CHAPTER TWELVE

Ecological Influence and Pathways of Land Use in Sagebrush

Steven T. Knick, Steven E. Hanser, Richard F. Miller, David A. Pyke, Michael J. Wisdom, Sean P. Finn, E. Thomas Rinkes, and Charles J. Henny

Abstract. Land use in sagebrush (*Artemisia* spp.) landscapes influences all sage-grouse (*Centrocercus* spp.) populations in western North America. Croplands and the network of irrigation canals cover 230,000 km^2 and indirectly influence up to 77% of the Sage-Grouse Conservation Area and 73% of sagebrush land cover by subsidizing synanthropic predators on sage-grouse. Urbanization and the demands of human population growth have created an extensive network of connecting infrastructure that is expanding its influence on sagebrush landscapes. Over 2,500 km^2 are now covered by interstate highways and paved roads; when secondary roads are included, 15% of the Sage-Grouse Conservation Area and 5% of existing sagebrush habitats are >2.5 km from roads. Density of secondary roads often exceeds 5 km/km^2, resulting in widespread motorized access for recreation, creating extensive travel corridors for management actions and resource development, subsidizing predators adapted to human presence, and facilitating spread of exotic or invasive plants. Sagebrush lands also are being used for their wilderness and recreation values, including off-highway vehicle use. Approximately 12,000,000 animal use months (AUM = amount of forage to support one livestock unit per month) are permitted for grazing livestock on public lands in the western states. Direct effects of grazing on sage-grouse populations or sagebrush landscapes are not possible to assess from current data. However, management of lands grazed by livestock has influenced sagebrush ecosystems by vegetation treatments to increase forage and reduce sagebrush and other plant species unpalatable to livestock. Fences (>2 km/km^2 in some regions), roads, and water developments to manage livestock movements further modify the landscape. Oil and gas development influences 8% of the sagebrush habitats with the highest intensities occurring in the eastern range of sage-grouse; >20% of the sagebrush distribution is indirectly influenced in the Great Plains, Wyoming Basin, and Colorado Plateau SMZs. Energy development physically removes habitat to construct well pads, roads, power lines, and pipelines; indirect effects include habitat fragmentation, soil disturbance, and facilitation of exotic plant and animal spread. More recent development of alternative energy, such as wind and geothermal, creates infrastructure in new regions of the sage-grouse distribution. Land use will continue to be a dominant stressor on sagebrush systems; its individual and cumulative

Knick, S. T., S. E. Hanser, R. F. Miller, D. A. Pyke, M. J. Wisdom, S. P. Finn, E. T. Rinkes, and C. J. Henny. 2011. Ecological influence and pathways of land use in sagebrush. Pp. 203–251 *in* S. T. Knick and J. W. Connelly (editors). Greater Sage-Grouse: ecology and conservation of a landscape species and its habitats. Studies in Avian Biology (vol. 38), University of California Press, Berkeley, CA.

effects will challenge long-term conservation of sage-grouse populations.

Key Words: agriculture, Conservation Reserve Program, energy development, land use, livestock grazing, off-highway vehicle, prescribed fire, sagebrush, sage-grouse, urbanization.

Influencia Ecológica y Circuitos del Uso del Suelo en Artemisa

Resumen. La utilización del suelo en paisajes de artemisa (*Artemisia* spp.) influencia a todas las poblaciones de sage-grouse (*Centrocercus* spp.) en Norteamérica occidental. Las tierras de cultivo y la red de canales de irrigación cubren 230,000 km^2 e influencian indirectamente hasta un 77% del Área de Conservación del Sage-Grouse (Sage-Grouse Conservation Area) y el 73% de la cubierta de suelo de artemisa, al subvencionar a depredadores sinántropos sobre el sage-grouse. La urbanización y las demandas del crecimiento demográfico humano han creado una extensa red de infraestructura de conexión la cual está ampliando su influencia en paisajes de artemisa. Hoy en día más de 2,500 km^2 se encuentran cubiertos por carreteras interestatales y caminos pavimentados; cuando se incluye a los caminos secundarios, el 15% del Área de Conservación del Sage-Grouse y el 5% de los hábitats existentes de sagebrush se encuentran a >2.5 km de los caminos. La densidad de caminos secundarios a menudo excede los 5 km/km^2, dando como resultado el acceso motorizado extensivo para fines recreativos, creando extensos corredores para acciones de manejo y desarrollo de recursos, subvencionando a depredadores adaptados a la presencia humana, y facilitando la expansión de plantas exóticas o invasoras. Las tierras de artemisa también están siendo utilizadas por sus valores naturales y recreativos, incluyendo el uso de vehículos fuera de las carreteras. Aproximadamente se permitieron 12,000,000 de meses de uso animal (animal use months o AUM = cantidad de forraje necesario para soportar una unidad de ganado por mes) para el ganado de pastoreo en tierras públicas en los estados occidentales. Los efectos directos del pastoreo sobre poblaciones del sage-grouse o paisajes de artemisa no son posibles de determinar utilizando datos actuales. Sin embargo, el manejo de tierras pastadas por el ganado ha influenciado ecosistemas de artemisa mediante el uso de tratamientos de la vegetación para aumentar el forraje y reducir el sagebrush y otras especies vegetales desagradables para el ganado. Las cercas (>2 km/km^2 en algunas regiones), los caminos, y las obras sobre los recursos de agua para manejar los movimientos del ganado han modificado el paisaje aun más. El desarrollo del petróleo y el gas influencian el 8% de los hábitats de artemisa con las intensidades más altas encontrándose en la extensión este del territorio de sage-grouse; >20% de la distribución del sagebrush se encuentra indirectamente influenciada en las áreas de manejo de los Great Plains, Wyoming Basin, and Colorado Plateau. El desarrollo de energía físicamente remueve el hábitat para construir las plataformas para los pozos, los caminos, las líneas eléctricas, y las tuberías; los efectos indirectos incluyen la fragmentación del hábitat, disturbio del suelo, y la facilitación de la expansión de plantas y animales exóticos. El reciente desarrollo de energías alternativas, tales como la eólica y geotérmica, crea la infraestructura en nuevas regiones de la distribución del sage-grouse. La utilización del suelo continuará siendo un factor de estrés dominante en sistemas de artemisa sus efectos individuales y acumulativos desafiarán la conservación a largo plazo de las poblaciones de sage-grouse.

Palabras Clave: agricultura, artemisa, desarrollo energético, fuego prescrito, pastoreo de ganado, Programa Reserva para la Conservación (Conservation Reserve Program), sage-grouse, urbanización, uso de la tierra, vehículos fuera de carretera.

Lands dominated by sagebrush (*Artemisia* spp.) provide a broad array of resources used by humans. Areas used primarily for traditional industries, such as mining, livestock grazing, and energy development, are juxtaposed with urban areas, crossed by infrastructure network to transport people and resources, or fragmented by agriculture and expanding exurban development. Recreation, wildlife conservation, and wilderness amenities also have intangible values, impose physical demands on sagebrush and surrounding landscapes, and often have legal designations or restrictions that can affect land management and other uses. Thus, resources contained in sagebrush systems range from consumptive commodities having a negotiated market value to aesthetic qualities that defy monetary currency despite efforts of natural resource economists.

Human land use has been a significant force shaping sagebrush systems, particularly since Euro-American settlement (West 1999, Griffin 2002). However, quantifying and understanding effects of land use across the range-wide distribution of Greater Sage-Grouse (*Centrocercus urophasianus*; hereafter, sage-grouse) is challenging because of the following conditions:

1. Demand for different resources and intensity of use have changed over time due to local, national, and global needs coupled with changes in technological capabilities to extract and use resources.
2. Social and economic importance of traditional use varies spatially and temporally relative to nonconsumptive use.
3. Effects of land use differ from distinct impacts occurring at delineated locations to more diffuse spatial and temporal influences.
4. Multiple land uses often combine in synergistic relationships with environmental factors to create a cumulative effect.
5. Sagebrush systems vary spatially along gradients of elevation, annual patterns of precipitation, and soils that influence their resistance and resilience to disturbance.
6. Complex dynamics of sagebrush systems can result in less predictable transitions to alternate states of vegetation communities rather than following well-defined trajectories of vegetation succession.

Adopting narrow management paradigms or espousing single solutions ignores these complexities (Crawford et al. 2004).

We described the dominant anthropogenic land uses in the Sage-Grouse Conservation Area (SGCA; the pre-settlement distribution of sage-grouse buffered by 50 km [Connelly et al. 2004, Schroeder et al. 2004]) and their influence on patterns and processes of sagebrush habitats and sage-grouse populations. We organized land uses into broad categories of agriculture, urbanization and infrastructure, livestock grazing, energy development (nonrenewable and renewable), and military training. The cumulative influence of anthropogenic land use is presented elsewhere as the human footprint (Leu et al. 2008; Johnson et al., this volume, chapter 17; Leu and Hanser, this volume, chapter 13).

Land uses have impacted sagebrush ecosystems at multiple temporal and spatial scales. Our first objective was to provide the historical development of each category of land use and the background against which it became a significant influence. We present temporal information on changes in frequency, intensity, or location of the land use when data were available. Our second objective was to describe the current status of land use. We mapped the distribution of land use and quantified, when possible, the potential area altered directly by physical habitat displacement or influenced indirectly through changes in plant or wildlife dynamics (Leu et al. 2008). Our last objective was to discuss the influence of each land use on sagebrush habitats or sage-grouse populations. We have presented a significant amount of background information, when available from published literature, because many of these interactions require a detailed understanding of the dynamics of sagebrush ecosystems.

We recognized but did not evaluate resource commodity needs or demand, nor did we assess public perceptions of land use (Kennedy et al. 1995, Donahue 1999). We did not determine societal benefits and costs associated with a land use. We also did not present strategies for mitigating use or recommend alternative levels of use. Rather, we attempted to answer the ecological questions about land uses (actions or choices), and how they influence pattern and functions of sagebrush systems (reactions or consequences). Thus, we presented the ecological context for management and land use discussions that also include political, economic, and social considerations (Mills and Clark 2001, Foley et al. 2005, Lackey 2007).

METHODS

Study Area

We considered the primary land uses within the range-wide distribution of Greater Sage-Grouse, which encompasses >2,000,000 km^2 (Connelly et al. 2004). Regional analyses were based on seven Sage-Grouse Management Zones (SMZs; Stiver et al. 2006), which were delineated from floristic regions that contain similar environmental influences on vegetation communities (Miller and Eddleman 2001). SMZs also reflected boundaries of broad regional populations of sage-grouse within the range-wide distribution. Estimated connectivity among sage-grouse leks primarily was contained within each SMZ rather than among zones (Garton et al., this volume, chapter 15; Knick and Hanser, this volume, chapter 16). State-wide summaries are presented when source data could not be delineated into SMZs.

Sagebrush is the dominant land cover on 530,000 km^2 within the sage-grouse range (Knick, this volume, chapter 1) and consists primarily of 20 taxa encompassing 11 major *Artemisia* species and subspecies groups (McArthur and Plummer 1978). Vegetation and wildlife communities vary greatly across the range covered by sagebrush as a function of differences in underlying soils, climate, topographic position, landform, and geographic location (West and Young 2000; Miller and Eddleman 2001; Davies et al. 2007a; Miller et al., this volume, chapter 10). Approximately 70% of the sagebrush land cover is on public land managed by state or federal agencies (Knick, this volume, chapter 1); reserves or landscapes managed to maintain a natural character represent <1% of the total land surface covered by sagebrush.

We assumed that land use at local scales can be aggregated across regional or range-wide extents (Allen and Starr 1982, Wiens 1989b, Peterson and Parker 1998) to assess broader influences on Greater Sage-Grouse populations or sagebrush landscapes. Dominant patterns then can form the basis for regional or range-wide conservation actions, such as prioritizing restoration (Wisdom et al. 2005c, Meinke et al. 2009), developing monitoring approaches (Connelly et al. 2003b, Washington-Allen et al. 2006), or relating environmental factors to sage-grouse population trends (Reese and Bowyer 2007; Garton et al., this volume, chapter 15).

Data Sources

Spatial Information

Most spatial information used in this study was developed initially for the range-wide Conservation Assessment for Greater Sage-Grouse and Sagebrush Habitats (Connelly et al. 2004) and was updated when new data became available. Analyses using land cover information first derived from the SageStitch map (Comer et al. 2002) now have been conducted using the more recent LANDFIRE Existing Vegetation Map (LANDFIRE 2006). We did not compare results to assess changes in land cover or other land-use estimates and accuracies when different methods were used.

Our primary challenge was obtaining comprehensive data spanning a study area that included all or part of 14 states and three provinces. Spatially explicit data (one or more values referenced to a map location) of important environmental and land-use factors often were limited to administrative boundaries such as counties, states, or Bureau of Land Management (BLM) field offices. Thus, we often merged spatial data from multiple sources to create seamless data layers in a geographic information system (GIS) for regional or range-wide analyses. We used the coarsest resolution when resolving GIS layers, thematic classifications, and terminology when compiling information from different sources.

We converted linear features to unit length/unit area to map relative density and create more meaningful measures of distribution across the landscape. We also converted point data to a contoured distribution of densities. Specific methods and values used for individual coverages are shown in figure or table captions, accompanying text, or included in online metadata.

Disturbance can influence an area beyond its immediate boundaries, although the function relating distance and magnitude of effect can be difficult to define (Turner and Dale 1991). For example, roads can provide dispersal corridors for invasive plants to spread into the surrounding region, influencing plant community dynamics beyond the physical road itself (Belcher and Wilson 1989, Gelbard and Belnap 2003). Other disturbances or threats (e.g., insecticide use on specific crops) may be confined locally, but long movements by sage-grouse among widely spaced seasonal ranges may result in exposure during a critical period in the annual life cycle or at a small location in the annual home range (Blus et al. 1989, Walker et al. 2007a, Doherty et al. 2008). We used an ecological rationale for estimating the area around points, lines, or polygons from which land use potentially influenced land cover or sage-grouse populations. Estimates for effect sizes into surrounding areas were based on foraging movements of human-subsidized predators, distance of exotic plant species spread, or on distribution data relative to land-use features (Gelbard and Belnap 2003, Connelly et al. 2004, Bradley and Mustard 2006, Leu et al. 2008).

Many of our primary analyses quantified overlap between land use or its influence and sagebrush cover types or other environmental variables. This approach can be appropriate for land uses or disturbances that have well-defined effects in space and time (Pickett and White 1985). Diffuse disturbances, such as livestock grazing, that alter plant composition or influence community processes may not result in altered landscape patterns readily mapped in a GIS and are more difficult to quantify at broad scales (Turner and Bratton 1987).

Nonspatial Information

Tabular and summaries of nonspatial data were created from online sources, field records or archives, or published literature (Connelly et al. 2004). We often relied on statistics available from or estimated for a single management entity. Public land statistics presented in annual reports by the BLM represent activities by the largest federal land management steward for sagebrush lands in the United States (Knick et al. 2003, Wisdom et al. 2005b). However, these statistics cannot be extrapolated to activities on private lands or to other agencies because environmental characteristics of lands differ among stewards (Knick, this volume, chapter 1). Thus, they represent only part of the collective scenario for sagebrush regions.

We also used public land statistics to assess land uses, management issues, habitat characteristics, and treatments. Public land statistics often compile summary numbers that may not adequately represent land use, may contain data that were not updated from previous years, or may fail to capture many complexities inherent in management and response of sagebrush ecosystems. We used that information to characterize management actions and use of sagebrush lands because these reports are used to document agency activities on public lands. Agency personnel reviewed our use of public land statistics, but interpretations and conclusions remain our own.

Documentation of Data and Sources

All nonproprietary and nonsensitive spatial data sets used in our analysis are available for download on the SAGEMAP website (United States Department of the Interior 2001c). Each data set is accompanied by a metadata record documenting original source and GIS procedures.

AGRICULTURE

Agriculture can include many types of production of food and goods through practices such as cultivating soils, producing crops, and raising livestock. The mapped category of agriculture used in our analysis was principally cropland although mapped pasturelands also were included in the land cover definition. We discuss agricultural land uses primarily related to croplands unless otherwise noted.

Historical Development and Current Status

Most lands dominated by sagebrush in the western United States were acquired by the federal government through purchases and cessions of large territories in the early and mid-1800s (Dombeck et al. 2003). The United States government followed policies to transfer these vast acquisitions to private entities by encouraging conversion and development of sagebrush and other arid lands (Clawson and Held 1957). Public lands were given to private entities under a succession of homestead acts (1862, 1877, 1909, 1912, and 1916) that required settlers to build homes and develop land for agriculture. The prime areas for growing crops, characterized by deep, fertile soils and available water for irrigation, were claimed early during Euro-American settlement. The initial establishment of settlements throughout the Great Basin occurred between the 1850s and 1860s (Oliphant 1968, Miller et al. 1994, Flores 2001, Young and Sparks 2002). Lands transferred to private entities and converted to cropland were also predominantly at lower elevations and on relatively flat terrain (Talbert et al. 2007; Knick, this volume, chapter 1).

Homesteaders arrived in Washington state by the late 1800s, and the proportion of virgin prairie and brush in southeastern Washington under cultivation increased from 25% in 1890 to >80% in 1920 (Buss and Dziedic 1955). Use of tractors for wheat farming further increased technological capabilities, and almost all available lands were cultivated by 1945 (Buss and Dziedic 1955). Grasslands, which once covered 25% of eastern Washington, were reduced to 2% (McDonald and Reese 1998). Approximately 170,000 km^2 of the pre-settlement distribution of 420,000 km^2 of shrub steppe in Washington was present in 1986 (Dobler et al. 1996).

The Carey Act, passed in 1894, transferred additional lands to states, which then could be privatized provided that irrigation was developed. Large irrigation projects too expensive for private enterprise were developed with federal funding through the Newlands Reclamation Act passed in 1902 (Clawson and Held 1957). The first private irrigation projects in southwestern Idaho were started in the 1840s and on the upper Snake River in Idaho near Wyoming in the 1870s (Nokkentved 2008). Almost all of the Snake River Plain in southern Idaho that contains deep loamy soils and once supported basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*) now has been converted to cropland (Hironaka et al. 1983).

An estimated 10% of sagebrush steppe that existed prior to Euro-American settlement has been converted to agriculture; irrigation is not feasible on the remaining 90%, topography and soils are limiting, or temperatures are too extreme for certain crops (West 1996). However, economic advantages or technological improvements in irrigation methods now permit agriculture development on steeper terrains and in regions further from river floodplains (Brown et al. 2005, Vander Haegen 2007). For example, it was economically feasible for an additional 800 km^2 of public land in the Snake River Plain to be developed for irrigation in the late 1980s (Hamilton and Gardner 1986).

Agriculture, mostly mapped croplands, currently covers >230,000 km^2 (11%) of the Sage-Grouse Conservation Area (Table 12.1). The total area influenced by agriculture was >1,600,000 km^2 when a high effect buffer was used to include potential movements out to 6.9 km away from agricultural developments by human-subsidized predators (Boarman and Heinrich 1999, Leu et al. 2008). Almost three-fourths of all sagebrush within the range of Greater Sage-Grouse was influenced by agriculture at this level of effect (Table 12.1). Proportion of agricultural lands within SMZs varied due to topography, soil characteristics, temperature, water availability, and type of crop grown. Primary agricultural regions were within the Columbia Basin (32% of total area in agriculture) and Great Plains (19%) SMZs (Fig. 12.1). Less than 5% of the land area in the Wyoming Basin, Southern Great Basin, Northern Great Basin, and Colorado Plateau was mapped as agriculture land cover. Irrigation canals covered <0.1% of the land area within the SGCA or SMZ (Table 12.1).

Government Conservation Programs

The Conservation Reserve Program (CRP) is a voluntary program, authorized in 1985 under the Food Security Act, in which landowners receive annual payments in return for establishing permanent vegetation on idle or erodible lands that previously had been used for growing crops (Barbarika et al. 2004). The purpose of the program is to control soil erosion, improve water retention, and provide wildlife habitat. Lands placed into the program are to be set aside for 10 years and cannot be grazed except under emergency drought conditions. The amount of lands placed in CRP has markedly increased since the program inception in 1987 (Fig. 12.2). The increase was primarily in agricultural regions of the Columbia Basin and Great Plains SMZs. Other federal government programs, such as the Wildlife Habitat Incentives Program authorized in 1996, provide support to landowners to implement measures specific to conserving wildlife habitat (Riley 2004, Gray and Teels 2006).

The Permanent Cover Program was established in Canada in 1986 as part of the National Agricultural Strategy to reduce soil degradation by planting perennial vegetation. Lands placed in the Permanent Cover Program through 10- or 21-year agreements can be used for hay or pasture, unlike CRP under which lands set aside can be grazed only during emergency drought (McMaster and Davis 2001).

Ecological Influences and Pathways

The capability of agricultural regions within the sage-grouse range to support viable populations likely depends on the quantity and configuration of sagebrush remaining within the mosaic (Wisdom et al. 2002a,b; Aldridge et al. 2008; Johnson et al., this volume, chapter 17; Wisdom

TABLE 12.1

Area (km²) and percent of area influenced by agriculture (cropland and irrigation canals) in Sage-Grouse Management Zones and the Sage-Grouse Conservation Area (SGCA).

Effect area was the total area of land use and surrounding buffer.

			Effect area					
	Area		Low		High		Sagebrush area[a] (%)	
Agriculture	km^2	(%)	km^2	(%)	km^2	(%)	Low	High
Cropland[b]								
Great Plains	66,052	(18.7)	240,021	(68.1)	319,483	(90.7)	47.4	83.7
Wyoming Basin	8,723	(3.6)	100,300	(41.5)	169,011	(69.8)	36.4	67.6
Southern Great Basin	6,943	(2.2)	87,437	(27.4)	196,668	(61.6)	24.4	61.1
Snake River Plain	28,657	(9.5)	156,729	(51.8)	254,539	(84.2)	48.1	83.1
Northern Great Basin	5,467	(3.8)	45,061	(31.1)	94,308	(65.1)	27.7	61.3
Columbia Basin	20,759	(32.3)	53,984	(83.9)	58,085	(90.3)	95.8	99.2
Colorado Plateau	6,804	(4.7)	73,353	(51.1)	115,933	(80.8)	58.2	85.4
SGCA	232,643	(11.2)	1,049,310	(50.4)	1,603,517	(77.0)	40.7	73.1
Irrigation canals[c]								
Great Plains	58	(<0.1)						
Wyoming Basin	158	(0.1)						
Southern Great Basin	101	(<0.1)						
Snake River Plain	430	(0.1)						
Northern Great Basin	119	(0.1)						
Columbia Basin	50	(0.1)						
Colorado Plateau	75	(0.1)						
SGCA	1,093	(<0.1)						

[a] Sagebrush area was delineated from the LANDFIRE (2006) map of land cover and covered 529,708 km^2 (25.4%) of the Sage-Grouse Conservation Area.

[b] Areas for low (2.5 km) and high (6.9 km) ecological effect were estimated around agriculture lands based on spread of exotic plant species (Bradley and Mustard 2006) and foraging distances of mammalian and corvid predators (Boarman and Heinrich 1999, Leu et al. 2008).

[c] Area of irrigation canals estimated by linear distance × width (12.8 m). We did not delineate areas for ecological effect associated with irrigation canals.

et al., this volume, chapter 18). Range-wide, sage-grouse were more likely to be extirpated from areas containing >25% cultivated cropland and in which <25% of the landscape was dominated by sagebrush (Aldridge et al. 2008). Sage-grouse populations declined by 73% on a study area in south-central Montana concurrent with a 16% decrease in sagebrush land cover, including 30% of the wintering habitat, which was plowed and converted to croplands (Swenson et al. 1987). Declining populations of sage-grouse in the upper Snake River Plain of southeastern Idaho were correlated with amount of cropland area (Leonard et al. 2000). Little residual sagebrush was left in areas converted to croplands. Cropland area increased 74% from 403 km^2 in 1975 to 635 km^2 in 1985 and to 701 km^2 in 1992. Cropland as a percentage of the 2,249 km^2 study area increased from 18% in 1975 to 28% in 1985 and was 31% of the land surface in 1992.

Loss of 20% of the sagebrush between 1958 and 1993 within the range of Gunnison Sage-Grouse

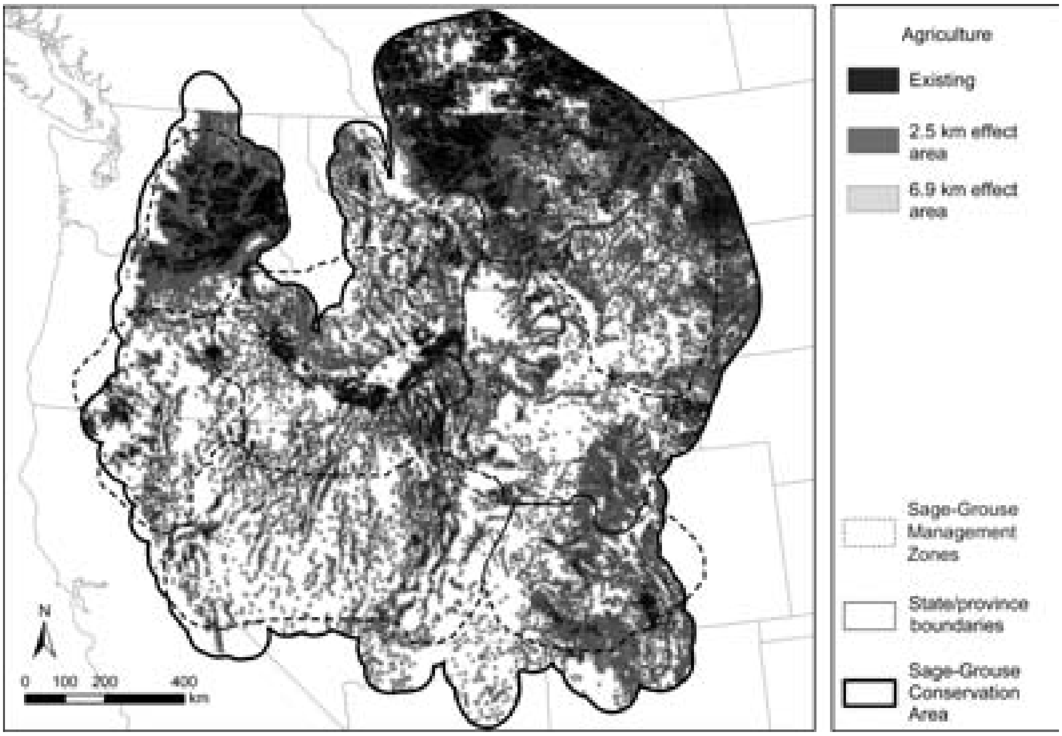

Figure 12.1. Agricultural lands within the Sage-Grouse Conservation Area. Mapped land cover primarily depicts croplands, although pasture was included in the agriculture category (LANDFIRE 2006).

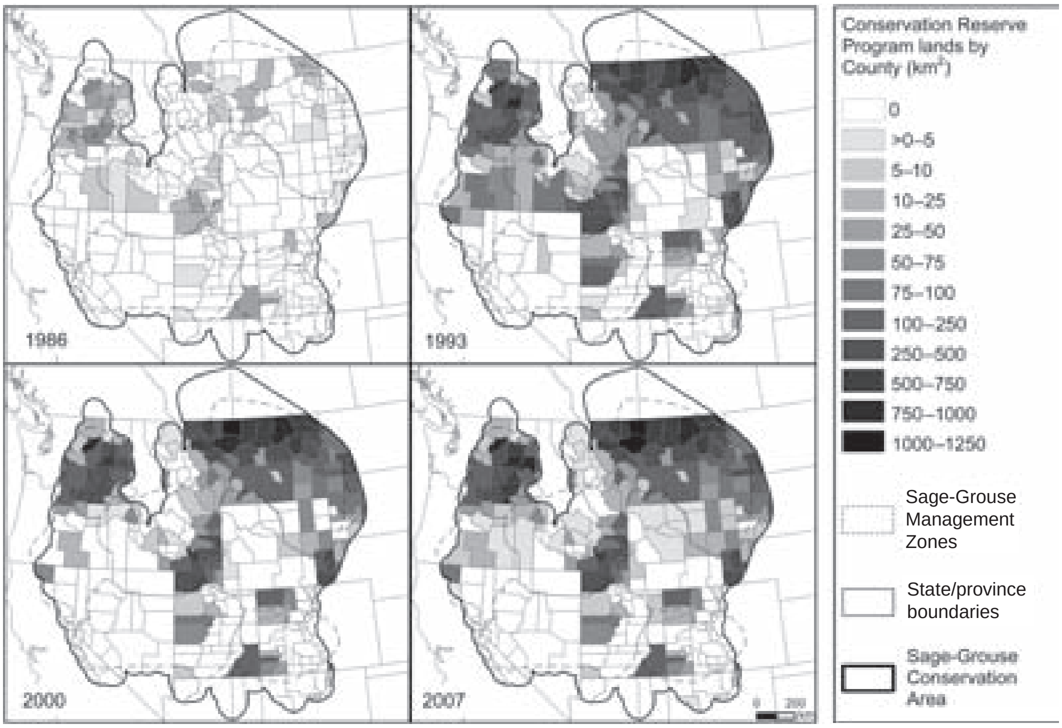

Figure 12.2. Total area (ha) under contract within the Conservation Reserve Program for counties in the United States by five-year intervals from 1987 through 2004 (United States Department of Agriculture 2009).

(*Centrocercus minimus*) in southwestern Colorado was coupled with increased landscape fragmentation by conversion to cropland (Oyler-McCance et al. 2001). This study was not directly linked to population trends, but Gunnison Sage-Grouse now occupy 10% of their historical range primarily due to habitat loss (Schroeder et al. 2004).

Numerous patches of sagebrush interspersed at small scales potentially can provide sufficient habitat if the landscape maintains sufficient sagebrush land cover at broader scales. Shrub steppe was increasingly isolated and mean size of remaining patches decreased in the Columbia Basin due to conversion to agriculture (McDonald and Reese 1998). Sage-grouse persist within this matrix (Schroeder and Vander Haegen, this volume, chapter 22), although populations are undergoing long-term declines (Garton et al., this volume, chapter 15) and are genetically isolated from populations in neighboring SMZs (Oyler-McCance et al. 2005b) by regions more intensively developed for agriculture.

Near-total conversion to cropland and other agriculture practices in southern Idaho has separated sagebrush-dominated landscapes into higher-elevation, less-productive, and less-arable regions north and south of the Snake River Plain (Knick et al. 2003). Sage-grouse populations that once were continuous across this region now are disconnected (Schroeder et al. 2004; Knick and Hanser, this volume, chapter 16). In comparison, agricultural regions of the Great Plains containing smaller-scale dispersion of sagebrush habitat of the Great Plains still support sage-grouse populations.

Cropland Insecticides

Cropland expansion into historic sagebrush habitat has resulted in some sage-grouse using irrigated lands in summer. Sage-grouse typically avoid cultivated croplands and areas dominated by human development (Aldridge and Boyce 2007). However, green vegetation, such as alfalfa, and insects associated with crops or livestock operations can be attractive foods during brood-rearing when forbs in native sagebrush communities become desiccated (Patterson 1952; Hagen et al. 2007; Connelly et al., this volume, chapter 4). At least 18% of 82 radio-marked birds in southern Idaho were attracted to lush croplands adjacent to sagebrush habitat that were sprayed with the insecticides dimethoate and methamidophos (Blus et al. 1989). Intoxicated or dead sage-grouse were found in or near six fields. Brain cholinesterase activities and residue analysis of crop contents indicated that 5% of the marked sage-grouse in 1985 and 16% in 1986 died from these organophosphorus insecticides. Another 63 of an estimated 200 sage-grouse using a block of alfalfa sprayed with dimethoate died of organophosphorus poisoning.

Croplands and insecticide spraying potentially influence sage-grouse populations over broad regions. Sage-grouse in southern Idaho are migratory; individuals can move >80 km from winter areas and leks to summer ranges and have annual ranges >2,500 km^2 (Dalke et al. 1963, Connelly et al. 1988). Distances traveled by females with broods from nesting areas to late brooding areas ranged from 3 to 21 km (Gates 1983). Total extent of the area of effect cannot be estimated because actual distances that sage-grouse move to irrigated and sprayed fields is unknown. Similarly, the impact on sage-grouse populations from exposure to organophosphorus insecticides has not been estimated relative to other causes of mortality or their timing within an annual cycle.

Government Conservation Programs

The CRP places vegetation cover on lands that otherwise would not be used by many species of wildlife. Large-area set-asides in CRP, however, are constrained by limits on total area that can be enrolled within a region. Instead, CRP set-asides typically focus on providing riparian or grassland buffer strips rather than large areas of upland vegetation (Riley 2004). Consequently, species that have benefited from CRP primarily include grassland birds with relatively small home ranges that use early successional vegetation or a mosaic of cropland bordered by grassland buffers (Haroldson et al. 2006).

Sage-grouse respond to vegetation and landscape structure, not program or landownership. Thus, the value of lands placed in the CRP program for sage-grouse likely is related to size and quality of individual CRP patches as well as the cumulative amount and distribution of CRP lands within a larger matrix of croplands and sagebrush. Sage-grouse in the Columbia Basin used CRP lands that had been set aside sufficiently long to permit perennial grasses and sagebrush to become dominant vegetation (Schroeder and Vander Haegen, this volume, chapter 22). Sage-grouse populations stabilized in the region containing 17% CRP, compared to a population that continued to decline in an adjacent region containing <2% CRP (Schroeder and Vander Haegen, this volume, chapter 22).

Capability of lands placed in CRP to benefit sage-grouse also should be considered relative to other alternative uses for those sites. Lands set aside in CRP provide some habitat components in contrast to cropland, development, or barren land susceptible to erosion. Gunnison Sage-Grouse used CRP lands in proportion to their availability in southeastern Utah (Lupis et al. 2006). Suitable, if not optimal, habitat was available through CRP on >30% of the study area that otherwise would have been used for crops and would not be likely to have supported sage-grouse.

URBANIZATION AND INFRASTRUCTURE

Historical Development and Current Status

Indigenous people have inhabited sagebrush regions for 13,000 years BP or earlier (Thomas 1973, Grayson 1993). Local densities of humans estimated for pre-American settlement periods were 0.3 persons/km^2 in the Columbia Plateau, 0.08 in the Great Basin, and 0.13 in the Great Plains (Vale 2002a). Low densities limited their impact on the biophysical landscape, although hunting, gathering, and burning may have had a locally significant influence (Flores 2001, Griffin 2002, Vale 2002b, Kay 2007).

Human populations have increased and expanded, primarily over the past century and in the western portion of the sagebrush distribution (Fig. 12.3). In 1900, 51% of the 325 counties within the historical distribution of sage-grouse had <1 person/km^2 and 4% of the counties had densities of >10 persons/km^2. By 1950, 39% of the counties had <1 person/km^2 and 9% had >10 persons/km^2. In the most recent census in 2000, 31% of the counties had <1 person/km^2 and 22% had >10 persons/km^2.

The Columbia Basin has the highest density of humans (Fig. 12.4) in contrast to the low densities in the Great Plains. Differences in population trends among SMZs reflect a general movement in the United States from midwestern plains to western states (Brown et al. 2005). Population densities in the Great Plains in the 2000 census had increased more slowly since 1990 (7%) and 1920 (49%) relative to other management zones (Fig. 12.4). In comparison, population densities have increased between 19% (Wyoming Basin) and 31% (Colorado Plateau) from 1990–2000, and between 166% (Wyoming Basin) and 666% (Northern Great Basin) from 1920–2000 (Fig. 12.4).

Availability of resources often limited areas that could be settled by early inhabitants of arid regions (West 1999). Early settlements by Euro-Americans were along transportation corridors, such as rivers or railroad lines, or in regions where minerals had been discovered (Young and Sparks 2002). The dominant urban areas in the sage-grouse range are in the Columbia River Valley of Washington, the Snake River Valley of southwestern Idaho, and the Bear River Valley of northern Utah. Most urban areas within the sage-grouse range are on the edge of regions dominated by sagebrush land cover with the exception of cities and towns in the Southern Great Basin SMZ. Area of influence of urban development ranged from 16% of the area within the Great Plains to 49% of the Columbia Basin (Table 12.2).

Rural areas also have been developed throughout the sagebrush region, particularly around urban centers and major highways. Much of this development has been in recent decades. The amount of uninhabited area (0 people/km^2) within the Great Basin ecoregion decreased from 90,000 km^2 in 1990 to <12,000 km^2 in 2004 (Torregrosa and Devoe 2008). Economic opportunities combined with availability of public lands for recreation and other natural or wilderness qualities are major reasons for this population expansion (Hansen et al. 2002, Brown et al. 2005). Increased affluence, change in social values, and ability to conduct business from remote locations through electronic commerce also has resulted in home development on large acreages surrounding cities. Many existing ranches that had been used primarily for livestock production are being sold for the rural or wildland amenities that they provide and subdivided into ranchettes (Riebsame et al. 1996, Holechek 2001, Gosnell and Travis 2005, Holechek 2006). This is best documented for the Colorado Front Range and the greater Yellowstone ecosystem, but ranchette and subdivisions are being developed throughout the sage-grouse range, particularly in the Great Basin (Torregrosa and Devoe 2008).

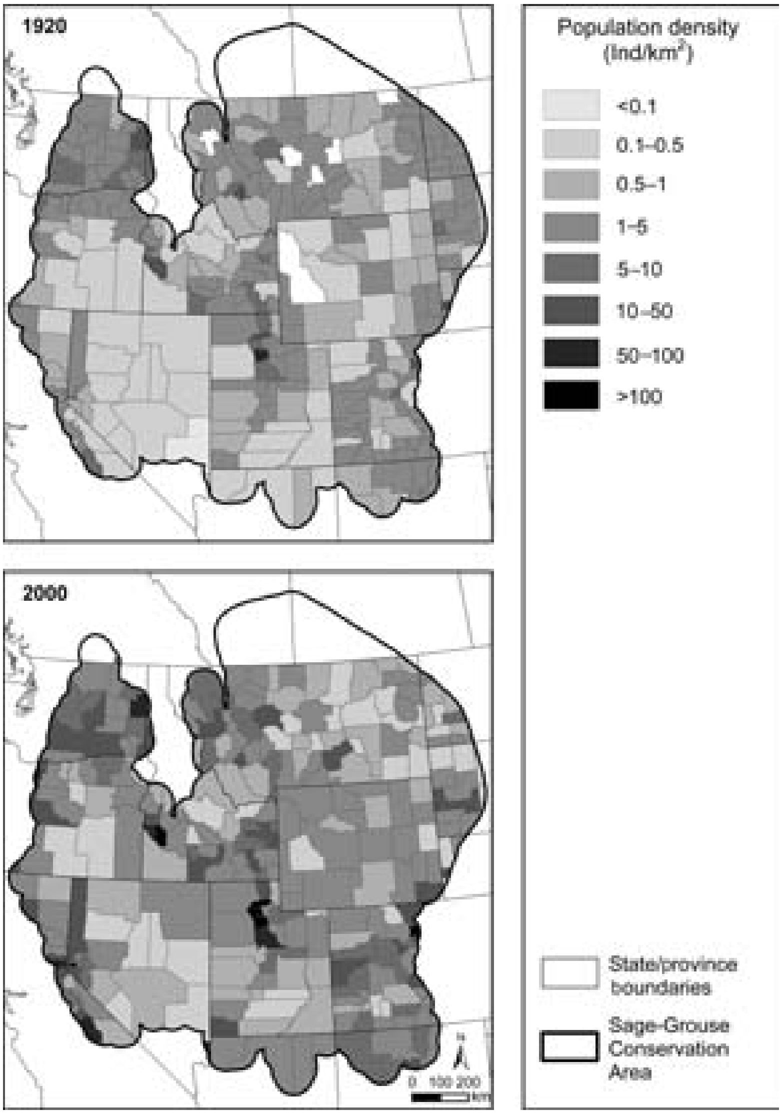

Figure 12.3. Change in population density for counties within the Sage-Grouse Conservation Area from 1920 (top) to 2000 (bottom). http://arcdata.esri.com/data/tiger2000/tiger_download.cfm; http://www.census.gov/population/www/censusdata/cencounts/index.html

Infrastructure

Interstate and other major paved highways covered an estimated 2,500 km^2 (0.1%) of the SGCA (Table 12.3). Interstates and highways influenced 851,044 km^2 (41%) of the total area and 38% of the sagebrush land cover (Table 12.3, Fig. 12.5). These major roads tend to follow river valleys and traverse lower elevations. In contrast, secondary paved roads exist throughout most sagebrush regions (Fig. 12.6) in densities up to >5 km/km^2. Less than 5% of the entire sage-grouse range was >2.5 km from a mapped road, and almost no area of sagebrush was >6.9 km (Table 12.3). Railroads covered 487 km^2 (<0.1%) of the landscape but influenced 10% of the SGCA and 7% of the sagebrush (Table 12.3).

Power lines covered a minimum of 1,089 km^2 (Fig. 12.7, Table 12.3) and had an ecological influence on almost 50% of all sagebrush within the SGCA. We were unable to map or estimate the density of smaller distribution lines in rural areas. Similar to roads, power lines also followed major river valleys and crossed lower elevations.

The Energy Policy Act of 2005 directed that corridors for transporting energy (oil, gas, hydrogen, electricity) be designated on federal land (United States Departments of Energy and the

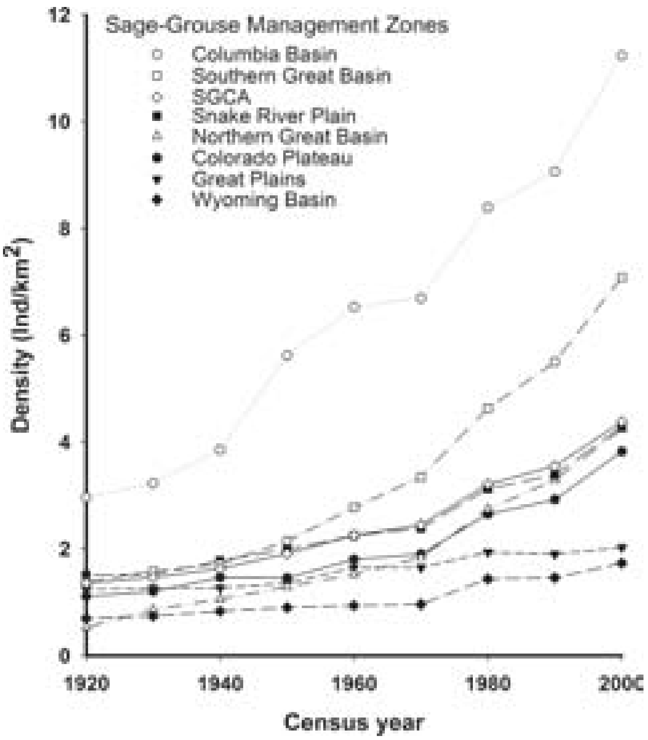

Figure 12.4. Population density (ind/km^2) within the Sage-Grouse Management Zones in the Sage-Grouse Conservation Area (United States Census Statistics 1900–2000). Densities were averaged from census results for individual counties within Sage-Grouse Management Zones. http://arcdata.esri.com/data/tiger2000/tiger_download.cfm; http://www.census.gov/population/www/censusdata/cencounts/index.html

TABLE 12.2

Area (km^2) and percent of area influenced by urban development in Sage-Grouse Management Zones and the Sage-Grouse Conservation Area (SGCA).

Effect area was the total area of land use and surrounding buffer.

	Area		Effect area[a]		
Urban development	km^2	(%)	km^2	(%)	Sagebrush area[b] (%)
Great Plains	653	(0.2)	57,652	(16.4)	16.0
Wyoming Basin	457	(0.2)	49,970	(20.7)	18.4
Southern Great Basin	1,824	(0.6)	54,587	(17.1)	13.5
Snake River Plain	1,131	(0.4)	78,159	(25.8)	18.8
Northern Great Basin	741	(0.5)	28,694	(19.8)	12.5
Columbia Basin	679	(1.1)	31,185	(48.5)	48.4
Colorado Plateau	780	(0.5)	42,288	(29.5)	29.2
SGCA	8,612	(0.4)	454,193	(21.8)	18.6

[a] Area for ecological effect (6.9 km) was estimated from foraging distances of mammalian and corvid predators (Boarman and Heinrich 1999, Leu et al. 2008).

[b] Sagebrush area delineated from the LANDFIRE (2006) map of land cover and included 529,708 km^2 (25.4%) of the Sage-Grouse Conservation Area.

TABLE 12.3

Area (km^2) and percent of area influenced by infrastructure in Sage-Grouse Management Zones and the Sage-Grouse Conservation Area (SGCA).

Effect area was the total area of land use and surrounding buffer.

	Area		Effect area: Low		Effect area: High		Sagebrush area[a] (%)	
Land use	km^2	(%)	km^2	(%)	km^2	(%)	Low	High
Interstates/highways[b]								
Great Plains	371	(0.1)	52,524	14.9	129,582	(36.8)	13.1	35.0
Wyoming Basin	283	(0.1)	42,431	17.5	103,479	(42.8)	17.9	45.5
Southern Great Basin	403	(0.1)	52,192	16.4	126,224	(39.5)	14.6	36.8
Snake River Plain	368	(0.1)	46,565	15.4	110,650	(36.6)	12.7	32.8
Northern Great Basin	125	(0.1)	20,314	14.0	50,160	(34.6)	11.5	29.5
Columbia Basin	168	(0.3)	17,904	27.8	39,338	(61.1)	28.3	61.6
Colorado Plateau	185	(0.1)	27,792	19.4	66,095	(46.0)	20.8	47.6
SGCA	2,552	(0.1)	353,803	17.0	851,044	(40.9)	15.3	38.3
All roads[b]								
Great Plains	2,738	(0.8)	302,754	(85.9)	323,551	(91.8)	91.3	98.7
Wyoming Basin	2,228	(0.9)	214,456	(88.6)	231,103	(95.5)	98.5	99.7
Southern Great Basin	2,495	(0.8)	285,839	(89.5)	313,396	(98.2)	94.3	99.8
Snake River Plain	2,575	(0.9)	272,400	(90.1)	297,782	(98.5)	94.7	99.7
Northern Great Basin	1,599	(1.1)	138,158	(95.4)	144,469	(99.7)	95.6	100.0
Columbia Basin	870	(1.4)	63,097	(98.1)	64,270	(99.9)	98.7	100.0
Colorado Plateau	1,210	(0.8)	127,848	(89.1)	142,121	(99.0)	95.3	99.3
SGCA	17,681	(0.8)	1,776,936	(85.3)	1,923,694	(92.3)	95.2	99.6
Railroads[c]								
Great Plains	65	(<0.1)	34,805	(9.9)			8.8	
Wyoming Basin	34	(0.0)	17,391	(7.2)			7.4	
Southern Great Basin	48	(<0.1)	20,646	(6.5)			3.8	
Snake River Plain	110	(<0.1)	28,668	(9.5)			7.0	
Northern Great Basin	57	(<0.1)	13,927	(9.6)			5.7	
Columbia Basin	34	(0.1)	15,013	(23.3)			26.2	
Colorado Plateau	20	(<0.1)	7,326	(5.1)			4.2	
SGCA	487	(<0.1)	200,109	(9.6)			7.1	
Power lines[d]								
Great Plains	159	<0.1	52,362	14.9	112,697	32.0	15.4	33.5
Wyoming Basin	162	0.1	53,545	22.1	107,774	44.5	27.7	54.2
Southern Great Basin	124	<0.1	43,799	13.7	98,506	30.9	11.8	27.8
Snake River Plain	158	0.1	53,217	17.6	112,855	37.3	17.1	36.8

TABLE 12.3 (*continued*)

TABLE 12.3 (CONTINUED)

Land use	Area km^2	Area (%)	Effect area Low km^2	Effect area Low (%)	Effect area High km^2	Effect area High (%)	Sagebrush area[a] (%) Low	Sagebrush area[a] (%) High
Northern Great Basin	64	<0.1	22,275	15.4	49,634	34.3	13.8	31.4
Columbia Basin	85	0.1	25,280	39.3	44,116	68.6	43.8	76.1
Colorado Plateau	67	<0.1	24,364	17.0	55,635	38.8	21.4	46.9
SGCA	1,089	<0.1	366,298	17.6	777,983	57.3	18.7	39.0
Communication towers[e]								
Great Plains	9	<0.1			14,544	4.1		4.0
Wyoming Basin	6	<0.1			11,775	4.9		4.9
Southern Great Basin	12	<0.1			14,293	4.5		3.0
Snake River Plain	12	<0.1			16,615	5.5		3.6
Northern Great Basin	5	<0.1			6,556	4.5		2.7
Columbia Basin	6	<0.1			8,573	13.3		12.2
Colorado Plateau	5	<0.1			7,934	5.5		5.5
SGCA	74	<0.1			106,795	5.1		4.2

[a] Sagebrush area was delineated from the LANDFIRE (2006) map of land cover and included 529,708 km^2 (25.4%) of the Sage-Grouse Conservation Area.

[b] Effect area of 7 km estimated from distribution of Greater Sage-Grouse leks relative to Interstate 80 in Wyoming (Connelly et al. 2004). Surface area of roads was estimated from linear distance × width (interstate highways 73.2 m; federal and state highways 25.6 m; secondary roads 12.4 m).

[c] Surface area of railroads estimated from linear distance × width (9.4 m). Buffer size for ecological effect was 3 km to estimate spread of exotic plants. We did not estimate a high effect area for railroads.

[d] Low (2.5 km) and high (6.9 km) effect areas were estimated based on spread of exotic plant species (Bradley and Mustard 2006) and foraging distances of mammalian and corvid predators (Boarman and Heinrich 1999, Leu et al. 2008).

[e] We combined three categories of communications towers, which are based on height and location relative to glide paths around airports. Surface area was estimated at 1 ha/tower.

Interior 2008). New corridors, as currently proposed (Fig. 12.7), would affect an additional 2% (12,000 km^2) of the sagebrush across the SGCA currently not influenced by a mapped power line. Amount of additional sagebrush habitat that would be affected by new corridors ranged from <0.2% in the Columbia Basin (13 km^2) and Great Plains (85 km^2), which already have a large proportion influenced by power lines and infrastructure, to >5% in the Northern Great Basin (3,552 km^2).

A minimum of 10,182 communications towers >62 m in height were present in the SGCA (Fig. 12.5). The area potentially influenced included 4% of the current sagebrush distribution (Table 12.3).

Recreation and Off-highway Vehicle Use

Off-highway vehicle (OHV) use is defined as any motorized use by motorcycles, all-terrain vehicles, four-wheel-drive jeeps, and other vehicles capable of off-highway terrestrial travel, and which occurs predominantly on unpaved roads and single-track and two-track motorized trails (Ouren et al. 2007). A major part of OHV use on public lands is for recreation. Off-highway vehicle use and recreation, however, have not been well-documented for the SGCA or for sagebrush ecosystems. Over 8,400,000 people live within 5 km of sagebrush, and 7,600,000 live within 5 km of public lands. Many people live in these locations primarily because of access to public lands for recreation (Hansen et al. 2002, 2005).

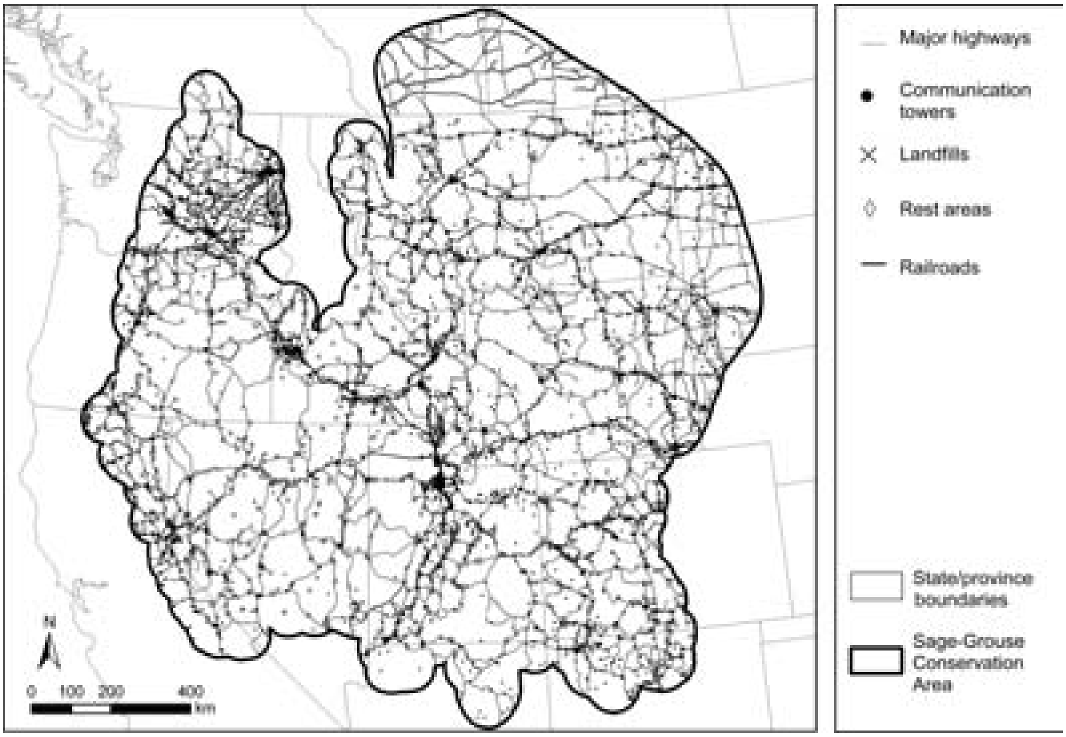

Figure 12.5. Communication towers, landfills, rest areas, major highways, and railroads within the western United States. Landfill locations obtained from waste management agencies of individual states. Location of rest areas obtained from transportation agencies of individual states. Communications tower locations obtained from Federal Communications Commission. Interstate and major highway (10-km buffer) locations obtained from U.S. Bureau of Transportation Statistics and Geo Gratis for Canada. Major railroad locations obtained from U.S. Bureau of Transportation Statistics and Geo Gratis for Canada.

Recreational use of OHVs is one of the fastest-growing outdoor activities, primarily in the western United States, where >27% of the population used OHVs for recreation during the survey period in 1999–2004 (Cordell et al. 2005). More than one in three persons in rural areas and one in four living in cities participated in OHV recreation an average of 24 days/year during 1999–2004.

Executive Order 11644 (Nixon 1972) required federal agencies to designate approved sites, or zones of use, for OHVs on public lands. Areas designated for OHV use were to minimize damage to soils, watersheds, vegetation, and wildlife as well as minimize conflict with other recreational uses. Agencies were required to monitor the effects of OHV use and adjust designated areas if required.

Ecological Influences and Pathways

Urban areas by themselves represent inhospitable environments for sage-grouse. However, most urban areas within the SGCA are on the edge of the current distribution of sagebrush and sage-grouse rather than within core regions. Nationally, urbanization is a major cause of species endangerment, particularly in association with recreation and agriculture, but had only a minor influence in the western states of Idaho, Utah, and Nevada because large amounts of public lands prevent urban development (Czech et al. 2000). However, the recent pace of development in these regions (Torregrosa and Devoe 2008) may increase the effect of urbanization on sagebrush and sage-grouse.

The expanding urbanization gradient through development of ranchettes or subdivisions influences wildlands through spatial and temporal changes in the physical environment that result in habitat loss and reduction of native species or changes in biodiversity (McKinney 2002, Hansen et al. 2005). Ranchettes and subdivisions continue to provide some sagebrush habitat, in contrast to total conversion in urban areas. Subdivided ranchettes had lower densities of shrub and grassland

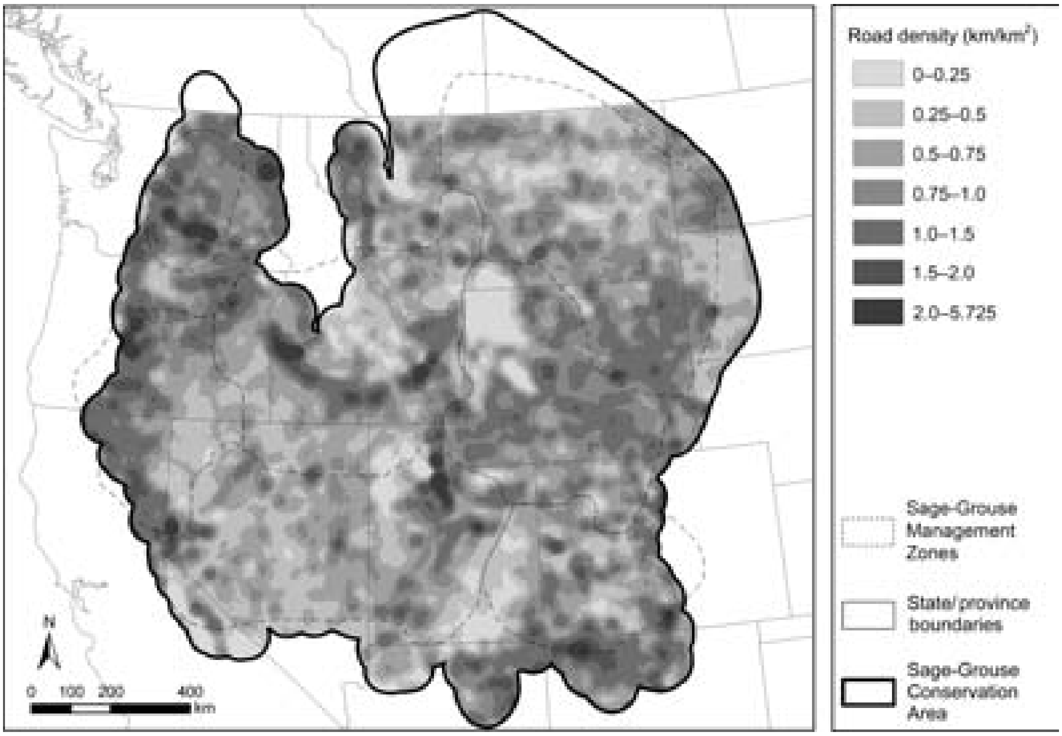

Figure 12.6. Contoured secondary roads in the Sage-Grouse Conservation Area (density [km/km^2] within an 18-km radius) (GIS coverages obtained from U.S. Census Bureau).

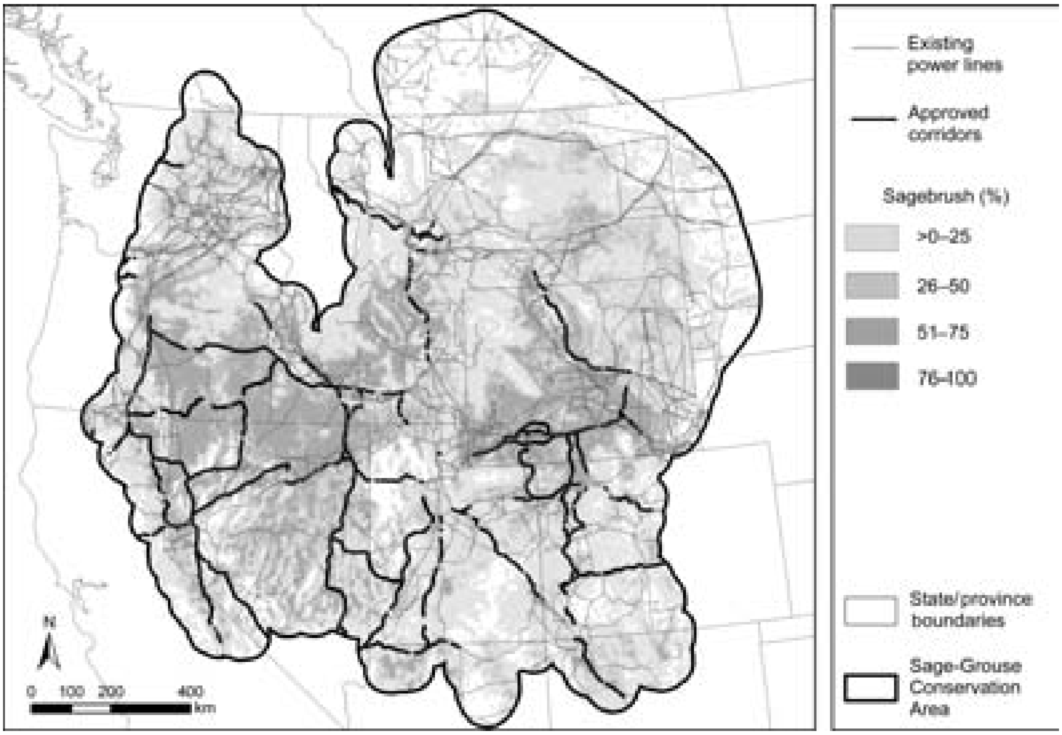

Figure 12.7. Power lines and proposed energy corridors within the Sage-Grouse Conservation Area (compiled from GIS coverages obtained from individual state, provincial, and federal sources).

birds, more domestic than native predators, and fewer native plant species when compared to full-scale ranches (Maestas et al. 2003, Hansen et al. 2005). Consequently, road fragmentation and disturbance from human activities in and around human dwellings (Mitchell et al. 2002) probably make many of these areas inhospitable to sage-grouse and other wildlife that depend on landscape arrangement and amount of sagebrush land cover (Aldridge et al. 2008; Hanser and Knick, this volume, chapter 19).

The physical boundaries of cities may be small relative to total area in the SGCA, but people living in cities require resources from immediately surrounding regions or that need to be transported from elsewhere. Often, the needs supporting urbanization extend well beyond the city (Theobald 2001). Increases in technological capabilities have reduced limitations to moving resources and increased connectivity between supply and demand. Proposed water development to support the growth of Las Vegas (located outside of the southern Great Basin SMZ) would potentially trigger declines in groundwater across at least 78 basins covering nearly 130,000 km^2, including areas within the Southern Great Basin (Deacon et al. 2007).

The connecting infrastructure of roads, motorized trails, railways, power lines, and communications corridors fragment or remove sagebrush land cover (Leu and Hanser, this volume, chapter 13). The ecological impact of roads and motorized trails include: (1) increased mortality of wildlife from collisions with vehicles, (2) modification of animal behavior because of habitat changes or noise disturbance, (3) alteration of physical environment, (4) alteration of chemical environment through leaching or erosion, (5) spread of exotic and invasive plant and wildlife, and (6) increased habitat alteration and use by humans (Forman and Alexander 1998, Forman 2000, Trombulak and Frissell 2000, Ouren et al. 2007). Unpaved roads fragment sagebrush landscapes as well as provide disturbed surfaces that facilitate spread of invasive plant species (Belcher and Wilson 1989, Gelbard and Belnap 2003).

Recreation, including hiking, hunting, fishing, and OHV use, was a major cause of species endangerment in the Great Basin and was a primary factor endangering 12 species in Utah and Nevada (Czech et al. 2000). Even activities that often are perceived as low impact or benign, such as hiking and mountain biking, have an influence on wildlife (Miller et al. 1998, Taylor and Knight 2003). Any human activity of high frequency along established roads or corridors, whether motorized or nonmotorized, can affect wildlife habitats and species negatively through habitat loss and fragmentation, facilitation of exotic plant spread, population displacement or avoidance, establishment of population barriers, or increased human-wildlife encounters that increase wildlife mortality (Gaines et al. 2003). These effects appear to be common across a variety of habitats and species that span the full range of forested to arid terrestrial environments (Gaines et al. 2003, Ouren et al. 2007). Nationally, recreation was listed in the Federal Register as a primary factor for 27% of the endangered, threatened, or proposed species (Wilcove et al. 1998).

Off-highway vehicle use can increase noise disturbance while also increasing soil compaction and erosion through surface disturbance and vegetation loss or alteration (Webb and Wilshire 1983, Lovich and Bainbridge 1999). OHVs were a primary factor given in the Federal Register for 13% of the species listed as endangered or threatened or proposed for listing (Wilcove et al. 1998). Direct effects of OHV use on wildlife populations have varied by species but appear similar to effects from motorized use of roads (Havlick 2002). Reduced nesting success of songbirds near OHV trails was offset by lower numbers of predators using these areas (Barton and Holmes 2007). Despite widespread and increasing use of OHVs (Cordell et al. 2005), potential effects on sagebrush habitats and most obligate wildlife species, including sage-grouse, have not been studied.

LIVESTOCK GRAZING

Historical Development and Current Status

Livestock grazing is the most widespread land use across the sage-grouse range (Brussard et al. 1994, Noss 1994, Crawford et al. 2004). Almost all sagebrush habitats have been grazed in the past century (Saab et al. 1995, West 1996, West and Young 2000, Hockett 2002). Areas ungrazed by livestock exist only in regions in which natural or human-developed water sources are not available, such as in inaccessible kipukas or tops of physically isolated buttes. Even lands on which grazing is currently restricted often have a previous history of livestock grazing (e.g., United States Department of Energy Idaho National Laboratory; Anderson and Holte 1981).

Livestock grazing in western shrublands became significant in the ecological and political landscape in the late 1800s (Oliphant 1968, Young and Sparks 2002). Completion of the first transcontinental railroad in the 1860s greatly expanded the livestock industry, because products could be shipped to markets on the East and West Coasts (Holechek 1981, Mitchell and Hart 1987, Flores 2001). Early grazing was largely unregulated by either fences or a legal system, and competition was intense among ranchers, homesteaders, and free-rangers as well as between cattle grazers and sheepherders (Carpenter 1981, Poling 1991, Donahue 1999).

Major increases in numbers of livestock and areas grazed from 1880 to 1905 altered the condition of western landscapes (Griffiths 1902, Mitchell and Hart 1987, Box 1990). Grazing on public lands was unregulated during this period without boundaries or controls on number or kind of livestock grazed (Carpenter 1981). Number of livestock increased from 4,100,000 cattle and 4,800,000 sheep in 1870 to 19,600,000 cattle and 25,100,000 sheep in 1900 (Donahue 1999). Native perennial bunchgrasses in the Intermountain West lacked seed production and morphological characteristics to sustain anything greater than low levels of grazing disturbance (Mack and Thompson 1982, Miller et al. 1994). Large declines of native grasses and winterfat (*Krascheninnikovia lanata*) occurred between 1870 and 1900 (Griffiths 1902, Cottam and Stewart 1940, Christiansen and Johnson 1964); reduction and loss of palatable forage species and increases in plant species of low palatability may have taken only 10–15 years at any given site under heavy uncontrolled grazing (Hull 1976). Forage production that would support livestock dropped between 60% and 90% of the site potential following depletion of the vegetation community by the early 1930s (Aldous and Shantz 1924, McArdle et al. 1936).

A drought in the 1920s followed the period of heavy grazing and became severe in the 1930s. Native grasses and forbs were depleted from the vegetation community and replaced in much of the Great Basin and surrounding region by exotic annual grasses (Robertson and Kennedy 1954, Young et al. 1972, Yensen 1981, Billings 1990, Miller et al. 1994). Loss of protective vegetation cover and trampling in some communities resulted in extensive soil disturbance and erosion (McArdle et al. 1936, Cottam and Stewart 1940). Shrub density also increased with heavy grazing and loss of understory grasses and forbs, although total distribution of shrubs across a landscape or region likely remained similar (Vale 1975).

The Taylor Grazing Act (1934) created grazing districts on public lands, established a permit and fee system to limit numbers of livestock, and developed administration of public land grazing under the United States Grazing Service, which became the BLM in 1946 (Poling 1991). A portion of the grazing fees was returned to the grazing districts for land improvements. Prescriptive management of grazing also was introduced to reduce grazing impacts through periodic rest and rotations rather than season-long grazing. Land improvements were implemented primarily to restore grasses in the herbaceous understory to maximize forage production for livestock. Other management objectives were to reduce plants poisonous to livestock, stabilize soils, and reduce shrub cover.

Herbicides, plowing, burning, and a diversity of other methods were used to remove the competitive woody overstory, particularly sagebrush, to maximize forage production for livestock by encouraging growth of grasses and forbs over large areas of the western states (Pechanec et al. 1965, Vale 1974, Young et al. 1981, Cluff et al. 1983). Estimates vary on how much sagebrush was treated or eradicated. Between 200,000 and 240,000 km^2 were estimated to have been treated over a 30-year period beginning in the 1940s (Schneegas 1967). Other studies estimated that 10–12% of the total sagebrush distribution (400,000–480,000 km^2) was treated by the 1970s (Vale 1974, Pechanec et al. 1965). Total area of sagebrush treated on lands managed by the BLM was 180,000 km^2 between 1940 and 1994; during the peak period of sagebrush removal in the 1960s, 11,000 km^2/year were treated (Miller and Eddleman 2001).

Replanting areas after sagebrush was removed with nonnative perennial grasses such as crested wheatgrass (*Agropyron cristatum*), desert wheatgrass (*A. desertorum*), and Siberian wheatgrass (*A. fragile*) reduced the necessity of a preexisting understory and was particularly successful at increasing forage that could be grazed by livestock (Shane et al. 1983). The first reseedings in southern Idaho were conducted in 1932 (Hull 1974).

Land treatments or burned areas currently are reseeded to reduce the spread of invasive plants, stabilize soils and reduce erosion, and create wildlife habitat (Monsen et al. 2004). With the exception of mineland reclamation, revegetation guidelines currently emphasize introduced species, although policies encourage the use of native seed mixes when available and affordable (Richards et al. 1998, Asay et al. 2001, Pyke et al. 2003). Total area seeded by the BLM to improve wildlife habitat averaged >400 km^2/yr and ranged from 55 km^2 in 1998 to 1,673 km^2 in 2000 (Table 12.4). However, seed mixtures used in these treatments may have been selected to benefit other wildlife and not targeted specifically to benefit sage-grouse.

Legislation enacted during the 1960s and 1970s directed management on public lands to maintain or improve ecosystem integrity and to provide sustainable uses of resources for multiple purposes, including recreation and wildlife, and not solely to produce livestock forage (Ross 1984, 2006; Poling 1991). Management paradigms also shifted because public lands were now to be retained, rather than disposed of to private entities. Consequently, sustaining resource productivity in perpetuity rather than as a temporary landholder placed importance on managing grazing impacts that were compatible with the land's productivity and in compliance with environmental laws.

Livestock Numbers on Public Lands

Numbers of livestock grazed on public lands are indexed by animal unit month (AUM), which is the amount of forage required to feed one 454-kg (1,000-lb) cow and her calf, one horse, five sheep, or five goats for 1 month. Permitted AUMs, as defined by BLM, represent potential maximum use based on land condition and trend. Actual use varies because of economics, nonuse due to forage or drought conditions, and unreported trespass. Number of AUMs increased following enactment of the Taylor Grazing Act in 1934 to >15,000,000 beginning in the 1940s (Clawson and Held 1957). Permitted AUMS have declined slowly since the late 1960s (Mitchell 2000). Approximately 12,700,000 AUMs were permitted annually on public lands in the western states from 2005 to 2007 (Table 12.5).

Condition of Public Lands

Land condition traditionally has been assessed by relative departure of the seral stage of the current vegetation from a climax community (West 2003a). Seral stage has been estimated for approximately half of the lands managed by the BLM in 13 states within the SGCA (Table 12.6). Less than 10% of the surveyed lands were potential natural communities at climax (excellent condition), 76% were in late or mid-seral stages (good to fair condition), and 15% were in early seral (poor) condition.

TABLE 12.4

Total area (km^2) seeded on lands managed by the BLM from 1997 to 2006 for wildlife habitat improvement.

Dash indicates that a state did not submit information for publication year.

State	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Arizona	16	0	1	57	<1	1	0	1	1	1
California	4	5	<1	—	1	—	—	—	58	—
Colorado	<1	1	1	3	21	25	40	—	0	2
Idaho	283	—	4	—	—	—	101	—	—	116
Montana	3	1	2	—	8	<1	0	—	0	0
Nevada	23	45	90	1,582	202	265	300	26	<1	25
New Mexico	<1	—	6	2	1	<1	4	10	2	—
Oregon	6	3	1	20	93	—	0	40	40	32
Utah	74	—	67	7	—	14	21	220	46	83
Wyoming	0	—	<1	2	12	1	0	0	1	—
Total area	410	55	173	1,673	339	306	466	297	148	259

SOURCE: Public Land Statistics (United States Department of the Interior 1997, 1998, 1999, 2000d, 2001b, 2002b, 2003f, 2004e, 2005d, 2006c).

TABLE 12.5
Grazing permits and leases in force on public lands from 2005–2007.
AUMs = animal units/month.

State	2005		2006		2007	
	Permits	AUMs	Permits	AUMs	Permits	AUMs
Arizona	758	660,528	757	660,007	765	660,086
California	555	361,430	548	355,726	541	345,164
Colorado	1,594	664,003	1,591	650,168	1,575	641,314
Idaho	1,889	1,351,806	1,890	1,348,526	1,889	1,358,417
Montana	3,743	1,283,126	3,755	1,281,144	3,765	1,281,748
Nebraska	17	578	17	578	17	578
Nevada	662	2,187,729	644	2,137,635	650	2,132,155
New Mexico	2,286	1,861,231	2,275	1,856,795	2,275	1,862,572
North Dakota	75	9,226	76	9,233	76	9,233
Oklahoma	4	138	4	132	4	132
Oregon	1,284	1,026,548	1,277	1,026,463	1,275	1,028,553
South Dakota	470	73,924	472	73,828	475	73,737
Utah	1,519	1,238,877	1,499	1,239,786	1,490	1,225,890
Washington	294	32,144	283	33,603	279	33,078
Wyoming	2,790	1,949,789	2,792	1,960,956	2,798	1,937,041
Total	17,940	12,701,077	17,880	12,634,580	17,874	12,589,698

SOURCE: Public Land Statistics (United States Department of the Interior 2005d, 2006c, 2007a).

NOTE: Number of grazing permits were combined for Section 15 (lands within grazing districts) and Section 3 (isolated tracts outside of grazing districts).

Current assessment of land condition is based on ecological criteria rather than on seral stages of plant communities, livestock preferences for a plant species, or a plant species resistance to livestock grazing (National Research Council 1994). Indicators of soil characteristics and erosion, hydrologic function, biotic integrity, and ecological processes are integrated into evaluations of the upland's functioning (Whitford et al. 1998, Pyke et al. 2002, West 2003b). Evaluation of land condition is not directly transferrable to assessments for seral stage. Similarly, riparian areas are evaluated for different criteria using techniques that reflect stream geomorphology, stream bank stability, and plant community potential (Pritchard et al. 1998).

Standards and guidelines for management of public grazing lands are established by local resource advisory councils and also must address habitats and conservation measures for endangered, threatened, proposed, candidate, or other at-risk or special status species (United States Department of the Interior 2003d,e). Sixty-three percent (>402,000 km^2) of the public lands managed by the BLM have been assessed according to standards and guidelines. Under established criteria, 40% of assessed lands (25% of all lands under management by the BLM, including nonsagebrush habitats) met standards or were making progress toward meeting those standards (category A, Table 12.7). Livestock were a factor in 19% of the assessed lands not meeting standards (categories B and C). Another 5% of the assessed lands were not meeting standards for causes other than livestock grazing (category D).

TABLE 12.6

Percent of lands inventoried and by seral condition on public lands managed by the BLM in 2007.

Similarity to the climax vegetation community at a site was 76–100% for potential natural communities, 51–75% for late seral, 26–50% for mid-seral, and 0–25% for early seral stages[a].

State	Inventoried	Potential natural community	Late seral	Mid seral	Early seral	Unclassified/not inventoried
Arizona	56	8	44	37	11	37
California	15	3	21	45	31	72
Colorado	47	7	27	41	25	50
Idaho	74	2	25	41	33	9
Montana[b]	74	9	66	24	1	25
Nevada	40	4	38	46	12	58
New Mexico	76	4	24	43	30	24
Oregon and Washington	57	1	28	59	12	36
Utah	61	12	30	44	13	33
Wyoming	59	27	38	30	5	41
Total	54	8	35	41	15	42

SOURCE: United States Department of the Interior (2007a). Statistics were reported for 2007, although surveys to classify sites may have been conducted in previous years or decades.

[a] Potential natural communities are considered by BLM to be in excellent condition, late seral stages to be good, mid-seral to be fair, and early seral to be poor, based on the relationship of current conditions relative to a perceived natural climax condition (West 2003a).

[b] Montana statistics also include North Dakota and South Dakota.

Management Actions on Public Lands

Large numbers of treatments are conducted on public lands, including those dominated by sagebrush, for different purposes (Table 12.8). The BLM addressed use of habitat treatments and concluded that treating vegetation was necessary to develop or restore a desired plant community, create biological diversity, increase forage or cover for animals, protect buildings and other facilities, manage fuels to reduce wildfire hazard, manage vegetation community structure, rejuvenate late successional (old-growth) vegetation, enhance forage/browse quality, or remove noxious weeds and poisonous plants (United States Department of the Interior 1991). Over 24,000 km^2 managed by the BLM, most of it in Nevada, Idaho, Oregon, and Wyoming, would be treated annually as the preferred strategy to reduce fire risk and to control unwanted vegetation (United States Department of the Interior 2007b,c).

Different combinations of herbicides and seasons of applications have been developed to remove sagebrush, other unwanted woody shrubs, and weedy annuals (Tueller and Evans 1969; Evans and Young 1975, 1977; McDaniel et al. 1991). More recent treatment objectives have emphasized thinning density of sagebrush and control of noxious weeds. Small irregular patchworks of habitat are created in some regions, in contrast to total removal of sagebrush from large areas. The most common herbicides used on lands managed by the BLM are 2,4-D, picloram, and tebuthiuron (United States Department of the Interior 2007c). Under the preferred alternative to reduce fire risk and control unwanted vegetation, tebuthiuron would be used on 25%, 2,4-D on 18%, and picloram on 15% of the 3,770 km^2 treated annually by the BLM (United States Department of the Interior 2007c). Herbicide use can result in short-term decreases in exotic plants. However, long-term benefits (4–16 years) may not be obtained because exotic plants are capable of recolonizing treated sites, particularly when native plant species have also been reduced by herbicide treatments (Rinella et al. 2009).

TABLE 12.7

Total area (km²) and percent of assessed lands[a] managed by the BLM meeting standards and guidelines established for rangeland health[b].

	Category A[c]		Category B[d]		Category C[e]		Category D[f]		Assessed		Not assessed		Total area
State	km²	%	km²	%	km²	%	km²	%	km²	%	km²	%	km²
Arizona	28,839	62	1,452	3	1,035	2	83	0	31,409	68	14,793	32	46,203
California	10,561	32	5,824	18	2,524	8	2,535	8	21,444	65	11,427	35	32,871
Colorado	19,013	60	5,418	17	272	1	4,284	14	28,987	92	2,621	8	31,609
Idaho	13,694	29	15,766	34	2,736	6	4,608	10	36,804	79	10,018	21	46,822
Montana[g]	25,740	77	3,997	12	420	1	1,598	5	31,755	96	1,478	4	33,233
Nevada	60,572	34	35,726	20	3,524	2	5,060	3	104,882	58	74,488	42	179,370
New Mexico	8,439	17	1,072	2	53	0	397	1	9,961	20	40,816	80	50,777
Oregon/ Washington	19,763	35	5,833	10	4,645	8	1,944	3	32,184	58	23,775	42	55,959
Utah	33,961	39	5,147	6	1,576	2	6,508	7	47,191	54	40,624	46	87,816
Wyoming	32,536	45	20,192	28	2,715	4	2,071	3	57,513	80	14,139	20	71,653
Total	253,117	40	100,427	16	19,499	3	29,088	5	402,131	63	234,181	37	636,312

[a] Percentages were calculated from total assessed area because data do not represent random or stratified sampling of lands managed by the BLM, and no inference could be assumed for lands that have not been assessed.

[b] http://www.blm.gov/nstc/rangeland/rangelandindex.html.

[c] Category A = Meeting standards or making significant progress toward meeting standards.

[d] Category B = Not meeting all standards or making significant progress, but appropriate action has been taken to ensure significant progress toward meeting standards (livestock is a significant factor).

[e] Category C = Not meeting standards or making significant progress toward meeting the standards, and no appropriate action has been taken to ensure significant progress (livestock is a significant factor).

[f] Category D = Not meeting standards or making significant progress toward meeting the standards, due to causes other than livestock grazing.

[g] Montana statistics include North Dakota and South Dakota.

Primary actions to facilitate prescriptive livestock grazing on lands managed by the BLM include construction of fences, development or control of water, and habitat modifications (Table 12.8). From 1962 to 1997, >51,000 km of fence were constructed on land administered by the BLM in states supporting sage-grouse populations (Connelly et al. 2000c). More than 1,000 km of fences were constructed each year from 1996 through 2002, and density of fences exceeds 2 km/km² in some regions; most fences were constructed in Montana, Nevada, Oregon, and Wyoming (Table 12.8, Fig. 12.8). Water developments were also widespread throughout public lands (Fig. 12.9).

Prescribed fire is one of the most common management tools for reducing density of sagebrush, facilitating growth of grasses and forbs, and controlling juniper (*Juniperus* spp.) and pinyon (*Pinus* spp.) woodland expansion into sagebrush habitats (Miller and Eddleman 2001, Baker and Shinneman 2004, Baker 2006a), and for assisting in controlling annual grasses (DiTomaso et al. 2006). Prescribed fires were conducted on >3,700 km² of public lands from 1997 through 2006 (Table 12.9). Most areas treated by prescribed fire were in Oregon and Idaho.

Area treated under the Emergency Stabilization and Rehabilitation program, designed to rehabilitate areas following fire, varied from 281 km² in 1997 to 16,135 km² in 2002 (Table 12.10). The majority of areas treated after burning were reseeded with differing mixes of shrubs, forbs, and grasses following extensive fires in Idaho, Nevada, and Oregon. The main purpose of this program is to stabilize soils and maintain site productivity, not to regain site suitability for wildlife.

TABLE 12.8

Number of habitat treatments (1929–2004) on lands managed by the BLM.

Habitat treatment	AZ	CA	CO	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY	Totals
Unknown	9	20	15	23	30		12	40	18		91		25	283
Fences	1,489	669	3,051	3,717	5,790	48	1,445	3,489	3,451	357	3,265	239	5,278	32,288
Fence modification	1	6	9	149	17		7	23	89		17	4	23	345
Hazard reduction	1	8	28	47	9		1	5	10		2		4	115
Lake/wetland improvement	21		8	8	17		2		7	1	2	10	8	84
Land treatment[a]	30	15	253	158	82		78	77	54	4	141	11	73	976
Misc. facility improvement	468	173	1,038	1,254	1,420		368	1,480	1,263	10	1,300	41	644	9,459
Perch/nesting structure			2	6	7		2	3	3		6	11	44	84
Stream bank stabilization	1		18	4	13		1	2	11		1	3	2	56
Stream improvement		8	35	11	13		3	1	14		17	4	22	128
Timber stand improvement		8	23	9	1		3	1	15		1	1	12	74
Vegetation manipulation	220	207	880	1,585	445	9	681	895	1,089	14	824	66	481	7,396
Weed control[b]		2	138	67	320	3	31	12	126	15	14	294	42	1,064
Water development/control	2,180	1,180	9,189	5,017	10,587	56	2,247	5,163	7,555	561	5,292	130	7,813	56,970
Water facilities modified		15	49	65	15		3	3	126	1	20	2	38	337
Total habitat treatments	4,420	2,311	14,736	12,120	18,766	116	4,884	11,194	13,831	963	10,995	816	14,509	109,661

SOURCE: Bureau of Land Management Range Improvement Projects database.

[a] Includes contour furrowing, ripping and deep tillage, pitting, terracing, checks, and scalping.

[b] Includes biological and chemical treatments, blading, cutting or beating, chaining or cabling, chipping, log and scatter, plowing, prescribed fire, and wildfire.

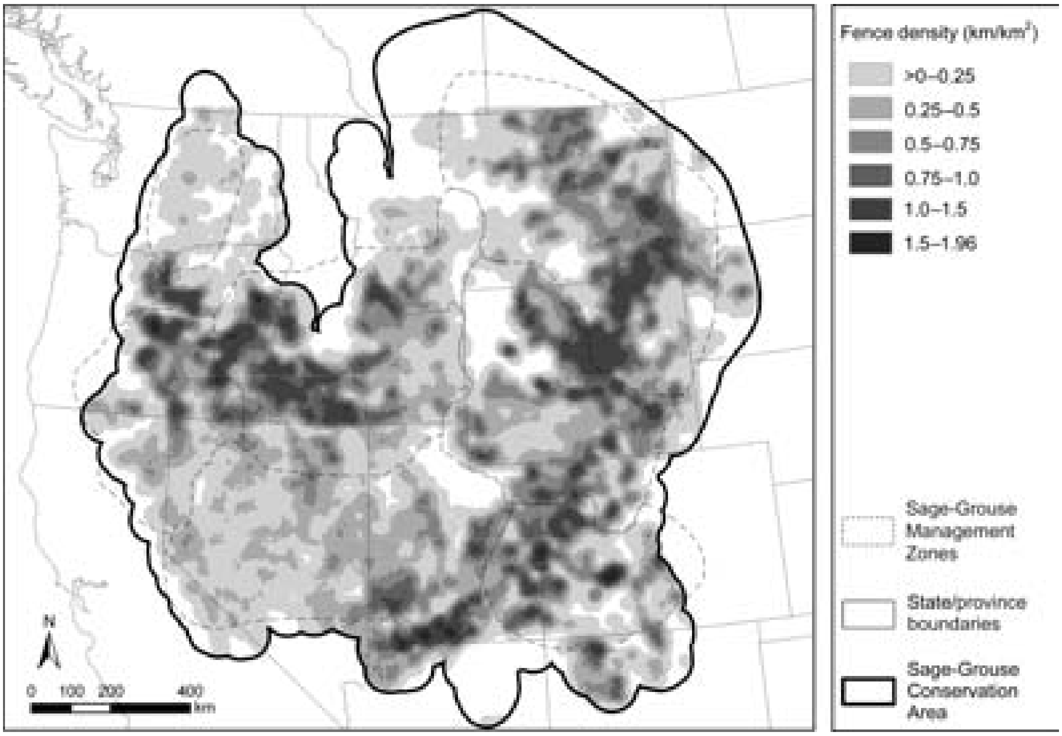

Figure 12.8. Linear density (km/km^2) of fences (estimated from allotment and pasture boundaries) on public lands in the Sage-Grouse Conservation Area (GIS coverages obtained from Bureau of Land Management Geocommunicator).

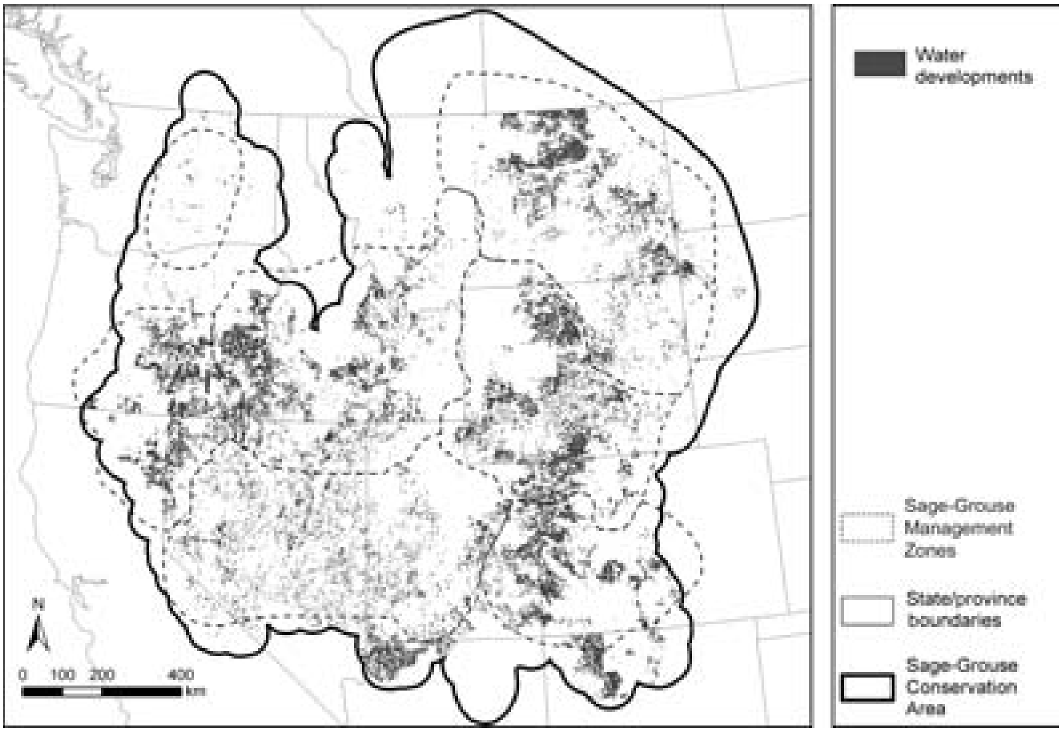

Figure 12.9. Water developments on lands managed by the Bureau of Land Management (Bureau of Land Management Range Improvement database). Locations of water development are recorded to the nearest 2.59 km^2.

TABLE 12.9

Total area (km²) treated by prescribed fire on lands managed by the BLM from 1997–2006.

Dashes indicate states that did not submit information for publication year.

State	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Arizona	8	95	94	40	48	52	15	3	57	0
California	16	45	21	22	3	7	—	—	4	—
Colorado	3	56	46	2	2	24	4	—	0	2
Idaho	11	64	102	43	100	59	8	—	—	6
Montana	3	18	31	15	34	12	10	—	0	20
Nevada	10	2	3	<1	10	28	13	7	24	2
New Mexico	60	131	71	15	34	53	95	3	8	—
Oregon	72	169	225	55	86	223	59	81	81	73
Utah	11	24	30	33	64	19	25	19	15	32
Wyoming	59	117	138	23	11	20	43	43	74	—
Total area	253	720	764	251	393	497	272	156	263	135

SOURCE: Public Land Statistics (United States Department of the Interior 1997, 1998, 1999, 2000d, 2001b, 2002b, 2003f, 2004e, 2005d, 2006c).

TABLE 12.10

Number of projects (N) and total area (km²) treated for emergency fire rehabilitation on lands managed by the BLM from 2002–2007.

	2002		2003		2004		2005		2006		2007	
State	N	km²	N	km²	N	km²	N	km²	N	km²	N	km²
Arizona	0	0	2	1	4	9	15	4	17	138	15	6
California	19	34	11	278	37	467	27	432	27	396	21	476
Colorado	16	52	7	170	18	138	15	99	19	9	20	26
Idaho	85	2,900	51	1,524	53	1,345	52	926	92	3,611	115	5,943
Montana	3	8	4	82	6	601	6	311	11	335	4	211
Nevada	103	11,226	111	3,099	108	2,235	65	278	182	6,926	176	15,697
New Mexico		0	1	3	1	1	5	1	10	1	7	1
Oregon	50	1,392	46	2,858	39	2,318	24	493	58	593	63	1,689
South Dakota		0	1	8	1	4	1	<1	1	8	0	0
Utah	27	409	54	925	76	627	77	974	115	1,931	122	2,124
Washington		0	2	1	2	32	2	35	1	2	2	9
Wyoming	5	113	6	301	6	17	6	0	5	25	4	0
Total	308	16,134	296	9,250	351	7,794	295	3,553	538	13,975	549	26,182

SOURCE: Public Land Statistics (United States Department of the Interior 2002b, 2003f, 2004e, 2005d, 2006c, 2007a).