CHAPTER TWENTY-FOUR

Conservation of Greater Sage-Grouse

A SYNTHESIS OF CURRENT TRENDS AND FUTURE MANAGEMENT

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Abstract. Recent analyses of Greater Sage-Grouse (*Centrocercus urophasianus*) populations indicate substantial declines in many areas but relatively stable populations in other portions of the species' range. Sagebrush (*Artemisia* spp.) habitats necessary to support sage-grouse are being burned by large wildfires, invaded by nonnative plants, and developed for energy resources (gas, oil, and wind). Management on public lands, which contain 70% of sagebrush habitats, has changed over the last 30 years from large sagebrush control projects directed at enhancing livestock grazing to a greater emphasis on projects that often attempt to improve or restore ecological integrity. Nevertheless, the mandate to manage public lands to provide traditional consumptive uses as well as recreation and wilderness values is not likely to change in the near future. Consequently, demand and use of resources contained in sagebrush landscapes plus the associated infrastructure to support increasing human populations in the western United States will continue to challenge efforts to conserve Greater Sage-Grouse. The continued widespread distribution of sage-grouse, albeit at very low densities in some areas, coupled with large areas of important sagebrush habitat that are relatively unaffected by the human footprint, suggest that Greater Sage-Grouse populations may be able to persist into the future. We summarize the status of sage-grouse populations and habitats, provide a synthesis of major threats and challenges to conservation of sage-grouse, and suggest a roadmap to attaining conservation goals.

Key Words: Centrocercus urophasianus, Greater Sage-Grouse, habitats, management, populations, restoration, sagebrush.

Conservación del Greater Sage-Grouse: Una Síntesis de las Tendencias Actuales y del Manejo Futuro

Resumen. Los análisis recientes de poblaciones de Greater Sage-Grouse (*Centrocercus urophasianus*) indican declinaciones substanciales en muchas áreas, pero con poblaciones relativamente estables en otras porciones de la distribución de esta especie. Los hábitats de artemisa (*Artemisia* spp.)

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necesarios para sustentar al sage-grouse están siendo quemados por grandes incendios naturales, invadidos por plantas introducidas, y desarrollados para recursos energéticos (gas, petróleo, y energía eólica). El manejo de tierras públicas, las cuales contienen el 70% del hábitat de sagebrush, ha cambiado durante los últimos 30 años: desde grandes proyectos de control del sagebrush dirigidos a aumentar el pastoreo de ganado, a un mayor énfasis en los proyectos que intentan a menudo mejorar o restaurar la integridad ecológica. Sin embargo, el mandato que incita a manejar tierras públicas para proporcionar aplicaciones de consumo tradicionales, así como valores de recreación y de áreas naturales, probablemente no vaya a cambiar en un futuro cercano. Por lo tanto, la demanda y el uso de los recursos contenidos en paisajes de artemisa, más la infraestructura asociada al soporte de las crecientes poblaciones humanas en el oeste de los Estados Unidos, continuarán desafiando los esfuerzos para conservar al Greater Sage-Grouse. La incesante extensa distribución del sage-grouse, no obstante sus bajas densidades en algunas áreas, junto con grandes áreas del importante hábitat de artemisa que se encuentran relativamente inafectadas por la mano del hombre, sugieren que las poblaciones del Greater Sage-Grouse podrán persistir en el futuro. Resumimos el estado de las poblaciones y de los hábitats del sage-grouse, proporcionamos una síntesis de amenazas y de desafíos importantes a la conservación del sage-grouse, y sugerimos un mapa para lograr metas de conservación.

Palabras Clave: artemisa (sagebrush), *Centrocercus urophasianus*, gestión, Greater Sage-Grouse, hábitats, poblaciones, restauración.

The Greater Sage-Grouse (*Centrocercus urophasianus*; hereafter, sage-grouse), now occupies only 56% of its likely distribution prior to European settlement (Schroeder et al. 2004). Range-wide, populations have been declining at an average of 2.0% per year from 1965 to 2003 (Connelly et al. 2004). Concerns about declining sage-grouse populations (Braun 1995, Connelly and Braun 1997, Connelly et al. 2004, Schroeder et al. 2004) coupled with information on habitat loss (Connelly et al. 2004) have prompted multiple petitions to list the species under the Endangered Species Act (Stiver, this volume, chapter 2).

The United States Fish and Wildlife Service determined in 2010 that listing Greater Sage-Grouse under the Endangered Species Act was biologically warranted but was precluded by other higher priorities (United States Department of the Interior 2010). During the four years since the first detailed range-wide analysis of sage-grouse populations and sagebrush habitats (Connelly et al. 2004), negative impacts of energy development and West Nile virus on Greater Sage-Grouse were documented (Naugle et al. 2004, 2005; Holloran et al. 2005; Aldridge and Boyce 2007; Doherty et al. 2008; Walker 2008). Hundreds of thousands of hectares of sagebrush (*Artemisia* spp.) steppe were also burned by wildfire (Miller et al., this volume, chapter 10; Baker, this volume, chapter 11). Large-scale conversion of sagebrush-dominated landscapes to exotic annual grasslands following these fires further increases the likelihood of future fire (Miller et al., this volume, chapter 10) and decreases any potential for recovery or restoration (Pyke, this volume, chapter 23). Along with these habitat changes, sage-grouse populations in some portions of the species' range have continued to decline (Garton et al., this volume, chapter 15) despite the collaborative efforts of many local working groups (Stiver, this volume, chapter 2).

We do not expect land uses to decrease, because growing human populations will increase demand for traditional consumptive resources and recreation. Thus, the human footprint (Leu and Hanser, this volume, chapter 13) is likely to continue to influence sagebrush-dominated landscapes (Knick et al., this volume, chapter 12). Nevertheless, the continued widespread distribution of sage-grouse (although some areas have very low densities) and relatively large areas providing key sagebrush habitats suggest that long-term conservation of sage-grouse populations should be possible. This chapter summarizes information on Greater Sage-Grouse populations and habitats presented in this volume, provides a synthesis of major threats and challenges to conservation of Greater Sage-Grouse, and suggests a roadmap to attaining conservation goals.

CURRENT KNOWLEDGE OF POPULATIONS

The Greater Sage-Grouse is genetically distinct from the congeneric Gunnison Sage-Grouse (*Centrocercus minimus*). Greater Sage-Grouse populations in Washington and the Lyon-Mono population, spanning the border between Nevada and California, also have unique genetic characteristics (Oyler-McCance and Quinn, this volume, chapter 5) but have not been described as separate species. The distribution of genetic variation has shifted gradually across the range, suggesting movement among neighboring populations is not yet likely across the species' range (Oyler-McCance et al. 2005b). Most populations have similar levels of genetic diversity even at the periphery of the range. With declining populations and habitat as well as increased threats from anthropogenic sources, however, current connectivity among populations may become eroded.

Although Moynahan et al. (2006) reported relatively high mortality during one winter of their study, sage-grouse generally have low over-winter mortality (<20%) and relatively high annual survival (30–78%). The average likelihood of a female nesting in a given year varies from 63% to 100% and averages 82% in the eastern part of the species' range and 78% in the western portion of the range (Connelly et al., this volume, chapter 3). Clutch size of sage-grouse averages six to nine eggs and nest success rates average 52% in relatively nonaltered habitats, while those in altered habitats average 37% (Connelly et al., this volume, chapter 3). Adult female sage-grouse survival is greater than adult male survival and adults have lower survival than yearlings, but not all estimates of survival rates are directly comparable (Zablan et al. 2003; Connelly et al., this volume, chapter 3). These relatively high survival rates and low reproductive rates suggest that sage-grouse populations may be slow to respond to improved habitat conditions.

Many populations are migratory (Connelly et al., this volume, chapter 3). Lengthy migration between separate seasonal ranges is one of the more distinctive characteristics of many sage-grouse populations (Connelly et al. 1988, 2000b). These migratory movements (>20 km) and large annual home ranges (>600 km^2) help integrate sage-grouse populations across vast landscapes of sagebrush-dominated habitats (Connelly et al., this volume, chapter 3; Knick and Hanser, this volume, chapter 16).

All state and provincial fish and wildlife agencies monitor sage-grouse breeding populations annually, but monitoring techniques have varied somewhat among areas and years both within and among agencies. This methodological variation complicates attempts to understand grouse population trends and make comparisons among areas (Connelly et al. 2004). Population monitoring efforts increased substantially between 1965 and 2007 throughout the range of sage-grouse (Garton et al., this volume, chapter 15). The largest increases in effort occurred in the Great Plains Sage-Grouse Management Zone (SMZ)(parts of Alberta, Saskatchewan, Montana, North Dakota, South Dakota, and Wyoming) and Colorado Plateau SMZ (representing parts of Utah and Colorado). In 2007, a minimum of 88,816 male sage-grouse were counted on 5,042 leks throughout western North America (Garton et al., this volume, chapter 15).

CURRENT KNOWLEDGE OF HABITATS

Invasive plant species, wildfires, weather, and climate change are major influences on sagebrush habitats and present significant challenges to long-term conservation (Miller et al., this volume, chapter 10; Baker, this volume, chapter 11). All of these factors are spatially pervasive and have considerable potential to influence processes within sagebrush communities. In addition, habitat loss or degradation can have a significant influence on sage-grouse populations by increasing the role of predation and disease (Hagen, this volume, chapter 6; Walker and Naugle, this volume, chapter 9).

Cheatgrass (*Bromus tectorum*) has invaded many of the lower-elevation, more-xeric sagebrush landscapes in the western United States. A large proportion of the remaining sagebrush communities is at moderate to high risk of invasion by cheatgrass (Connelly et al. 2004; Wisdom et al. 2005a; Miller et al., this volume, chapter 10). Moreover, juniper (*Juniperus* spp.) and pinyon (*Pinus* spp.) woodlands have expanded into sagebrush habitats at higher elevations (Miller et al., this volume, chapter 10). Numbers of fires and total area burned have increased since 1980 throughout most sagebrush-dominated habitats.

Sage-grouse have been eliminated from many former areas of their likely distribution prior to Euro-American settlement (Schroeder et al. 2004, Aldridge et al. 2008). Extirpated ranges had a lower percent area of sagebrush compared to those currently occupied by sage-grouse. Extirpated ranges also were at lower elevation, contained greater levels of human infrastructure such as transmission lines and communication towers, and had more private landownership relative to occupied regions (Wisdom et al., this volume, chapter 18). Moreover, this analysis identified those areas currently occupied by sage-grouse but characterized by environmental features most similar to extirpated range. These areas generally were concentrated in small, disjunct portions of occupied range and along peripheries of the current sage-grouse distribution (Wisdom et al., this volume, chapter 18). These regions will likely not support populations far into the future without active restoration or management that improves habitat conditions. In contrast, areas characterized by environmental factors where sage-grouse were most likely to persist were concentrated in the largest, most contiguous portions of occupied range in Oregon, Idaho, Nevada, and western Wyoming (Wisdom et al., this volume, chapter 18).

Urbanization and increasing human populations throughout much of the sage-grouse distribution have resulted in an extensive system of roads, power lines, railroads, and communication towers with an expanding influence on sagebrush habitats (Knick et al., this volume, chapter 12). Less than 5% of current sagebrush habitats was >2.5 km from a mapped road (Knick et al., this volume, chapter 12). Roads and other corridors promote invasion of exotic plants, provide travel routes for predators, and facilitate human access into sagebrush habitats. Human-caused fires also were closely related to existing roads.

Wildfire dynamics under the historic range of variation were likely characterized in all sagebrush landscapes by infrequent episodes of large, high-severity fires followed by long interludes with smaller, patchier fires, allowing mature sagebrush to dominate for extended periods (Baker 2006). Fire rotation, estimated from recent fire records, suggests fire exclusion had little effect on fire in sagebrush ecosystems, especially in more xeric areas. Instead, cheatgrass invasion, increases in number of human-set fires, and global warming have resulted in greatly increased amounts of fire relative to the historic variation in the Columbia Basin, Northern Great Basin, Southern Great Basin, and Snake River Plain SMZs (Baker, this volume, chapter 11). In addition, global climate change is likely to further promote cheatgrass and increase frequency of fire (Miller et al., this volume, chapter 10).

Additional fire created by widespread prescribed burning of sagebrush is unnecessary and exacerbates this increasing dominance of fire, particularly in lower-elevation landscapes dominated by Wyoming big sagebrush (*Artemisia tridentata* spp. *wyomingensis*) (Baker 2006a; Baker, this volume, chapter 11). Sagebrush ecosystems in these low-productivity regions characterized by low resilience and resistance to disturbance would benefit from rest, rather than the increased levels of disturbance that prescribed fire contributes to the natural regime. Thus, fire suppression is appropriate where cheatgrass invasion or expansion is likely to impede restoration treatments or natural recovery of native plant communities (Baker, this volume, chapter 11; Pyke, this volume, chapter 23).

Energy development for oil and gas influences sagebrush habitats by physical removal of habitat to construct well pads, roads, power lines, and pipelines (Naugle et al., this volume, chapter 20; Doherty et al., this volume, chapter 21). Indirect effects include habitat fragmentation and soil disturbance along roads, spread of exotic plants, and increased predation from raptors that have access to new perches for nesting and hunting (Knick et al., this volume, chapter 12; Naugle et al., this volume, chapter 20). Available evidence clearly supports the conclusion that conserving large landscapes with suitable habitat is important for conservation of sage-grouse, but that doing so involves overcoming numerous environmental challenges (Miller et al., this volume, chapter 10).

By creating habitat characteristics specific to sage-grouse requirements (Connelly et al., this volume, chapter 4), managers have adopted an umbrella concept that should similarly benefit other wildlife species dependent on sagebrush (Hanser and Knick, this volume, chapter 19). Passerine birds associated with sagebrush steppe habitats had high levels of overlap with sage-grouse along multiscale environmental gradients. However, this overlap was primarily a function of the broad range of sagebrush habitats used by sage-grouse (Hanser and Knick, this volume, chapter 19). Management that focuses on creating a narrow set of plot-scale conditions for a single species or site restoration will likely be less effective in addressing the needs of multiple species than restoration efforts that recognize landscape heterogeneity and multiscale organization of habitats (Hanser and Knick, this volume, chapter 19).

THREATS

Predation is often identified as a potential threat to sage-grouse (Schroeder and Baydack 2001; Hagen, this volume, chapter 6). However, predator management studies have not provided sufficient evidence to support implementation of predator control to improve sage-grouse populations over broad geographic or temporal scales. The limited information available suggests predator management may provide short-term relief for a sage-grouse population sink in the few cases where this situation has been documented (Hagen, this volume, chapter 6).

Hunting has also been identified as a management concern for sage-grouse populations (Connelly et al. 2003a; Reese and Connelly, this volume, chapter 7). Nine of 11 states with sage-grouse presently have hunting seasons for this species. Sage-grouse normally experience high survival over winter (Wik 2002, Hausleitner 2003, Beck et al. 2006, Battazo 2007); thus, mortality from hunter harvest in September and October may not be totally compensatory. Nevertheless, harvest mortality is low on most populations of sage-grouse, and no studies have demonstrated that hunting is a primary cause reducing populations (Reese and Connelly, this volume, chapter 7).

Despite the prevalence of organisms that may infect individual birds, population-level effects of parasites and disease have rarely been documented in sage-grouse (Christiansen and Tate, this volume, chapter 8). However, West Nile virus has shown greater impact on sage-grouse populations than any other infectious agent detected to date. This virus was an important new source of mortality in low- and mid-elevation sage-grouse populations range-wide from 2003 to 2007 (Naugle et al. 2004; Walker et al. 2007b; Walker 2008; Walker and Naugle, this volume, chapter 9). West Nile virus can significantly reduce survival and may lead to local and regional population declines. Simulations of West Nile virus mortality projected reduced growth of susceptible sage-grouse populations by an average of 0.06% to 0.09% per year. However, marked spatial and annual fluctuations in nest success, chick survival, and other sources of adult mortality may mask population-level impacts in most years. Resistance to West Nile virus–related disease appears to be low but is expected to increase slowly over time (Walker et al. 2007b; Walker and Naugle, this volume, chapter 9).

Livestock grazing is the most widespread use of sage-grouse habitats, but data used by agencies (e.g., permitted animal unit months) do not provide information on management regime, habitat condition, or type of livestock that allows the assessment of direct effects of grazing at large spatial scales (Milchunas and Lauenroth 1993; Jones 2000; Knick et al., this volume, chapter 12). These data may be collected for individual allotments. However, they often are subjective estimates or are not collected systematically across a region or through time in a way that permits an evaluation of grazing levels and intensity relative to habitat condition. Consequently, the significance of decreased numbers of livestock on public lands (Mitchell 2000) cannot be interpreted without corresponding information on changes in habitat productivity. Thus, the direct effect of livestock grazing expressed through habitat changes to population-level responses of sage-grouse cannot be addressed using existing information.

The effects of livestock grazing management, however, can have significant influences on landscape patterns and processes (Freilich et al. 2003; Miller et al., this volume, chapter 10; Knick et al., this volume, chapter 12). Large treatments designed to remove sagebrush and increase forage for livestock may no longer be the primary emphasis by agencies for management of public lands. Nevertheless, habitat manipulations, water developments, and fencing are still widely implemented to manage livestock grazing, and large-scale treatments still occur on some private lands. More than 1,000 km of fences were constructed annually on public lands from 1996 to 2002; linear density of fences exceeded 2 km/km^2 in some regions of the sagebrush biome (Knick et al., this volume, chapter 12). Fences provide perches for raptors and modify access and movements by humans and livestock, thus exerting a new mosaic of disturbance and use on the landscape (Freilich et al. 2003).

Development of oil and gas resources will continue to be a major influence on sagebrush habitats and sage-grouse because advanced technology allows access to reserves, high demand for these resources will continue, and a large number of applications have been approved and are still being submitted and approved annually. Future oil and gas development is projected to cause a 7–19% decline from 2007 sage-grouse lek population counts and impact 3,700,000 ha of sagebrush shrublands and 1,100,000 ha of grasslands throughout much of the current and likely historical range of sage-grouse (Copeland et al. 2009). Sagebrush landscapes developed for energy production contained twice as many roads and power lines, and in some areas where ranching, energy development, and tillage agriculture coincided, human features were so dense that every 1 km^2 could be bounded by a road and bisected by a power line (Naugle et al., this volume, chapter 20). Sage-grouse respond negatively to different types of development, and conventional densities of oil and gas wells likely far exceed the species' threshold of tolerance (Naugle et al., this volume, chapter 20). Noise disturbance from construction activities and vehicles may also disrupt sage-grouse breeding and nesting (Lyon and Anderson 2003).

Highly productive regions with deeper soils throughout the sagebrush biome have been converted to agriculture, in contrast to relatively xeric areas with rather shallow soils that characterize the larger landscapes still dominated by sagebrush. Agriculture currently influences 49% of sagebrush habitats within the sage-grouse range through habitat loss or by large-scale fragmentation of remaining sagebrush. Potential predators on sage-grouse nests, such as Common Ravens (*Corvus corax*; Coates 2007), are subsidized by agriculture and associated practices. In addition, insecticides can be a major cause of mortality for sage-grouse attracted to lush croplands during summer brood-rearing (Blus et al. 1989).

The human footprint is defined as the cumulative extent to which anthropogenic resources and actions influence sagebrush ecosystems within the range of sage-grouse (Leu and Hanser, this volume, chapter 13). The levels and broad-scale effects of the human footprint across the sage-grouse distribution strongly support the importance of managing and maintaining sagebrush habitats at larger spatial scales than currently recognized by land management agencies (Leu and Hanser, this volume, chapter 13). The greatest influence of the human footprint was within the Columbia Basin SMZ, followed by the Wyoming Basin, Great Plains, Colorado Plateau, Snake River Plain, Southern Great Basin, and Northern Great Basin SMZs (Leu and Hanser, this volume, chapter 13). Populations within the Columbia Basin, which had the highest levels of human footprint, are decreasing and have a reasonably high likelihood of declining to <50 sage-grouse within 100 years (Garton et al., this volume, chapter 15).

The cumulative and interactive impact of multiple disturbances, continued spread and dominance of invasive species, and increased impacts of land use have the most significant influence on the trajectory of sagebrush ecosystems, rather than any single source (Knick et al., this volume, chapter 12). Sage-grouse populations and sagebrush habitats that once were continuous now are separated by agriculture, urbanization, and development. Thus, understanding how to conserve sage-grouse involves multiscale patterns and dynamics in sagebrush ecosystems as well as population trends, behavior, and ecology of sage-grouse (Knick et al., this volume, chapter 12).

Fifteen major threats (Table 24.1) have been identified in recent syntheses of sage-grouse conservation issues (Connelly and Braun 1997; Braun 1998; Connelly et al. 2004; Knick and Connelly, this volume). These reports generally agreed that energy development, drought, and wildfire posed a serious risk to sage-grouse conservation. Drought was listed in all reports, while energy development and wildfire were listed in three of four reports. Invasive species, grazing management, and urban development were listed in two of the three reports (Table 24.1). In addition, one federal agency and two state agencies convened expert panels to assess threats to sage-grouse populations (Table 24.2). Together, these panels listed 15 threats to sage-grouse and collectively identified energy development, wildfire, urban development, West Nile virus, conifer encroachment, and invasive species as the most serious threats to sage-grouse conservation. Considered as a whole, these seven different assessments of threats identified two levels of risk. Energy development, invasive species, drought, grazing management, and wildfire, listed on five threat assessments, constitute the first level and could be judged as the most significant range-wide threats to sage-grouse conservation. Urbanization and West Nile virus, listed on three or four assessments, represent the second level, suggesting a broad concern about these issues as well. Infrastructure was listed on two assessments and fences, roads, and reservoirs (all potential energy-related infrastructures) were listed separately on a third assessment. In summary, these efforts to identify threats

TABLE 24.1

Threats to sage-grouse identified by recent reviews.

Threat	Connelly and Braun (1997)	Braun (1998)	Connelly et al. (2004)	This volume
Agriculture		X		
Drought[a]	X	X	X	X
Energy development		X	X	X
Fences		X		
Grazing management	X			X
Hunting		X		
Invasive species			X	X
Predation		X		
Power lines		X		
Reservoirs		X		
Roads		X		
Urban development[b]		X		X
Vegetation treatments		X		
West Nile virus[c]				X
Wildfire	X		X	X

[a] Includes climate change induced drought.

[b] Includes factors associated with the human footprint.

[c] West Nile virus was first detected within Greater Sage-grouse range in 2002 after completion of the 1997 and 1998 assessments (Naugle et al. 2004).

suggest that energy development, invasive species, wildfire, grazing management, urbanization, West Nile virus, and infrastructure pose the greatest risk to long-term conservation of sage-grouse. The relative importance of each of these threats undoubtedly varies throughout the range of sage-grouse.

POPULATION AND HABITAT TRAJECTORIES

Lek size declined over the assessment period (1965–2007) for 20 of 28 (71%) populations that had sufficient data for analysis (Garton et al., this volume, chapter 15). Average rates of change declined between the 1995–1999 and 2000–2007 analysis periods for 20 of 26 (77%) populations (Garton et al., this volume, chapter 15). Nevertheless, 20 of 29 (69%) populations had an average rate of change ≥1 while nine of 29 (31%) populations had an average rate of change ≤1.0 for the 2000–2007 analysis period. Although lek size and average rates of change declined for six of seven management zones, all but one had an average rate of change ≥1.0 during the 2000–2007 analysis period. Only the Columbia Basin management zone had an average rate of change ≤1.0 during the last analysis period (Garton et al., this volume, chapter 15).

For 86% of management zones and 50% of populations, the best statistical model indicated a declining carrying capacity through time of −1.8% to −11.6% per year, and 18% of models for all populations and management zones indicated a lower carrying capacity in the last 20 years (1987–2007) compared to the first 20 years (1967–1987) of analysis (Garton et al., this volume, chapter 15). These lower carrying capacities support other findings in this volume suggesting that declines in quality and quantity of habitat for sage-grouse are continuing across regional and range-wide scales (Miller et al., this volume, chapter 10; Baker, this volume, chapter 11; Knick et al., this volume, chapter 12; Leu and Hanser, this volume, chapter 13). Forecasts of future population

TABLE 24.2

Threats to Greater Sage-Grouse identified by expert panels.

Threat	USFWS[a] panel	IDFG[b] panel	WGF[c] panel
Agriculture	X		
Climate change		X	
Conifer encroachment	X	X	
Energy development	X		X
Grazing management	X	X	X
Infrastructure	X	X	
Invasive species	X	X	X
Human disturbance		X	
Prescribed fire		X	
Seeded grassland		X	
Strip/coal mining	X		
Urbanization	X		X
West Nile virus		X	X
Wildfire	X	X	
Weather	X		

[a] U.S. Fish and Wildlife Service.

[b] Idaho Department of Fish and Game.

[c] Wyoming Game and Fish Department.

viability across 27 populations and all management zones suggest that 96% of populations and all management zones will likely remain above effective population sizes of 50 within the next 30 years. However, 78% of populations and 29% of management zones are likely to decline below effective population sizes of 500 within 100 years if current conditions and trends persist (Garton et al., this volume, chapter 15). Sage-grouse populations in the Colorado Plateau, Columbia Basin, and Snake River Plain management zones appear to be at higher risk than populations in core regions enclosed within the Great Plains, Northern Great Basin, Southern Great Basin, and Wyoming Basin management zones.

Trends in number of male sage-grouse counted at leks were correlated with several habitat features, although the relationships differed across the sage-grouse range (Johnson et al., this volume, chapter 17). In low-elevation regions, trends tended to be greater at higher elevations (i.e., positive correlations with elevation); the reverse was true in higher-elevation areas. Lek trends across all management zones increased steadily with cover of tall sagebrush at 5- and 18-km radii. Similarly, lek trends across all management zones increased with cover of all sagebrush (combined categories for tall sage and low sagebrush) at both radii (Johnson et al., this volume, chapter 17). In contrast, associations were negative with the coverage of agriculture and exotic plant species. Trends also tended to be lower for leks at which a greater proportion of the surrounding landscape had been burned (Johnson et al., this volume, chapter 17). Few leks were within 5 km of developed land, and trends were lower for those leks with more developed land within 5 or 18 km of the lek. Lek counts were reduced where communication towers were nearby, whereas no effects of power lines were detected. Producing oil or natural gas wells and paved highways, but not secondary roads, were also associated with lower counts (Johnson et al., this volume, chapter 17). Roads, power lines and other disturbances that have been in place for many years may have affected lek attendance in years prior to this analysis period (1997–2007), while other disturbances, such as communication towers, are relatively new; their effects may be expressed in the current data or may not have been detected due to lags in population response. Conversion of sagebrush habitats to cultivation and paved highways that occurred before the 1997–2007 study period likely continues to influence sage-grouse populations (Johnson et al., this volume, chapter 17).

Sage-grouse now occupy <60% of their probable historical range prior to European settlement (Connelly and Braun 1997, Schroeder et al. 2004). Moreover, synergistic feedbacks among invasive plant species, fire, and climate change coupled with current trajectories of habitat changes and rates of disturbance, both natural and human-caused, likely will continue to change sagebrush communities and create challenges for future conservation and management of sage-grouse populations and habitat.

CHALLENGES TO SAGE-GROUSE CONSERVATION

Conservation programs for sage-grouse populations and habitat can be developed to address threats (Stiver, this volume, chapter 2), but administrative or natural impediments to development and implementation of successful programs may still exist (Forbis et al. 2006). Land management agencies continually make decisions regarding land use actions and vegetation management (Knick et al., this volume, chapter 12). These agencies also develop programs to address potential or actual environmental issues including wildfire, invasive species, and vegetation restoration or rehabilitation efforts (Miller et al., this volume, chapter 10; Baker, this volume, chapter 11; Pyke, this volume, chapter 23). The continued interest in prescribed burning and other forms of sagebrush reduction in sagebrush-dominated landscapes (Wyoming Interagency Vegetation Committee 2002; Davies et al. 2008, 2009), despite a large body of evidence documenting the negative effects of these actions on sage-grouse, may continue to degrade and fragment sage-grouse habitats. Similarly, development of energy-related projects in key habitats will continue to negatively affect important sage-grouse habitat (Knick et al., this volume, chapter 12; Naugle et al., this volume, chapter 20).

Natural phenomena may act to degrade or eliminate sage-grouse habitat. Wildfire (Baker et al. 2006, this volume, chapter 11; Miller et al., this volume, chapter 10) and drought (Patterson 1952, Connelly and Braun 1997, Connelly et al. 2000a) can negatively affect sage-grouse populations. The incidence of wildfire may be reduced by suppression efforts, but fire will never be eliminated as a threat to sagebrush-dominated landscapes. Periodic drought will also be part of the arid west and pose a threat to sage-grouse productivity by reducing nest and chick survival (Connelly et al. 2000a). In addition, restoration following treatments, such as prescribed fire, often is severely hindered or is unsuccessful because of unpredictable weather and lack of precipitation necessary for plant establishment (Pyke, this volume, chapter 23).

Climate change also has an important influence on sagebrush landscapes (Miller et al., this volume, chapter 10). Climate change scenarios for the sagebrush region predict increasing temperature, atmospheric carbon dioxide, and severe weather events, all of which favor cheatgrass expansion and increased wildfire (Miller et al., this volume, chapter 10). Approximately 12% of the current distribution of sagebrush is predicted to be replaced by expansion of other woody vegetation for each 1°C increase in temperature (Miller et al., this volume, chapter 10). All of these factors are likely to result in a loss of sagebrush and decline of sage-grouse.

A broad array of invasive plants is widely distributed across the range of sage-grouse, has a major influence on the structure and function of sagebrush habitats, and presents significant challenges to the long-term conservation of sagebrush-dominated landscapes (Miller et al., this volume, chapter 10). Many sagebrush communities at low elevations are at moderate to high risk of invasion by cheatgrass (Wisdom et al. 2005b; Miller et al., this volume, chapter 10). At higher elevations, woodland expansion has altered the fire regime and resulted in loss of sagebrush and the understory of grasses and forbs (Miller et al., this volume, chapter 10).

Invasions into native plant communities may be sequential as initial invaders are replaced by a series of new exotics or by species adapting to new habitats within their range (Young and Longland 1996). For example, areas that were once dominated by cheatgrass in some locations in southwestern Idaho are now characterized by medusahead (*Taeniatherum caput-medusae*; Miller et al., this volume, chapter 10). Rush skeletonweed (*Chondrilla juncea*), which originally was localized to disturbed areas in drier sagebrush grassland communities, is now invading areas previously dominated by medusahead (Sheley et al. 1999) and following wildfire (Kinter et al. 2007).

Free-roaming equids (horses [*Equus caballus*] and burros [*E. asinus*]) in the United States were introduced to North America near the end of the 16th century. These species could be considered invasive, but they have unique management status and by law are neither hunted nor as intensively managed as livestock (Beever and Aldridge, this volume, chapter 14). Free-roaming horses can exert direct influences on structure and composition of vegetation and soils in sagebrush communities, as well as indirectly affect numerous animal groups whose abundance collectively may indicate the ecological integrity of such communities (Beever and Aldridge, this volume, chapter 14). Compared to ecologically similar sites in which horses were removed in the western Great Basin, sites that still supported wild horses had lower shrub cover, higher compaction of soil surfaces, more fragmented shrub canopy, lower grass cover, lower total vegetative cover, lower plant species richness, and lower density of ant mounds (Beever and Aldridge, this volume, chapter 14). Greater density of ant mounds at horse-free sites than at horse-occupied sites suggests that at least a portion of the invertebrate community is more robust at horse-removed sites, and may also reflect differences in level of ecological function (Beever and Herrick 2006).

Restoration of sage-grouse habitat is more complex than typical restoration projects, which often focus on individual sites and have objectives specific to that location (Pyke, this volume, chapter 23). Successful restoration of sage-grouse habitat will not only necessitate vegetation changes in a single area but will also require connectivity among patches of currently intact vegetation (Wisdom et al. 2005b; Meinke et al. 2009; Knick and Hanser, this volume, chapter 16; Pyke, this volume, chapter 23). Additionally, availability and cost are major obstructions to the use of native seeds in revegetation projects (McArthur 2004), and equipment for planting native seeds is not widely available (Wiedemann 2005).

Many partnerships and working groups throughout the West have begun to initiate efforts to assist in conservation of sage-grouse, including some restoration projects (Western Governors' Association 2004). Unfortunately, to the best of our knowledge, the effectiveness of these actions in stabilizing or increasing sage-grouse populations has yet to be documented. In part, this is because some projects are too recent to demonstrate positive effects, while others may have had competing interests or lacked a complete understanding of the ecological challenges during planning and implementation.

A ROADMAP TO CONSERVATION

Realistic approaches to issues, understanding threats, and implementing levels of effort appropriate to combat inherent challenges are important considerations in developing long-term conservation plans. We discuss many of the key issues presented in this volume and, based on the chapters within this volume, attempt to provide some insight and guidance to addressing these issues, threats, and challenges within the broad context of sage-grouse conservation.

Population Management

Harvest Management

Hunting opportunity for sage-grouse has been reduced where data suggested a negative impact from hunting and in response to general population declines of known and unknown origin. Seasons may need to be adjusted or reduced as necessary in those regions where sage-grouse continue to decline or are at risk of extirpation from other causes of mortality (Reese and Connelly, this volume, chapter 7). A risk-sensitive harvest strategy (Williams et al. 2004a) that avoids reducing individual populations of sage-grouse will require new research and continued routine population monitoring. We suggest social implications, as well as biological effects, are important considerations for management in areas where harvest is strictly controlled or altered to better conserve sage-grouse (Reese and Connelly, this volume, chapter 7).

Predation Management

Thus far, little information suggests that predator management should be routinely applied to conserve sage-grouse populations (Schroeder and Baydack 2001; Hagen, this volume, chapter 6). Where predator management is necessary, both lethal and nonlethal methods might be needed to buffer population sinks to increase survival and recruitment of grouse in these areas in the short-term (two to three years) from adverse effects of predation rates. The relatively broad financial and political costs to removing predators at a scale and extent that may be effective is no longer likely to be socially or ecologically viable (Messmer et al. 1999). Because of these considerations, predator management for sage-grouse has generally been accomplished most efficiently by manipulating habitat rather than by predator removal to enhance populations (Schroeder and Baydack 2001). For future sage-grouse conservation efforts, we recommend quantifying predator communities as they relate to demographic rates and habitat variables so the predator-cover complex as it pertains to sage-grouse life history can be better understood (Hagen, this volume, chapter 6). Additionally, information is needed on how species that prey on sage-grouse respond to anthropogenic changes on sagebrush-dominated landscapes (Coates 2007).

Disease Management

Documentation of population-level effects of parasites, infectious diseases, and noninfectious diseases related to toxicants is rare (Christiansen and Tate, this volume, chapter 8). Thus, little recent emphasis has been placed on managing this aspect of sage-grouse biology. Within the last few years, West Nile virus has had severe effects on some sage-grouse populations (Walker and Naugle, this volume, chapter 9). The severity of the potential impact and the need for more information require future studies to better document effects and relate outbreaks to environmental variables. The potential implications of climate change further underscore the need to effectively monitor disease impacts on sage-grouse (Christiansen and Tate, this volume, chapter 8; Miller et al., this volume, chapter 10). Many pathogens are sensitive to temperature, rainfall, and humidity (Harvell et al. 2002). Warmer climates can increase pathogen development and survival rates, disease transmission, and host susceptibility. Most host-parasite systems are likely to experience more frequent or severe disease impacts with warming climates (Harvell et al. 2002).

Habitat Management

Habitat Protection

Much sage-grouse habitat has been lost or altered, but substantial habitat still exists to support this species in many parts of its range (Connelly et al. 2004; Schroeder et al. 2004; Leu and Hanser, this volume, chapter 13). Characteristics of important habitats and general guidelines for protecting and managing these habitats are well known (Connelly et al. 2000b, Crawford et al. 2004, Hagen et al. 2007). We suggest the most effective strategy to stabilize or recover many sage-grouse populations will be protecting existing sagebrush habitat (Stiver et al. 2006). Energy development and other anthropogenic change represent substantial challenges to protecting existing habitat, and will require development and implementation of broad-scale and long-term conservation plans (Stiver et al. 2006; Stiver, this volume, chapter 2) that are carefully developed using the best available data. A wide range of local and regional concerns may need to be considered, including urban development, fire, grazing (livestock, equid, and wildlife), fragmentation, roads, structures, invasive species, West Nile virus, and habitat quality and quantity. The importance of each of these issues varies spatially and temporally.

Landscapes with high biological value for sage-grouse and high risk for development represent the greatest challenge facing land use managers. This is a concern because 44% of areas with high biological value are at risk for energy development (Doherty et al., this volume, chapter 21). The rapid pace and scale of energy development is a major issue, because areas being developed include some of the largest remaining sagebrush landscapes with the highest densities of sage-grouse in North America (Connelly et al. 2004; Doherty et al., this volume, chapter 21). Sage-grouse conservation faces major challenges in the eastern portion of the species' range, where 44% of the lands that the federal government has authority to control for oil and gas development has been authorized for exploration and development (Naugle et al., this volume, chapter 20; Doherty et al., this volume, chapter 21). Severity of impacts and extensive leasing of the public mineral estate suggest a need for landscape-scale conservation (Holloran 2005, Aldridge and Boyce 2007, Walker et al. 2007a). Lease sales continue, despite concerns, because no policy is in place that would permit an environmental assessment of risk at the scale at which impacts occur.

Areas of high biological value combined with low energy potential represent regions where conservation actions can be immediately implemented (Doherty et al., this volume, chapter 21). Currently, 17% of the eastern sage-grouse range has high biological value and low risk from energy development (Doherty et al., this volume, chapter 21). Maintaining these quality sage-grouse habitats, especially in areas adjacent to development or where development is planned, will be critical to ensure genetic connectivity (Oyler-McCance et al. 2005a,b) and persistence of source populations for natural recolonization after energy development activities have ceased (Gonzalez et al. 1998). Reducing risks from other stressors to sagebrush habitats will be an important component of conservation strategies in high value and low energy potential areas (Klebenow 1970; Connelly et al. 2000a,b; Leonard et al. 2000; Smith et al. 2005; Walker et al. 2007a). Habitat loss to agricultural development (Farrell et al. 2006, United States Government Accounting Office 2007), urban and exurban expansion (Theobald 2003, 2005), and conversion to communities dominated by invasive plants (e.g., cheatgrass; Bergquist et al. 2007) are significant concerns in many of these regions.

Conservation easements are one tool to reduce residential development and agricultural conversion on private lands (Kiesecker et al. 2007). A preponderance of private surface ownership in Montana and Utah coupled with low risks of development make core regions in many parts of these states ideal places to develop incentives for ranching and rural lifestyles through long-term programs such as the Conservation Reserve Program (CRP; Schroeder and Vander Haegen, this volume, chapter 22). Opportunities for easements and management programs are available in other states, but long-term viability of them is a public policy decision (Doherty et al., this volume, chapter 21).

Areas of low biological value and low energy potential represent low-conflict opportunities for sage-grouse and could be important in maintaining connectivity to high value core regions (Doherty et al., this volume, chapter 21). Restoration of these linkage habitats will be a key strategy in some areas. Many of the low value and low potential areas identified by Doherty et al. (this volume, chapter 21) are the same areas where continued range contraction is expected to be most severe (Aldridge et al. 2008; Garton et al., this volume, chapter 15). Aggressive habitat protection and restoration programs may be necessary to maintain the biological integrity of fringe populations in North Dakota, South Dakota, northern Montana, and Canada. Explicitly combining information about vulnerability of landscapes to anthropogenic risk allows planners to consider the relative urgency and likelihood of success of a given conservation strategy (Wilson et al. 2005, Copeland et al. 2007, Pressey and Bottrill 2008). Core regions and assessment of potential impacts these regions may experience represent a starting point to begin conservation of landscapes where results will have the largest benefit to populations. Prioritizing landscapes simply reflects the reality that threats are large, resources are limited, and conservation actions targeting all remaining populations are not feasible (Wisdom et al. 2005c, Meinke et al. 2009). Identification of core regions represents a proactive attempt to maintain a viable and connected set of populations before the opportunity to do so is lost (Knick and Hanser, this volume, chapter 16; Doherty et al., this volume, chapter 21).

Strategies that are integrated among all states and provinces involved for landscape-scale conservation are most likely to be successful. Successful implementation of conservation strategies in one state or province may not be sufficient to compensate for losses in other areas. Conservation concerns related to sage-grouse will present challenges until collaborative landscape planning and conservation are implemented. Doherty et al. (this volume, chapter 21) provide a framework for planning across political boundaries and suggestions for measuring success.

Habitat Restoration

Much of the original sage-grouse habitat has been permanently lost to agricultural development and urban areas, and the remaining habitat ranges in condition from high quality to inadequate (Pyke, this volume, chapter 23). Sage-grouse require somewhat different seasonal habitats distributed over large areas to complete their life cycle. Thus, restoration that incorporates a broad perspective when considering when and where to restore lands is likely to be the most effective for improving sage-grouse habitat. Restoration decisions are often difficult because of economics, restoration potentials, status of existing habitat, and logistics such as landownership or topography (Knick, this volume, chapter 1).

Prioritization is an important first step in a successful restoration plan for selecting sites when resources are limited (Wisdom et al. 2005c, Meinke et al. 2009). The triage approach is an initial prioritization technique where ecosystems are grouped into three categories, one that receives immediate care and two others where no urgent care is warranted (Pyke, this volume, chapter 23). The category provided immediate care and intervention has significant damage requiring immediate intervention to aid likely recovery. The second category needs no immediate intervention and, with some later treatment, will likely recover, whereas the third category represents areas so severely damaged they could not recover even with intervention (Kennedy et al. 1996, Samways 2000). A framework was presented (Doherty et al., this volume, chapter 21) that demonstrated tradeoffs between sage-grouse conservation and energy development. However, landscape planning for sage-grouse is likely to be most successful if it includes restoration and identifies core regions (Doherty et al., this volume, chapter 21) that reflect seasonal habitats and migration of radio-marked sage-grouse (Connelly et al. 1988, Aldridge and Boyce 2007, Doherty et al. 2008) to ensure priority landscapes meet, or with restoration will contribute to, all habitat needs. Moreover, future modeling of other relevant risks, such as invasive species, will help ensure that gains in conservation will not be offset by unknown risks (Doherty et al., this volume, chapter 21).

Functioning landscapes that consist of an integrated mosaic of individual sites are important objectives when considering type and level of restoration intervention for improving sage-grouse habitat (Pyke, this volume, chapter 23). Reasons for considering larger areas than the restoration site alone are based on criteria relating to sage-grouse biology as well as the likelihood of restoration success. Sage-grouse have large annual and seasonal home ranges (Connelly et al. 2000b) that often exceed the size of restoration projects. In addition to enhancing existing native habitats, restoring adjacent lands presently in tillage agriculture to sagebrush-dominated grasslands could facilitate the larger goal of landscape restoration (Schroeder and Vander Haegen, this volume, chapter 22).

Effective restoration and rehabilitation of sage-grouse habitat focuses on maintaining or improving key habitat components necessary for survival and reproductive success. We caution that simply replacing vegetation components may not produce the intended benefit to sage-grouse populations. The negative influence of fire and the human footprint, not sagebrush quantity or configuration, were the significant factors in persistence of sage-grouse leks (Knick and Hanser, this volume, chapter 16). Reestablishing suitable vegetation will be difficult because of increasing fire frequencies throughout much of the sage-grouse range coupled with long periods for vegetation recovery (Baker, this volume, chapter 11). Increasing levels of all land uses for traditional commodity development as well as for recreation and exurban living by a growing human population also indicate that the human footprint will continue to be a primary impediment to successful restoration.

Passive restoration goals focus on maintaining sagebrush cover while increasing grass cover and height and increasing forb cover and reproduction (Pyke, this volume, chapter 23). This could be achieved through setting appropriate livestock stocking levels while shifting grazing seasons to periods when active growth is slow and plant reproduction has not been initiated (Kirby and Grosz 1995, Norton 2005, Sidle 2005). Active restoration is necessary in some situations to reestablish a sagebrush overstory with an understory mixture of native forbs and short, mid, and tall grasses (Pyke, this volume, chapter 23). Appropriate native sagebrush species and subspecies for the site are significant factors in successful restoration for sage-grouse. Nevertheless, we recognize that some efforts may require introduced species such as palatable forbs and bunchgrasses to quickly stabilize soils as well as different techniques to achieve similar goals.

Effective restoration will require protection and proper management for maintenance of intact, healthy sagebrush grasslands, while identifying those lands where modifications to management might improve quality habitat for sage-grouse (Pyke, this volume, chapter 23). Strategic placement will be critical for enhancing the likelihood of restoration success while minimizing costs. Unfortunately, sagebrush grassland restoration is largely in its infancy. Large acreages are still being affected by invasive species and wildfire, while funding and resources necessary for rehabilitating these areas are often severely limited. Farm programs such as the CRP have the potential to affect large portions of the landscape and positively influence sage-grouse populations in some parts of the species' range (Schroeder and Vander Haegen, this volume, chapter 22). However, these programs can only be applied to private lands; comparable programs to affect public land at a similar scale with effective restoration are needed. We are concerned that many lands currently in the CRP and benefiting sage-grouse populations are increasingly being converted to other uses, such as production of biofuels (Fargione et al. 2009).

Monitoring and Assessment

Throughout the sagebrush biome, various natural and anthropogenic actions are and will be occurring that may have positive (e.g., restoration work) or negative (e.g., energy development, wildfire) effects on sage-grouse. Monitoring and assessment activities are necessary to provide an objective appraisal of the effects of potentially positive activities and assess the relative damage to sage-grouse populations or habitats of potentially negative actions.

Protocols that include statistically sound sampling and analysis designs are necessary to obtain unbiased information. Casual field surveys, ocular assessment, and other forms of subjective evaluation provide unreliable information. For proposed projects that occupy spatially discrete (as opposed to dispersed) areas, a before-after-control-impact (BACI) design may provide the most powerful statistical approach.

To assess population effects, we recommend that BACI include marking sage-grouse at each impact and control site. Required sample sizes of marked birds will vary depending on size and extent of the grouse population being considered, questions being asked, and marking technology employed. We recommend capturing and marking birds in a manner that allows sampling of the entire project area, focusing on leks most proximate to the proposed impact site(s). We also recommend marking additional female grouse in an 18-km buffer zone to characterize the migratory status of the population, but this sample will not allow evaluation of avoidance behavior. Because of the effect of lag periods on population response, a minimum of at least three years pre-construction and four years post-construction may be required in addition to the year of construction to fully assess project effects on grouse populations. Given the lifespan of sage-grouse, strong fidelity to breeding areas, and lag effects in population dynamics, some longer-term (8–12 years), less-intensive monitoring will be necessary to fully assess impacts.

Unbiased characterization of habitat use or habitat change requires a random sampling approach and often a stratified random sample. Strata will depend on vegetation, treatment, and topographic characteristics of the area. Most habitat assessments will include measurements of one or more of the following: cover, height, density, frequency, and visual obstruction for individual plant species or groups of species (Connelly et al. 2003b). Density, height, and frequency are direct measurements or counts, but canopy or foliar cover can be estimated by several techniques. Well-recognized techniques that are largely free of observer bias and that can be easily replicated in other studies are important in ensuring widespread application and interpretation of results.

We have emphasized throughout this volume that the Greater Sage-Grouse is a landscape species. Although regional and range-wide dynamics of sage-grouse populations are monitored (Reese and Bowyer 2007), we have yet to develop protocols to assess landscape change in sagebrush habitats (West 2003a,b). Recent analyses suggest that >25–30% sagebrush and <25% agriculture are threshold levels at a landscape scale important to maintaining sage-grouse populations (Aldridge et al. 2008; Wisdom et al., this volume, chapter 18). Other studies have emphasized the importance of the landscape surrounding sage-grouse leks for distances up to 54 km (Holloran and Anderson 2005; Walker et al. 2007a; Knick and Hanser, this volume, chapter 16). Landscape effects also were significant in winter habitat selection by sage-grouse (Doherty et al. 2008). Thus, monitoring approaches that detect changes in quantity, composition, and configuration in regional and range-wide landscapes would significantly improve our ability to relate environmental features at the primary scales driving population dynamics.

Well-planned and carefully implemented monitoring and assessment will allow an objective evaluation of conservation measures over varying temporal and spatial frames. It will also provide an unbiased assessment of impacts that can be used to guide appropriate mitigation efforts.

CONSERVATION IMPLICATIONS

Much is known about the biology of sage-grouse and its response to various management actions as well as natural and anthropogenic disturbance. Despite this knowledge, many threats to sage-grouse and numerous constraints to successful conservation for this species and its habitats remain. Rigorously and objectively addressing these threats and constraints should result in sound management practices and decisions that perpetuate sage-grouse populations.

A minimum of 88,816 male sage-grouse were counted on 5,042 leks in 2007 (Garton et al., this volume, chapter 15), and sagebrush is the dominant land cover on approximately 530,000 km^2 within sage-grouse range (Knick, this volume, chapter 1). Therefore, even though some populations are declining and a few have a relatively low likelihood of persistence, opportunities to conserve sage-grouse throughout much of the species' current range still exist.

Land and wildlife managers, as well as policymakers, face many challenges and difficult decisions. We have attempted to assemble a volume that presents unbiased, current information spanning multiple facets of Greater Sage-Grouse and their habitats. The information, presented from an ecological perspective, is intended to aid sage-grouse conservation efforts, including those currently undertaken for the very similar Gunnison Sage-Grouse. We hope that this volume on sage-grouse populations and their habitats will be used to inform these decisions and guide policies in a manner that will allow future generations to enjoy this icon of the West.

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