Service Agency, 2008). Several States across the sage-grouse range have directed SAFE efforts toward enhancing sagebrush habitat. In Colorado, SAFE project partners hope to enroll 12,600 acres (51 km^2) in CRP to restore and enhance habitat for several species of grouse, including sage-grouse. Montana and North Dakota are each aiming to enroll 1,000 acres (4 km^2) in SAFE to restore cropland to sagebrush habitat to benefit sage-grouse and other sagebrush obligate birds. South Dakota is looking to add 500 acres (2 km^2) to SAFE for the same purpose. Lastly, the SAFE program in northeast Wyoming is working to add 10,000 acres (40 km^2) to restore critical habitat by converting cropland to perennial plant communities (U.S. Farm Service Agency, 2008).

Other Federal Agencies

In addition to BLM (Department of Interior [DOI]) and the Forest Service (USDA, USFS), the United States Departments of Defense (DOD), Energy (DOE), and other Interior Bureaus (DOI, including USFWS, National Park Service [NPS], and Bureau of Indian Affairs [BIA]) manage publically owned lands across sage-grouse range, and many of these lands have use restrictions that will also help support sage-grouse (table 28, fig. 30). Although BLM and USFS manage most of the sagebrush and sage-grouse habitats—other entities and agencies, combined, manage only 5 percent of sagebrush lands in the United States (Stiver, 2011)—cooperative management strategies may have local impacts or benefits and lands managed for other specified purposes remain part of distribution and management of the sage-grouse across the landscape.

Fish and Wildlife Service, National Park Service, and Other Federal Designations

The USFWS directly manages only 1 percent of sage-grouse habitats as part of the National Wildlife Refuge System (Knick and Connelly, 2011b). Refuges are administered under the National Wildlife Refuge Administration Act of 1966 (16 U.S.C. §668dd–668ee), as amended, for the purpose of “conservation, management and, where appropriate, restoration of the fish, wildlife and plant resources.” Several refuges within the range are currently revising their Comprehensive Conservation Plans (CCPs) as required by the 1997 National Wildlife Refuge Improvement Act. For instance, Hart Mountain National Antelope Refuge, which consists of 277,893 acres (1,125 km^2) of sagebrush-steppe in Lake County, Oregon, published a Notice of Intent in the Federal Register to revise its CCP in May 2012 (U.S. Fish and Wildlife Service, 2012,). The Notice of Intent identifies key issues to be analyzed in the CCP, many of which can benefit the refuge’s sage-grouse population: the impact of fire and juniper encroachment on the refuge’s sagebrush habitat, invasive species control, and land protection and planning to reduce habitat fragmentation (U.S. Fish and Wildlife Service, 2012). Sheldon National Wildlife Refuge, which encompasses 575,000 acres (2,327 km^2) of sagebrush-steppe in northwest Nevada, issued its Draft CCP in 2011 (U.S. Fish and Wildlife Service, 2011). Sage-grouse conservation is a major component of the CCP, which calls for, among other actions, restoration of sagebrush and riparian habitats through removal of all wild horses within the refuge,

Table 28. Summary of areas managed for conservation and (or) protection* across Management Zones (MZ) by acres of preliminary priority and preliminary general habitat (PPH and PGH, respectively).

		PPH		PGH		
Management Zone Entity	SG Habitat (acres)	Area (acres)	Area (%)	SG Habitat (acres)	Area (acres)	Area (%)
MZ I–GP	**11,636,400**	**364,800**	**3.13**	**34,663,000**	**811,000**	**2.34**
BLM	2,994,300	68,600	2.29	4,524,900	103,900	2.30
Forest Service	292,400	100	0.03	515,300	0	0.00
Tribal and Other Federal	219,700	91,400	41.60	2,427,700	373,700	15.39
Private	7,132,500	195,700	2.74	24,682,800	315,800	1.28
State	995,600	9,000	0.90	2,498,400	17,600	0.70
Other	1,900	0	0.00	13,900	0	0.00
MZ II and VII–WB & CP	**17,476,000**	**624,700**	**3.57**	**19,200,200**	**1,068,300**	**5.56**
BLM	9,021,200	241,300	2.67	9,012,500	511,100	5.67
Forest Service	162,000	2,500	1.54	452,500	46,800	10.34
Tribal and Other Federal	784,000	93,300	11.90	1,354,600	105,700	7.80
Private	6,233,900	217,100	3.48	7,394,800	358,900	4.85
State	1,244,800	44,000	3.53	979,800	41,400	4.23
Other	30,100	26,500	88.04	6,000	4,400	73.33
MZ III–SGB	**10,028,500**	**295,600**	**2.95**	**3,970,100**	**191,500**	**4.82**
BLM	6,309,400	170,900	2.71	3,199,800	130,800	4.09
Forest Service	1,236,200	93,900	7.60	356,200	56,200	15.78
Tribal and Other Federal	260,800	11,000	4.22	29,100	3,700	12.71
Private	1,836,200	12,900	0.70	384,800	500	0.13
State	385,900	6,900	1.79	200	200	100.00
MZ IV–SRP	**21,930,600**	**1,760,600**	**8.03**	**10,958,500**	**1,181,600**	**10.78**
BLM	13,710,700	1,510,700	11.02	4,928,200	741,400	15.04
Forest Service	1,613,800	26,600	1.65	1,113,500	3,000	0.27
Tribal and Other Federal	633,600	76,000	11.99	522,500	254,800	48.77
Private	4,890,200	124,800	2.55	3,516,700	164,300	4.67
State	1,019,400	22,500	2.21	846,200	16,600	1.96
Other	62,900	0	0.00	31,400	1,500	4.78
MZ V–NGB	**7,097,200**	**2,113,400**	**29.78**	**5,808,000**	**1,050,300**	**18.08**
BLM	5,117,500	1,400,900	27.37	4,196,700	955,900	22.78
Forest Service	62,200	0	0.00	114,900	100	0.09
Tribal and Other Federal	717,100	695,700	97.02	101,800	74,900	73.58
Private	798,000	11,700	1.47	1,199,000	13,400	1.12
State	64,900	2,900	4.47	115,800	5,300	4.58
Other	337,500	2,200	0.65	79,800	800	1.00

*Data Sources: National Conservation Easement Database; USGS Protected Areas Database (PAD-US); BLM NLCS, ACECs, and Wilderness and USFS Wilderness. Small differences between individual entity totals and MZ summary values may exist due to rounding of estimates during calculations.

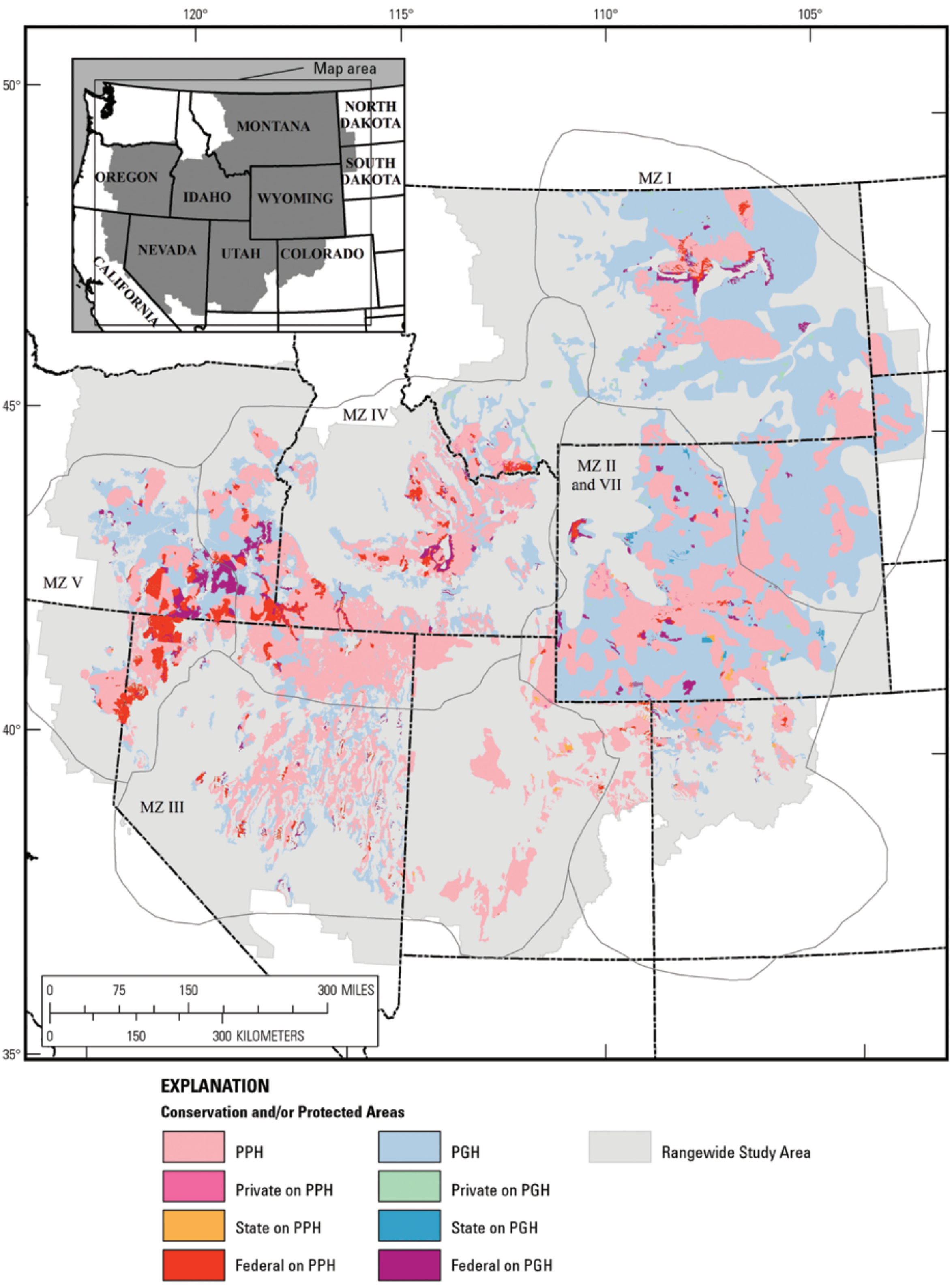


Figure 30. Overlap of Federal, State, and private (includes Non-government Organizations) conservation areas within preliminary priority and preliminary general habitats (PPH and PGH, respectively).

aggressive reduction of encroaching juniper, and control of invasive species, namely cheatgrass (*Bromus tectorum*; U.S. Fish and Wildlife Service, 2011). Again, where BLM or USFS administered lands border National Wildlife Refuges, there exists the potential for collaborative efforts that may have localized benefits to sage-grouse populations.

Several units within the National Park System are also planning for sage-grouse and sagebrush conservation. The City of Rocks National Reserve (CIRO, which is co-managed by the Idaho Department of Parks and Recreation) and Craters of the Moon National Monument and Preserve (CRMO, which is co-managed by the BLM) are located in the Upper Columbia River Basin in southern Idaho (MZ IV). Additionally, habitat selection studies have been conducted on the Jackson Hole sage-grouse population in and around Grand Teton National Park (Chong and others, 2011), a small, but high-profile population in Wyoming.

CRMO encompasses roughly 737,700 acres (2,985 km^2) in south-central Idaho, of which 70 percent is designated as either Wilderness Study Area or Wilderness (U.S. National Park Service and Bureau of Land Management, 2006). Observations by the Idaho Department of Fish and Game indicate a 36 percent decrease in the number of sage-grouse leks in the last quarter century with 53 known leks recorded on BLM-administered lands within the monument (U.S. National Park Service and Bureau of Land Management, 2006). As described in the CRMO General Management Plan (2006), the agencies intend to prioritize vegetation restoration projects relative to sage-grouse populations (including enlarging and connecting habitats), as well as implement protective measures from the Idaho Sage-grouse Advisory Committee's Conservation Plan, including use restrictions where needed near occupied leks (U.S. National Park Service and Bureau of Land Management, 2006). CIRO is currently in the process of revising its General Management Plan.

Wilderness designations may also play a role in sustaining sage-grouse populations and conserving their habitat, however very few Wilderness areas contain sagebrush (table 28); expansion to include current roadless areas could increase the area from about 6 percent to 9 percent of the sagebrush landscape (Crist and others, 2005). Lands designated as Wilderness must generally contain at least 5,000 acres (20 km^2) and are managed by the agency having jurisdiction over such lands before they were included in the National Wilderness Preservation System (16 U.S.C. § 1131 *et seq*.). Wilderness designations are subject to the political process because only Congress can designate Wilderness areas (16 U.S.C. § 1131 *et seq*.). Wilderness areas are characterized by the absence of motorized equipment and mechanical transport, and commercial enterprises are prohibited (16 U.S.C. § 1131 *et seq*.); therefore, they do not host many of the anthropogenic threats to sage-grouse identified in the USFWS 2010 Listing Decision, such as habitat conversion for agriculture, urbanization, infrastructure, and energy development.

Department of Defense

There are approximately 87 Department of Defense (DoD) managed facilities distributed across the sage-grouse range with various operations and intensity of use among and within those facilities (Connelly and others, 2004). Because human access to many military installations is limited, these lands present an opportunity to conserve sage-grouse habitat; however, with only 26 percent (6,815 km^2 [1.7 million acres]) of DoD managed lands being sagebrush dominated, they represent approximately 0.01 percent of the currently estimated sage-grouse range (670,000 km^2 [165.5 million acres]). Seven military installations have confirmed sage-grouse populations, five of which are under the control of the Army: Dugway Proving Ground (Utah), Sheridan Training Area (Wyo.), Camp Guernsey (Wyo.), Hawthorne Army Depot (Nev.), and the Toole Army Depot (Utah). Two Air Force Bases (AFB) manage for known populations: Nellis AFB in Nevada and Mountain Home AFB, which administers the Saylor Creek and Juniper Butte Ranges in Idaho (U.S. Department of Defense and U.S. Fish and Wildlife Service, 2006).

At sites where military training exercises occur, such activities are generally destructive by their nature (Connelly and others, 2004) and may have substantial effects on habitats including the spread of exotic species, the potential for soil erosion, and the possibility of reduced ecosystem productivity from tracked and wheeled vehicle maneuvering, as well as fires from ordnance impacts (Belcher and Wilson, 1989; Shaw and Diersing, 1990; Watts, 1998). Obvious land-use impacts were evident on approximately 17 percent of the military lands surveyed by the Land Condition Trend Analysis, leaving substantial portions of some facilities available for conservation and management of native species (Knick and others, 2011).

Although the land-use and conservation activities of DOD may have important local effects on the distribution of sage-grouse habitats (including effects on disturbance regimes) as well as some populations, they represent only a small portion of the species' range and therefore a small component of the conservation effort. When DOD facilities with sagebrush habitats fall within (partially or entirely) or adjacent to BLM or USFS planning and management units, then actions and planning that address sage-grouse conservation may benefit from recognition of resources, authorities, and activities associated with DOD lands that may benefit or harm sage-grouse in the planning process. Cooperation and collaboration with DOD, and other agencies that affect land-use patterns and habitat conditions (such as, Bureau of Reclamation, Department of Energy, USFS), during regional planning processes is important to ensure sound management and efficient use of public resources across political boundaries.

Department of Energy

The Idaho National Laboratory (INL) site consists of 2,305 km^2 (570,000 acres) in the Upper Snake River Plain of southeastern Idaho (Whiting and Bybee, 2011) of which 115 square miles was designated as the Sagebrush-Steppe

Ecosystem Reserve in July 1999 by the Secretary of Energy (INL Campus Development Office and North Wind, Inc., 2011). The INL site is home to several sage-grouse populations and hosts numerous sage-grouse leks (INL Campus Development Office and North Wind, Inc., 2011; Whiting and Bybee, 2011). The INL includes most of the same issues found on the larger sage-grouse range. Wildland fires are relatively common on the site and an on-site fire department provides wildfire management in cooperation with the BLM and local authorities (INL Campus Development Office and North Wind, Inc., 2011). BLM administers permits to graze cattle and sheep on up to 340,000 acres (1,375 km^2) of the INL (INL Campus Development Office and North Wind, Inc., 2011). Nearly six percent of INL (approximately 34,000 acres, [138 km^2]) consists of public roads and utility rights of way (INL Campus Development Office and North Wind, Inc., 2011). Other infrastructure includes an extensive power delivery system, including substations and a 62 mi (100 km) (60 miles of which are above ground) transmission loop (INL Campus Development Office and North Wind, Inc., 2011).

From 1978 to 1980, fixed-wing aircraft and four-wheel-drive surveys identified 59 sage-grouse leks on or near the INL (Connelly, 1980). According to these data, it was determined that the INL populations were stable or increasing (Connelly, 1980). Monitoring of the INL sage-grouse populations was sporadic until a recent study collected data on lek attendance, activity, and distribution within the INL during the springs of 2009 and 2010 (Whiting and Bybee, 2011). Upon revisit, the number of active sage-grouse leks within the INL was less than half of historical leks (Whiting and Bybee, 2011), although uncertainty associated with historic data and dynamic populations may confound these data. The authors concluded that the INL likely follows the regional trend of sage-grouse with populations declining in the 1980s and 1990s but stabilizing at the current low levels during the past decade (Garton and others, 2011; Whiting and Bybee, 2011). Annual spring surveys will be conducted on the INL to ultimately produce an index of population trends at the site (Whiting and Bybee, 2011).

State and Local Working Group Conservation Efforts

States generally have broad authority to manage wildlife within their borders. All States within the range of sage-grouse have laws addressing wildlife conservation, but such laws are general in nature without specific mention of sage-grouse (U.S. Fish and Wildlife Service, 2010b, p. 13,974); nevertheless, States and local working groups (LWGs) across the sage-grouse range have developed conservation plans that direct management efforts at the State and regional level (Stiver, 2011). Although such plans generally provide a management framework rather than regulations, they are a valuable mechanism for implementing efforts that conserve sage-grouse populations and their habitat.

In addition to developing State and LWG conservation strategies, States can affect sage-grouse conservation by several other means. Governors of several States have issued executive orders (White and others, 1997) to offer greater regulatory force to sage-grouse conservation. Moreover, in addition to State fish and wildlife agencies, other State-level agencies may have authority to regulate activities that are threats to sage-grouse. This includes State agencies or commissions responsible for regulating oil and gas developments or siting power transmission lines. Lastly, all 10 States within the sage-grouse range own State trust lands, which each State manages for the benefit of various trustees (U.S. Fish and Wildlife Service, 2010b). Trust lands consist of two sections per township (four sections in Utah) and therefore usually represent a checkerboard of lands scattered around each State (Culp, 2005). Nevertheless, the cumulative area of State trust lands can be large—Montana's trust lands include 5 million acres (20,230 km^2) of surface property, Utah holds 3.5 million (14,150 km^2) surface acres in trust, Wyoming and Colorado each have about 3 million (12,140 km^2) surface acres, and Idaho holds about 2.5 million acres (10,100 km^2) in trust (Culp, 2005). States generate revenue on State trust lands through various activities—disposition or leases for residential or commercial development, timber harvesting, mineral development, agricultural uses and recreation including fishing and hunting (Culp, 2005). These lands represent a potentially important component of long-term sage-grouse conservation; however, there are limitations due to the scattered distribution of these lands (reducing the potential benefit unless coordinated with management efforts on adjacent lands) and potential change in ownership and management due to the fiduciary trust responsibilities.

The following section presents a brief overview of conservation efforts within each State and, where applicable, the major threats those efforts seek to mitigate. A complete description of management efforts in each State is out of the scope of this report, and such information is available from individual States and LWGs. In 2011, the Western Governors Association released an inventory of State and local conservation initiatives for sage-grouse (Western Governors' Wildlife Council, 2011).

California/Nevada

In August 2000, then Nevada Governor Kenny Guinn appointed a Sage-Grouse Conservation Team that developed a conservation strategy for sage-grouse (Nevada Sage-Grouse Conservation Team, 2004). Through collaboration with the California Department of Fish and Game, the strategy was later expanded to include eastern California and LWGs in each State were identified and tasked with designing practical solutions for their respective region. The seven LWGs (including a Bi-State Planning Group) developed local conservation plans, which were submitted to the Governor's Team for synthesis into a conservation plan for Nevada and eastern California (Nevada Sage-Grouse Conservation Team, 2004).

The Greater Sage-Grouse Conservation Plan for Nevada and Eastern California prioritizes conservation efforts within both States. Immediate priorities identified include a comprehensive spatial analysis to determine those areas that support large populations of sage-grouse and are at high risk for wildfire or invasion of cheatgrass (Nevada Sage-Grouse Conservation Team, 2004). In 2012, the Nevada Department of Wildlife published its sage-grouse habitat categorization analysis, which delineated five classes of sage-grouse habitat ranging from essential/irreplaceable habitat to unsuitable habitat, to direct mitigation and conservation efforts within Nevada and California (Nevada Department of Wildlife, 2012).

Other top priorities identified by the Governor's Team include wildfire pre-suppression treatments, fire control and vegetation management. The average fire size in the Southern Great Basin (MZ III) increased from 1980 to 2007 (U.S. Fish and Wildlife Service, 2010a). As much as 80 percent of the land within the Great Basin ecoregion (MZs III, IV, and V) is at risk of being displaced by cheatgrass in the next 30 years, and an estimated 35 percent of sagebrush in the region is at high risk of displacement by pinyon-juniper in the same time (Connelly and others, 2004).

The Nevada Department of Wildlife, in cooperation with various Federal agencies, has implemented numerous conservation projects to confront these threats dedicating more than $2 million and totaling nearly 69,000 treated acres (280 km^2) on private lands and lands administered by Federal agencies from 2001 to 2009. These projects include pinyon-juniper removal, weed treatments, and fire rehabilitation (Nevada Department of Wildlife, 2011). More recently, Governor Brian Sandoval issued an Executive Order forming the Governor's Greater Sage-Grouse Advisory Committee to recommend policies for the protection of sage-grouse (Nevada Executive Order, Mar. 30, 2012). The recommendations, released in July 2012, provide management strategies to achieve "no net loss" for controllable activities and aggressive pre-suppression, initial attack, and restoration for uncontrollable events (Nevada Greater Sage-Grouse Advisory Committee, 2012).

Colorado

Colorado's Greater Sage-Grouse Conservation Plan (2008) prioritized threats across each of the State's six sage-grouse populations: Meeker-White River, Middle Park, North Park, northern Eagle-southern Routt Counties, northwest Colorado, and Parachute-Piceance-Roan (Colorado Greater Sage-Grouse Steering Committee, 2008). Urbanization and associated habitat fragmentation are substantial threats to sage-grouse in portions of the sage-grouse range in Colorado (U.S. Fish and Wildlife Service, 2010a). The Colorado Division of Wildlife, through its Habitat Protection Program, secured 40,000 acres (162 km^2) of sage-grouse habitat through land purchases and conservation easements (Western Governors' Wildlife Council, 2011). Such actions are part of the State's strategy to mitigate what the USFWS described as the "key cause, if not the primary cause, of the decline of sage-grouse populations," namely habitat fragmentation (U.S. Fish and Wildlife Service, 2010a). Within these recognized habitat regions, urbanization is occurring most heavily in Middle Park and northern Eagle-southern Routt Counties. Conservation easements benefiting sage-grouse total 8,883 acres (36 km^2) and 2,430 acres (10 km^2) of occupied habitat in the Middle Park and northern Eagle-southern Routt County areas, respectively (Colorado Greater Sage-Grouse Steering Committee, 2008).

Oil and gas development has expanded at a rapid rate in portions of Colorado (threats to sage-grouse associated with such development are presented in previous sections of this report). Applications for permits-to-drill increased 50 percent between 2004 and 2005 and increased by an additional 35 percent from 2005 to 2006. In 2005, 99 percent of these permits were for new wells. Current oil and gas development is concentrated in northwest Colorado (described as "moderate; increasing exponentially") and Parachute-Piceance-Roan ("high; increasing exponentially") areas (Colorado Greater Sage-Grouse Steering Committee, 2008). In 2009, then Colorado Governor Bill Ritter signed into law regulations to address sage-grouse conservation applicable to the Colorado Oil and Gas Conservation Commission. Pursuant to an MOU among that Commission, BLM, and USFS, these regulations apply to oil and gas permitting decisions on both private and Federal land within the State (Interagency MOU, 2009; U.S. Fish and Wildlife Service, 2010a). The new regulations require operators seeking a permit to drill to first determine if the proposed development occurs within "sensitive wildlife habitat" (C.R.S. § 34-60-128 and COGCC Rules and Regulations § 1201). Operators are required to consult with the Colorado Division of Wildlife to avoid impacts on wildlife resources and mitigate any unavoidable impacts (COGCC Rules and Regulations § 1202a).

Idaho

Wildfire, infrastructure, and proliferation of invasive species were the three most pressing threats (in order of priority) to sage-grouse in Idaho as determined by a panel of leading scientists in 2006 (Idaho Sage-Grouse Advisory Committee, 2006). The Idaho Sage-Grouse Conservation Plan contemplates the full spectrum of threats; several are addressed here. On March 9, 2012, Idaho Governor C.L. Otter issued Executive Order 2012-02, which established a 15-member Sage-Grouse Task Force to provide recommendations on the long-term viability of the species within the State.

As in other States, the potential for wildfire to negatively affect vast acres of sage-grouse habitat represents a substantial threat to the persistence of the species and remains a top management priority in Idaho (Idaho Sage-Grouse Advisory Committee, 2006). Spread and establishment of cheatgrass and other annuals have contributed to reduced fire-return intervals in portions of the Snake River Plain (Young and others, 1987; Connelly and others, 2004). The Governor's Sage-Grouse Task Force recommended identifying perennial grasslands with the highest risk for wildfire that are most likely to benefit from fuel-break construction (Idaho Sage-Grouse Task

Force, 2012). Numerous weed and fuel-break efforts have been undertaken, and a substantial number of acres has been treated on private, State, and Federally managed lands within the State with funds from the Governor's Office of Species Conservation. The State has also focused efforts on fire restoration; several reseeding and rehabilitation projects have occurred since 2002, totaling 3,399 treated acres (13.75 km^2) (Idaho Sage-grouse Advisory Committee Technical Assistance Team, 2012).

Infrastructure is also perceived as a substantial threat to sage-grouse in Idaho. There are approximately 1,500 miles (2,414 km) of major power transmission lines within the State's sage-grouse planning areas (Idaho Sage-Grouse Advisory Committee, 2006). Including a 3.1 mi (5 km) buffer on either side of these lines expands the affected area to more than 4.5 million acres (18,200 km^2) (Idaho Sage-grouse Advisory Committee 2006). There are approximately 975 mi (1,560 km) of major paved roads (interstate, Federal, and State) within Idaho sage-grouse planning areas, which, when a 6.2-mi (10-km) buffer is considered, account for more than 6.8 million acres (27,500 km^2) of affected area (Idaho Sage-Grouse Advisory Committee, 2006). A Governor's Task Force recommended several management practices to mitigate the effects of infrastructure on sage-grouse including co-locating linear facilities, building new roads to the minimum specifications necessary, and time restrictions on construction of new facilities (Idaho Sage-Grouse Task Force, 2012).

Spatial studies reveal several large tracts of annual grasslands, totaling nearly one million acres (4,050 km^2) within Idaho's sage-grouse planning areas in south-central, southwestern, and western Idaho. The BLM manages approximately 62 percent of these identified grasslands, whereas 29 percent are under private ownership (Idaho Sage-Grouse Advisory Committee, 2006). LWGs report numerous weed control efforts across various types of land ownership within the State. As of 2011, nearly 9,300 acres (38 km^2) have been treated to control weeds (Idaho Sage-Grouse Advisory Committee Technical Assistance Team, 2012). The Governor's Task Force recently recommended best-management practices regarding invasive species control to be incorporated into land-use-plan revisions (Idaho Sage-Grouse Task Force, 2012).

Montana and the Dakotas

Energy development, grazing, and habitat conversion to agriculture are among the primary threats to sage-grouse in Montana (U.S. Fish and Wildlife Service, 2010a). Portions of two geological basins within the State are experiencing increased levels of energy development—the Powder River Basin (predominately coal-bed methane) in southeastern Montana and northeastern Wyoming and the Williston Basin in eastern Montana and the Dakotas (U.S. Fish and Wildlife Service, 2010a). The Powder River Basin serves as a link between the Wyoming Basin and central Montana sage-grouse populations; it is anticipated that this connectivity could be lost in the near future, in part, due to the intensive development in this region (U.S. Fish and Wildlife Service, 2010a). Montana's Management Plan and Conservation Strategy for Sage Grouse (2005) proposed several conservation actions to meet energy demands while minimizing effects to sage-grouse including surface occupancy restrictions (0.25 miles around existing leks), restricting noise levels near leks, and avoidance of leks and critical habitat in siting infrastructure. Notably, in 2007, the Montana Department of Natural Resources and Conservation rejected a recommendation from the State's Department of Fish, Wildlife and Parks to amend a stipulation placed on State trust land oil and gas leases to include sage-grouse protections (this amendment would have increased the no-surface-occupancy buffer radius to between 1 and 1.8 miles and included timing restrictions on lands within 4 miles from known leks). The decision cited concerns that the recommended restrictions would prevent the Department of Natural Resources and Conservation from protecting oil and gas resources under State lands from drainage by adjacent mineral owners (Montana Department of Natural Resources and Conservation Trust Land Management Division, 2007).

Although sagebrush communities in the Northern Great Plains, including Montana, likely evolved with periodic grazing, many of these rangelands were overstocked in the late 1800s and early 1900s, which altered the composition and productivity of sagebrush communities (Montana Sage-Grouse Work Group, 2005). Montana's State Plan (2005) prescribes grazing management actions that maintain and enhance sagebrush rangelands while providing for agricultural commodities. These include incentives for private landowners to help achieve sage-grouse objectives (Montana Sage Grouse Work Group, 2005). As described above, the NRCS is working with private landowners around the State to implement improved grazing systems on more than 246,000 acres (995 km^2) in the State through its SGI program (U.S. Natural Resources Conservation Service, 2012a). The Montana Department of Fish, Wildlife and Parks, through contracts with private landowners, implemented grazing standards on more than 550,000 acres (2,226 km^2) of privately owned land in the State (Montana Sage Grouse Work Group, 2005).

Large losses of sagebrush resulting from conversion to agriculture have occurred in the Great Plains MZ (MZ I). Across the State, the amount of acres converted to tilled agriculture increased annually from 2005 to 2009, with more than 25,000 acres (101 km^2) converted in that time. This threat is particularly prominent in the eastern two-thirds of the State (U.S. Fish and Wildlife Service, 2010a). Montana's State Plan reported that the State's Department of Fish, Wildlife and Parks intended to continue to negotiate conservation easements to conserve native rangelands by prohibiting subdivision and conversion to cropland. With funding through the Landowner Incentive and Upland Game Bird Programs, the Department of Fish, Wildlife and Parks anticipates protecting 183,000 acres (740 km^2) of occupied private lands from herbicide spraying, prescribed burning, and conversion to cropland (Montana Sage Grouse Work Group, 2005).

The populations at the eastern reaches of the range, in North and South Dakota, occupy a relatively small area in the western portions of both States and are known to be well-connected to populations and habitats in eastern Montana. The issues threatening these populations are the same as the threats associated with neighboring populations in southeastern Montana and northeastern Wyoming including oil and gas development. Fourteen percent of the Federal mineral estate (902,000 acres [3,550 km^2], combined) within the sage-grouse conservation area in North and South Dakota are authorized for development (U.S. Fish and Wildlife Service, 2010a). Both States have management plans that address sage-grouse conservation, and BLM habitat management is coordinated among Montana, North Dakota, and South Dakota (within a single Field Office).

Oregon

Oregon's "Wildlife Policy," codified in Section 496.012 of the Oregon Revised Statutes states "[i]t is the policy of the State of Oregon that wildlife should be managed to prevent serious depletion of any indigenous species…" Oregon's Greater Sage-Grouse Conservation Assessment and Strategy provides a framework to maintain and enhance sage-grouse in the State. It accomplishes this by combining a "core area" approach, modeled after Doherty and others (2011b) with a complementary method to estimate connectivity corridors to approximate seasonal ranges (Oregon Department of Fish and Wildlife, 2011). Once core areas were identified, various sagebrush habitats within the State were categorized based on suitability for sage-grouse, and management guidelines were recommended for each category with greater restrictions in higher value habitat (Oregon Department of Fish and Wildlife, 2011).

The Oregon conservation plan addresses many of the threats identified by the USFWS in the 2010 Listing Decision. The plan offers voluntary guidelines to mitigate each threat. Implementation of the guidelines will be directed by local Implementation Teams, consisting of Oregon Department of Fish and Wildlife personnel, Federal land management agency representatives and private entities. There are five Implementation Teams, corresponding to various BLM district boundaries within the State. Implementation Teams have initiated projects under the guidance of the State plan—from removing 90,000 acres (365 km^2) of juniper within the Burns District to treating nearly 30,000 acres (121 km^2) of invasive weeds in the Vale District (Oregon Department of Fish and Wildlife, 2011).

Utah

Four MZs divide Utah (Connelly and others, 2004) representing the State's diverse ecological and biological composition. Such variation also presents numerous threats to the State's sage-grouse populations. Utah's Sage-Grouse Planning Committee comprises members representing various backgrounds from public and private entities who prioritized threats to the species across the State. This prioritization incorporated the identification and prioritization of threats within Utah's 11 Management Areas by LWGs (Utah Division of Wildlife Resources, 2009).

State-wide, the Planning Committee identified six major threats: invasive species expansion, habitat conversion, conifer encroachment, energy development, altered fire cycles, and predation (Utah Division of Wildlife Resources, 2009). Utah's Greater Sage-Grouse Management Plan (2009) seeks to protect and maintain occupied habitat, while restoring 175,000 acres (700 km^2) of habitat by 2014. The plan provides an overall strategy for use in implementing conservation actions by LWGs. LWGs in Utah provide annual updates detailing those actions taken for specific strategies identified in each LWG plan. According to a recent report, for the Strawberry Valley Adaptive Resource Management Area, 10,223 acres (41 km^2) have been purchased within the Management Area by the Utah Reclamation and Mitigation Commission. A full discussion of the management efforts within the State is available from the Utah State University Cooperative Extension.

Wyoming

Estimates of sage-grouse populations indicate that Wyoming is home to the largest number of birds in the range of the species (U.S. Fish and Wildlife Service, 2010a). The State's sage-grouse populations face a variety of threats—intensive energy development in the Powder River and Greater Green River Basins and extensive infrastructure, including power lines, fences, and roads (U.S. Fish and Wildlife Service, 2010a). Eight LWGs around the State have completed conservation plans, many of which prioritize threats and prescribe management actions at the LWG scale.

At the State level, Wyoming Governor Matt Mead issued an executive order (Wyoming Executive Order June 2, 2011) that complemented (and replaced) several executive orders issued by his predecessor, Governor Dave Freudenthal (Wyoming Executive Order August 1, 2008 and August 18, 2010). The 2011 order further articulates the State's Core Population Area Strategy (as initially described in the 2008 executive order) as an approach to balance sage-grouse conservation and development. It provides an approach to mitigating anthropogenic disturbances to sage-grouse. The USFWS believes that Wyoming's Core Population Strategy, if extended to all landowners via regulatory mechanisms, would provide adequate protection for sage-grouse (U.S. Fish and Wildlife Service, 2010a); however, universal implementation remains uncertain due to variety in ownership and management.

Specifically, the 2011 order contains consultation requirements with the Wyoming Game and Fish Department for proposed activities requiring a State permit (Wyoming Executive Order June 2, 2011)—the Wyoming Game and Fish Department has no authority to either approve or deny the project. The order does apply to State trust lands in Wyoming covering almost 23 percent of sage-grouse habitat and contributing habitat benefiting approximately 80 percent of the estimated breeding population in the State (U.S. Fish and Wildlife Service, 2010a). The executive order does not restrict activities with a defined project boundary existing prior to August 1, 2008. All proposed activities are evaluated through a Density-Disturbance Calculation Tool to determine if the project would exceed recommended density-disturbance thresholds. Additionally, the 2011 order includes stipulations to be included in such permits with varying restrictions depending on whether the proposed development activity occurs within or outside delineated Core Population Areas (Wyoming Executive Order June 2, 2011). Wyoming's Industrial Siting Council (within the State's Department of Environmental Quality), which permits large development projects on all lands within the State, regardless of ownership, is subject to the terms of the executive order. This could offer sage-grouse considerable regulatory protection when considering large wind energy and other development projects within Wyoming (U.S. Fish and Wildlife Service, 2010a).

V. Risk, Policies, and Actions: Assessment of Dominant Threats and Potential Interactions within Management Zones

Increasing human populations with concurrent increases in demand for resources, dynamic ecological processes, fire and fire effects, highly variable climate conditions, and potential synergistic feedbacks with ecological processes such as the distribution of invasive plant species will combine to increase disturbance and disruption of the sagebrush ecosystem. These interactions, and the subsequent distribution of habitats, represent the dynamic playing field where management and planning may influence changes to sagebrush-dominated landscapes throughout the Western United States, and this complicated framework will continue to present challenges for conservation of sage-grouse populations and habitats into the future (Knick and others, 2011). Projections for urban and exurban (suburban and rural subdivisions) growth across the Western United States mirror national projections, and some urban-growth areas are outpacing national trends (see U.S. Census Bureau Web site at *http://www.census.gov/population/www/projections*). Fences, power transmission lines, communication towers, and roads are ubiquitous, albeit not evenly distributed, across sage-grouse range, and these structures have known, or sometimes presumed, effects on sage-grouse populations. Conversion of land for crops, livestock, resource extraction, and domestic expansion has long been a basic tenant of western civilization, and though the land has provided these essential goods and services, alteration of resource conditions, wildlife habitats, and ecosystem function creates a critical trade-off between land use and conservation of resources and natural heritage values (Defries and others, 2004). Further, industrial development of public and private lands, including traditional fossil fuels, tar sands, and coal bed methane along with expansion of "renewable" energy sources such as wind, solar, and geothermal and the infrastructure required to support these operations represent widespread, unevenly distributed, pressures and impacts on sagebrush ecosystems and sage-grouse populations. This apparently philosophical or sociological debate regarding the balance among different land uses may seem peripheral to sage-grouse conservation; however, the management of these competing uses also involves fundamental, practical issues that affect the successful conservation of sage-grouse and sagebrush ecosystems. Thus, long-term challenges for regional planning, local habitat management, and wildlife conservation may be summarized by our ability to understand and manipulate a complicated and changing landscape for a balance among multiple uses and demands of some citizens and protection of common heritage and public interests including functioning ecosystems and wildlife habitat.

Sage-grouse are currently widespread (although in some areas densities are low), and relatively large areas continue to provide essential sagebrush habitats for the species; thus, long-term conservation of sage-grouse populations should be possible (Connelly and others, 2011b). The distributions of habitats, species, and human land uses are notably heterogeneous across large landscapes, and understanding the relations and processes that create these patterns, correlations, and aversions will assist in long-term planning. By helping to identify risks to habitat and resource conservation success, control and mitigation activities can be efficiently implemented by management agencies to reduce impacts and insure resiliency, and ultimately, to protect and conserve our natural heritage and natural resources for future generations. Rather than any single source of habitat degradation, the cumulative and synergistic impact of multiple disturbances, continued spread and dominance of invasive species, and increased impacts of land use continue to have the most significant influence on the trajectory of sagebrush ecosystems and sage-grouse populations (Connelly and others, 2011b). Future patterns of land use, combined with *effective* restoration and management, may improve, or degrade, the remaining sage-grouse ranges, but natural dynamics and unforeseen stochasticity promise to add complexity to future plans and landscapes, and these interactions are more difficult to control. Finally, population and habitat dynamics may be exaggerated for sage-grouse due to their strong affinity (obligate relation) with extensive, intact, and well-functioning sagebrush ecosystems, and because habitat limitations may magnify the effects of population stressors such as disease and disturbances such as wildfires.

Actions and Activities

The numerous efforts undertaken to identify threats to sage-grouse cumulatively suggest that invasive species, wildfire, grazing management and energy development—with the relative importance of each varying throughout the range of the species—pose the greatest risk to long-term conservation of sage-grouse (Connelly and others, 2011b). The Greater Sage-Grouse Comprehensive Conservation Strategy (GSGCCS; Stiver, 2011b) ranked potential habitat issues by region (eastern and western portions of the sage-grouse range) in order of immediacy, and the Greater Sage-Grouse Conservation Objectives Team: Final Report (2013) discusses details of populations which are not addressed here.

In the western portion of the range (especially MZs III, IV, and V), control of fire (removal from management, reduced human ignitions, and suppression of wildfires) and management of dispersed recreation have been identified as regional priorities for reducing disturbance to habitats and populations. Combating habitat degradation due to invasive plants was also deemed critical, and the current wide distribution and dominance by several invasive species (for example, cheatgrass and Medusahead) require risk assessment, prioritization, and strategic planning to focus funds and efforts to strategically protect and improve habitats. A combination of regional planning to determine the highest value areas, followed by local planning and implementation, will likely be required to address these species, which both degrade local habitats and agricultural productivity. These species are widespread across the region with severe infestations providing extensive seed sources and the necessity to manage across vast areas, multiple management units, and mixed ownership and administration. Manipulation of livestock grazing rotations and intensity to support conservation objectives for habitat condition and invasive plant control was identified as an important tool for managers throughout western portions of the sage-grouse range. In addition, increasing land use on, and around, public lands increases displacement of sage-grouse due to noise and activities; consideration of both near- and long-term habitat impacts of dispersed recreation and urban and exurban development were also identified as issues requiring attention. Trends in resource conditions and utilization, assessed locally and adapted seasonally, will be the most likely actions to affect short-term population trends when they are supported by regional planning and policy to reduce industrial impacts, eliminate new developments in priority habitats, and promote intact sagebrush ecosystems providing the necessary structure to substantiate local actions.

Similarly, on the eastern portion of the range (MZs I, II, and VII), invasive plant management and fire suppression remain important components of the conservation strategy. However, the GSGCCS (Stiver and others, 2006a) identified the reduction of impacts from the development of nonrenewable energy, and the support infrastructure (pipelines, roads, and structures) necessary for these developments, as top regional priorities for addressing declining sage-grouse populations. The potential for impacts across scales makes careful and deliberate planning at local *and* regional scales relevant to local populations. Consistent criteria for locating energy corridors, facilities, and infrastructure with minimal impacts to intact sagebrush communities and associated sage-grouse populations may incur benefits by concentrating activities and directing them away from the most sensitive areas and populations. To be useful and accurate, monitoring effectiveness of restoration and remediation projects may be coupled to landscape accounting for cumulative effects to insure treated and restored lands have required habitat values before additional sagebrush habitat is disturbed.

Historically, sagebrush was common across the range of sage-grouse (all MZs), but it was least common on the Colorado Plateau (eastern half of MZ III), Columbia Plateau (MZ VI), and Great Plains (MZ I). Historically and currently, sagebrush is most common in the northern Great Basin (MZ V) and eastward across the sagebrush-steppe found in the Snake River Plain and the Wyoming Basin (MZs II and IV); however, as previously noted, the best big sagebrush ecological sites (those with deep loamy soils) have been largely converted to agriculture. Because sage-grouse depend on sagebrush through all seasons with consistent selection for areas with more sagebrush canopy cover (Johnson and others, 2011), landscape-scale management for greater extent and connectivity of sagebrush communities and management and monitoring to maintain suitable shrub and herbaceous cover within that matrix are basic defining goals to direct conservation in all regions. Lek trends across the species' range are positively associated with sagebrush cover at multiple scales; functioning sagebrush ecosystems that provide cover and forage during all seasons are a necessary condition for viable sage-grouse populations (Johnson and others, 2011). Treatments that reduce sagebrush cover in the near-term are not recommended but may be successful if carefully prescribed within a region possessing "excess sagebrush cover" and with reasonable expectations for realization of increased sagebrush cover and habitat quality in the future (likely 25 years or more). Importantly, the risk of wildfire, estimated using fuel models, is pronounced across several MZs with the greatest risk in the Great Basin region (MZs III, IV, and V) due largely to the influence of cheatgrass (see figs. 26 and 27*A*); however, large portions of other regions (MZs I and II) are also projected to be at high risk. Fuel mitigation while maintaining and sustaining sagebrush habitat values across large landscapes will remain an important and challenging balance for habitat managers into the future.

Management Zone Summaries

MZ I—Northern Great Plains

Management Zone I consists of four sage-grouse populations, each encompassing relatively large regions: the Dakotas, northern Montana, Powder River Basin, and Yellowstone watershed populations (Garton and others, 2011). Predicted population trends indicate that populations in this MZ have an 11 percent chance of falling below 200 males by 2037, and a 24 percent chance of falling below 200 males by 2107 (Garton and others, 2011). A majority (66 percent) of the sagebrush landscape in this MZ is privately owned; however, sage-grouse leks in the region remain relatively well connected (Knick, 2011; Knick and Hanser, 2011). Because a majority of the sage-grouse habitats within MZ I are privately owned, current options for habitat conservation—for example, conservation easements and farm bill programs that can only be applied to private lands—are a viable option for effective sage-grouse conservation throughout the region. Some CRP lands may create habitat refugia within converted landscapes when they include sagebrush cover; enrollment of 17 percent of an agricultural landscape in eastern Washington succeeded in reversing short-term population declines (Schroeder and Vander Haegen, 2011). Cover and productivity of native rangelands, including silver sagebrush (*Art. cana*) and big sagebrush (*Art. tridentata*), are essential for effective conservation of sage-grouse in this region. Limited sagebrush cover (naturally, due to environmental gradients favoring grassland systems) coupled with historic agricultural uses and current energy-production infrastructure make natural and induced habitat limitations a fundamental, limiting factor for local sage-grouse populations in this region.

Major threats to sage-grouse habitats and populations occurring across populations in this MZ include oil and gas developments and conversion of native rangeland to crops (Conservation Objectives Team, 2013). Regional assessments estimated that 7.2 percent of priority and general habitats in MZ I are directly influenced by agricultural development, and >99 percent of these habitats are within 4.3 mi (6.9 km) of agriculture (table 4). Less than 1 percent of sage-grouse habitats are directly influenced by a natural gas or oil well; however, nearly 60 percent of the designated habitats lie within 11.8 mi (19 km) of a well (table 11, fig. 15)—the estimated effects area (Johnson and others, 2011; Taylor and others, 2012). More than 6.3 million acres (25,500 km^2, 14 percent) of sage-grouse habitat is currently leased for the development of Federal fluid minerals (table 13). Additionally, most sage-grouse habitats within the MZ have the potential to be influenced by mining and (or) energy development (figs. 21 and 22), although current coal and mineral developments directly influence less than 1 percent of the lands in the region (tables 16 and 17). BLM managed grazing allotments "not meeting land health standards for wildlife with grazing as the causal factor" constitute 2 percent of MZ I and are not widespread throughout the region (fig. 28); however, most of the sage-grouse habitats in MZ I are privately owned and were not addressed in this analysis. Inappropriate livestock management is recognized for its potential to influence habitat quality and sage-grouse populations across the region (Conservation Objectives Team and others, 2013); however, details of local conditions and grazing management were not summarized here. Fire risk is generally low across MZ I, with 17 percent of priority and general habitats having a high risk for fire (table 19); however, isolated areas, especially in central Montana, South Dakota, the border between Montana and Wyoming, and eastern Wyoming, are identified as having high fire risk (fig. 26). Risk of cheatgrass presence was not available for this region, but cheatgrass (and Japanese brome, *Bromus arvensis*) are known to occur across this region. Thus, risk of annual grass invasion, as well as annual-induced fire, appear to need better documentation across the region. To help prevent increasing cheatgrass dominance on these rangelands, potential for invasion can be assessed when planning habitat treatments and rehabilitating disturbed areas, with pre-disturbance abundance being a good indicator of potential for post-disturbance response (Davies and others, 2012). Urban development, power lines, vertical structures, and railroads directly influence less than 2 percent of the sage-grouse habitats in the region; however, this distribution is relatively dense compared to western portions of the range of sage-grouse (tables 5–9; figs. 10–13).

MZ II and VII—Wyoming Basin and the Colorado Plateau

Management Zones II and VII include nine sage-grouse populations with the bulk of the area constituting the Wyoming Basin population; several smaller areas occupied by sage-grouse are distributed around the Wyoming Basin population, especially south of this population on the Colorado Plateau (Garton and others, 2011). Northern portions of this MZ currently represent the highest abundance of sage-grouse relative to other MZs across the range of the species (Conservation Objectives Team and others, 2012); projections indicate that the chance of populations in this region falling below 200 males by 2037 is 0.3 percent and a 16 percent chance populations falling below 200 males by 2107 (Garton and others, 2011). Leks in northern portions of MZs II and VII are the most highly connected in the range (Knick and Hanser, 2011a). Conversely, populations in southern portions of MZs II and VII (Colorado Plateau) are not as robust with a projected 96 percent chance of populations declining below 200 males by 2037 and a 98 percent chance by 2107 (Garton and others, 2011). Additionally, leks in southern regions of the MZs are the least connected across the range of the species (Knick and Hanser, 2011). In contrast to MZ I, 54 percent of the sagebrush habitats in MZs II and VII are Federally managed (Knick and Connelly, 2011b). Therefore, conservation easements and farm bill programs that can only be applied to private lands will likely be ineffective as a sole means of conserving sage-grouse in these MZs; comparable programs affecting effective rehabilitation and restoration on public lands, at similar scales, are needed (Connelly and others, 2011b). The Wyoming Basin (MZ II) is currently home to the largest regional extent and highest breeding density of sage-grouse in the Western United States with several important satellite populations including Jackson Hole, Wyoming, and Routt County, Colorado. Livestock grazing has been ubiquitous across these sagebrush dominated ranges, which also have seasonal importance for native elk, mule deer, pronghorn, and several herds of feral horses, for more than a century. Nonrenewable energy extraction (coal, oil, and natural gas), and more recently renewable energy production (wind farms), are superimposed over the habitat gradients created by natural environmental patterns and historic land uses, and the current combination of use and natural dynamics are sufficiently intense to cause measureable changes in sagebrush cover (Xian and others, 2012). Therefore, trends in land cover and land use are recognized as contributing to population declines, in this region, in the recent past.

The major threat to sage-grouse habitats and populations occurring across populations in MZs II and VII is energy development—primarily oil and gas development—and supporting infrastructure (Conservation Objectives Team and others, 2012); less than 1 percent of priority and general habitats are directly influenced by natural gas or oil wells; however, more than 75 percent of PPH and more than 80 percent of PGH lie within the likely effects buffer (11.8 mi [19 km]) providing an indication of the widespread and cumulative influence of energy infrastructure (table 11, fig. 14). Further, approximately 7.8 million acres (31,500 km^2, 21 percent) of the sage-grouse habitats in these MZs are currently leased for development of Federal natural gas or oil reserves (table 13). This region also has Federal leases for the research of oil shale extraction overlapping the southern populations (fig. 19*A*). The potential for coal mining, geothermal energy development, oil shale development, and wind energy development are also widespread throughout this MZ (figs. 18–24). In spite of these competing factors, the loss of habitat from subdivision and housing development and associated infrastructure (for example, roads) has been identified as the greatest threat to sage-grouse populations in southern portions of MZs II and VII (Conservation Objectives Team, 2013). Urban development, power lines, vertical structures, and railroads directly influence less than 5 percent of the sage-grouse habitats in the entire MZ, and these infrastructures are relatively dense in MZs II and VII compared to western portions of the range of sage-grouse (tables 5–9, figs. 10–13). For example, the proportion of sage-grouse habitat influenced directly by urban development in MZs I, II, and VII combined is 3.1 times higher; the amount directly influenced by power lines is 2.1 times higher, and the amount directly influenced by railroads is 1.9 times higher than the proportion directly influenced in the other MZs combined (tables 5–9).

BLM managed grazing allotments not meeting wildlife standards consist of 4 percent of MZs II and VII and are not widespread throughout the region except in southern portions of the MZ (table 22, fig. 28); however, considerable portions of this region have not been recently assessed. Although areas not meeting standards are not widespread in the region, the Greater Sage-Grouse Comprehensive Conservation Strategy (Stiver and others, 2006a) ranked livestock grazing just below energy development and urbanization as an issue requiring immediate attention in eastern portions of the range of sage-grouse. Additionally, a large portion of central regions of this MZ (close to 5 million acres [20,200 km^2] across the entire MZ; table 23) is Federally managed wild horse and burro range (fig. 29), suggesting potential effects to sage-grouse of livestock grazing, and the compounding effects of feral grazers need to be considered across the region. Fire risk is generally low across MZ II and VII with 10 percent of priority and general habitats at high risk for fire (table 19); however, areas in northern and southern portions of the MZ are identified as having high fire risk (fig. 26).

Cheatgrass is distributed across the region, however, generally not with the same abundance observed in the Great Basin region; some portions of this region, for example, the ownership “checkerboard” in southern Wyoming, are notably more thoroughly invaded than cooler parts of the region. Where severe infestation overlaps with PPH and PGH, management-intensive restoration may be considered. Current levels of disturbance have been sufficient to spread invasive species, and the historic combination of drought-stress and overutilization left sufficient niche space among native perennials for local proliferation. In many areas, short-term adaptations of grazing rotations to increase the cover of native perennials may be sufficient to restore high-quality habitats. Despite the perceived abundance and persistence of sagebrush in some parts of this region, extensive (or cumulative) treatments that remove sagebrush cover (even temporarily) are discouraged, unless said treatments represent a very small portion of an extensive, intact sagebrush stand (very rare) or are expressly designed to rehabilitate degraded, underutilized habitats.

MZ III—Southern Great Basin and Western Colorado Plateau

Management Zone III consists of 12 sage-grouse populations distributed throughout the region including the Southern Great Basin population in central and eastern Nevada, which contains the largest numbers of sage-grouse in MZ III (Conservation Objectives Team and others, 2013), several small populations in central Utah, and the Bi-State Distinct Population Segment along the California-Nevada border (Garton and others, 2011). Predicted population trends indicate that populations in this MZ have almost no chance of falling below 200 males by 2037 and an 8 percent chance of falling below 200 males by 2107 (Garton and others, 2011); however, these scenarios are limited in their ability to predict the future, especially stochastic events and novel environmental conditions, so caution is warranted. A majority (82 percent) of the sagebrush landscape in this MZ is Federally managed (predominantly BLM and USFS; table 26), indicating that actions on Federal lands are expected to have measurable population effects, and conservation measures on private lands may be less influential, as a whole, for conserving sage-grouse in this MZ. However as noted in sections above, large areas of influence exist from some threats; therefore, cooperation and prioritization of habitats across jurisdictions is still important in this Management Zone. This region is best characterized (for sage-grouse) by the large Southern Great Basin population, which occupies much of central and eastern Nevada; however, several smaller but significant populations persist, and priority management issues and challenges associated with these small populations may be distinctive from other populations in the region.

Sagebrush cover is naturally limited and patchy across much of this region, as dictated by geologic substrates and formations that also help dictate (via topography) microclimates and local environmental conditions that enable sagebrush dominance, and this is evident in the lack of connectivity among subpopulations in this region (Knick and Hanser, 2011). Well densities are currently low compared to other MZs (for example, MZs I and II). Current energy developments influence sage-grouse habitats in eastern portions of the MZ but are not widespread (figs. 14 and 16); however, more than 1.8 million acres (7,285 km^2; 13 percent) of the sage-grouse habitats in the MZ are currently leased for Federal fluid-mineral development (table 13) suggesting that some areas may receive increased pressure from energy development in the future. Additionally, coal and oil shale potential are high in eastern areas (Utah) of MZ III (figs. 19 and 23) indicating that development of these resources could affect already isolated populations in Utah. High potential for geothermal energy development coincides with sage-grouse habitats in central and western portions of MZ III (fig. 21*B*), and solar-energy potential is high in southern portions of the region indicating that these alternate energy sources could have impacts on sage-grouse habitats in southern Nevada and Utah in the future (depending on technology, financial markets, and public policies).

In contrast, the number and size of areas affected annually by fire in this MZ are an order of magnitude greater than is typical in the Wyoming Basin (MZ II) to the east, suggesting that land-use disturbance has been replaced, or substituted, with frequent fire in these areas; this condition is often closely tied to the invasion and dominance of annual grasses, especially cheatgrass, due to their effect on fuels and fire-return intervals (figs. 25 and 26). Since 2000, 404,000 acres (1,635 km^2; 2.8 percent) of priority and general sage-grouse habitats (PPH and PGH combined) have burned in this MZ. Annual means suggest that only 13,500 acres (54 km^2; <2 percent) of habitats (PPH and PGH) burn each season; however, the observed maximum is more than 55,000 acres (220 km^2; 0.5 percent of PPH and 1.4 percent of PGH in this region). Importantly, 63 percent of the region is considered at high risk for fire (tables 19, fig. 26). Conifer encroachment potentially affects more than 1.8 million acres (7,285 km^2; 13 percent) of priority and general habitats in MZ III (table 21). Precise estimates of actual impact are not available; therefore, evaluation of local habitat priorities and potential treatment benefits to inform planning efforts may require higher resolution data. Cheatgrass invasion has been widespread in this region for decades, and some former (historic) habitats are likely "unrecoverable" without unreasonable infusion of restoration effort (that is, it would be too expensive given current knowledge and technology); many of these areas are already excluded from current habitat distributions (fig. 1). Nonetheless, current estimates indicate more than 30 percent of PPH and 40 percent of PGH remain at high risk of invasion with notable risks remaining in some areas. Beyond managing risk, restoration of potentially valuable areas, such as those that would increase connectivity among seasonal habitats or subpopulations, or simply increase area and quality of current seasonal ranges, may become an important management option where natural and anthropogenic patterns and processes have fragmented and degraded habitats.

In addition to cheatgrass, widespread, intense land use coupled with natural variability and limitations of climate has resulted in measurable effects on rangeland conditions. Currently (2006), 1.6 million acres (6,475 km^2) of the BLM managed sage-grouse habitats in MZ III (17 percent) do not meet wildlife standards due to grazing impacts (table 22). Further, more than 4.1 million acres (16,590 km^2; 29 percent) of this area is designated wild horse and burro range; most of these areas are in central Nevada (table 23, fig. 29*A*). Horse and burro herbivory has been connected to intense resource use and measureable effects on range conditions and habitat quality (Beever and Aldridge, 2011).

Urbanized areas, power lines, and railroads influence habitats in eastern portions (Utah) of this MZ but are not widespread in central and western portions. Agricultural development influences less than 1 percent of the MZ, however due to indirect influences, 78 percent (the lowest proportion across MZs) of priority and general habitats are estimated to be affected by cropland (table 4, fig. 9).

MZ IV—Snake River Plain

Management Zone IV consists of 11 sage-grouse populations distributed throughout the region with the bulk of the occupied area consisting of the Northern Great Basin and Snake-Salmon-Beaverhead, Idaho populations (Garton and others, 2011). Similarly to other regions, the Snake River Plain of southern Idaho has a long history of agricultural land uses that include irrigated crops and open-range livestock management. Historic conversion of the best sites (deepest soils) to agriculture (a practice that was widespread with nearly complete conversion in this region) has resulted in a residual sagebrush landscape that is inherently less productive than those of the past (prior to European colonization). Subsequently, most known populations in the region are relatively small and (or) separated from adjacent populations; important exceptions are the large population living in central Idaho (the largest outside of the Wyoming Basin) within the upper watershed of the Snake, Salmon, and Beaverhead Rivers, and the Northern Great Basin population living on the Snake River Plain (Conservation Objectives Team, 2013). Several small, isolated populations are located in predominantly northern portions of this MZ (Garton and others, 2011). Nonetheless, habitat availability remains a primary limiting factor in this region due to the combination of land-use and disturbance (fire) influences, and influences of current and historic land uses add to these effects through effects on the health and condition of available ranges.

Population trends and vulnerability models indicate that populations in this MZ have an 11 percent chance of falling below 200 males by 2037, and a 40-percent chance of falling below 200 males by 2107 (Garton and others, 2011). A majority (63 percent) of the sagebrush landscape in this MZ is Federally managed (Knick 2011), suggesting conservation measures on public lands may be expected to have measurable effects on sage-grouse populations, and the role of private lands will remain important but limited, in general, as a means of conserving sage-grouse in this MZ. Local importance and effectiveness of projects may be greater than rangewide effects due to local contributions to seasonal habitat quality and connectivity.

Primary threats to sage-grouse habitats and populations occurring across populations in MZ IV include habitat loss and fragmentation as a result of wildfire (Conservation Objectives Team, 2013). Since 2000, more than 4.9 million acres (21,000 km^2; 14 percent of PPH and 17 percent of PGH) of priority and general sage-grouse habitats have burned in this MZ, with an average of more than 239,000 acres (970 km^2) of priority habitats burned annually; more than 1 million acres (4,047 km^2) burned in some years (table 18, fig. 25). For example, the Murphy Fire in Idaho and Nevada affected more than 650,000 acres (2,630 km^2) of habitat in this MZ in 2007 (Conservation Objectives Team, 2013). Additionally, 81 percent of the region is considered at high risk for fire (table 19, fig. 26). Approximately 11.6 million acres (47,175 km^2; 53 percent) of PPH and 6.4 million acres (25,900 km^2, 58 percent) of PGH in MZ IV are considered high risk for cheatgrass, and these high-risk areas are widespread throughout the MZ (table 20, fig. 27*A*).

Geothermal energy development potential is particularly high throughout MZ IV (fig. 21*B*). Very few active oil and gas wells exist in the MZ (fig. 14), although there has been some exploration historically, and less than 350,000 acres (1,400 km^2; 1 percent) of sage-grouse habitats are currently leased for Federal fluid-mineral exploration (table 13). Additionally, coal and solar potential are low throughout the MZ (figs. 20 and 22). Urbanized areas, power lines, and railroads influence habitats predominantly in eastern portions (eastern Idaho and southwestern Montana) of MZ IV (tables 5–9, figs. 10–13). However, designated energy corridors are located in southern portions of the MZ, and transmission lines are proposed in these areas, for example Gateway West (see *http://www.wy.blm.gov/nepa/cfodocs/gateway_west/map.html*). Agricultural development influences 1 percent of the MZ, and 85 percent of priority and general habitats are within 4.3 mi (6.9 km) of cropland (table 4, fig. 9).

Finally, historic and current land-use patterns affect habitat conditions, in addition to regional distributions. Currently (2006 assessment) more than 3.5 million acres (14,160 km^2) of BLM managed sage-grouse habitats (19 percent) do not meet wildlife standards due to livestock (table 22, fig. 28) in this MZ; this is the largest area, absolutely and proportionally, of all MZs (albeit large portions of some other MZs were not assessed). Compounding the effects of large herbivores on ecosystem conditions, some habitat within this MZ (6 percent) is Federally managed wild horse and burro range including a relatively large area of priority habitat in northern Nevada (table 23, fig. 29*A*). Though managed grazing remains a part of the tools used to manage habitats into the future, with a potential role for addressing fuel accumulation and fire potential, invasive plants, and vegetation structure and composition, non-prescribed grazing (over-grazing), as determined by local conditions and climate patterns, is clearly implicated for its detrimental effects on rangeland health as well as habitat conditions, in some areas. Thus in this MZ, and other areas, where the interactions of ecosystem conditions, climate, and multiple herbivores may result in habitat degradation, close monitoring of productivity and off-take to manipulate and adjust use levels to maintain seasonal habitat quality may be necessary. Importantly, local conditions and environmental patterns (such as climate) are highly variable, and direct assessments are dated (>5 years old in most cases); therefore, trends and conditions assessed here may have changed. This reinforces the need for frequent evaluation and adjustments to balance multiple uses with habitat requirements of the native wildlife.

MZ V—Northern Great Basin

This MZ includes three large populations living on the western one-third of the Northern Great Basin region and a fourth, relatively large population in central Oregon (Garton and others, 2011). Predicted population trends indicate that populations in this MZ have a low (2 percent) chance of falling below 200 males by 2037 and a greater (29 percent) chance of falling below 200 males by 2107 (Garton and others, 2011). A majority of the sagebrush landscape in this MZ (77 percent) is Federally managed (Knick and Connelly, 2011b), suggesting conservation measures that can only be applied to private lands may be insufficient for conserving sage-grouse in this region, but Federal habitat management may be expected to have a strong influence on these populations. Sage-grouse leks in this region are relatively well connected (second in rank behind Wyoming Basin; Knick and Hanser, 2011b); however, a national team of experts identified habitat loss and fragmentation due to wildfire and conifer encroachment as primary threats to sage-grouse in this region (Conservation Objectives Team, 2013).

The Northern Great Basin region contains less “moderately” and “highly’ affected sage-grouse habitat than the westwide average. But it also contains the most extensive “low” land-use intensity distribution of all MZs indicating priorities focused on managing low-intensity, distributed land uses to conserve and improve habitat for grouse (passive approaches should be effective and efficient) may be critical to regional conservation success. Similarly, areas with intensive use that overlap priority habitats (PPH and PGH) may be readily prioritized for habitat improvements because these areas are less extensive than in adjacent regions. However, since 2000 more than 1.5 million acres (6,400 km^2; 12.2 percent) of priority (17.5 percent) and general (5.8 percent) sage-grouse habitats burned with an average size of more than 95,000 acres (385 km^2) per year during this time span (table 18, fig. 25). Additionally, 67 percent of the region is considered at high risk for fire (table 19, fig. 26). Despite these fires, conifers have encroached on approximately 1.4 million acres (5,670 km^2; 11 percent) of priority and general habitats in MZ V (table 21) indicating, again, that the spatial heterogeneity in habitat threats and conditions require local interpretation and adaptation to differentiate threats and develop specific management solutions. As another example, low sagebrush (*A. arbuscula*) is common only in the Northern Great Basin, although it occurs throughout the range at varying abundance (Johnson and others, 2011), and it is utilized by sage-grouse consistently here, in multiple seasons, including nesting and brood-rearing, making proper management and conservation of this ecological type important for sage-grouse conservation in this region.

More than 5.6 million acres (22,735 km^2; 43.5 percent) of MZ V are considered moderate to high risk for cheatgrass; a large block of high-risk priority habitat is located in northwestern Nevada (table 20, fig. 27*A*). More than 3.6 million acres (14,570 km^2; 28 percent) of sage-grouse habitats distributed throughout MZ V is Federally managed wild horse and burro range (table 23, fig. 29*A*). Approximately 6 percent of BLM managed sage-grouse habitats in MZ V do not meet wildlife standards (table 22, fig. 28), with again a relatively large block of priority habitat not meeting standards in northwestern Nevada.

Finally, though no single threat supersedes others, there are various forms of industrial development that affect habitats in this region. No active oil and gas wells currently exist in the MZ (fig. 15), and no measurable additional acreage has been leased for fluid-mineral exploration (table 13). However, geothermal energy potential is high throughout the region indicating potential for future development (fig. 21). Urbanized areas, power lines, and railroads are less dense in MZ V than in eastern portions of the sage-grouse range (tables 5–9, figs.10–13*A*). However, the Warm Springs Valley population, a small area on the California-Nevada border (Garton and others, 2011), is known to be influenced by urbanization and a transmission line (Conservation Objectives Team, 2013). Agricultural developments currently influence less than 1 percent of the MZ; however, 75 percent of priority and general habitats are within the influence of cropland (table 4, fig. 9) indicating a high likelihood of influence, without direct displacement.

MZ VI—Columbia Basin

The sage-grouse habitats within the Columbia Basin are among the most developed (primarily agriculture) and heavily used landscapes still occupied by sage-grouse. These two, small populations are also affected by living near the distribution limits of the species and suitable sagebrush habitats. Washington populations do not significantly occupy BLM lands, so while important to the overall conservation of the species, this region is not directly addressed in this assessment. CRP lands can create habitat refugia within converted landscapes when they include sagebrush cover; enrollment of 17 percent of an agricultural landscape in eastern Washington succeeded in reversing short-term population declines, whereas declines continued on adjacent landscape with fewer CRP-designated lands (Schroeder and Vander Haegen, 2011). These populations are recognized here but are part of an independent plan and assessment process.

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References Cited

Aldrich, J.W., 1946, New subspecies of birds from western North America: Proceedings of the Biological Society of Washington, Biological Society of Washington, v. 59, p.129–136.

Aldrich, J.W., 1963, Geographic orientation of American *tetraonidae*: Journal of Wildlife Management, v. 27, no. 4, p. 529–545.

Aldrich, J.W., and Duvall, A.J., 1955, Distribution of American gallinaceous game birds: U.S. Fish & Wildlife Service: Circular 34, p.12–17.

Aldridge, C.L., 2000, Reproduction and habitat use by Sage Grouse (*Centrocercus urophasianus*) in a northern fringe population: Saskatchewan, Canada, University of Regina, M.S. thesis, 109 p.

Aldridge, C.L., and Boyce, M.S., 2007, Linking occurrence and fitness to persistence: Habitat–based approach for endangered Greater Sage-Grouse: Ecological Applications, v. 17, no. 2, p. 508–526.

Aldridge, C.L., and Brigham, R.M., 2003a, Distribution, abundance, and status of the Greater Sage-Grouse, *Centrocercus urophasianus*, in Canada: Canadian Field–Naturalist, v. 117, p. 25–34.

Aldridge, C.L., and Brigham, R.M., 2003b, Sage-grouse nesting and brood habitat use in southern Canada: Journal of Wildlife Management, v. 67, p. 910–910.

Aldridge, C.L., Nielsen, S.E., Beyer, H.L., Boyce, M.S., Connelly, J.W., Knick, S.T., and Schroeder, M.A., 2008, Range-wide patterns of greater sage-grouse persistence: Diversity and Distributions, v. 14, p. 983–994.

Aldridge, C.L., Saher, D.J., Childers, T.M., Stahlnecker, K.E., and Bowen, Z.H., 2012, Crucial nesting habitat for Gunnison sage-grouse: A spatially explicit hierarchical approach: Journal of Wildlife Management, v. 76, p. 391–406.

Allendorf, F.W., and Leary, R.W., 1986, Heterozygosity and fitness in natural populations of animals, *in* Soule, M.E., ed., Conservation biology: the science of scarcity and diversity: Sunderland, Mass., U.S.A., Sinauer Associates, p. 51–65.

American Ornithologists' Union, 1957, Check–list of North American birds, 5th ed., 139 p.

Anderson, E.D., Long, R.A., Atwood, M.P., Kie, J.G., Thomas, T.R., Zager, P., and Bowyer, R.T., 2012, Winter resource selection by female mule deer *Odocoileus hemionus*: functional response to spatio-temporal changes in habitat: Wildlife Biology, v. 18, p. 153–163.

Anderson, J.E. and Inouye, R.S., 2001, Landscape–scale changes in plant species abundance and biodiversity of a sagebrush steppe over 45 years: Ecological Monographs, v. 71, p. 531–556.

Anderson, L.D., 1991, Bluebunch wheatgrass defoliation effects and vigor recovery: Salmon, Idaho, Bureau of Land Management, 25 p.

Angell, R.F., 1997. Crested wheatgrass and shrub response to continuous or rotational grazing: Journal of Range Management, v. 50, p. 160–164.

Aspbury, A., and Gibson, R.M., 2004, Long-range visibility of greater sage grouse leks: a GIS-based analysis: Animal Behaviour, v. 67, p. 1127–1132.

Assal, T.J., Veblen, K.E., Farinha, M.A., Aldridge, C.L., Cassaza, M.E., and Pyke, D.A., 2012, Data resources for range-wide assessment of livestock grazing across the Sagebrush Biome: U.S. Geological Survey Data Series 690.

Atamian, M.T., Sedinger, J.S., Heaton, J.S., and Blomberg, E.J., 2010, Landscape-level assessment of brood rearing habitat for Greater Sage-Grouse in Nevada: Journal of Wildlife Management, v. 74, p. 1533–1543.

Autrienth, R.E., 1981, Sage grouse management in Idaho: Boise, Idaho, Idaho Department of Fish and Game, Research Report, available at *http://fishandgame.idaho.gov/public/wildlife/sageGrouse/*.

Baker, W.L., 2006, Fire and restoration of sagebrush ecosystems: Wildlife Society Bulletin, v. 34, p. 177–185.

Baker, W.L., 2011, Pre- Euro-American and recent fire in sagebrush ecosystems, *in* Knick, S.T. and Connelly, J.W., eds., Greater sage-grouse: ecology and conservation of a landscape species: Berkeley, Calif., University of California Press, p. 185–202 .

Balch, J.K., Bradley, B.A., D'Antonio, C.M., and Gomez-Dans, J., 2012, Introduced annual grass increases regional fire activity across the arid western USA (1980–2009): Global Change Biology, v. 19, p. 173–183.

Bartmann, R.M., White, G.C., Carpenter, L.H., and Garrott, R.A., 1987, Aerial mark-recapture estimates of confines mule deer in pinyon-juniper woodland: Journal of Wildlife Management, v. 51, p. 41–46.

Bates, J.D., Davies, K.W., and Sharp, R.N., 2011, Shrub-steppe early succession following juniper cutting and prescribed fire: Environmental Management, v. 47, p. 468–481.

Bates, J.D., Rhodes, E.C., Davies, K.W., and Sharp, R., 2009, Postfire succession in Big Sagebrush Steppe with livestock grazing: Rangeland Ecology & Management, v. 62, p. 98–110.

Bates, J.D., Svejcar, T., Miller, R.F., and Angell, R.A., 2006, The effects of precipitation timing on sagebrush steppe vegetation: Journal of Arid Environments, v. 64, p. 670–697.

Baughman, C., Forbis, T.A., and Provencher, L., 2010, Response of two sagebrush sites to low-disturbance, mechanical removal of pinyon and juniper: Invasive Plant Science and Management, v. 3, p. 122–129.

Baxter, R.J., Flinders, J.T., and Mitchell, D.L., 2008, Survival, movements, and reproduction of translocated greater sage-grouse in Strawberry Valley, Utah: Journal of Wildlife Management, v. 72, p. 179–186.

Beck, J.L., Connelly, J.W., and Reese, K.P., 2009, Recovery of Greater Sage–Grouse habitat features in Wyoming Big Sagebrush following prescribed fire: Restoration Ecology, v. 17, p. 393–403.

Beck, J.L., Connelly, J.W., and Wambolt, C.L., 2012, Consequences of treating Wyoming Big Sagebrush to enhance wildlife habitats: Rangeland Ecology and Management, v. 65, no. 5, p. 444–455.

Beck, J.L., and Mitchell, D.L., 2000, Influences of livestock grazing on sage grouse habitat: Wildlife Society Bulletin, v. 28, p. 993–1002.

Beck, J.L., Mitchell, D.L., and Maxfield, B.D., 2003, Changes in the distribution and status of sage-grouse in Utah: Western North American Naturalist, v. 63, p. 203–214.

Beck, J.L., Reese, K.P, Connelly, J.W., and Lucia, M.B., 2006, Movements and survival of juvenile greater sage-grouse in southeastern Idaho: Wildlife Society Bulletin, v. 34, p. 1070–1078.

Beck, T.D.I., 1977, Sage grouse flock characteristics and habitat selection in winter: Journal of Wildlife Management, v. 41, p. 18–26.

Beever, E.A., and C.L., Aldridge, 2011, Influences of free-roaming equids on sagebrush ecosystems, with focus on greater sage-grouse, *in* Knick, S.T., and Connelly, J.W,. eds., Studies in avian biology, no.38: University of California Press, Berkeley, Cooper Ornithological Union, p. 273–291.

Belcher, J.W., and Wilson, S.D., 1989, Leafy spurge and the species composition of mixed grass prairie: Journal of Range Management, v. 42, p. 172–175.

Benedict, N.G., Oyler–McCance, S.J., Taylor, S.E., Braun, C.E., and Quinn, T.W., 2003, Evaluation of the eastern (*Centrocercus urophasianus urophasianus*) and western (*Centrocercus urophasianus phaios*) subspecies of sage–grouse using mitochondrial control-region sequence data: Conservation Genetics, v. 4, p. 301–310.

Berry, J.D., and Eng, R.L., 1985, Interseasonal movements and fidelity to seasonal use areas by female sage-grouse. Journal of Wildlife Management, v. 49, p. 237–240.

Bi-State Local Planning Group, 2004, Greater sage-grouse conservation for the bi-state plan area of Nevada and eastern California: Bi-State Local Planning Group, First Edition, 193 p.

Blickley, J.L., Blackwood, D., and Patricelli, G.L., 2012, Experimental evidence for the effects of chronic anthropogenic noise on abundance of Greater Sage-Grouse at leks: Conservation Biology, v. 26, p. 461–471.

Blomberg, E.J., Sedinger, J.S., Atamian, M.T., and Nonne, D.V., 2012, Characteristics of climate and landscape disturbance influence the dynamics of Greater Sage-Grouse populations: Ecosphere, v. 3, p. 55–65.

Blus, L.J., Staley, C.S., Henny, C.J., Pendleton, G.W., Craig, T.H., Craig, E.H., and Halford, D.K., 1989, Effects of organophosphorus insecticides on sage grouse in southeastern Idaho: Journal of Wildlife Management, v. 53, p. 1139–1146.

Bouzat, J.L., Cheng, H.H., Lewin, H.A., Westemeier, R.L., Brawn, J. D., and Paige, K.N., 1998, Genetic evaluation of a demographic bottleneck in the greater prairie chicken: Conservation Biology, v. 12, p. 836–843.

Boyce, M.S., 1990, The red queen visits sage grouse leks: American Zoology, v. 30, p. 263–270.

Boyko, A.R., Gibson, R.M., and Lucas, 2004, How predation risk affects the temporal dynamics of avian leks: Greater Sage-Grouse versus golden eagles: American Naturalist, v. 163, p. 154–165.

Bradley, B.A., 2010, Assessing ecosystem threats from global and regional change: hierarchical modeling of risk to sagebrush ecosystems from climate change, land use and invasive species in Nevada, U.S.A.: Ecography, v. 33, p. 198–208.

Braun, C.E., 1998, Sage grouse declines in western North America: what are the problems?, *in* Proceedings of the Western Association of State Fish and Wildlife Agencies (WAFWA), p. 139–156.

Braun, C.E., Baker, M.F., Eng, R.L., Gashwiler, J.W., and Schroeder, M.H., 1976, Conservation committee report on effects of alteration of sagebrush communities on the associated avifauna: The Wilson Bulletin, v. 88, p. 165–171.

Braun, C.E., and Beck, T.D.I., 1985, Effects of changes in hunting regulations on sage grouse harvest and populations, *in* Beason, S.L., and Roberson, S.F., eds., Game harvest mangement: Kingsville, Tex., Caesar Kleberg Wildlife Research Institute, p. 335–343.

Braun, C.E., Oedekoven, O.O., and Aldridge, C.L., 2002, Oil and gas development in western North America: Effects on sagebrush steppe avifauna with particular emphasis on sage grouse, *in* Rahm, J., ed., Transactions of the sixty-seventh North American wildlife and natural resource conference: Wildlife Management Inst., Washington, p. 337–349.

Briske, D.D., Derner, J.D., Brown, J.R., Fuhlendorf, S.D., Teague, W.R., Havstad, K.M., Gillen, R.L., Ash, A.J., and Willms, W.D., 2008, Rotational grazing on rangelands: reconciliation of perception and experimental evidence: Rangeland Ecology & Management, v. 61, p. 3–17.

Briske, D.D., S.D. Fuhlendorf, and F.E. Smeins, 2003, Vegetation dynamics on rangelands: a critique of the current paradigms: Journal of Applied Ecology, v. 40, p. 601–614.

Briske, D.D., and Hendrickson, J.R., 1998, Does selective defoliation mediate competitive interactions in a semiarid savanna? A demographic evaluation: Journal of Vegetation Science, v. 9, p. 611–622.

Brockway, D.G., Gatewood, R.G. and Paris, R.B., 2002, Restoring grassland savannas from degraded pinyon-juniper woodlands: effects of mechanical overstory reduction and slash treatment alternatives: Journal of Environmental Management, v. 64, p. 179–197.

Brown, J.K., 1982, Fuel and fire behavior prediction in big sagebrush: Research paper INT-290 83–B, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Bruce, J.R., Robinson, W.D., Petersen, S.L., and Miller, R.F., 2011, Greater Sage-Grouse movements and habitat use during winter in central Oregon: Western North American Naturalist, v. 71, p. 418–424.

Bui, T.D., 2009, The effects of nest and brood predation by common ravens (*Corvus corax*) on Greater Sage-Grouse (*Centrocercus urophasianus*) in relation to land use in western Wyoming: University of Washington.

Bureau of Land Management, 1999, Out of ashes, An opportunity: Report of the Great Basis Restoration Initiative: Boise, Idaho, BLM National Office of Fire and Aviation, 28 p., available at *http://www.sagestep.org/educational_resources.*

Bureau of Land Management, 2008, Wildfire season and sage-grouse conservation: Washington, D.C. Bureau of Land Management.

Bureau of Land Management, 2011a, BLM National Sage–Grouse Land Use Planning Strategy: Washington, D.C., Bureau of Land Management, Instruction Memorandum.

Bureau of Land Management, 2011b, Greater Sage-Grouse interim management policies and procedures: Washington, D.C., Bureau of Land Management, Instruction Memorandum.

Bureau of Land Management, 2011c, Notice of intent to prepare environmental impact statements and supplemental revironmental impact statements to incorporate Greater Sage-Grouse conservation measures into land use plans and land management plans*:* Washington, D.C, Federal Register 40 CFR 1501.7.

Bureau of Land Management, 2012, Notice of correction to notice of intent to prepare environmental impact statements and supplemental environmental impact statements to incorporate Greater Sage-Grouse conservation measures into land use plans and land management plans: Washington, D.C., Federal Register 43 CFR 1610.2., p. 7178–7179.

Bureau of Land Management, 2012b, Oil shale and tar sands programmatic EIS information center: Bureau of Land Management, BLM–WO–GI–08–005–3900, DOI No. DES 12–01, accessed December 2012 at *http://ostseis.anl.gov*.

Bureau of Land Management, 2012c, Final solar energy development programmatic EIS: Bureau of Land Management, FES 12–24: DOE/EIS–0403, final EIS published July 2012, available at *http://solareis.anl.gov*.

Burkhardt, J.W., and Tisdale, E.W., 1976, Causes of juniper invasion in southwestern Idaho: Ecology, v. 57, p. 472–484.

Bush, K.L., 2009, Genetic diversity and paternity analysis of endangered Canadian Greater Sage–Grouse (*Centrocercus urophasianus*): Edmonton, Alberta, Canada, University of Alberta, Ph.D. dissertation.

Cagney, J., Bainter, E., Budd, R., Christiansen, T., Herren, V., Holloran, M.J., Rashford, B., Smith, M.D., and Williams, J., 2010, Grazing influence, objective development, and mangement in Wyoming’s Greater Sage–Grouse habitat: Laramie, University of Wyoming, Cooperative Extension Service Report.

Call, M., and Maser, W.C., 1985, Wildlife habitats in managed rangelands—The Great Basin of southeastern Oregon sage grouse: La Grande, Oreg., U.S. Department of Agriculture, Forest Service, General Technical Report, 30 p.

Canada Gazette, 2002, Species at risk act: Canada Gazette, 428 p.

Carpenter, J., Aldridge, C., and Boyce, M.S., 2010, Sage-grouse habitat selection during winter in Alberta: Journal of Wildlife Management, v. 74, p. 1806–1814.

Carr, H.D., and Glover, F.A., 1970, Effects of sagebrush control on sage grouse: North American Wildlife and Natural Resources Conference Transcripts, p. 205–215.

Chong, G.W., Wetzel, W.C., and Holloran, M.J., 2011, Greater Sage–Grouse of Grand Teton National Park: Where do they roam?: Park Science, v. 27, p. 42–49.

Chong, G.W., and Anderson, P.J., 2010, Applying greenness indices to evaluate sagebrush treatments in the WLCI region, *in* Bowen, Z.H., and others, U.S. Geological Survey science for the Wyoming landscape conservation initiative—2009 Annual Report: U.S. Geological Survey Open-File Report 2010–1231, p. 59–63.

Christen, D.C., and Matlack, G.R., 2009, The habitat and conduit functions of roads in the spread of three invasive plant species: Biological Invasions, v. 11, p. 453–465.

Christensen, N.L., 1985, Shrubland fire regimes and their evolutionary consequences, *in* Pickett, S.T.A., and White, P.S., The ecology of natural disturbance and patch dynamics: San Diego, Calif., Academic Press, , p. 85–100.

Christiansen, T., 2009, Fence marking to reduce Greater Sage–Grouse (*Centrocercus urophasianus*) collisions and mortality near—Summary of interim results: Farson, Wyo., Wyoming Game and Fish Department.

Christiansen, T.J., and Tate, C.M., 2011, Parasites and infectious disease of Greater Sage-Grouse, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology and conservation of a landscape species and its habitats: Berkeley, University of California Press, Cooper Ornithological Union, no. 38, 47 p.

Clark, L., Hall, J., McLean, R., Dunbar, M., Klenk, K., Bowen, R., and Smeraski, C.A. 2006, Susceptibility of Greater Sage-Grouse to experimental infection with West Nile virus: Journal of Wildlife Diseases, v. 42, p. 14–22.

Clifford, M.J., Cobb, N.S., and Buenemann, M., 2011, Long-term tree cover dynamics in a pinyon-juniper woodland: climate-change-type drought resets successional clock. Ecosystems, v. 14, p. 949–962.

Coates, P.S., 2007, Greater Sage-Grouse (*Centrocercus urophasianus*) nest predation and incubation behavior: Boise, Idaho State University.

Coates, P.S., Connelly, J.W., and Delehanty, D.J., 2008, Predators of Greater Sage-Grouse nests identified by video monitoring: Journal of Field Ornithology, v. 79, p. 421–428.

Colorado Greater Sage-Grouse Steering Committee, 2008, Colorado Greater Sage-Grouse conservation plan: Denver, Colorado Division of Wildlife.

Condon, L., Weisberg, P.J., and Chambers, J.C., 2011, Abiotic and biotic influences on *Bromus tectorum* invasion and *Artemisia tridentata* recovery after fire: International Journal of Wildland Fire, v. 20, p. 597–604.

Connelly, J., 2005, Challenging dogma—Changing paradigms—Sage grouse harvest management in the United States: Sage Grouse News, v. 29, p. 7–11.

Connelly, J.W., 1980, Ecology of sage grouse on the INEL Site: Idaho Department of Fish and Game, Report Federal Aid Project W–160–R–7.

Connelly, J.W., 1982, An ecological study of sage grouse in southeastern Idaho: Pullman, Wash., Washington State University.

Connelly, J.W., Apa, A.D., Smith, R.B., and Reese, K.P., 2000a, Effects of predation and hunting on adult sage grouse *Centrocercus urophasianus* in Idaho: Wildlife Biology, v. 6, p. 227–232.

Connelly, J.W., Arthur, W.J., and Markham, O.D., 1981, Sage grouse leks on recently disturbed sites: Journal of Range Management, v. 34, p. 153–154.

Connelly, J.W., and Blus, L.J., 1991, Effects of pesticides on upland game—A review of herbicides and organophosphate and carbamate insecticides: Corvallis, Oreg., U.S. Environmental Protection Agency, p. 238–239.

Connelly, J.W., and Braun, C.E., 1997, A review of long-term changes in sage grouse populations in western North America: Wildlife Biology, v. 3, p. 229–234.

Connelly, J.W., and Doughty, L.A., eds., 1989, Sage grouse use of wildlife water developments in southeastern Idaho: Boise, Idaho.

Connelly, J.W., Hagen, C.A., and Schroeder, M.A., 2011a, Characteristics and dynamics of Greater Sage-Grouse populations, *in* Knick S.T., and Connelly, J.W., eds., Greater Sage–Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union, Studies in Avian Biology No. 38, p. 53–68.

Connelly, J.W., Knick, S.T., Braun, C.E., Baker, W.L., Beever, E.A., Christiansen, T., Doherty, K.E., Garton, E.O., Hagen, C.A., Hanser, S.E., Johnson, D.H., Leu, M., Miller, R.F., Naugle, D.E., Oyler-McCance, S.J., Pyke, D.A., Reese, K.P., Schroeder, M.A., Stiver, S.J., Walker, B.L., and Wisdom, M.J., 2011b, Conservation of Greater Sage-Grouse: a synthesis of current trends and future management, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage–Grouse: Ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornthological Union, no. 38, p. 549–563.

Connelly, J.W., Knick, S.T., Schroeder, M.A,. and Stiver, S.J., 2004, Conservation assessment of Greater Sage-Grouse and sagebrush habitats: Report to the Western Association of Fish and Wildlife Agencies (WAFWA), 610 p.

Connelly, J.W., Reese, K.P., Garton, E.O., and Commons-Kemner, M.L., 2003a, Response of Greater Sage-Grouse *Centrocercus urophasianus* populations to different levels of exploitation in Idaho, U.S.A.: Wildlife Biology, v. 9, p. 335–340.

Connelly, J.W., Reese, K.P., and Schroeder, M.A., 2003b, Monitoring of Greater Sage-Grouse habitats and populations: Moscow, Idaho, University of Idaho, College of Natural Resources Experiment Station.

Connelly, J.W., Rinkes, E.T., and Braun, C.E., 2011d, Characteristics of Greater Sage-Grouse habitats—A landscape species at micro and macro scales, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union, p. 69–84.

Connelly, J.W., Schroeder, M.A., Sands, A.R., and Braun, C.E., 2000b, Guidelines to manage sage grouse populations and their habitats: Wildlife Society Bulletin, v. 28, p. 967–985.

Conservation Objectives Team, Abele, S., Budd, R., Budeau, D., Connelly, J., Deibert, P.A., Delevan, J., Espinosa, S., Gardner, S.C., Griffin, K., Harja, J., Northrup, R., Robinson, A., Schroeder, M., and Souza, P, 2013, Sage-grouse conservation objectives report: Denver, Colo., U.S. Fish and Wildlife Service, 62 p., appendix, available at *http://www.fws.gov/mountain-prairie/species/birds/sagegrouse/*.

Copeland, H.E., Doherty, K.E., Naugle, D.E., Pocewicz, A., and Kiesecker, J.M., 2009, Mapping oil and gas development potential in the U.S. Intermountain West and estimating impacts to species: *PLoS One*, v. 4, p. e7400.

Copeland, H.E., Pocewicz, A., and Kiesecker, J.M., 2011, Geography of energy development in western North America: potential impacts on terrestrial ecosystems, *in* Naugle, D.E., ed., Energy development and wildlife conservation in western North America: Washington, D.C., Island Press, p. 7–25.

Cote, I.M., and Sutherland, W.J., 1997, The effectiveness of removing predators to protect bird populations: Conservation Biology, v. 11, p. 395–405.

Crawford, J.A., 1982, History of sage grouse in Oregon: Oregon Wildlife, p. 3–6.

Crawford, J.A., Olson, R.A., West, N.E., Mosley, J.C., Schroeder, M.A., Whitson, T.D., Miller, R.F., Gregg, M.A., and Boyd, C.S., 2004, Ecology and management of sage-grouse and sage-grouse habitat: Journal of Range Management, v. 57, p. 2–19.

Cresswell, W., Lind, J., and Quinn, J.L., 2010, Predator-hunting success and prey vulnerability: quantifying the spatial scale over which lethal and nonlethal effects of predation occur: Journal of Animal Ecology, v. 79, p. 556–562.

Crist, M.R., Wilmer, B., and Aplet, G.H., 2005, Assessing the value of roadless areas in a conservation reserve strategy: biodiversity and landscape connectivity in the northern Rockies: Journal of Applied Ecology, v. 42, p. 181–191.

Culp, P.W., Conradi, D.B., and Tuell, C.C., 2005, Trust lands in the American West: a legal overview and policy assessment: Cambridge, Mass., Lincoln Institute of Land Policy/Sonoran Institute Joint Venture on State Trust Lands.

D'Antonio, C.M., Chambers, J.C., Loh, R., and Tunison, J.T., 2009, Applying ecological concepts to the management of widespread grass invasions: Management of Invasive Weeds, p. 123–149.

Dalgleish, H.J., Koons, D.N. Hooten, M.B., Moffet, C.A., and Adler, P.B., 2011, Climate influences the demography of three dominant sagebrush steppe plants: Ecology, v. 92, p. 75–85.

Davies, G.M., Bakker, J.D., Dettweiler-Robinson, E., Dunwiddie, P.W., Hall, S.A., Downs, J., and Evans, J., 2012, Trajectories of change in sagebrush steppe vegetation communities in relation to multiple wildfires: Ecological Applications, v. 22, p. 1562–1577.

Davies, K.W., 2010, Revegetation of medusahead—Invaded sagebrush Steppe: Rangeland Ecology & Management, v. 63, p. 564–571.

Defries, R.S., Foley, J.A., and Asner, G.P., 2004, Land-use choices: balancing human needs and ecosystem function: Ecology Abstracts.

Deibert, P.A., 1995, The effects of parasites on sage grouse (*Centrocercus urophasianus*) mate selection: Laramie, University of Wyoming, M.S. thesis.

Delong, A.K., Crawford, J.A., and Delong, D.C., Jr., 1995, Relationships between vegetational structure and predation of artificial sage grouse nests: Journal of Wildlife Management, v. 59, p. 88–92.

Dobkin, D.S., Rich, A.C., and Pyle, W.H., 1998, Habitat and avifaunal recovery from livestock grazing in a riparian meadow system of the northwestern Great Basin: Conservation Biology, v. 12, p. 209–221.

Doherty, K.E., Beck, J.L., and Naugle, D.E., 2011a, Comparing ecological site descriptions to habitat characteristics influencing Greater Sage-Grouse nest site occurrence and success: Rangeland Ecology & Management, v. 64, p. 344–351.

Doherty, K.E., Naugle, D.E., Copeland, H., Pocewicz, A., and Kiesecker, J., 2011b, Energy development and conservation tradeoffs: systematic planning for Greater Sage-Grouse in their eastern range, *in* Knick S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Society, p. 505–516.

Doherty, K.E., Naugle, D.E., and Evans, J.S., 2010a, A currency for offsetting energy development impacts: horse-trading sage-grouse on the open market: Plos One, v. 5, electronic.

Doherty, K.E., Naugle, D.E., and Walker, B.L., 2010b, Greater Sage-Grouse nesting habitat: the importance of managing at multiple scales: Journal of Wildlife Management, v. 74, p. 1544–1553.

Doherty, K.E., Naugle, D.E., Walker, B.L., and Graham J.M., 2008, Greater Sage-Grouse winter habitat selection and energy development: Journal of Wildlife Management, v. 72, p. 187–195.

Doherty, K.E., Tack, J.D., Evans, J.S., and Naugle, D.E., 2010c, Mapping breeding densities of Greater Sage-Grouse: atool for range-wide conservation planning: Denver, Colo., Bureau of Land Management.

Doherty, M.K., 2007, Mosquito populations in the Powder River Basin, Wyoming—A comparison of natural, agricultural and effluent coal bed natural gas aquatic habitats: Bozeman, Montana State University, M.S. thesis.

Dow AgroSciences, LLC, 1999, Spike*80 DF herbicide: Indianapolis, Ind., Dow AgroSciences, LLC.

Drut, M.S., 1994, Status of sage grouse with emphasis on populations in Oregon and Washington, 42 p.

Dunn, P.O., and Braun, C.E., 1985, Natal dispersal and lek fidelity of sage-grouse: Auk, v. 102, p. 621–627.

Dzialak, M.R., Olson, C.V., Harju, S.M., Webb, S.L., and Winstead, J.B., 2012, Temporal and hierarchical spatial components of animal occurrence: conserving seasonal habitat for greater sage-grouse: Ecosphere, v. 3, p. 1–17.

Dzialak, M.R., Webb, S.L., Harju, S.M., Winstead, J.B., Wondzell, J.J., Mudd, J.P., and Hayden-Wing, L.D., 2011, The spatial pattern of demographic performance as a component of sustainable landscape management and planning: Landscape Ecology, v. 26, p. 775–790.

Ellis, K.L., 1985, Effects of a new transmission line on distribution and aerial predation of breeding male sage grouse: Final report, 28 p.

Eng, R.L., 1952, A two-summer study of the effects on bird populations of chlordane bait and aldrin spray as used for grasshopper control: Journal of Wildlife Management, v. 16, p. 326–337.

Eng, R.L., 1963, Observations of the breeding biology of male sage grouse: Journal of Wildlife Management: v. 27, p. 841–846.

Epanchin-Niell, R., Englin, J., and Nalle, D., 2009, Investing in rangeland restoration in the Arid West, U.S.A.: countering the effects of an invasive weed on the long-term fire cycle: Journal of Environmental Management, v. 91, p. 370–379.

Erichsen-Arychuk, C., Bork, E.W., and Bailey, A.W., 2002, Northern dry mixed prairie responses to summer wildlife and drought: Journal of Range Management, v. 55, p. 164–170.

Fedy, B.C., Aldridge, C.L., Doherty, K.E., O'Donnell, M., Beck, J.L., Bedrosian, B., Holloran, M.J., Johnson, G.D., Kaczor, N.W., Kirol, C.P., Mandich, C.A., Marshall, D., McKee, G., Olson, C., Swanson, C.C., and Walker, B.L., 2012, Interseasonal movements of greater sage-grouse, migratory behavior, and an assessment of the core regions concept in Wyoming: Journal of Wildlife Management, v. 76, p. 1062–1071.

Fedy, B.C. and Doherty, K.E., 2011, Population cycles are highly correlated over long time series and large spatial scales in two unrelated species: Greater Sage-Grouse and cottontail rabbits: Oecologia, v. 165, p. 915–924.

Fedy, B.C., Martin, K., Ritland, C., and Young, J.R., 2008, Genetic and ecological data provide incongruent interpretations of population structure and dispersal in naturally subdivided populations of white-tailed ptarmigan (*Lagopus leucura*): Molecular Ecology, v. 17, p. 1905–1917.

Finch, D.M, ed., 2012, Climate change in grasslands, shrublands, and deserts of the interior American West: a review and needs assessment: Fort Collins, Colo., USDA Forest Service, Rocky Mountain Research Station, Gen. Tech. Rep. RMRS–GTR–285, 139 p.

Finch, W.I., 1996, Uranium provinces of North America—Their definition, distribution and models: Department of Energy, 24 p.

Fischer, R.A., Apa, A.D., Wakkinen, W.L., and Reese, K.P., 1993, Nesting-area fidelity of sage grouse in southeastern Idaho: Condor, v. 95, p. 1038–1041.

Forman, R.T.T, 2000, Estimate of the area affected ecologically by the road system in the United States: Conservation Biology, v. 14, p. 31–35.

Forman, R.T.T., and Alexander, L.E., 1998, Roads and their major ecological effects: Annual Review of Ecology and Systematics, v. 29, p. 207-217.

Frankham, R., 1995, Effective population size/adult population size ratios in wildlife: a review: Genetical Research, v. 66, p. 95–107.

Friend, M.R., McLean, G., Dein, F.J., 2001, Disease emergence in birds—Challenges for the twenty–first century: The Auk, v. 118, p. 290–303.

Friggens, M.M., Warwell, M.V., Chambers, J.C., and Kitchen, S.G., 2012, Modeling and predicting vegetation response of Western USA grasslands, shrublands, and deserts to climate change, *in* Finch, D.M., ed., Climate change in grasslands, shrublands, and deserts of the interior American West: a review and needs assessment: USDA Forest Service, Rocky Mountain Research Station, RMRS–GTR–285, p. 1–12.

Garton, E.O., Connelly, J.W., Horne, J.S., Hagen, C.A., Moser, A., and Schroeder, M., 2011, Greater Sage-Grouse population dynamics and probability of persistence, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union, p. 293–381.

Gavin, S.D., and Komers, P.E., 2006, Do pronghorn (*Antilocapra americana*) perceive roads as a predation risk?: Canadian Journal of Zoology–Revue Canadienne De Zoologie 84, p. 1775–1780.

Gervais, J.A., Luukinen, B., Buhl, K., and Stone, D., 2008, 2,4–D technical fact sheet: Oregon State University Extension Services.

Gibson, R.M., Bleich, V.C., McCarthy, C.W., and Russi, T.L., 2011, Hunting lowers population size in Greater Sage-Grouse, *in* Sandercock, B.K., Martin, K., and Segelbacher, G., ed., Ecology, conservation and management of grouse: Berkeley, Calif., University of California Press, p. 307–315.

Gillies, J.A., Etyemezian, V., Kuhns, H., Nikolic, D., and Gillette, D.A., 2005, Effect of vehicle characteristics on unpaved road dust emissions: Atmospheric Environment, v. 39, p. 2341–2347.

Gilpin, M., and Hanski, I., 1991, Metapopulation dynamics: empirical and theoretical investigations: London, United Kingdom, Academic Press.

Gilpin, M.E., and Soule, M.E., 1986, Minimum viable populations: processes of species extinctions, *in* Soule, M.E., ed., Conservation biology: the science of scarcity and diversity: Sunderland, Mass., Sinauer Associates, p. 19–34.

Gregg, M.A., 1991, Use and selection of nesting habitat by sage grouse in Oregon: Corvallis, Oreg., Oregon State University, M.S. thesis.

Gregg, M.A., Crawford, J.A., Drut, M.S., and DeLong, A.K., 1994, Vegetational cover and predation of sage grouse nests in Oregon: Journal of Wildlife Management, v. 58, p. 162–166.

Gregg, M.A., Dunbar, M.R., and Crawford, J.A., 2007, Use of implanted radiotransmitters to estimate survival of Greater Sage-Grouse chicks: Journal of Wildlife Management, v. 71, p. 646–651.

Hagen, C.A., 2010, Impacts of energy development on prairie grouse ecology: a research synthesis: Transactions North American Wildlife and Natural Resources Conference, v. 75, p. 96–103.

Hagen, C.A., 2011, Predation on Greater Sage-Grouse—Facts, process and effects, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union, p. 95–100.

Hagen, C.A., and Bildfell, R.J., 2007, An observation of *Clostridium perfringens* in Greater Sage-Grouse: Journal of Wildlife Diseases, v. 43, p. 545–547.

Hagen, C.A., Connelly, J.W., and Schroeder, M.A., 2007, A meta-analysis of Greater Sage-Grouse *Centrocercus urophasianus* nesting and brood-rearing habitats: Wildlife Biology, v. 13, p. 42–50.

Hagen, C.A., Willis, M.J., Glenn, E.M., and Anthony, R.G., 2011, Habitat selection by Greater Sage-Grouse during winter in southeastern Oregon: Western North American Naturalist, v. 71, p. 529–538.

Hall, F.C., and Bryant, L., 1995, Herbaceous stubble height as a warning of impending cattle grazing damage to riparian areas: Portland, Oreg., USDA Forest Service, Pacific Northwest Research Station, PNW-GTR-362.

Hansen, A.J., Knight, R.L., Marzluff, J.M., Powell, S., Brown, K., Gude, P.H., and Jones, K., 2005, Effects of exurban development on biodiversity—Patterns, mechanisms and research needs: Ecological Applications, v. 15, p. 1893–1905.

Hanski, I., 1998, Metapopulation dynamics: Nature, v. 396, p. 41–49.

Hanski, I., and Thomas, C.D., 1994, Metapopulation dynamics and conservation: a spatially explicit model applied to butterflies: Biological Conservation, v. 68, p. 167–180.

Harju, S.M., Dzialak, M.R., Taylor, R.C., Hayden-Wing, L.D., and Winstead, J.B., 2010, Thresholds and time lags in effects of energy development on Greater Sage-Grouse populations: Journal of Wildlife Management, v. 74, p. 437–448.

Hausleitner, D., 2003, Population dynamics, habitat use and movements of Greater Sage-Grouse in Moffat County, Colorado: Moscow, University of Idaho.

Hausleitner, D., Reese, K.P., and Apa, A.D., 2005, Timing of vegetation sampling at Greater Sage-Grouse nests: Rangeland Ecology & Management, v. 58, p. 553–556.

Hedrick, P.W., and Kalinowski, S.T., 2000, Inbreeding depression in conservation biology: Annual Review of Ecology and Systematics, v. 31, p. 139–162.

Hess, J.E., and Beck, J.L., 2012, Burning and mowing Wyoming Big Sagebrush: do treated sites meet minimum guidelines for Greater Sage-Grouse breeding habitats? Wildlife Society Bulletin, v. 36, p. 85–93.

Holechek, J., Galt, D., Joseph, J., Navarro, J., Kumalo, G., Molinar, F., and Thomas, M., 2003, Moderate and light cattle grazing effects on Chihuahuan Desert rangelands: Journal of Range Management, v. 56, p. 133–139.

Holechek, J.L., Pieper, R.D., and Herbel, C.H., 1989, Range management: principles and practices: Englewood Cliffs, N.J., Regents-Prentice Hall.

Holloran, M.J., 2005, Greater Sage-Grouse (*Centrocercus urophasianus*) population response to natural gas field development in western Wyoming: Laramie, University of Wyoming, M.S. Thesis.

Holloran, M.J., and Anderson, S.H., 2005, Spatial distribution of Greater Sage-Grouse nests in relatively contiguous sagebrush habitats: Condor, v. 107, p. 742–752.

Holloran, M.J., Fedy, B.C., and Dahlke, J., in press, Winter habitat selection of Greater Sage-Grouse relative to activity levels at natural gas well pads: Journal of Wildlife Management.

Holloran, M.J., Heath, B.J., Lyon, A.G., Slater, S.J., Kuipers, J.L., and Anderson, S.H., 2005, Greater Sage-Grouse nesting habitat selection and success in Wyoming: Journal of Wildlife Management, v. 69, p. 638–649.

Holloran, M.J., Kaiser, R.C., and Hubert, W.A., 2010, Yearling Greater Sage-Grouse response to energy development in Wyoming: Journal of Wildlife Management, v. 74, p. 65–72.

Honess, R.F., and Post, G., 1968, History of an epizootic in sage grouse: University of Wyoming Agricultural Extension Station, Science Monograph, v. 14, 32 p.

Hornaday, W.T., 1916, Save the sage grouse from extinction—A demand from civilization to the Western States: New York Zoological Park Bulletin, v. 5, p. 179–219.

Huebner, C.D., 2010, Spread of an invasive grass in closed-canopy deciduous forests across local and regional environmental gradients: Biological Invasions, v. 12, p. 2081–2089.

Hull, S.D., Robel, R.J., and Kemp, K.E., 1996, Summer avian abundance, invertebrate biomass, and forbs in Kansas CRP: Prairie Naturalist, v. 28, p. 1–12.

Hupp, J.W., and Braun, C.E., 1991, Geographic variation among sage-grouse in Colorado: Wilson Bulletin, v. 103, p. 255–261.

Hupp, J.W., and Braun, C.E., 1989, Topographic distribution of sage grouse foraging in winter: Journal of Wildlife Management, v. 53, p. 823–829.

Idaho Sage-Grouse Advisory Committee, 2006, Conservation plan for the Greater Sage-Grouse in Idaho.

Idaho Sage-Grouse Advisory Committee Technical Assistance Team, 2012, Idaho sage–grouse local working groups Statewide annual report 2011.

Idaho Sage-Grouse Task Force, 2012, Idaho Governor's Sage-Grouse Task Force recommendations.

INL Campus Development Office and North Wind, Inc., 2011, Idaho National Laboratory comprehensive land use and environmental stewardship report: Idaho Falls, Idaho National Laboratory, unpublished Federal report.

Interagency MOU, 2009, Memorandum of understanding Among Bureau of Land Management (Colorado State Office), U.S. Forest Service (United States Forest Service, Rocky Mountain Region), and Colorado Oil and Gas Conservation Commission Concerning Oil and Gas Permitting on BLM and NFS Lands in Colorado.

IPCC, 2007, An assessment of the Intergovernmental Panel on Climate Change: Intergovernmental Panel on Climate Change.

Jamison, B.E., Robel, R.J., Pontius, J.S., and Applegate, R.D., 2002, Invertebrate biomass: associations with lesser prairie-chicken habitat use and sand sagebrush density in southwestern Kansas: Wildlife Society Bulletin, v. 30, p. 517–526.

Jensen, B.M., 2006, Migration, transition range and landscape use by Greater Sage-Grouse (*Centrocercus urophasianus*): Laramie, University of Wyoming.

Jimenez, J.A., Hughes, K.A., Alaks, G., Graham, L., and Lacy, R.C., 1994, An experimental study of inbreeding depression in a natural habitat: Science, v. 266, p. 271–273.

Johnsgard, P.A., 1983, The grouse of the world: Lincoln, University of Nebraska Press, 411 p.

Johnson, D.J., Holloran, M.J., Connelly, J.W., Hanser, S.E., Amundson, C.L., and Knick, S.T., 2011, Influences of environmental and anthropogenic features on Greater Sage-Grouse population, 1997–2007, *in* Knick, S.T., and Connelly, J.W., eds., Studies in avian biology: Berkeley, Calif., University of California Press, Cooper Ornithological Union, p. 407–450.

Johnson, G.D., and Boyce, M.S., 1991, Survival, growth and reproduction of captive- reared sage grouse: Wildlife Society Bulletin, v. 19, p. 88–93.

Johnson, J.A., and Dunn, P.O., 2006, Low genetic variation in the heath hen prior to extinction and implications for the conservation of prairie-chicken populations: Conservation Genetics, v. 7, p. 37–48.

Kahn, N.W., Braun, C.E., Young, J.R., Wood, S., Mata, D.R., and Quinn, T.W., 1999, Molecular analysis of genetic variation among large- and small-bodied sage grouse using mitochondrial control-region sequences: Auk, v. 116, p. 819–824.

Keane, R.E., Agee, J.K., Fule, P., Keeley, J.E., Key, C., Kitchen, S.G., Miller, R., and Schulte, L.A., 2008, Ecological effects of large fires on US landscapes: benefit or catastrophe?: International Journal of Wildland Fire, v. 17, p. 696–712.

Keller, L.F., Arcese, P., Smith, J.N.M., Hochachka, W.M., and Stearns, S.C., 1994, Selection against inbred song sparrows during a natural population bottleneck: Nature, v. 372, p. 356–357.

Keller, L.F., and Waller, D.M., 2002, Inbreeding effects in wild populations: Trends in Ecology & Evolution, v. 17, p. 230–241.

Kirol, C.P., 2012, Quantifying habitat importance for Greater Sage-Grouse population persistence in an energy development landscape: Laramie, University of Wyoming, M.S. thesis.

Kirol, C.P., Beck, J.L., Dinkins, J.B., and Conover, M.R., 2012, Microhabitat selection for nesting and brood-rearing by the Greater Sage-Grouse in xeric big sagebrush: Condor, v. 114, p. 75–89.

Klebenow, D.A., 1970, Sage grouse versus sagebrush control in Idaho [Herbicides]: Journal of Range Management, v. 23, p. 396–400.

Klebenow, D.A., and Gray, G.M., 1968, Food habits of juvenile sage grouse: Journal of Range Management, 21, p. 80–83.

Klemmedson, J.O., and Smith, J.G., 1964, Cheatgrass (*Bromus tectorum* L.): Botanical Review, v. 30, p. 226–262.

Knapp, P.A., 1996, Cheatgrass (*Bromus tectorum* L.) dominance in the Great Basin Desert—History, persistence, and influences to human activities: Global Environmental Change—Human and Policy Dimensions, v.6, p. 37–52.

Knick, S.T., 2011, Historical development, principal Federal legislation and current management of sagebrush habitats implications for conservation, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Society, p. 13–32.

Knick, S.T., and Connelly, JW., 2011a, Greater Sage-Grouse and sagebrush—Introduction to the landscape, *in* Knick, S.T., and Connelly, J.W., eds., GreaterSage-Grouse: ecology and conservation of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Society, p. 1–9.

Knick, S.T., and Connelly, J.W., eds., 2011b, Greater Sage-Grouse: ecology and conservation of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union Studies in Avian Biology no. 38.

Knick, S.T., Dobkin, D.S., Rotenberry, J.T., Schroeder, M.A., Vander Haegen, W.M., and Van Riper, C., III., 2003, Teetering on the edge or too late? Conservation and research issues for avifauna of sagebrush habitats: Condor, v. 105, p. 611–634.

Knick, S.T., and Hanser, S.E., 2011, Connecting pattern and process in Greater Sage-Grouse populations and sagebrush landscapes, *in* Knick S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union, p. 383–406.

Knick, S.T., Hanser, S.E., Miller, R.F., Pyke, DA., Wisdom, M.J., Finn, S.P., Rinkes, E.T., and Henny, C.J., 2011, Ecological influence and pathways of land use in sagebrush, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union, p. 203–252.

Knight, R.L., Knight, H.A.L., and Camp, R.J., 1993, Raven populations and land-use patterns in the Mojave Desert, California: Wildlife Society Bulletin, v. 21, p. 469–471.

Kolada, E.J., Sedinger, J.S., and Casazza, M.L., 2009, Nest site selection by Greater Sage-Grouse in Mono County, California: Journal of Wildlife Management, v. 73, p. 1333–1340.

Kuipers, J.L., 2004, Grazing system and linear corridor influences on Greater Sage-Grouse (*Centrocercus urophasianus*) habitat selection and productivity: Laramie, University of Wyoming, M.S. thesis.

Lacy, R.C., 1997, Importance of genetic variation to the viability of mammalian populations: Journal of Mammalogy, v. 78, p. 320–325.

Lacy, R.C., Alaks, G., and Walsh, A., 1996, Hierarchical analysis of inbreeding depression in *Peromyscus polionotus*: Evolution, v. 50, p. 2187–2200.

Larson, T.A., 1978, History of Wyoming (3rd ed.): Lincoln, Nebr., Univerisity of Nebraska Press.

Laycock, W.A., 1978, Factors affecting choice of management strategies within the sagebrush ecosystem United States, *Artemisia tridentata*, *in* The sagebrush ecosystem: a symposium: Logan, Utah State University, College of Natural Resources, p. 230–236.

LeBeau, C.W., 2012, Evaluation of Greater Sage-Grouse reproductive habitat and response to wind energy development in south-central, Wyoming: Laramie, University of Wyoming, M.S. thesis.

Lee, C.H., Shih, C.A., Chien, C.C., Fang, S.S., Lin, L.L., and Lin, M.D., 2007, Estimation of fugitive dust emission factor for truck moving on dredging road: Journal of the Chinese Institute of Civil and Hydraulic Engineering, v. 19, p. 467.

Leonard, K.M., Reese, K.P. and Connelly, J.W., 2000, Distribution, movements and habitats of sage grouse, *Centrocercus urophasianus,* on the Upper Snake River Plain of Idaho: changes from the 1950s to the 1990s: Wildlife Biology, v. 6, p. 265–270.

Lesica, P., Cooper, S.V., and Kudray, G., 2007, Recovery of big sagebrush following fire in southwest Montana: Rangeland Ecology & Management, v. 60, p. 261–269.

Leu, M., and Hanser, S.E., 2011, Influences of the human footprint on sagebrush landscape patterns, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union, p. 253–271.

Leu, M., Hanser, S.E., and Knick, S.T., 2008, The human footprint in the west—A large scale analysis of anthropogenic impacts: Ecological Applications, v. 18, p. 1119–1139.

Lowe, B.S., Delehanty, D.J., and Connelly, J.W., 2009, Greater Sage-Grouse *Centrocercus urophasianus* use of threetip sagebrush relative to big sagebrush in south-central Idaho: Wildlife Biology, v. 15, p. 229–236.

Lyon, A.G., and Anderson, S.H., 2003, Potential gas development impacts on sage grouse nest initiation and movement: Wildlife Society Bulletin, v. 31, p. 486–491.

Manier, D.J., and Hobbs, N.T., 2007, Large herbivores in sagebrush steppe ecosystems: livestock and wild ungulates influence structure and function: Oecologia, v. 152, p. 739–750.

Manier, D.J., Hobbs, N.T., Theobald, D.M., Reich, R.M., Kalkhan, M.A., and Campbell, M.R., 2005, Canopy dynamics and human caused disturbance on a semi-arid landscape in the Rocky Mountains, U.S.A.: Landscape Ecology, v. 20, p. 1–17.

Manville, A.M., 2002, Bird strikes and electrocutions at power lines, communication towers and wind turbines—State of the art and state of the science—next steps toward mitigation, 28 p.

Marra, P.P., Griffing, S., Caffrey, C., Kilpatrick, A.M., McLean, R., Brand, C., Saito, E., Dupuis, A.P., Kramer, L., and Novak, R., 2004, West Nile virus and wildlife: BioScience, v. 54, p. 393–402.

McLean, R.G., 2006, West Nile virus in North American birds: Ornithological Monographs, v. 60, p. 44–64.

Meinke, C.W., Knick, S.T., and Pyke, D.A., 2009, A spatial model to prioritize sagebrush landscapes in the Intermountain West (U.S.A.) for restoration: Restoration Ecology, v. 17, p. 652–659.

Mensing, S., Livingston, S., and Barker, P., 2006, Long-term fire history in Great Basin sagebrush reconstructed from macroscopic charcoal in spring sediments, Newark Valley, Nevada: Western North American Naturalist, v. 66, p. 64–77.

Mezquida, E.T., Slater, S.J., and Benkman, C.W., 2006, Sage-grouse and indirect interactions: Potential implications of coyote control on sage-grouse populations: Condor, v. 108, p. 747–759.

Miller, M.E., 2008, Broad-scale assessment of rangeland health, Grand Staircase-Escalante National Monument, U.S.A.: Rangeland Ecology & Management, v. 61, p. 249–262.

Miller, R.F., 2001, Pre- and post-settlement fire regimes in mountain big sagebrush steppe and aspen, the northwestern Great Basin: Final report 2001 to the National Interagency Fire Center.

Miller, R.F., and Eddleman, L.L., 2000, Spatial and temporal changes of sage grouse habitat in the sagebrush biome: Corvallis, Oregon State University Agricultural Experiment Station.

Miller, R.F., and Heyerdahl, E.K., 2008, Fine-scale variation of historical fire regimes in sagebrush-steppe and juniper woodland: an example from California, U.S.A.: International Journal of Wildland Fire, v. 17, p. 245–254.

Miller, R.F., Knick, S.T., Pyke, D.A., Meinke, C.W., Hanser, S.E., Wisdom, M.J. and Hild, A.L., 2011, Characteristics of sagebrush habitats and limitations to long-term conservation, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union, p. 145–184.

Miller, R.F., and Rose, J.A., 1995, Historic expansion of *Juniperus occidentalis* (Western juniper) in southeastern Oregon: Great Basin Naturalist, v. 55, p. 37–45.

Miller, R.F., Svejcar, T.J., and Rose, J.A., 2000, Impacts of western juniper on plant community composition and structure: Journal of Range Management, v. 53, p. 574–585.

Miller, R.F., Svejcar, T.J., and West, N.E., 1994, Implications of livestock grazing in the intermountain sagebrush region—Plant composition, *in* Vavra, M., Laycock, W.A., and Pieper, R.D., eds., Ecological implications of livestock herbivory in the west, p. 101–146.

Montana Department of Natural Resources & Conservation Trust Land Management Division, 2007, Sage grouse mitigation for oil & gas operations on State school trust lands: Montana Department of Natural Resources & Conservation Trust Land Management Division, unpublished report on file in Montana State office.

Montana Sage Grouse Work Group, 2005, Management plan and conservation strategies for sage grouse in Montana—Final: Montana Fish, Wildlife & Parks.

Mooney, H.A., and Cleland, E.E., 2001, The evolutionary impact of invasive species: Proceedings of the National Academy of Science, v. 98, p. 5446–5451.

Moynahan, B.J., Lindberg, M.S., Rotella, J.J., and Thomas, J.W., 2007, Factors affecting nest survival of Greater Sage-Grouse in northcentral Montana: Journal of Wildlife Management, v. 71, p. 1773–1783.

Moynahan, B.J., Lindberg, M.S., and Thomas, J.W., 2006, Factors contributing to process variance in annual survival of female Greater Sage-Grouse in Montana: Ecological Applications, v. 16, p. 1529–1538.

Mueggler, W.F., 1950, Effects of spring and fall grazing by sheep on vegetation of the upper snake river plains: Journal of Range Management, v. 3, p. 308–315.

Natural Resources Conservation Service, 2011, Introduction to NRCS' new sage-grouse initiative: wildlife conservation through sustainable ranching: Washington, D.C., Department of Agriculture.

Naugle, D.E., Aldridge, C.L., Walker, B.L., Cornish, T.E., Moynahan, B.J., Holloran, M.J., Brown, K., Johnson, G.D., Schmidtmann, E.T., Mayer, R.T., Kato, C.Y., Matchett, M.R., Christiansen, T.J., Cook, W.E., Creekmore, T., Falise, R.D., Rinkes, E.T., and Boyce, M.S., 2004, West Nile virus—Pending crisis for Greater Sage-Grouse: Ecology Letters, v. 7, p. 704–713.

Naugle, D.E., Aldridge, C.L., Walker, B.L., Doherty, K.E., Matchett, M.R., McIntosh, J., Cornish, T.E., and Boyce, M.S., 2005, West Nile virus and sage-grouse—What more have we learned?: Wildlife Society Bulletin, v. 33, p. 616–623.

Naugle, D.E., Doherty, K.E., Walker, B.L., Holloran, M.J., and Copeland, H.E., 2011, Energy development and Greater Sage-Grouse, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union, p. 489–504.

Neel, L.A., 1980, Sage grouse response to grazing management in Nevada: Reno, University of Nevada, M.S. thesis.

Neilson, R.P., Lenihan, J.M., Buchelet, D., and Drapek, R.J., 2005, Climate change implication for sagebrush ecosystems: North American Wildlife and Natural Resources, 70th Conference, Transactions of Wildlife Management Institute, Arlington, Va., p. 145–159.

Nelle, P.J., Reese, K.P., and Connelly, J.W., 2000, Long-term effects of fire on sage grouse habitat: Journal of Range Management, v. 53, p. 586–591.

Nevada Department of Wildlife, 2011, NDOW actions to avoid ESA listing of Greater Sage-Grouse: Nevada Board of Wildlife Commissioners Meeting Procedings.

Nevada Department of Wildlife, 2012, Greater Sage-Grouse habitat categorization: Reno, Nevada Department of Wildlife, unpublished report.

Nevada Executive Order, Mar. 30, 2012, Establishing a Greater Sage-Grouse advisory committee: Reno, Nev., Governor's Office, State of Nevada, No. 2012–09.

Nevada Greater Sage-Grouse Advisory Committee, 2012, Strategic plan for conservation of sage-grouse in Nevada: Reno, Nevada Greater Sage-Grouse Advisory Committee, unpublished report.

Nevada Sage-Grouse Conservation Team, 2004, Greater Sage-Grouse conservation plan for Nevada and eastern California: Reno, Nevada Sage-Grouse Conservation Team, unpublished report.

Norrdahl, K., and Korpimaki, E., 2000, Do predators limit the abundance of alternative prey? Experiments with vole-eating avian and mammalian predators: Oikos, v. 91, p. 528–540.

Oregon Department of Fish and Wildlife, 2011, Greater Sage-Grouse conservation assessment and strategy for Oregon: a plan to maintain and enhance populations and habitat: Oregon Department of Fish and Wildlife.

Ouren, D.S., Hass, C., Melcher, C.P., Stewart, P., Ponds, D., Sexton, N.R., Burris, L. Fancher, T., and Bowen, Z.H., 2007, Environmental effects of off-highway vehicles on Bureau of Land Management lands: a literature synthesis, annotated bibliographies, and internet resources: Reston, Va., U.S. Geological Survey.

Owens, M.K., and Norton, B.E., 1990, Survival of juvenile basin sagebrush under different grazing regimes: Journal of Range Management, v. 43, p. 132–135.

Oyler-McCance, S.J., Burnham, K.P., and Braun, C.E., 2001, Influence of changes in sagebrush on Gunnison sage grouse in southwestern Colorado: Southwestern Naturalist, v. 46, p. 323–331.

Oyler-McCance, S.J., Kahn, N.W., Burnham, K.P., Braun, C.E., and Quinn, T.W., 1999, A population genetic comparison of large- and small-bodied sage grouse in Colorado using microsatellite and mitochondrial DNA markers: Molecular Ecology, v. 8, p. 1457–1465.

Oyler-McCance, S.J., St. John, J., Taylor, S.E., Apa, A.D., and Quinn, T.W., 2005a, Population genetics of Gunnison sage-grouse: implications for management: Journal of Wildlife Management, v. 69, p. 630–637.

Oyler-McCance, S.J., Taylor, S.E., and Quinn, T.W., 2005b, A multilocus population genetic survey of the Greater Sage-Grouse across their range: Molecular Ecology, v. 14, p. 1293–1310.

Padgett, P.E., Meadows, D., Eubanks, E., and Ryan, W.E., 2008, Monitoring fugitive dust emissions from off-highway vehicles traveling on unpaved roads and trails using passive samplers: Environmental Monitoring and Assessment, v. 144, p. 93–99.

Parker, R.R., Philip, C.B., and Davis, G.E., 1932, Tularaemia occurrence in the sage hen, *Centrocercus urophasianus*: Public Health Reports, v. 47, p. 479–487.

Patterson, R.L., 1952, The sage grouse in Wyoming: Denver, Colo., Sage Books, Inc., Wyoming Game and Fish Commission, 344 p.

Petersen, S.L., Stringham, T.K., and Roundy, B.A., 2009, A process-based application of State-and-transition models: a case study of Western Juniper (*Juniperus occidentalis*) encroachment: Rangeland Ecology & Management, v. 62, p. 186–192.

Peterson, M.J., 2004, Parisites and infectious diseases of prairie grouse: should managers be concerned?: Wildlife Society Bulletin, v. 32, p. 35–55.

Pickett, S.T.A., and White, P.S., 1985, Patch dynamics: a synthesis, *in* Pickett, S.T.A., and White, P.S., The ecology of natural disturbance and patch dynamics: San Diego, Calif., Academic Press, p. 371–384.

Piertney, S.B., MacColl, A.D.C., Bacon, P.J. ,and Dallas, J.F., 1998, Local genetic structure in red grouse (*Lagopus lagopus scoticus*): evidence from microsatellite DNA markers: Molecular Ecology, v. 7, p. 1645–1654.

Ponzetti, J.M., McCune, B., and Pyke, D.A., 2007, Biotic soil crusts in relation to topography, cheatgrass and fire in the Columbia Basin, Washington: Bryologist, v. 110, p. 706–722.

Poulin, J.F., and Villard, M.A., 2011, Edge effect and matrix influence on the nest survival of an old forest specialist, the Brown Creeper (*Certhia americana*): Landscape Ecology, v. 26, p. 911–922.

Provencher, L., Forbis, T.A., Frid, L., and Medlyn, G., 2007, Comparing alternative management strategies of fire, grazing, and weed control using spatial modeling: Ecological Modelling, v. 209, p. 249–263.

Pyke, D.A., 2011, Restoring and rehabilitating sagebrush habitats, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union, p. 531–548.

Rau, B.M., Johnson, D.W., Blank, R.R., Tausch, R.J., Roundy, B.A., Miller, R.F., Caldwell, T.G., and Lucchesi, A., 2011, Woodland expansion's influence on belowground carbon and nitrogen in the Great Basin U.S.: Journal of Arid Environments, v. 75, p. 827–835.

Reed, D.H., and Bryant, E.H., 2000, Experimental tests of minimum viable population size: Animal Conservation, v. 3, p. 7–14.

Reed, D.H., and Frankham, R., 2003, Correlation between fitness and genetic diversity: Conservation Biology, v. 17, p. 230–237.

Reese, K.P., and Connelly, J.W., 1997, Translocations of sage grouse *Centrocercus urophasianus* in North America: Wildlife Biology, v. 3, p. 235–241.

Reese, K.P., and Connelly, J.W., 2011, Harvest management for Greater Sage-Grouse, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union, p. 101–112.

Reisen, W.K., Fang, Y., and Martinez, V.M., 2006, Effects of temperature on the transmission of West Nile virus by *Culex tarsalis* (*Diptera–Culicidae*): Journal of Medical Entomology, v. 43, p. 309–317.

Remington, T.E., and Braun, C.E., 1991, How surface coal mining affects sage grouse, North Park, Colorado: Colorado Division of Wildlife, unpublished report.

Rhodes, E.C., Bates, J.D., Sharp, R.N., and Davies, K.W., 2010, Fire effects on cover and dietary resources of sage-grouse habitat: Journal of Wildlife Management, v. 74, p. 755–764.

Ritchie, M.E., and Tilman, D., 1992, Interspecific competition among grasshoppers and their effect on plant abundance in experimental field environments: Oecologia, v. 89, p. 524–532.

Romme, W.H., Allen, C.D., Balley, J.D., Baker, W.L., Bestelmeyer, B.T., Brown, P.M., Eisenhart, K.S., Floyd, M.L., Huffman, D.W., Jacobs, B.F., Miller, R.F., Muldavin, E.H., Swetnam, T.W., Tausch, R.J. ,and Weisberg, P.J., 2009, Historical and modern disturbance regimes, stand structures, and landscape dynamics in pinon-juniper vegetation of the Western United States: Rangeland Ecology & Management, v. 62, p. 203–222.

Root, H.T., and McCune, B., 2012, Regional patterns of biological soil crust lichen species composition related to vegetation, soils, and climate in Oregon, U.S.A.: Journal of Arid Environments, v. 79, p. 93–100.

Rowland, M.M., Leu, M., Hanser, S., Finn, S.P., Aldridge, C.L., Knick, S.T., Suring, L.H., Boyd, J.M., Wisdom, M.J., and Meinke, C.W., 2006, Assessment of threats to sagebrush habitats and associated species of concern in the Wyoming basins: Boise, Idaho, U.S. Geological Survey, unpublished report on file.

Rowland, M.M., Suring, L.H., and Wisdom, M.J., 2010, Assessment of habitat threats to shrublands in the Great Basin: a case study, *in* Pye, J.M., Rauscher, H.M., Sands, Y., Lee, D.C., and Beatty, J.S., eds., Environmental threat assessment and application to forest and rangeland management: USDA Forest Service, General Technical Report, PNW-GTR-802, p. 673–685.

Sankey, T.T., and Germino, M.J., 2008, Assessment of juniper encroachment with the use of satellite imagery and geospatial data: Rangeland Ecology & Management, v. 61, p. 412–418.

Saunders, D.A., Hobbs, R.J., and Margules, C.R., 1991, Biological consequences of fragmentation: a review: Conservation Biology, v. 5, p. 18–32

Scherber, C., Heimann, J., Kohler, G., Mitschunas, N., and Weisser, W.W., 2010, Functional identity versus species richness: herbivory resistance in plant communities: Oecologia, v. 163, p. 707–717.

Schlaepfer, D.R., Lauenroth, W.K., and Bradford, J.B., 2012, Effects of ecohydrological variables on current and future ranges, local suitability patterns, and model accuracy in big sagebrush: Ecography, v. 35, p. 374–384.

Schroeder, M.A., 1997, Unusually high reproductive effort by sage grouse in a fragmented habitat in north-central Washington: Condor, v. 99, p. 933–941.

Schroeder, M.A., 2008, Variation in Greater Sage-Grouse morphology by region and population: U.S. Fish and Wildlife Service, unpublished report, 19 p.

Schroeder, M.A., Aldridge, C.L., Apa, A.D., Bohne, J.R., Braun, C.E., Bunnell, S.D., Connelly, J.W., Deibert, P.A., Gardner, S.C., Hilliard, M.A., Kobriger, G.D., McAdam, S.M., McCarthy, C.W., McCarthy, J.J., Mitchell, D.L., Rickerson, E.V., and Stiver, S.J., 2004, Distribution of sage-grouse in North America: Condor, v. 106, p. 363–376.

Schroeder, M.A., and Baydack, R.K., 2001, Predation and the management of prairie grouse: Wildlife Society Bulletin, v. 29, p. 24–32.

Schroeder, M.A., and Robb, L.A., 2003, Fidelity of Greater Sage-Grouse *Centrocercus urophasianus* to breeding areas in a fragmented landscape: Wildlife Biology, v. 9, p. 291–299.

Schroeder, M.A., and Vander Haegen, W.M., 2006, Use of conservation reserve program fields by Greater Sage-Grouse and other shrub steppe-associated wildlife in Washington State: Olympia, Wash., Washington Department of Fish and Wildlife, Wildlife Program.

Schroeder, M.A., and Vander Haegen, W.M., 2011, Response of GreaterSage-Grouse to the conservation reserve program in Washington State, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union, p. 517–530.

Schroeder, M.A., Young, J.R., and Braun, C.E., 1999, Sage grouse (*Centrocercus urophasianus*), *in* Poole A.W., and Gill, F.,eds., The birds of North America, no.425: Ithaca, N.Y., p. 28.

Scott, J.W., 1940, The role of coccidia as parasites of wildlife: Journal of the Colorado-Wyoming Academy of Science, v. 2, p. 45.

Sedinger, B.S., Sedinger, J.S., Espinosa, S., Atamian, M.T., and Blomberg, E.J., 2011, Spatial-temporal variation in survival of harvested Greater Sage-Grouse, *in* Sandercock, B.K., Martin, K., and Segelbacher, G., eds., Ecology, conservation and management of grouse: Berkeley, Calif., University of California Press, p 317–328.

Sedinger, J.S., White, G.C., Espinosa, S., Partee, E.T., and Braun, C.E., 2010, Assessing compensatory versus additive harvest mortality: An example using Greater Sage-Grouse: Journal of Wildlife Management, v. 74, no. 2, p. 326–332.

Shaw, R.B., and Diersing, V.E., 1990, Tracked vehicle impacts on vegetation at the Pinon Canyon Maneuver Site, Colorado: Journal of Environmental Quality, v. 19, p. 234–243.

Shinneman, D.J., and Baker, W.L., 2009, Environmental and climatic variables as potential drivers of post-fire cover of cheatgrass *(Bromus tectorum*) in seeded and unseeded semiarid ecosystems: International Journal of Wildland Fire, v. 18, p. 191–202.

Shinneman, D.J., Baker, W.L., and Lyon, P., 2008, Ecological restoration needs derived from reference conditions for a semi-arid landscape in western Colorado, U.S.A.: Journal of Arid Environments, v. 72, p. 207–227.

Simberloff, D., 1988, The contribution of population and community biology to conservation science: Annual Review of Ecology and Systematics, v. 19, p. 473–511.

Slater, S.J., 2003, Sage-grouse (*Centrocercus urophasianus*) use of different-aged burns and the effects of coyote control in southwestern Wyoming: Laramie, University of Wyoming.

Smith, J.T., Flake, L.D., Higgins, K.F., Kobriger, G.D., and Homer, C.G., 2005, Evaluating lek occupancy of Greater Sage-Grouse in relation to landscape cultivation in the Dakotas: Western North American Naturalist, v. 65, p. 310–320.

Smith, R.E., 2013, Conserving Montana's sagebrush highway: long distance migration in sage-grouse: Missoula, University of Montana, Department of Wildlife Biology, M.S. thesis.

Sovada, M.A., Sargeant, A.B., and Grier, J.W., 1995, Differential effects of coyotes and red foxes on duck nest success: Journal of Wildlife Management, v. 59, p. 1–9.

State of Wyoming, 2011, Greater Sage-Grouse core area protection: Casper, State of Wyoming.

Steenhof, K., Kochert, M.N., and Roppe, J.A., 1993, Nesting by raptors and common ravens on electrical transmission line towers: Journal of Wildlife Management, v. 57, p. 271–281.

Stevens, B.S., 2011, Impacts of fences on Greater Sage-Grouse in Idaho: collision, mitigation, and spatial ecology: Moscow, University of Idaho, M.S. thesis.

Stevens, B.S., Reese, K.P., and Connelly, J.W., 2011, Survival and detectability bias of avian fence collision surveys in sagebrush steppe: Journal of Wildlife Management, v. 75, p. 437–449.

Stevens, B.S., Reese, K.P., Connelly, J.W., and Musil, D.D., 2012, Greater Sage-Grouse and fences: does marking reduce collisions?: Wildlife Society Bulletin, v. 36, p. 297–303.

Stiver, S.J., 2011, The legal status of Greater Sage-Grouse: organizational structure of planning efforts, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union, p. 33–49.

Stiver, S.J., Apa, A.D., Bohne, J., Bunnell, S.D., Deibert, P.A., Gardner, S.C., Hilliard, M.A., McCarthy, C.W., and Schroeder, M.A., 2006, Greater Sage-Grouse: comprehensive conservation strategy: Cheyenne, Wyo., Western Association of Fish and Wildlife Agencies (WAFWA).

Stiver, S.J., Rinkes, E.T., and Naugle, D.E., 2010, Sage-grouse habitat assessment framework: multiscale habitat assessment tool: Boise, Idaho, U.S. Bureau of Land Management Report, Idaho State Office, 135 p.

Strand, E.K., Robinson, A.P., and Bunting, S.C., 2007, Spatial patterns on the sagebrush steppe/Western juniper ecotone: Plant Ecology, v. 190, no. 2, p.159–173.

Strickland, M.D., Harju, H.J., McCaffery, K.R., Miller, H.W., Smith, L.M., and Stoll, R.J., 1994, Harvest management, *in* Bookhout, T.A. ,ed., Research and management techniques for wildlife and habitats: Bethesda, Md., The Wildlife Society, p. 445–473.

Suter Ii, G.W., 1978, Effects of geothermal energy development on fish and wildlife: Topical briefs, Fish and Wildlife resources and electrical power generation FWS/OBS–76/206, 26 p.

Sveum, C.M., Crawford, J.A., and Edge, W.D., 1998a, Use and selection of brood-rearing habitat by sage grouse in south-central Washington: Great Basin Naturalist, v. 58, p. 344–351.

Sveum, C.M., Edge, W.D., and Crawford, J.A., 1998b, Nesting habitat selection by sage grouse in south-central Washington: Journal of Range Management, v. 51, p. 265–269.

Swenson, J.E., Simmons, C.A., and Eustace, C.D., 1987, Decrease of sage grouse *Centrocerus urophasianus* after ploughing of sagebrush steppe: Biological Conservation, v. 41, p. 125–132.

Tack, J.D., 2009, Sage-grouse and the human footprint: implications for conservation of small and declining populations: Missoula, University of Montana.

Tack, J.D., Naugle, D.E., Carlson, J.C., and Fargey, P.J., 2012, Greater Sage-Grouse *Centrocercus urophasianus* migration links the U.S.A. and Canada: a biological basis for international prairie conservation: Oryx, v. 46, p. 64–68.

Taylor, R.L., Walker, B.L., Naugle, D.E., and Mills, L.S., 2012, Managing multiple vital rates to maximize Greater Sage-Grouse population growth: Journal of Wildlife Management, v. 76, p. 336–347.

Taylor, S.E., and Young, J.R., 2006, A comparative behavioral study of three Greater Sage-Grouse populations: The Wilson Journal of Ornithology, v. 118, p. 36–41.

Tewalt, S.J., Kinney, S.A., and Merrill, M.D., 2008, GIS representation of coal-bearing areas in North, Central, and South America: U.S. Geological Survey Open-File Report 2008–1257, available at *http://pubs.usgs.gov/of/2008/1257/*.

Thompson, T.R., 2012, Dispersal ecology of Greater Sage-Grouse in northwestern Colorado: evidence from demographic and genetic methods: Moscow, University of Idaho, Ph.D. dissertation.

Thorne, E.T., Kingston, N., Jolley, W.R., and Bergstrom, R.C., 1982, Diseases of wildlife in Wyoming (2nd ed.), 353 p.

Thurow, T.L., and Taylor, C.A., 1999, Viewpoint: the role of drought in range management: Journal of Range Management, v. 52, p. 413–419.

Tischendorf, L., and Fahrig, L., 2000, On the usage and measurement of landscape connectivity: Oikos, v. 90, p. 7–19.

Tu, M., Hurd, C., and Randall, J.M., 2001, Weed control methods handbook—Tools & techniques for use in natural areas: The Nature Conservancy, 219 p.

U.S. Department of Defense and U.S. Fish and Wildlife Service, 2006, Greater Sage-Grouse Fact Sheet.

U.S. Farm Service Agency, 2008, Conservation Reserve Program State Acres for Wildlife Enhancement (SAFE) Fact Sheet.

U.S. Farm Service Agency, 2010, Record of Decision for Conservation Reserve Program Supplemental Environmental Impact Statement.

U.S. Fish and Wildlife Service, 2010a, Conference Report for the Natural Resource Conservation Service Sage-Grouse Initiative.

U.S. Fish and Wildlife Service, 2010b, Endangered and threatened wildlife and plants, 12-month findings for petitions to list the Greater Sage-Grouse (*Centrocercus urophasianus*) as threatened or endangered: Washington, D.C., FWS–R6–ES–2010–0018, Federal Register, v. 75, no. 55 (March 23, 2010), 107 p.

U.S. Fish and Wildlife Service, 2011, Sheldon National Wildlife Refuge Draft Comprehensive Conservation Plan and Environmental Impact Statement: U.S. Fish and Wildlife Service.

U.S. Fish and Wildlife Service, 2012, Hart Mountain National Antelope Refuge, Lake County, OR, draft comprehensive conservation plan and draft environmental impact statement: Washington, D.C., Federal Register, v. 77, no. 102 (May 25, 2012).

U.S. National Park Service and Bureau of Land Management, 2006, Craters of the Moon National Monument and Preseve Management Plan: U.S. National Park Service and Bureau of Land Management.

U.S. Natural Resources Conservation Service, 2012a, Contributions to the annual status review for Greater Sage-Grouse: U.S. Natural Resources Conservation Service , unpublished report.

U.S. Natural Resources Conservation Service, 2012c, Sage-grouse initiative status report fiscal year 2010–2011: U.S. Natural Resources Conservation Service.

Utah Division of Wildlife Resources (UDWR), 2009, Utah Greater Sage-Grouse management plan: Salt Lake City, Utah Department of Natural Resources, Division of Wildlife Resources, Publication 09–17.

Vallentine, J.F., 1990, Kind and mix of grazing animals, *in* J.F. Vallentine, ed., Grazing management (1st ed.): San Diego, Calif., Academic Press, p. 217–242.

Valone, T.J., Meyer, M., Brown, J.H., and Chew, R.M., 2002, Timescale of perennial grass recovery in desertified arid grasslands following livestock removal: Conservation Biology, v. 16, p. 995–1002.

Van Poolen, H.W., and Lacey, J.R., 1979, Herbage response to grazing systems and stocking intensities: Journal of Range Management, v. 32, p. 250–253.

Vander Haegen, W.M., Schroeder, M.A., and DeGraaf, R.M., 2002, Predation on real and artificial nests in shrub steppe landscapes fragmented by agriculture: The Condor, v. 104, p. 496–506.

Veblen, K.E., Pyke, D.A., Aldridge, C.L., Casazza, M.L., Assal, T.J., and Farinha, M.A., 2011, Range-wide assessment of livestock grazing across the sagebrush biome: Reston, Va., U.S. Geological Survey.

Vitousek, P.M., 1990, Biological invasions and ecosystem processes—Towards an integration of population biology and ecosystem studies: Oikos, v. 57, p. 7–13.

Walker, B.L., and Naugle, D.E., 2011, West Nile virus ecology in sagebrush habitat and impacts on Greater Sage-Grouse populations, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union, p.127–143.

Walker, B.L., Naugle, D.E., and Doherty K.E., 2007a, Greater Sage-Grouse population response to energy development and habitat loss: Journal of Wildlife Management, v. 71, p. 2644–2654.

Walker, B.L., Naugle, D.E., Doherty, K.E., and Cornish, T.E., 2004, Outbreak of West Nile virus in Greater Sage-Grouse and guidelines for monitoring, handling and submitting dead birds: Wildlife Society Bulletin, v. 32, p. 1–7.

Walker, B.L., Naugle, D.E., Doherty, K.E., and Cornish, T.E., 2007b, West Nile virus and Greater Sage-Grouse: estimating infection rate in a wild bird population: Avian Diseases, v. 51, p. 691–696.

Wambolt, C.L., Harp, A.J., Welch, B.L., Shaw, N., Connelly, J.W., Reese, K.P., Braun, C.E., Klebenow, D.A., McArthur, E.D., Thompson, J.G., Torell, L.A., and Tanaka, J.A., 2002, Conservation of Greater Sage-Grouse on public lands in the Western U.S.: implications of recovery and management policies: Policy Analysis Center for Western Public Lands (PACWPL).

Watts, S.E., 1998, Short-term influence of tank tracks on vegetation and microphytic crusts in shrubsteppe habitat: Environmental Management, v. 22, p. 611–616.

Weins, J.A., Stenseth, N.C., Van Horn, B., and Ims, R.A., 1993, Ecological mechanisms and landscape ecology: Oikos, v. 66, p. 369–380.

West, N.E., 1983, Western intermountain sagebrush steppe, *in* West, N.E., ed., Ecosystems of the World, p. 351–374.

West, N.E., 1988, Intermountain deserts, shrub steppes, and woodlands, *in* Barbour, M.G., and Billings, W.D., eds., North American terrestrial vegetation: New York, Cambridge University Press, p. 209–230.

West, N.E., and Yorks, T.P., 2002, Vegetation responses following wildfire on grazed and ungrazed sagebrush semi-desert: Journal of Range Management, v. 55, p. 171–181.

West, N.E., and Young, J.A., 2000, Intermountain valleys and lower mountain slopes, *in* Barbour, M.G., and Billings, eds., North American terrestrial vegetation (2nd ed.): New York, Cambridge University Press, p. 256–284.

Westemeier, R.L., Brawn, J.D., Simpson, S.A., Esker, T.L., Jansen, R.W., Walk, J.W., Kerschner, E.L., Bouzat, J.L., and Paige, K.N., 1998, Tracking the long-term decline and recovery of an isolated population: Science, v. 282, p. 1695–1698.

Western Association of Fish and Wildlife Agencies, 2008, Greater Sage-Grouse population trends: an analysis of lek count databases 1965–2007: Denver, Colo., Western Association of Fish and Wildlife Agencies, 126 p.

Western Governors' Association, 2011, Policy resolution 11–9: sage-grouse and sagebrush conservation: Denver, Colo., Western Governors' Association.

Western Governors' Wildlife Council, 2011, Inventory of State and local governments' conservation initiatives for sage grouse: Denver, Colo.,Western Governors' Association.

White, D., Minotti, P.G., Barczak, M.J., Sifneos, J.C., Freemark, K.E., Santelmann, M.V., Steinitz, C.F., Kiester, A.R., and Preston, E.M.,1997, Assessing risks to biodiversity from future landscape change: Conservation Biology, v. 11, p. 349–360.

Whiting, J.C., and Bybee, B., 2011, Annual report of surveys for historic sage-grouse leks on the Idaho National Energy Laboratory: Unpublished report.

Whittington, J., Hebblewhite, M., DeCesare, N.J., Neufeld, L., Bradley, M., Wilmshurst, J., and Musiani, M., 2011, Caribou encounters with wolves increase near roads and trails: a time-to-event approach: Journal of Applied Ecology, v. 48, p. 1535–1542.

Wiens, J., 2002, Predicting species occurrences: progress, problems, and prospects, *in* Scott, J.M., Heglund, P.J., Morrison, M.L., Haufler, J.B., Rapheal, M.G., Wall, W.A., and Samson, F.B., eds., Predicting species occurrences: issues of accuracy and scale: Washington, D.C., Island Press.

Winward, A.H., 2004, Sagebrush of Colorado—Taxonomy, distribution, ecology and management, 39 p.

Wisdom, M.J., Meinke, C.W., Knick, S.T., and Schroeder, M.A., 2011, Factors associated with extirpation of sage-grouse, *in* Knick, S.T., and Connelly, J.W., eds., Greater Sage-Grouse: ecology of a landscape species and its habitats: Berkeley, Calif., University of California Press, Cooper Ornithological Union, p. 451–474.

Wisdom, M.J., Rowland, M.M., Hemstrom, M.A., and Wales, B.C., 2005, Landscape restoration for Greater Sage-Grouse: implications for multiscale planning and monitoring, *in* Shaw, N.L., Pellant, M., and Monsen, S.B., eds., Sage grouse habitat restoration symposium proceedings, 2001 June 4–7, Boise, Idaho: Fort Collins, Colo., U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, p. 62–69.

Wisdom, M.J., Rowland, M.M., Wales, B.C., Hemstrom, M.A., Hann, W.J., Raphael, M.G., Holthausen, R.S., Gravenmier, R.A., and Rich, T.D., 2002, Modeled effects of sagebrush-steppe restoration on Greater Sage-Grouse in the interior Columbia Basin, U.S.A.: Conservation Biology, v. 16, p. 1223–1231.

With, K.A., 2004, Assessing the risk of invasive spread in fragmented landscapes: Risk Analysis, v. 24, p. 803–815.

Wright, H.A., 1970, Response of big sagebrush and three-tip sagebrush to season of clipping: Journal of Rangeland Management, v. 23, p. 20–22.

Wrobleski, D.W., and Kauffman, J.B., 2003, Initial effects of prescribed fire on morphology, abundance, and phenology of forbs in big sagebrush communities in southeastern Oregon: Restoration Ecology, v. 11, p. 82–90.

Wyoming Executive Order No. 2008–2, August 1, 2008, Greater Sage-Grouse core area protection: Casper, Wyo., Governor's Office, State of Wyoming.

Wyoming Executive Order No. 2010–4, August 18, 2010, Greater Sage-Grouse core area protection: Casper, Wyo., Governor's Office, State of Wyoming.

Wyoming Executive Order No. 2011–5, June 2, 2011, Greater Sage-Grouse core area protection: Casper, Wyo., Governor's Office, State of Wyoming.

Xian, G., Homer, C.G., and Aldridge, C.L., 2012, Effects of land cover and regional climate variations on long-term spatiotemporal changes in sagebrush ecosystems: Geoscience & Remote Sensing, v. 49, p. 378–396.

Yost, A.C., Petersen, S.L., Gregg, M., and Miller, R., 2008, Predictive modeling and mapping sage grouse (*Centrocercus urophasianus*) nesting habitat using Maximum Entropy and a long-term dataset from southern Oregon: Ecological Informatics, v. 3, p. 375–386.

Young, J.A., and Evans, R.A., 1978, Population dynamics after wildfires in sagebrush grasslands: Journal of Range Management, v. 31, p. 283–289.

Young, J.A., Evans, R.A., and Kay, B.L., 1987, Cheatgrass: Rangelands, v. 9, p. 266–270.

Young, J.R., Braun, C.E., Oyler-McCance, S.J., Hupp, J.W., and Quinn, T.W., 2000, A new species of sage–grouse (*Phasianidae:Centrocercus*) from southwestern Colorado: Wilson Bulletin, v. 112, p. 445.

Young, J.R., Hupp, J.W., Bradbury, J.W., and Braun, C.E., 1994, Phenotypic divergence of secondary sexual traits among sage grouse, *Centrocercus urophasianus*, populations: Animal Behaviour, v. 47, p. 1353–1362.

Zablan, M.A., Braun, C.E., and White, G.C., 2003, Estimation of Greater Sage-Grouse survival in North Park, Colorado: Journal of Wildlife Management, v. 67, p. 144–154.

Zou, L., Miller, S.N., and Schmidtmann, E.T., 2006, Mosquito larval habitat mapping using remote sensing and GIS—Implication of coalbed methane development and West Nile virus: Journal of Medical Entomology, v. 43, p. 1034–1041.

Zou, L., Miller, S.N., and Schmidtmann, E.T., 2007, A GIS tool to estimate West Nile virus risk based on a degree-day model: Environmental Monitoring and Assessment, v. 129, p. 413–420.

Appendix. Data Sources and Analysis for the Greater Sage-Grouse Threat Assessment

Introduction

The primary purpose of the geospatial analysis is to quantitatively assess the location, magnitude, and extent of the primary threats to Greater Sage-Grouse (hereafter, sage-grouse) habitats and populations. Understanding these factors and being able to compare differences between areas across the range of the species provides overarching biological information that informs planning. For landscape species (defined in this context as a species where populations occupy large ranges that cross traditional management boundaries), the evaluation of current and future status (such as the impact associated with alternatives in the context of the National Environmental Protection Act (NEPA) planning and review process) must take into account biologically meaningful scales, which may be larger than the planning area being assessed. This allows specific areas to be put into the larger context so that decision makers can understand more site-specific conditions, place finer resolution data into context, and make allocation and other land-use planning decisions. The tradeoffs and prioritization inherent in applying a conservation strategy first require understanding the nature and extent of threats across the range of a species and then looking at smaller scale areas in context to allocate resources to reduce threats in these areas that are meaningful for the species.

Therefore, we strove to collect geospatial data representing the threats to sage-grouse as identified by scientific research and outlined in the 2010 USFWS listing decision. We measured the direct impact to sage-grouse habitats, as well as the indirect impacts to habitats and populations through applying buffer distances representing impacts to the species as identified in the literature. These potential measures of impact were then compared to current BLM preliminary priority habitat and preliminary general habitat delineations (see Section 1) to understand the condition and threats across the highest densities of sage-grouse and sagebrush habitats as well as the rest of the currently occupied range. In addition, we examined surface-management entities in relation to each threat so that multiple landowners and managers across the range of the sage-grouse can understand impacts under their jurisdiction as well as neighboring jurisdictions. This landscape approach allows for population-level assessments despite checkerboards of surface-management entities. Overall this effort is intended to provide information to conservation planning teams to understand the issues, determine appropriate alternatives, and ultimately provide biologically meaningful analyses of sage-grouse populations (for example, information on the past and current conditions for cumulative impact analyses in the WAFWA Management Zones for sage-grouse).

Methodology

Identification of Threats

Threats for the sage-grouse are identified in the 2010 USFWS listing decision for five factors. These common threats and issues fall into categories that were recognized by USFWS in the published findings—habitat change (Factor A), over-utilization (Factor B), disease and predation (Factor C), policy and land use (Factor D), and chemical poisoning (Factor E). Primarily threats that can be represented spatially with current data are found in Factor A. Factors B through D are typically described qualitatively, although for this report, Factor D information was collected for management classifications with the purpose of identifying areas where habitats are protected from development. For each threat we collected information in up to four categories (if data were available):

1. Land Allocation and Management—management focus (conservation versus multiple use) and data associated with reduction and or limitation of threat categories (table A-1)

2. Current Threats—physical footprints and locations of anthropogenic features and natural processes that impact sage-grouse habitats (tables A-2, and A-3)

3. Valid Existing Rights—management decisions and projects approved but where features may not currently exist (includes leasing and allocation decisions from land management agencies where data could be collected in the project time frames) (tables A-2 and A-3)

4. Potential Threats—data on the potential of anthropogenic features and natural processes; in many cases these are associated where land uses may occur but do not take into account distribution, infrastructure, or other factors necessary for actual projects to be located in these areas (tables A-2 and A-3)

Determination of Direct and Indirect Distances

Direct impact of any particular threat was measured as acres of physical ground disturbance or linear miles of the feature. In many cases polygon data were available that represented the physical footprint of a feature, but in some cases, we buffered point features with appropriate distances to represent the typical footprint of development (see tables A-1 and A-4). These distances were derived from programmatic Environmental Impact Statement (EIS) documents, industry standards, or expert opinion (see tables A-1 and A-4).

Section 3 of this report identifies multiple literature sources that reported effects associated with the threats identified in the USFWS listing decision. We selected the indirect impact distances as appropriate for each threat, based on peer-reviewed scientific literature that represented impacts typical of sage-grouse populations across the range. These distances may not represent impact for all populations, but many come from rangewide or cross-population analyses where a statistical impact at the buffered distance was identified. They are used in the report to identify issues that should be looked at more closely during the creation of land management and conservation plans for sage-grouse (tables A-1 and A-4). We chose to use distances where an impact could be determined, not necessarily a more specific look at avoidance behaviors associated with a feature. Therefore, it is important to note that impacts across an indirect buffer distance are likely not uniform; typically there is a decay function that more fully represents the relation. In setting metrics or thresholds for site-specific applications and analyses, the additional scientific summaries in this document along with local knowledge on home-range size, migratory patterns, habitat availability, and other factors, are important when interpreting the effects on sage-grouse habitat and populations and addressing specific questions or objectives associated with impacts to sage-grouse habitats and populations.

Collection of Geospatial Data

All data analysis was conducted by the BLM's National Operations Center in Lakewood, Colo. Data was collected and assembled from National BLM sources, individual BLM States, USFS national sources, and external sources depending on the authoritative source for types of features (tables A-2 and A-3). In some cases data from multiple sources was aggregated to best represent the feature or phenomenon. In addition, some data was only available for Federal lands or for only a part of the study area.

Geospatial data were acquired for all threats identified in the USFWS listing decision that can be represented spatially. These data were acquired rangewide, as available, from both internal (BLM and USFS) and external sources beginning in August 2011 (tables A-2 and A-3). All data, both internal and external, were considered the "best available" at the time of data collection. National data were "frozen" in June and July of 2012, with updates made to some datasets as late as December 2012. Other data (for example, compiled from other sources) were the most current available, based on the supplying office, agency, or organization (see tables A-2 and A-3). Internal data were compiled using intra-agency data calls and often included data submitted in segments, from different administrative units, across the BLM and USFS management areas (see fig. A-1 for the full process). These datasets were aggregated and reviewed, but time constraints limited the ability to revise these data for quality and completeness, fix geometry errors (gaps and overlaps), and edge-match across jurisdictions (fig. A-1). The metadata associated with each dataset details the analysis and methodology procedures and provides details relating to specific data.

After data collection was complete, input datasets were preprocessed. Preprocessing steps included reclassification, attributing, buffering, and other formatting tasks. Categorizing datasets into relevant attributes and supplementing them with additional attributes was necessary for data compatibility. Collaboratively developed priority habitat designations (PPH and PGH) were combined with surface management agency (SMA) and WAFWA management-zone polygons into one master summary file (MSF) with a unique identification (ID) reflecting the specific combination of habitat (PPH or PGH), management entity, and WAFWA MZ for each polygon to provide for efficient, repeatable, and consistent data analysis. All datasets were clipped to the rangewide study area, and small and superfluous polygons were dissolved, to reduce the number of features and remove unnecessary attributes. Finally, data were sorted into point, line, and polygon features for different analyses that reflected the represented footprint and modeled effects (see table A-1).

Overlay comparisons were generated using ArcGIS Model Builder (version 10.0) with separate models created for point, line, and polygon input data (see fig. A-1). In brief, these models intersect the input data with the master summary file (MSF), which includes representation of the spatial summary units (MZs), and dissolve the resulting intersect file to single polygons based on the unique ID assigned in the intersection. Finally, statistics were calculated for each threat overlay using the number of points, linear miles, or area within the specific combination of habitat type, management entity, and MZ. The resulting data were then exported from the GIS to Microsoft Excel for summary calculations (fig. A-1). For each of the categories/types of data, the pre-processing steps were as follows:

Base Layers

Preliminary Priority Habitat/Preliminary General Habitat

This dataset is the consolidated submissions of State-submitted Greater Sage-Grouse Preliminary Priority and Preliminary General Habitats (table A-2). These data are a snapshot of State defined PPH/PGH polygons as of June 26th, 2012 – priority habitats may also be described as "core areas" in some contexts. States may have continued to refine the PPH/PGH designations beyond this date. Specifics on each State's submission follow:

- California—PPH and PGH: FINAL DRAFT; Developed cooperatively by California BLM and California Department of Fish and Game.

- Colorado—PPH and PGH: FINAL DRAFT; Developed by Colorado Parks and Wildlife in cooperation with Colorado BLM.

- Idaho—PPH and PGH: Version 2 (April 2012); Developed by the Idaho BLM State Office with input from Idaho BLM Field Offices, the U.S. Forest Service, and Idaho Department of Fish and Game. Version 2 reflects refinements and additional data that were incorporated into Version 1 following further analysis and public scoping for the BLM Sage-Grouse Conservation Planning effort.

- Montana—PPH and PGH: FINAL DRAFT; Developed by Montana Fish, Wildlife and Parks and reviewed by Montana BLM
- Nevada—PPH and PGH: SEMIFINAL DRAFT; Developed by Nevada Department of Wildlife in cooperation with Nevada BLM (90 percent completed).
- North Dakota—PPH: FINAL DRAFT; Developed by North Dakota Game and Fish Department in cooperation with Montana/Dakotas BLM; PGH: FINAL DRAFT; Distribution of Sage-Grouse in North America (Schroeder and others, 2004).
- Oregon—PPH and PGH: FINAL DRAFT; Developed by Oregon Department of Fish and Wildlife in cooperation with Oregon BLM.
- South Dakota—PPH and PGH: FINAL DRAFT; Acquired from Montana/Dakotas BLM.
- Utah—PPH: SEMIFINAL DRAFT; Developed by Utah Division of Wildlife Resources; under review by Utah Governor's Office; Utah BLM will use Division of Wildlife Resources (DWR) Occupied Habitat (9/2011) in the interim; PGH: All DWR Occupied Habitat is considered Priority, so PGH does not apply.
- Wyoming—PPH and PGH: PPH (June 2010): Core Management Areas-Version 3; Developed by the Wyoming Governor's Sage-Grouse Implementation Team and Wyoming Game and Fish Department in cooperation with Wyoming BLM (PGH modified from Distribution of Sage-Grouse in North America; Schroeder and others, 2004).

WAFWA Management Zones

This dataset depicts the Management Zone boundaries as defined by the Western Association of Fish and Wildlife Agencies for Greater and Gunnison Sage-Grouses in the Western United States and Canada. It was not altered in any way for this effort. MZ II and VII were combined for summary analyses.

Federal Agency Management (Surface Management)

This dataset provides management data for all Federal agencies, as well as State, local, and private lands. It was updated with U.S. Forest Service authoritative data provided in May 2012. Because of inconsistencies in the manner in which BLM States define and categorize SMA designations, and in order to focus analysis on BLM and USFS management at the landscape scale, the following Federal agencies and tribal entities were classified into one category called "Tribal and Other Federal": BIA, BOR, BPA, COE, DOD, DOE, Federal Aviation Administration (FAA), FWS, GSA, NPS, tribal and non-forest USDA. Other minor land management entities, topology errors, unknown areas, and unclassified areas were combined into an "other" category during final summary of the data. In addition, areas classified as water were removed to restrict the summary tables to terrestrial habitats.

Land Allocation and Management

Federal Fluid Minerals—Areas Closed to Oil and Gas Leasing

This polygon dataset is the consolidated submissions for locations closed to oil and gas development data from BLM States. Areas overlapping with submitted oil and gas leases and leases held-by-production polygons were removed.

Conservation Focused and Protected Areas

The National Conservation Easement polygon database was subset to include only those features where "Duration" = "Permanent."

USGS Protected Areas Database (PAD-US, v. 1.2) polygons with level of protection (GAP Status) codes 1 and 2 (see below) or unknown were subset to provide National Park Service and State and private lands polygon datasets. Additionally, Wilderness and USFWS Refuges datasets were supplemented with additional refuge or wilderness features found in PAD-US. Finally, ACEC (Areas of Critical Environmental Concern) and NLCS (National Landscape Conservation System) polygons were categorized by GAP Status code using PAD-US, and only those with codes 1, 2, or unknown were retained.

GAP Status codes 1 and 2 are defined as follows:

1. An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events (of natural type, frequency, intensity, and legacy) are allowed to proceed without interference or are mimicked through management.
2. An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality of existing natural communities, including suppression of natural disturbance.

National Landscape Conservation System (NLCS) and Areas of Critical Environmental Concern (ACEC) polygons provided by the BLM data steward were subset to include only those with PAD-US GAP Status categories 1, 2, or unknown. Input NLCS units included National Conservation Areas, Wilderness Study Areas, National Monuments, Cooperative Management and Protection Areas, and Outstanding Natural Areas.

Wilderness polygons were derived from all wilderness-land polygons from the BLM and USFS Wilderness databases, supplemented with NPS and FWS Wilderness from PAD-US.

USFWS Refuges polygons from the National Wildlife Refuge Boundary and Parcel Data database were supplemented with additional data from the PAD-US database where "Primary Designation Type" = "National Wildlife Refuge" and GAP Status category was 1, 2, or unknown.

National Park Service polygons were determined by pulling a subset of PAD-US where "Own_Name" = "0145" (NPS) and GAP Status was 1, 2, or unknown.

State and Private land polygons with GAP Status categories of 1, 2, or unknown were pulled from PAD-US by selecting "Own_Type" = "03"' OR "Own_Type" = "04" OR "Own_Type" = "05" (State, regional and local) or "Own_Type" = "07" (private).

Because there was overlap of polygons in the above datasets, they were merged and dissolved before conservation area on PPH and PGH statistics were calculated.

Current Threats

Agricultural Development

This polygon dataset is a subset of the USDA National Agricultural Statistics Service's (NASS) Cropland Data Layer (CDL). For the purpose of creating a crop-specific layer, the following features were excluded from this dataset: Barren, Deciduous Forest, Developed/High Intensity, Developed/Low Intensity, Developed/Med Intensity, Developed/Open Space, Evergreen Forest, Grassland Herbaceous, Herbaceous Wetlands, Mixed Forest, Open Water, Other Hay/Non Alfalfa, Pasture/Hay, Pasture/Grass, Perennial Ice/Snow, Shrubland, and Woody Wetlands. Raster data were converted to polygon vector data and were buffered to create indirect influence areas.

Urbanized Areas

This polygon dataset is a subset of the City Limits dataset from Tele Atlas ESRI Street Map Premium for ArcGIS v 9.0. City limit polygons falling on Bureau of Indian Affairs land, which were also found to be of limited development using aerial imagery inspection, were manually removed from this dataset. Features were buffered to create indirect influence areas.

Major Power Lines and Associated Infrastructure

This polygon dataset is a compiled layer of two power line datasets, which together provide the most complete spatial representation of this threat across the study area. Linear features from power lines in the Western United States, ICBEMP existing utility corridors dataset, 2004, and transmission lines, substations, electric power generation plants, and energy distribution control facilities from the EV Energy Map, Platts/Global Energy, 2005, were merged to create a combined layer. Features (lines and points) were then buffered to create direct and indirect influence areas. We did not calculate linear distances because minor spatial errors between the dataset resulted in sections of power lines being duplicated. Buffering and dissolving features off of these linear features represented direct impacts of development as an acre footprint and removed issues of double counting from a linear mile measurement.

Communication Towers and Other Vertical Structures

This dataset is compiled from the FAA Digital Obstacles point file and the Federal Communications Commission (FCC) communication towers point file. Points with "Type_" = "WINDMILL" were removed from the FAA file and were processed in a separate analysis. Additionally, all duplicate points were removed. Finally, features were buffered to create direct and indirect influence areas.

Fences

This dataset is a merged layer of allotment and pasture-data files submitted by the USFS and the BLM. This aggregate dataset identifies pasture and allotment borders, represented as linear features, for allotments within BLM and USFS managed public lands. This acts as a surrogate for fences for those areas with BLM or USFS management (in many cases only a portion of a pasture or allotment) and therefore does not represent fence density for areas with solely other Federal or non-Federal management.

Interstate, Highway, and Secondary Roads

This dataset is a subset of the ESRI Tele Atlas ESRI StreetMap Premium for ArcGIS v 9.0 2008, Dynamap Transportation version 5.2, 2003, Detailed Streets dataset. The following queries were used to select interstates, highways (primary and secondary), and secondary (other) road types: Interstates, "FCC" IN ('A10', 'A11', 'A12', 'A15', 'A16', 'A17', 'A18'); Highways, "FCC" IN ('A20', 'A21', 'A22', 'A23', 'A24', 'A25', 'A26', 'A27', 'A28', 'A30', 'A31', 'A32', 'A33', 'A34', 'A35', 'A36', 'A37', 'A38'); and Other roads, "FCC" IN ('A40', 'A41', 'A42', 'A43', 'A44', 'A45', 'A46', 'A47', 'A48', 'A50', 'A51', 'A52', 'A60', 'A64', 'A70'). Linear features were then buffered to create direct and indirect influence areas. The three-road-type buffer files were combined for each influence distance with overlap areas removed for analysis.

Major Railroads

This dataset includes abandoned and non-abandoned railroads from the Federal Railroad Administration (FRA) Rail Lines of the U.S.A. dataset. Abandoned and non-abandoned rail lines were separated into two linear files using the attribute indicating the status of the rail line. Non-abandoned linear features were buffered to create direct and indirect influence areas, whereas abandoned features were buffered to create only direct influence areas.

Large Wildfires

This dataset includes polygon data representing the perimeters of wildfires submitted to the Geospatial Multi-Agency Coordination (GeoMAC) Group occurring during the period 2000 through 2012. Polygon areas were used to represent direct influence.

Moderate to High Probability of Cheatgrass Occurrence

This is a modeled dataset created to depict the probability of cheatgrass occurrence in several floristic regions (Meinke and others, 2009). Inputs for regression analysis included elevation, precipitation, soil pH, soil depth, soil salinity, and available water capacity extracted at 6,736 field sampling locations where cheatgrass occurrence was determined. The data were subset using the 5–10 percentile range to reflect a “moderate to high” risk of cheatgrass occurrence as in Meinke and others (2009). Raster data were converted to polygon vector data. Polygon areas were used to represent direct influence.

Pinyon-Juniper and Other Conifer Encroachment Risk

This is a derived dataset using the methodology from the BLM Rapid Ecological Assessment of the Northern Basin and Range and Snake River Plain (DOI, 2010). To create this layer, GIS focal statistics were used to identify areas of adjacency between sagebrush and pinyon/juniper, and sagebrush and any other cells classified as conifer, as classified in the National GAP landcover GIS database. These cells were then buffered 120 meters into sagebrush to represent potential expansion into sagebrush areas. Raster data were converted to polygon vector data for analysis. Polygon areas were used to represent direct influence.

Grazing

This dataset consists of BLM grazing allotments and pastures polygon supplemented with the 2008 BLM Land Health database (Veblen and others, 2011; Assal and others, 2012). Allotments were selected from the database that were not meeting land-health standards for wildlife with grazing as the causal factor in the non-achievement, as well as those allotments where an assessment had not been completed. These allotments were then joined to the BLM Geospatial Science Support Program (GSSP), National Allotment GIS dataset on June, 28 2012, using the unique State allotment ID. Of the 1,135 allotment records from the spreadsheet, 21 were not able to be mapped. Polygon areas were used to represent direct influence.

Wild Horse and Burro Herd Management Areas (HMAs)

This polygon dataset is a compilation of BLM wild horse and burro and USFS wild horse and burro HMA polygons. Polygon areas were used to represent direct influence.

Oil and Gas Development Related Wells

This dataset is a compilation of two oil and gas well databases: the proprietary IHS Corporation Enerdeq database and the BLM Automated Fluid Minerals Support System (AFMSS) database. Wells producing within the last ten years from IHS and Active wells from AFMSS, as well as plugged and abandoned within the last 10 years from both datasets, were buffered by 62 m to provide direct effects. Producing wells from IHS and Active wells from AFMSS were buffered by 3 km and 19 km to provide indirect effects. We chose the ten-year criterion for inclusion of wells as our analysis of time-lag effects suggested that there is a delay of 2–10 years between activity associated with energy development and its measurable effects on lek attendance; therefore, flagging past development allows identification of areas where issues from production and development from fields may remain. The IHS dataset includes the following states: Calif., Colo., Idaho, Mont., N. Dak., Nev., Oreg., S. Dak., Utah, and Wyo. downloaded in December 2012. It was subset to exclude points occurring also in the BLM AFMSS database. AFMSS data are current as of December 19, 2012, for the following BLM States: Calif., Colo., Idaho, Mont., N. Dak., Nev., Oreg., S. Dak., Utah, and Wyo. Points from both datasets were aggregated by square mile to create the well density figure.

Federal Managed Coal, Surface Mining Development

This polygon dataset is the consolidated submissions for Federal coal lease data. Leases were defined as surface coal leases and subset from the original dataset based on guidance from BLM planners and mineral specialists. Polygon features were used for direct footprint and buffered for indirect influence areas.

Mining and Minerals Materials Disposal (Federal Minerals Only)

This polygon dataset is a compilation of two datasets consolidated from submissions from BLM States. The two datasets include mineral materials disposal sites and locatable mining claims. Both datasets were submitted as polygon data. Polygon areas were used to represent direct influence and were buffered to create indirect influence areas.

Wind Turbines

This dataset is compiled from the Federal Aviation Administration Digital Obstacles point file to include points where “Type_” = “WINDMILL”. Aerial imagery was used to verify that these points represent wind turbines. All duplicate points were removed and features were buffered to create direct and indirect influence areas.

Valid Existing Rights

Federal Geothermal Leasing

This polygon dataset is the consolidated submissions for geothermal lease and approved project data from BLM State offices. Lease boundaries defined polygons that represented direct influence areas with existing rights.

Federally Managed Fluid Minerals—Leased Areas and Status

These datasets (leased areas and leases held by production) are a compilation of polygon datasets consolidated from submissions from BLM States. The two datasets include (1) oil and gas leases (limited to “Authorized”: Case-types beginning with 310, 311, or 312 and not held by production, as needed) and (2) oil and gas leases held by production (limited to “Authorized”: Case-types beginning with 310, 311, or 312, and HbP codes of 650, 651 or other attribute field populated to indicate held by production).

Oil Shale Leases

This polygon dataset is the consolidated submissions for oil shale research, development, and demonstration lease data from BLM States.

BLM Wind Energy Rights of Way (ROW)

This polygon dataset is the consolidated submissions for wind energy rights of way and approved authorizations data from BLM States.

Potential Threats

Large Fire—High Burn Probability

A derived dataset based on a national burn probability (BP) raster dataset for the United States was generated for the 2012 Fire Program Analysis (FPA) System. These data were provided by the National Interagency Fire Center (NIFC). The source raster was subset to the rangewide analysis area and reclassified to nominal classifications creating two categories of data, plus a zero category: Non-burnable = 0, Low probability = 0.00002–0.0043, and High Probability = 0.0043–0.0732. The high-probability dataset was subset as a raster file and then converted to vector format for analysis.

Coal Potential

This dataset includes polygons from the America’s Coal Potential database compiled and published by the USGS (Tewalt and others, 2008).

Oil and Gas Potential

This is the raster dataset for relative oil and gas potential as described in Copeland and others (2009) “Mapping Oil and Gas Development Potential in the US Intermountain West and Estimating Impacts to Species.” This continuous dataset, ranked from 0–100, was categorized into Low = 0–33, Medium = 34–66, and High = >66 categories for map display.

Geothermal Potential

This dataset includes polygons from the Idaho National Engineering & Environmental Laboratory (INEEL) of regions favorable for the discovery and shallow depth (less than 1,000 m) of thermal water of sufficient temperature for direct-heat applications.

Solar Potential

This polygon dataset provides information on the photovoltaic solar resource potential (US 9805 latilt) for the 48 contiguous States as published by the National Renewable Energy Laboratory (NREL). Map display categories follow those used in the Draft Programmatic Environmental Impact Statement (PEIS) for Solar Energy Development in Six Southwestern States (DES 10-59, DOE/EIS-0403; solareis.anl.gov) to show areas with an occurrence potential greater than 5.5 kWh/m^2/day (kilowatt hours per square meter per day). Reaming areas have the potential for less than 5.5 kWh/m^2/day.

Oil Shale and Tar Sands

This polygon dataset is from the 2008 Oil Shale and Tar Sands PEIS. It includes merged features from the stratigraphic unit files for oil shale in Colo., Utah, and Wyo., which have been designated as “most geologically prospective,” as well as “special tar sand areas” in Utah.

Wind Potential

This polygon dataset is a consolidated annual average wind resource potential at a 50-m height from NREL State-level shapefile data. Categories for medium and high were created from the original data as follows: Medium = Fair (3 or 200–300) and High = Good (4 or 400–500), Excellent (5 or 500–600), Outstanding (6 or 600–800), and Superb (7 or >800). Original 50-m-resolution data was resampled to 5-km resolution.

Table A-1. Direct and indirect buffer distances used to represent effects of human infrastructure and activities on Greater Sage-Grouse for this Report with references to the literature describing these relations.

General Description	Data Source	Indicator	Area of Influence	Reference for Influence
Habitat Conversion to Agriculture	USDA Cropland (Categories identified by CEA Team)	Acres	Direct: polygon area Indirect: 6.9 km	Boarman and Heinrich, 1999, Leu and others, 2008, Connelly, 2011
Urbanization	Urban Areas—ESRI City Boundaries	Acres	Direct: polygon area Indirect: 6.9 km	Boarman and Heinrich, 1999, Leu and others, 2008
Infrastructure (Power lines)	Global Energy/ Platts, Market significant power lines (gen >115kV) & assoc. structures	Acres	Direct: 200 meters Indirect: 6.9 km	Ellis 1985, Connelly and others, 2004, Bradley and Mustard, 2006, Boarman and Heinrich, 1999, Leu and others, 2008
Infrastructure (Comm. Towers)	FCC	Acres	Direct: 1 ha (56.4 m) Indirect: 6.9 km	Boarman and Heinrich, 1999, Leu and others, 2008
Infrastructure (Other Vertical Structures)	FAA (non-wind)	Acres	Direct 1 ha (56.4 m) Indirect: 6.9 km	Boarman and Heinrich, 1999, Leu and others, 2008
Infrastructure (Fences)	BLM Range Allotment GSSP	Miles	Direct: Miles	Stevens and others, 2012
Infrastructure (Roads)	ESRI Roads (Interstate, Federal and State Highway, Secondary)	Acres	Direct: 73.2 m, 25.6 m, 12.4 m Indirect: 7.5 km, 3 km, 3 km	Holloran, 2005, Lyon, 2000, Connelly and others, 2004
Infrastructure (Railroads)	ESRI Railroads	Acres	Direct: 9.4 m Indirect: 3 km	Knick and others, 2011
Fire History	NIFC (Fire Polygons, 2001–2012)	Acres	Direct: Fire Acres	
Invasive Plant (Exotic Annual Grass)	Model—Cheatgrass (Great Basin only)	Acres	Direct: High and Moderate Probability Polygons	Meinke and others, 2009
P-J (Conifer) Encroachment	Northern Great Basin Assessment Model	Acres	Direct: 120m	DOI, 2010
Grazing (Domestic Livestock)	BLM Allotments (not meeting Land Health Standards [habitat due to livestock grazing])	Acres	Direct: “not meeting” Polygon Areas	
Grazing (Wild Horses & Burros)	BLM HMAs (GSSP), FS HMAs	Acres	Direct: Polygon Areas	

Table A-1. Direct and indirect buffer distances used to represent effects of human infrastructure and activities on Greater Sage-Grouse for this Report with references to the literature describing these relations.—Continued

General Description	Data Source	Indicator	Area of Influence	Reference for Influence
Energy (Nonrenewable; O&G)	IHS Well location data (non-plugged, or plugged only in the last 10 years)	Acres	Direct: 3 acres Indirect:19 km	Walker and others, 2007, USFWS, 2008, Johnson and others, 2011, Taylor and others, 2012
Energy (Nonrenewable; Coal)	BLM State Offices (Surface Mines)	Acres	Direct: Polygon Areas Indirect: 19 km	Johnson and others, 2011, Taylor and others, 2012
Mining (Locatable Mining Claims)	BLM State Offices—WO 300 Data Call	Acres	Direct: Polygon Areas Indirect: 2.5 km	Bradley and Mustard, 2006
Mining (Mineral Materials Disposal Sites)	BLM State Offices—WO 300 Data Call	Acres	Direct: Polygon Areas Indirect: 2.5 km	Bradley and Mustard, 2006
Energy (Renewable—Wind)	FAA	Acres	Direct: 3 acres (62m buffer) Indirect: 6.9 km	Bradley and Mustard, 2006, Boarman and Heinrich, 1999, Leu and others, 2008
Energy (Renewable—Geothermal)	BLM State Offices	Acres	Direct: Polygon Areas	Johnson and others, 2011, Taylor and others, 2012

Table A-2. Internal (BLM) data sources.

Analysis Dataset	Source	Data Type	Publication Date or Received Date	Data Currency Date
Base and Greater Sage-Grouse Habitat				
BLM Land Use Plans (LUP)	BLM Geospatial Services Strategic Plan (GSSP)	Polygon	June 2012	June 2012
BLM Subsurface Minerals Administration	BLM State offices: CO, MT, UT, WY	Polygon	May 2012	May 2012
Federal Surface Management Agency	BLM GSSP	Polygon	May 2012	May 2012
Forest Service Administrative Units	USFS Enterprise Data Warehouse	Polygon	July 2012	July 2012
GRSG Planning Regions and EIS Boundaries	Derived from BLM Land Use Plans GSSP	Polygon	May 2012	May 2012
Conservation				
ACEC	BLM GSSP	Polygon	May 2012	May 2012
NLCS (National Conservation Areas, Wilderness Study Areas, National Monuments, Cooperative Management and Protection Areas, Outstanding Natural Areas, and Forest Reserves)	BLM GSSP	Polygon	June 2012	July 2009
Wilderness (BLM)	BLM GSSP	Polygon	June 2012	July 2009
Wilderness (USFS)	USFS[1] Enterprise Data Warehouse	Polygon	April 2012	April 2012
Current Threat				
Coal Leases	Individual BLM State, District and Field offices	Polygon	November 2011–May 2012	November 2011–December 2012
Decadal Fires—Fire Perimeters, 2000–2012	Geospatial Multi-Agency Coordination (GeoMAC) Group	Polygon	January 2013	December 2012
Fences (BLM)—Grazing Allotments and Pastures	BLM GSSP	Line (converted from polygon)	May 24, 2012	May 24, 2012
Fences (USFS) —Grazing Allotments and Pastures	USFS Enterprise Data Warehouse	Line (converted from polygon)	July 2012	July 2012
Geothermal Leases	Individual BLM State, District and Field offices	Polygon	November 2011–May 2012	Varies 2009–2011
Grazing (BLM)—allotment/pasture designations	Veblen, K.E. and others, 2011, Assal, T.J. and others, 2012, BLM GSSP grazing allotment and pasture polygons	Polygon	May 24, 2012	May 24, 2012
Grazing (BLM)—Land Health Standards	Veblen and others, 2011, Assal and others, 2012, BLM GSSP	Polygon	May 24, 2012	2008
Grazing (USFS)	USFS[1] Enterprise Data Warehouse	Polygon	July 2012	July 2012
Mining and Mineral Materials Disposal—Mineral-Material Disposal Sites and Locatable Mining Claims	Individual BLM State, District and Field offices	Polygon	November 2011–December 2012	November 2011–December 2012

Table A-2. Internal (BLM) data sources.—Continued

Analysis Dataset	Source	Data Type	Publication Date or Received Date	Data Currency Date
Oil & Gas Wells (AFMSS)	BLM Automated Fluid Minerals Support System (AFMSS) Database	Point	December 2012	December 2012
Wild Horse and Burro Areas (USFS)	USFS[1] Enterprise Data Warehouse	Polygon	May 2012	May 2012
Wild Horse and Burro Herd Management Areas (BLM)	BLM GSSP	Polygon	May 2012	May 2012
Valid Existing Rights				
Federal Fluid Minerals—Areas Closed to Oil and Gas Leasing	Individual BLM State, District and Field offices	Polygon	November 2011–December 2012	November 2011–December 2012
Oil and Gas leases	Individual BLM State, District and Field offices	Polygon	October 2011–May 2012	October 2011–May 2012
Oil and Gas leases—Held by Production	Individual BLM State, District and Field offices	Polygon	October 2011–May 2012	October 2011–May 2012
Oil Shale Leases	Individual BLM State, District and Field offices	Polygon	November 2011–December 2012	Varies 2007–2012
Solar Right of Ways—Approved and Authorized	Individual BLM State, District and Field offices	Polygon	November 2011–May 2012	Varies 2011–2012
Wind Energy Rights of Way—Approved and Authorized	Individual BLM State, District and Field offices	Polygon	November 2011–May 2012	Varies 2011–2012
Potential Threat				
Fire Probability	USFS[1]—Missoula Fire Sciences Laboratory, Fire Program Analysis System, “High” category, NIFC	Raster	May 2012	September 2011

[1] The U.S. Forest Service makes no warranty, expressed or implied, including the warranties of merchantability and fitness for a particular purpose, nor assumes any legal liability or responsibility for the accuracy, reliability, completeness or utility of these geospatial data, or for the improper or incorrect use of these geospatial data. These geospatial data and related maps or graphics are not legal documents and are not intended to be used as such. The data and maps may not be used to determine title, ownership, legal descriptions or boundaries, legal jurisdiction, or restrictions that may be in place on either public or private land. Natural hazards may or may not be depicted on the data and maps, and land users should exercise due caution. The data are dynamic and may change over time. The user is responsible to verify the limitations of the geospatial data and to use the data accordingly.

Table A-3. External data sources

Analysis Dataset	Source	Data Type	Publication Date or Received Date	Data Currency Date	
Base and Greater Sage-Grouse Habitat					
Preliminary General Habitat	Individual State BLM offices and State wildlife agencies	Polygon	September 2011–June 2012	June 2012	*http://www.blm.gov/wo/st/en/prog/more/sagegrouse/documents_and_resources.html*
Preliminary Priority Habitat	Individual State BLM offices and State wildlife agencies	Polygon	September 2011–June 2012	June 2012	*http://www.blm.gov/wo/st/en/prog/more/sagegrouse/documents_and_resources.html*
WAFWA management zones, Version 2	Western Association of Fish and Wildlife Agencies	Polygon	October 2006	October 2006	*http://sagemap.wr.usgs.gov/ftp/SAB/sg_mgmtzones_ver2_20061018.zip*
Current Distribution of sage-grouse	Western Association of Fish and Wildlife Agencies	Polygon	February 2002	1999	*http://sagemap.wr.usgs.gov/FTP/regional/USGS/Sage-grouse_distribution_sgca.zip*
Sage-grouse Breeding Bird Density	BLM		August 2010	August 2010	*http://www.blm.gov/wo/st/en/prog/more/fish__wildlife_and/sage-grouse-conservation/bird_density.html*
Sage-grouse Populations	Western Association of Fish and Wildlife Agencies	Polygon	2004	2004	*http://sagemap.wr.usgs.gov/ftp/sab/sg_subpopulations.zip* and *http://sagemap.wr.usgs.gov/ftp/sab/sg_populations.zip*
Sage-grouse lek spatial connectivity	USGS (SAB)	Polygon	June 2010	December 2007	*http://sagemap.wr.usgs.gov/ftp/sab/sg_components.zip*
Distribution of sagebrush	Western Association of Fish and Wildlife Agencies	Polygon	2011	2006	*http://sagemap.wr.usgs.gov/ftp/sab/allsage_90m.zip*
Sage-grouse Genetic Sampling Sites	Oyler-McCance and others, 2005b	Point	2005	2005	See Oyler-McCance and others, 2005b
Sagebrush Biomes	Western Association of Fish and Wildlife Agencies	Polygon	2004	2004	*http://sagemap.wr.usgs.gov/FTP/regional/USGS/floristic_provinces_sgca.zip*
Conservation					
Conservation Easements	National Conservation Easement Database, Version 1	Polygon	August 2011	August 2011	*http://databasin.org/*
NPS Lands	Protected Areas Database, V 1.2	Polygon	April 2011	February 2011	*http://gapanalysis.usgs.gov/padus/data/*
Private Conservation Lands	Protected Areas Database, V 1.2	Polygon	April 2011	February 2011	*http://gapanalysis.usgs.gov/padus/data/*
Wilderness (NPS and FWS)	Protected Areas Database, V 1.2	Polygon	April 2011	February 2011	*http://gapanalysis.usgs.gov/padus/data/*
Wildlife Refuges (Other)	Protected Areas Database, V 1.2	Polygon	April 2011	February 2011	*http://gapanalysis.usgs.gov/padus/data/*
Wildlife Refuges (USFWS)	National Wildlife Refuge Boundary and Parcel Data	Polygon	April 2011	May 2011	*http://www.fws.gov/GIS/data/CadastralDB/FWS_Refuge_Boundaries.zip*

Table A-3. External data sources.—Continued

Analysis Dataset	Source	Data Type	Publication Date or Received Date	Data Currency Date	
Current Threat					
Agriculture—Cropland	National Agricultural Statistics Service Cropland Data Layer, crop categories	Raster	June 2012	2011	*http://nassgeodata.gmu.edu/CropScape/*
Cheatgrass Probability Model	Meinke and others, 2009; Mike Pellant, personal communication	Polygon	June 2012	2008	*http://sagemap.wr.usgs.gov/ftp/sab/cheat_dec.zip*
Communication Towers	Federal Communications Commission	Point	July 2009	April 2009	*http:/wireless.fcc.gov/geographic*
Oil & Gas Wells (buffered points)	Enerdeq IHS database	Point	December 2011	October 2001–November 2011	*Licensed proprietary data set http://www.ihs.com/products/oil-gas-information/index.aspx*
Pinyon-Juniper & Conifer Encroachment (derived)	National GAP Analysis Program	Raster	February 2010	February 2010	*http://gapanalysis.usgs.gov/*
Power lines (>115kv) and Associated Structures	EV Energy Map, Platts/Global Energy	Line	September 2005	September 2005	Licensed proprietary data set *http://www.platts.com*
Power lines in the Western United States, 2004	ICBEMP existing utility corridors data set	Line	2004	2003	*http://sagemap.wr.usgs.gov/ftp/regional/usgs/powerlines_hf.shp*
Railroads	Federal Railroad Administration (FRA) Rail Lines of the USA	Line	July 2011	July 2011	*http://app.databasin.org/app/pages/datasetPage.jsp?id=6d8a6878c3004fb38e59a6b08f965d5a*
Roads (interstates, highways, and secondary)	Tele Atlas ESRI StreetMap Premium for ArcGIS v 9.0, Dynamap Transportation version 5.2, 2003	Line	April 2008	July 2003	ESRI Data & Maps is available only as part of ESRI® software.
Urbanized Areas—City Limits	Tele Atlas ESRI StreetMap Premium for ArcGIS v 9.0	Polygon	April 2008	April 2008	ESRI Data & Maps available as part of ESRI® software.
Vertical Structures	Federal Aviation Administration Digital Obstacles File	Point	December 2011	September 2011	*https://nfdc.faa.gov/tod/public/TOD_DOF.html*
Water Developments	BLM Rangeland Improvement Project Database	Polygon	October 2007	October 2007	*http://sagemap.wr.usgs.gov/ftp/sab/Water_Developments_RIPS.zip*

Table A-3. External data sources.—Continued

Analysis Dataset	Source	Data Type	Publication Date or Received Date	Data Currency Date	
Wind Towers	Federal Aviation Administration Digital Obstacles File	Point	December 2011	September 2011	*https://nfdc.faa.gov/tod/public/TOD_DOF.html*
Potential Threat					
Coal Potential	Americas Coal Potential—USGS	Polygon	January 2008	January 2006	*http://pubs.usgs.gov/of/2008/1257*
Geothermal Potential	Idaho National Engineering & Environmental Laboratory	Polygon	November 2003	May 2003	*www.inel.gov*
Oil and Gas Potential	Copeland, H., K. Doherty, D. Naugle, A. Pocewicz, J. Kiesecker (2010) Mapping Oil and Gas Development Potential	Raster	2009	2009	*http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0007400*
Oil Shale and Tar Sands	Oil Shale and Tar Sands Programmatic Environmental Impact Statement (PEIS)—Argonne National Laboratory	Polygon	2008	1980–2008	*http://ostseis.anl.gov/guide/maps/index2008.cfm*
Solar Potential	National Renewable Energy Laboratory	Polygon	December 2005	December 2005	*http://www.nrel.gov/gis/data_solar.html*
Wind Potential	National Renewable Energy Laboratory	Polygon	December 2010	2003	*http://www.nrel.gov/gis/data_wind.html*

Table A-4. Summary of research documenting specific consequences, land-use development, and anthropogenic activities and infrastructure on Greater Sage-Grouse.

Threat or Issue	Location	Comparison	Covariate Investigated	Spatial Scale(s) Investigated	Sage-Grouse Response	Comment	Source
Agricultural Conversion	Wyoming, Montana, and Colorado	Lek count comparison	Proportion of land area converted from sagebrush	Variable scales surrounding leks	Conversion of ≥16% of sagebrush-dominated area around leks correlated with a 50 to 100% decline in male lek occupancy	Review of several studies	Swenson, 1987
Agricultural Conversion	Historic range	Currently occupied compared to unoccupied	Proportion of land area in cropland	2,975 km^2 around random points	Cropland exceeding 25% associated with extirpated range		Aldridge, 2008
Agricultural Conversion	Historic range	Currently occupied compared to unoccupied	Proportion of land area in cropland	1,018 km^2 around random points	Sagebrush cover <27% associated with extirpated range	Extirpated range had 3 times more area in agriculture compared to occupied range	Wisdom, 2011
Agricultural Conversion	Montana	Lek count comparison	Proportion of land area in cropland	202 km^2 of study area	Conversion of 30% of sagebrush-dominated habitat patches resulted in 73% decline in number of breeding males on leks	Habitats converted were used by sage-grouse predominantly in winter	Swenson, 1987
Agricultural Conversion	Current range	Lek count comparison	Proportion of land area in cropland	5 km (79 km^2) and 18 km (1,018 km^2) buffers of leks	Decline in lek trends to 2.5% of the area within 5 km or 1.5% of the area within 18 km of leks was cropland	Lek counts stabilized as percent cropland increased beyond these proportions; few leks occurred in areas where proportion of agricultural land exceeded 50%	Johnson, 2011
Infrastructure—Roads	Wyoming, Utah	Lek activity comparison	Distance to Interstate 80	7.5 km and 15 km buffer of Interstate 80	No leks within 2 km of the interstate; reduced numbers of leks within 7.5 km of the interstate compared to numbers of leks 7.5 to 15 km from interstate		Connelly, 2004
Infrastructure—Roads	Wyoming, Utah	Lek count comparison	Distance to Interstate 80	7.5-km and 15-km buffer of Interstate 80	Higher rates of decline in the number of males on leks (1970–2003) within 7.5 km compared to leks 7.5 to 15 km from the interstate		Connelly, 2004

Table A-4. Summary of research documenting specific consequences, land-use development, and anthropogenic activities and infrastructure on Greater Sage-Grouse.—Continued

Threat or Issue	Location	Comparison	Covariate Investigated	Spatial Scale(s) Investigated	Sage-Grouse Response	Comment	Source
Infrastructure—Roads	Montana, Canada	Comparison of occurrence of large (>25 males) vs. small leks	Length of road (road density)	3.2-km buffer of leks	Probability of occurrence of large lek approached 0% as the length of road exceeded 100 km		Tack, 2009
Infrastructure—Roads	Colorado	Lek count comparison	Traffic volumes	Unspecified	Increased traffic (coal mine road upgrade) correlated with 94% decline in number of sage-grouse over a 5-year period on leks <2 km from road		Remington and Braun, 1991
Infrastructure—Roads	Wyoming	Lek count comparison	Traffic volumes	3-km buffer of leks	Decline in lek counts positively correlated with increased traffic volumes	Vehicle activity on roads when grouse present on leks had greater influence on male lek attendance compared to roads with no vehicle activity during this period	Holloran, 2005
Infrastructure—Roads	Wyoming	Females breeding on impacted vs. unimpacted leks; nest site selection	Impacted leks within 3 km of road	N/A (study area)	Females from impacted leks: had 24% lower probability of initiating a nest; moved twice as far from lek to nest; were less likely to initiate nests in consecutive years compared to females from non-impacted leks		Lyon, 2003
Infrastructure—Transmission Lines	Utah	Lek count comparison	Distance to transmission line	200-m buffer of leks	72% decline in number of sage-grouse on a lek 2 years post-transmission line erection	Daily dispersal patterns from a lek during breeding season disrupted	Ellis, 1985
Infrastructure—Transmission Lines	Colorado	Pellet occurrence	Distance to transmission line	Unspecified	Pellet occurrence increased as distance from transmission line increased up to 600 m		Braun, 1998

Table A-4. Summary of research documenting specific consequences, land-use development, and anthropogenic activities and infrastructure on Greater Sage-Grouse.
—Continued

Threat or Issue	Location	Comparison	Covariate Investigated	Spatial Scale(s) Investigated	Sage-Grouse Response	Comment	Source
Infrastructure—Power Lines	Wyoming	Lek activity comparison	Distance to power line; Proportion of land area within 350 m of power line	Multiple buffers to 6.4 km (129 km²) of leks	Probability of an active lek decreased with closer proximity to poles and increasing proportion of area within 350 m of power line within 6.4 km of lek		Walker, 2007
Infrastructure—Transmission Lines	Wyoming	Sage-grouse female nesting and brood-rearing (early and late) occurrence	Distance to transmission line	N/A (study area)	Sage-grouse avoided brood-rearing habitats within 4.7 km of transmission line		LeBeau, 2012
Infrastructure—Fences	Idaho	Collision occurrence	Lek size; Distance to lek; Topography; Fence density	2.5-km buffer of leks	Probability of collision higher in areas with (1) increased fence density; (2) decreased distance to nearest lek; (3) increased lek size; (4) lower topographic ruggedness	Collisions more common on fences constructed of steel t-posts and/or with large distances between posts (decreased visibility)	Stevens, 2011, Stevens, 2012
Energy development—Natural gas	Eastern range of species	Lek count comparison	Well pad densities	3.2-km buffer of leks	Well pad densities exceeding 1 pad/mi² (section) negatively influence number of sage-grouse on leks	Review of several studies	Naugle, 2011
Energy development—Natural gas	Wyoming	Lek count comparison	Well pad densities	8.5-km buffer of leks	Impacts to the number of sage-grouse on leks found at well pad densities >0.4 to 0.8 well pads/km² (0.15 to 0.3 pads/section)	Common well pad densities of 1.5 and 3.1 pads/km² (4 and 8 pads/section) associated with lek count declines ranging from 13–74% and 77–79%, respectively	Harju, 2010

Table A-4. Summary of research documenting specific consequences, land-use development, and anthropogenic activities and infrastructure on Greater Sage-Grouse.—Continued

Threat or Issue	Location	Comparison	Covariate Investigated	Spatial Scale(s) Investigated	Sage-Grouse Response	Comment	Source
Energy development—Natural gas	Wyoming	Lek activity comparison	Well pad densities	1-km buffer of leks	0% probability of lek occurrence when well pad densities exceeded 6.5 pads/mi^2 (section)		Hess, 2012
Energy development—Natural gas	Montana, Canada	Comparison of occurrence of large (>25 males) vs. small leks	Well pad densities	12.3-km buffer of leks	Large leks did not occur in areas where well pad densities exceeded 2.5 pad/mi^2 (section)		Tack, 2009
Energy development—Natural gas	Wyoming	Lek count comparison	Distance to well pads (pad presence (1) vs. absence (0) within buffers of leks)	Multiple buffers to 4.8 km of leks	Well pads within smaller buffers (<1.6–2 km) around leks associated with 35–76% fewer sage-grouse on leks compared to leks with no well pads within these buffers	Leks that had at least 1 well pad within 0.4 km had 35 to 92% fewer sage-grouse compared to leks with no well pads within this buffer	Harju, 2010
Energy development—Natural gas	Eastern range of species	Lek count comparison	Distance to well pads	N/A (study area)	Impacts to the number of males on leks were most severe when infrastructure occurred near leks; impacts remained discernible out to distances of 6.2 to 6.4 km	Review of several studies	Naugle, 2011
Energy development—Natural gas	Wyoming	Sage-grouse female nesting occurrence	Distance to well pads	N/A (study area)	Yearling females avoided nesting within 950 m of well pads		Holloran, 2010
Energy development—Natural gas	Wyoming	Sage-grouse female nesting and brood-rearing (early and late) occurrence	Distance to well pads; proportion of buffer disturbed by gas development activities	Multiple buffers to 1.26 km (5 km^2) of seasonally selected sites	Females avoided nesting and brood-rearing in areas with increased numbers of visible wells within a 1-km^2 area; females avoided sites when the proportion of a 5-km^2 area disturbed by gas development exceeded 8%		Kirol, 2012

Table A-4. Summary of research documenting specific consequences, land-use development, and anthropogenic activities and infrastructure on Greater Sage-Grouse. —Continued

Threat or Issue	Location	Comparison	Covariate Investigated	Spatial Scale(s) Investigated	Sage-Grouse Response	Comment	Source
Energy development—Natural gas	Wyoming	Sage-grouse chicks survival	Proportion of buffer disturbed by gas development activities	Multiple buffers to 1.26 km (5 km^2) of seasonally selected sites	Chick survival decreased when the proportion of a 1-km^2 area disturbed by gas development exceeded 4%		Kirol, 2012
Energy development—Natural gas	Canada	Sage-grouse chicks survival	Well pad densities	Multiple buffers to 1 km (3 km^2) of seasonally selected sites	Chick survival decreased with increasing numbers of visible wells within 1 km of brood-rearing locations		Aldridge and Boyce, 2007
Energy development—Natural gas	Canada	Sage-grouse winter occurrence	Distance to well pads	N/A (study area)	Sage-grouse avoided habitats within 1.9 km of infrastructure during winter		Carpenter and others, 2010
Energy development—Wind	Wyoming	Sage-grouse nest and chick survival	Distance to wind turbine	N/A (study area)	Nest and chick survival decreased as distance to turbine decreased	Study investigated the short-term response of sage-grouse to a wind energy facility; impacts of the facility may not be realized within time-frame of study	LeBeau, 2012
Habitat Fragmentation	Idaho	Movement patterns		N/A (study area)	Sage-grouse used an annual range of at least 2,764 km^2		Leonard, 2000
Habitat Fragmentation	Historic range	Currently occupied compared to unoccupied	Proportion of land area in cropland	1,018 km^2 around random points	Sagebrush patch size in occupied range averaged 4,173 ha		Wisdom, 2011
Habitat Fragmentation	Idaho, Wyoming	Movement patterns		N/A (study area)	Sagebrush patch sizes >4,000 ha required for successful reproduction and over-winter survival		Leonard, 2000, Walker, 2007
Habitat Fragmentation	Wyoming	Movement patterns		N/A (study area)	314-km^2 area necessary to maintain breeding habitat around a single lek		Doherty, 2008

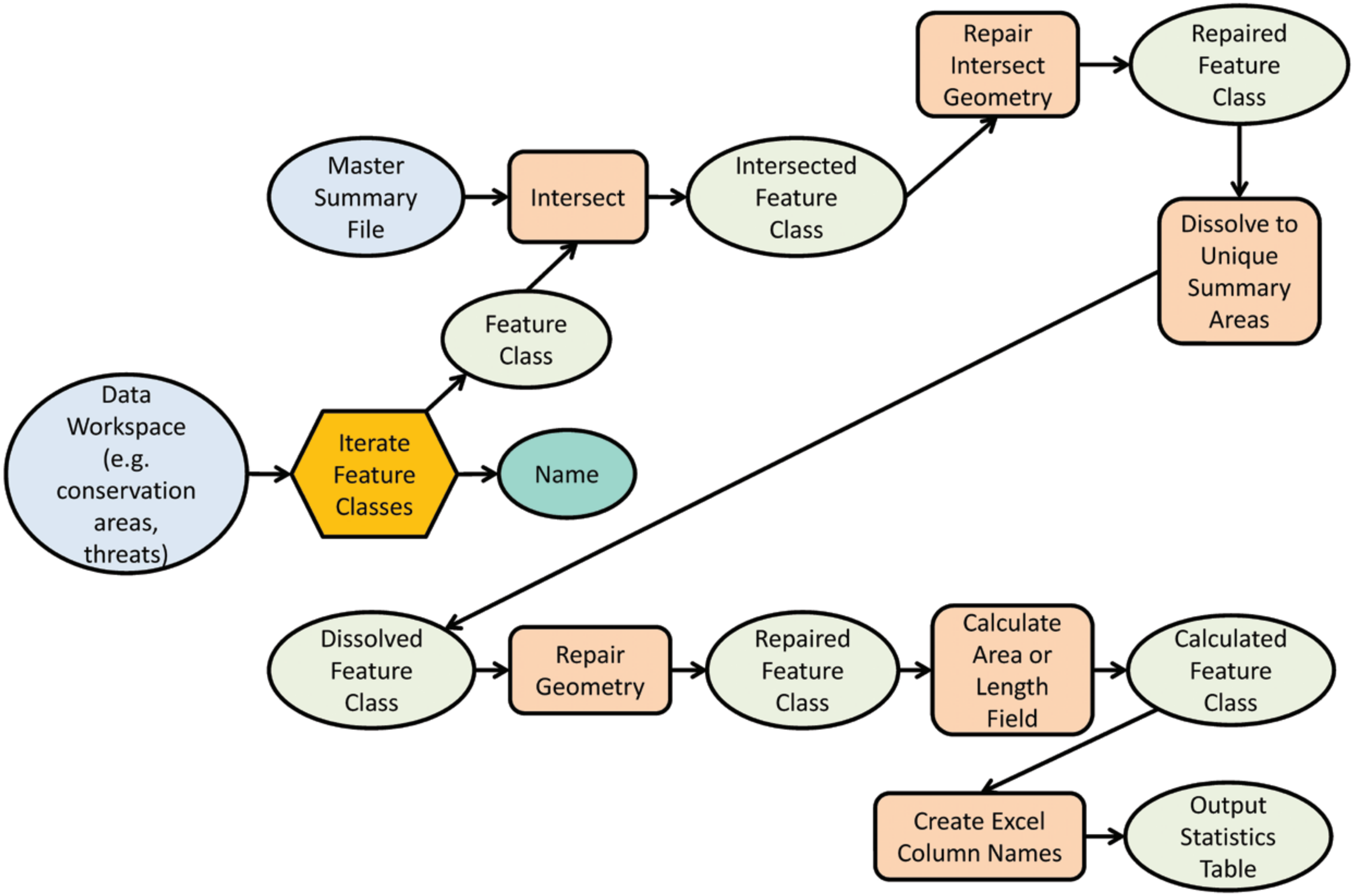

Figure A-1. Model-builder process flowchart.

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