IV. ISSUES POTENTIALLY AFFECTING GrSG

In this section, we list and provide a review of scientific and management literature on the issues that may impact GrSG populations and/or habitat. Some of the topics identified include both positive and adverse impacts to GrSG. Issues are presented in alphabetical order.

Agricultural Conversion

In the past, thousands of acres of native sagebrush were converted to cropland and non-native pasture through plowing or mechanical and chemical removal of sagebrush plants. Such conversion usually resulted in long-term loss of habitat and often occurred on the deepest and most productive soils, which supported favored wintering sites for sage-grouse. Loss of winter sage-grouse range, which usually makes up a small portion of year-round range, has been shown to result in long-term losses of sage-grouse population (Swenson et. al. 1987).

Native rangeland has been converted to cropland, hayland, and pasture throughout GrSG habitat in Colorado. Large areas of native range that were present in the early 20th century were converted to irrigated pasture and hayland. Initially, conversion was adjacent to streams and rivers where it was less difficult to divert water for irrigation. As more complicated irrigation systems were developed, native rangelands beyond those adjacent to streams and rivers were converted to irrigated pastures. Additionally, many areas of native GrSG habitat were converted to dry cropland during the 1960s and 1970s when small grain prices were high, especially in Moffat and Rio Blanco counties.

Due to factors such as loss of access to water resulting from erosion in waterways, abandonment of homesteads, changes in agricultural techniques, government assistance programs, transfer of water rights, and changes in agricultural markets, the number of acres of cropland, non-native pastureland and hayland has varied throughout the last century. Records are inconsistent, but as of 2002, the amount of land considered agricultural is less than in the 1950s and 1960s (Table 15). Initially some conversion may have benefited GrSG by providing brood areas on the fringes of fields where forbs and insects are plentiful. However, as the size and quantity of native range patches plowed for agriculture purposes increased, impacts on sage-grouse were also amplified.

Accurate historical data about specific types of cropland are not available, but it is likely the acreages peaked in the 1960s and 1970s and have since decreased in many counties due to conversion to non-agricultural uses such as commercial, residential, oil, and gas development (see “Energy and Mineral Development” [pg. 109] and “Housing Development” [pg. 154] issue sections).

Table 15. Acres of land in agricultural production, not including rangeland: includes irrigated cropland, non-irrigated cropland, irrigated pasture and hayland, non-irrigated pasture and hayland (U.S. Department of Agriculture 2006*b*).

County	Agricultural Acres 1910[a]	Agricultural Acres 1954	Agricultural Acres 2002
Eagle	25,401	28,542	6,399
Garfield	61,818	76,209	22,073
Grand	30,097	55,094	19,706
Jackson	74,737	103,527	44,248
Mesa	73,508	112,420	49,417
Moffat	Part of Routt[b]	107,947	40,370[c]
Rio Blanco	36,750	51,237	18,048[d]
Routt	92,328	127,599	44,987
Summit	6,503	8,689	2,299

[a] The 1910 agricultural statistics do not provide total cropland acres, but has "improved land in farms".
[b] In 1910 Routt County included the area currently known as Moffat County.
[c] Non-disclosed total cropland acres. The amount shown is the total irrigated acres, plus wheat, oat, and estimated fallow acres.
[d] Non-disclosed total cropland acres. The amount shown includes the irrigated acres, plus the one non-disclosed, non-irrigated farm, sized 500-999 acres.

The 1985 Farm Bill authorized the USDA Farm Service Agency (FSA) to administer the CRP (Conservation Reserve Program) for protecting highly erodable soils and reducing production of crops. Under the CRP, over 2.3 million acres of cropland in Colorado were planted to permanent cover, usually perennial grasses, which in many instances have become important wildlife habitat. Moffat, Routt, Rio Blanco and Garfield are the only counties with GrSG habitat and significant amounts of CRP. Most CRP contracts last for 10 - 15 years and, until recently, grazing and harvesting of the permanent cover were not allowed except during extreme drought or other emergency conditions. Beginning in 2003, limited (not during nesting season) haying and grazing have been allowed for stand maintenance. Many of the current CRP contracts are due to expire in 2007 (Table 16).

Table 16. CRP expiration status through 2008 (U.S. Department of Agriculture 2006*a*).

County	Acres of Cropland Enrolled in CRP, 2006	Acres of CRP Expiring 09/30/2007	Acres of CRP Expiring 09/30/2008
Eagle	0	0	0
Garfield	3,641	3,020	142
Grand	0	0	0
Jackson	17	0	17
Mesa	16	0	16
Moffat	32,984	26,441	6,359
Rio Blanco	2,762	1,799	560
Routt	17,604	14,619	1,516
Summit	0	0	0

FSA has announced that it will offer certain CRP participants the opportunity to re-enroll in new CRP contracts, or to extend their current contracts. The FSA has ranked each expiring contract according to the Environmental Benefits Index (EBI) factors at the time of the original offer, and whether the property fell within a national priority area. None of the national priority areas were located in Colorado, and few of the participants with expiring contracts will be given the opportunity to re-enroll. Of the 14,619 acres set to expire in Routt County, only 17 acres are eligible for re-enrollment (Table 16). The owners of the remaining 14,600 acres will be given the opportunity to extend their contract for a period of 2 to 5 years, depending on their properties' EBI score. Many of these lands will only be allowed a 3-year extension. The situation in Moffat County is similar, with few contracts eligible for re-enrollment and the vast majority of the 26,000 acres only eligible for an extension (Table 16).

The future of CRP and how it affects GrSG is uncertain. Some CRP lands have been out of crop production for over 15 years. Sagebrush, native forbs, and native grasses are beginning to reestablish. Because CRP establishes relatively permanent cover, it provides more year-round security to wildlife than does land under cultivation (Stinson et. al. 2004). Use of CRP lands by GrSG in Colorado is not well-documented, but in some instances they do use it (A. D. Apa, CDOW, personal communication). CRP is important sage-grouse habitat in the state of Washington, especially fields that have been planted with seed mixes that include sagebrush and native grasses (Schroeder et al. 2000). In Colorado, perennial grasses are dominant in CRP fields, with a few shrubs present. When such fields are located near other habitat with a significant sagebrush component, GrSG may use the field edges for food, and occasionally for nesting. If CRP lands are re-enrolled and maintenance practices are limited, native vegetation could re-establish and become suitable habitat for GrSG. CRP lands offer opportunity for restoration of suitable habitat. If CRP lands are not re-enrolled, most will likely remain in perennial grass, but management will become more intense (grazing and haying) and the establishment of native suitable GrSG habitat will be less likely. If for some reason agriculture markets for wheat, barley, or some other unforeseen crop become profitable, expiring CRP lands may be plowed out, resulting in severe impacts to GrSG and other wildlife.

Disease and Parasites

Nothing has been published about the types or pathology of diseases in GrSG; however, multiple bacterial and parasitic diseases have been documented in GrSG (Patterson 1952, Schroeder et al. 1999). Most infections reported produce no, or minor, ill effects in sage-grouse (Patterson 1952). Rangewide or statewide impacts of bacterial or parasitic diseases on sage-grouse have not been reported.

Bacterial Diseases

Diseases caused by bacteria are more common in wild birds than diseases caused by viruses (Friend and Franson 1999). The frequency of bird deaths related to infectious bacterial diseases has increased in recent years (Friend and Franson 1999).

Avian Cholera

Avian cholera is a contagious disease that results from a bacterial (*Pasteurella multocida*) infection, although several species of bacteria have also been implicated. Infections in free-ranging grouse have not been documented (Connelly et al. 2004); the group of birds most commonly found with avian cholera is waterbirds (Friend and Franson 1999). Avian cholera is not considered a significant issue for free-ranging grouse in Colorado.

Avian Tuberculosis

Avian tuberculosis is typically caused by a bacterium (*Mycobacterium avium*). Captive-reared gallinaceous birds (e.g., pheasants and quail) are more commonly infected than waterfowl, but free-ranging wild birds that contract the disease are more commonly found in close association with domestic stock or are scavenging species (e.g., crows, ravens, and gulls; Friend and Franson 1999). Avian tuberculosis is not considered a significant issue for GrSG rangewide (Connelly et al. 2004), or in Colorado.

Salmonellosis

Avian salmonellosis is caused by a group of bacteria (*Salmonella* spp). Different species of salmonella can cause pullorum disease (*S. pullorum*) or fowl typhoid (*S. gallinarum*), which are typically found in captive poultry operations. Infections in wild birds can occur, but infection rates are low and are typically caused by variants of salmonellae. Connelly et al. (2004) reported (from Post 1960) that only one case of a *Salmonella* spp. caused dysentery in Wyoming. All sage-grouse (n=73) tested for *S. pullorum* and *S. gallinarum* in northwestern Colorado in 2001 and 2002 were negative for the disease (Hausleitner 2003). Avian salmonellosis is not considered an issue to free-ranging Colorado sage-grouse populations.

Chlamydiosis

Chlamydiosis is an infection caused by bacteria (*Chlamydia* spp.), and the species *Chlamydia psittaci* is usually associated with birds (Friend and Franson 1999). It occurs infrequently in wild gallinaceous birds (Friend and Franson 1999) and is therefore not considered an issue in Colorado.

Mycoplasmosis

Mycoplasmosis is caused by an infection from a relatively unique group of bacteria (*Mycoplasma*). Although mycoplasmosis is generally considered to not be an important disease in wild birds (Friend and Franson 1999), *M. gallisepticum* is a known pathogen of upland gamebirds that are raised in captive situations. Chickens and turkeys are primary hosts for *M. gallisepticum, M. synoviae, and M. iowae.* Chickens and turkeys have been hosts for *M. gallopavonis, M. cloacale, M. gallinarum, M. gallinaceum, M. pullorum, M. iners, M. lipofaciens*, and *M. glycophilum*. A 2001 serology analysis on sage-grouse from northwestern Colorado found a 55% occurrence of *M. synovinae* in females and a 92% occurrence rate in males (Hausleitner 2003). In 2002, the occurrence of *M. synoviae* was 12% for females and 6% for males (Hausleitner 2003). Although tests were conducted by independent laboratories, there is concern for false positive tests. Hausleitner (2003) did not find any relationship with the presence of the disease and GrSG nest initiation rates, clutch initiation dates, clutch size, or nest success.

Tularemia

Tularemia is a disease typically associated with mammals, but natural infections by *Francisella tularensis* have caused die-offs in grouse (Friend and Franson 1999). Friend and Franson (1999) list ruffed, sharp-tailed, blue, and sage-grouse as susceptible to infections, along with ptarmigan, bobwhite quail, and pheasants. Parker et al. (1932) found that sage-grouse that died in an epizootic in Montana were infected with *Francisella tularensis*, although the grouse were also heavily infected with bird ticks (*Haemaphysalis chordeilis*).

<u>Fungal Diseases</u>

Aspergillosis

Aspergillosis is a respiratory tract infection caused by a fungus (*Asperillus fumigatus*; Friend and Franson 1999). This is the primary species that causes infections in wild birds. This fungus lives in dead or decaying organic matter associated with human activities, and thus is not considered an issue for wild populations of GrSG in Colorado. In Wyoming, the death of 1 sage-grouse due to aspergillosis was documented (B. Walker, CDOW, personal communication).

Viral Diseases

West Nile Virus

West Nile virus (WNV) is a relatively new and potentially important disease for sage-grouse (Naugle et al. 2004). The virus has rapidly spread through the country, occurring in all states by December 2004. Transmission occurs when mosquitoes acquire the virus by biting an infected bird, and then transfer it by feeding on a new host (avian or mammalian). WNV causes illness and death in birds that have no natural resistance to the infection. Mortalities from the virus have been discovered in 234 bird species (Centers for Disease Control and Prevention 2004). Most documented mortalities have occurred in the family Corvidae, which includes crows, ravens, and jays. The data are based on specimens brought to local health departments by the public for testing (Centers for Disease Control and Prevention 2002) and on laboratory tests (Komar et al. 2003). Six North American gallinaceous species, including the GrSG, are known to be susceptible to the virus (U.S. Geological Survey 2003).

Exposure to WNV is thought to be low in arid sagebrush habitats, but may increase with the addition of man-made water sources that support breeding populations of mosquitoes that vector the virus (especially *Culex tarsalis*; Naugle et al. 2004, Zou et al. 2006, Walker et al. 2007*b*). Sage-grouse typically die within 3 - 7 days of WNV infection (Clark et al. 2006), but a small proportion of birds (1.8 - 10.3%) appears to be resistant to the disease following infection (Walker et al. 2007*b*).

Through 2006, WNV had been detected in 5 of 8 Colorado counties (excluding Larimer County) occupied by GrSG (U.S. Geological Survey 2007). Although the virus was detected in wild bird, horse, and/or mosquito samples, it was not detected or was not widespread in sage-grouse through 2005. There have been no positive reports of WNV in mosquitoes, horses, or birds in Rio Blanco, Jackson, or Summit counties.

In early August 2004, WNV was confirmed in the remains of a radio-collared female GrSG in south Routt County, Colorado. Eight other radio-collared GrSG in the area continued to show normal activity. WNV surveillance was also conducted on sage-grouse in the 2005 season and no WNV mortalities were detected. Female and juvenile sage-grouse have been monitored in Moffat County from 2001–2007 and WNV mortalities were detected in 2006 and 2007 (Table 17).

Table 17. Date and location of GrSG mortalities due to WNV in northwestern Colorado in 2006 (CDOW, unpublished data).

Study Area[a]	Date Found Dead	Age at Death[b]	Location[c]
AB	8/2/06	A	MC
AB	8/19/06	A	MC
CSM	6/8/06	A	MC
AB	8/31/06	A	MC
CSM	5/30/06	Y	SC
AB	8/4/06	chick	MC
AB	8/23/07	A	MC

[a]AB = Axial Basin / Danforth Hills; CSM = Cold Springs Mountain
[b]A = adult; Y = yearling
[c]MC = Moffat County, Colorado; SC = Sweetwater County, Wyoming

Avian Pox

Avian pox is a mild-to-severe disease that is slow to develop and is caused by a virus that belongs to the avipoxvirus group and the poxviruses subgroup. Avian pox is transmitted primarily by mosquitoes. Avian pox is reported as having multiple occurrences in upland gamebirds (Friend and Franson 1999), and is suspected as a reason for the decline of northern bobwhite populations in the southeastern United States (Friend and Franson 1999). DuBose (1965) documented 1 captive greater sage-grouse with avian pox. Hansen (1999) suggests that the increase in the frequency of the disease and high visibility and involvement of new bird species suggests that avian pox might be emerging as an important viral disease.

Newcastle Disease

Newcastle disease is caused by an infection with an RNA (ribonucleic acid) virus within the avian paramyxovirus-1 group. It is highly contagious but the severity is dependent upon the virus strain (Friend and Franson 1999). The most virulent cases in chickens have shown mortality rates reaching 100%. The Newcastle disease virus is capable of infecting many species of birds. It has been detected in captive pheasants and grey partridge, but large-scale mortalities have not been found in wild birds with the exception of double-crested cormorants in the United States and Canada. Newcastle disease has never been documented in GrSG (Connelly et al. 2004) and is considered low for susceptibility to exposure.

Avian Influenza

Avian influenza is a viral infection in wild birds that is caused by a group of viruses called “type A” influenzas. The normal route of transmission is fecal-oral. Avian influenzas have been identified in several bird species, but they are typically associated with migratory waterfowl, specifically mallards (Friend and Franson 1999). Wild quail and pheasants have also contracted influenza viruses. Friend and Franson (1999) categorize the relative occurrence of avian influenza in upland gamebirds as occasional. Fifty-two greater sage-grouse were tested for avian influenza in 2001-2002 and all tests were negative (Hausleitner 2003).

Parasitic Diseases

Hemosporidiosis (Avian Malaria)

Avian malaria is caused by a protozoan (*Plasmodium pediocetti*). It is a parasitic protozoan found in the blood cells and tissues of avian hosts. It is transmitted to uninfected birds by many different biting flies, mosquitoes, black and louse flies that serve as vectors. Avian malaria has not been documented as causing widespread mortalities in wild bird populations but could have an adverse effect on populations. The daily cycle of the disease causes infected birds to be less active in morning hours, thus affecting male sage-grouse courtship and reproductive success (Boyce 1990, Johnson and Boyce 1991).

Intestinal Coccidiosis

Coccidiosis is caused by a protozoan, *Eimeria* spp. Coccidia are important to domestic animals, but are generally self-limiting in free-ranging bird species. Infections can become problematic if habitat or weather conditions cause abnormal concentrations of birds (Friend and Franson 1999). Coccidiosis has been documented in the Axial Basin and Great Divide areas of Moffat County (Carhart 1943, Grover 1944) and elsewhere (Patterson 1952, Honess and Post 1968), but such outbreaks do not appear common. Typically, outbreaks have occurred in summer when grouse may concentrate around water sources (Carhart 1943, Wallestad 1975). Disease transmission occurs through ingestion of water contaminated by infected feces. Birds that recover from the infection carry some level of immunity (Friend and Franson 1999).

Tracheal Worms

Tracheal worms can cause infections that result in respiratory distress because of their location in the trachea or bronchi, where they can obstruct air passage. Land-dwelling birds are usually infected by nematodes or roundworms (*Syngamus trachea*). Diseases caused by tracheal worms are not considered serious as they are not commonly reported for free-ranging ground dwelling birds (Friend and Franson 1999).

Gizzard Worms

Gizzard worms are represented in bird species by several species of parasitic nematodes and roundworms. Gizzard worms typically are nematodes (e.g., *Amidostomum* spp. and *Epomidiostomum* spp.), but other species of gizzard worms are found in gamebird species (Friend and Franson 1999).

Cestodes

Tapeworms are common in many wild bird species and have been documented in greater sage-grouse in Colorado (Carhart 1943). Little is known regarding their impact, but heavy loads of tapeworm have been found in many birds. The species documented with sage-grouse is *Raillietina centroceri* (Honess 1982).

Ectoparasites

Ectoparasites can transmit disease and can contribute to the direct mortality from illness and death. The fowl tick from the family Argasidae is most common in the poultry industry and therefore could be transferred to grouse. Heavy infestations of lice, mites, fleas, flies and other biting insects have been documented to cause the death of wild birds (Friend and Franson 1999), but may also be a sign of other health problems. More research needs to be conducted on ectoparasites because little is known.

Conclusions

WNV currently poses the greatest disease issue for wild GrSG, although the number of mortalities confirmed from WNV has been low in Colorado. Despite the fact that the most common game farm birds do not undergo disease testing when imported to Colorado, disease transmission from introduced gallinaceous birds to GrSG remains a possibility. As of December 2005, only 6 private bird farms have been licensed within counties that are occupied by GrSG. Eagle and Grand/Summit counties each have 1 farm, while Garfield and Moffat counties each have 2 farms. The potential impact of unpermitted releases of diseased pheasants and turkeys is unknown. The 2 diseases that have been documented in sage-grouse are coccidiosis and tularemia, and they are uncommon. The diseases tested for in imported grouse and turkeys (*Salmonella* and *Mycoplasma*) have not been studied or documented in wild sage-grouse. The possibility for diseases of introduced or captive birds to spread to GrSG may increase if efforts to raise GrSG in captivity are initiated.

Energy and Mineral Development

Introduction

Rising energy prices and new extraction technologies have recently led to an increased emphasis on developing domestic energy resources, many of which are located beneath sage-grouse habitat in the western United States.

One result is a dramatic increase in oil and gas development over the past 6 years on federal lands: "Nationwide, the total number of oil and gas drilling permits approved by BLM more than tripled, from 1,803 to 6,399 for fiscal years 1999 through 2004" (U.S. Government Accountability Office 2005:17). The majority of the increased oil and gas activity has been concentrated in Colorado, Montana, New Mexico, Utah, and Wyoming (U.S. Government Accountability Office 2005), and much of the activity in Colorado overlaps with GrSG habitat (Fig. 20).

The COGCC (Colorado Oil and Gas Conservation Commission 2006) reported that approved Applications for Permits-to-Drill (APDs) increased 50% from 2004 to 2005 (from 2,915 to 4,373; Fig. 21), and permits in 2006 increased another 35% over 2005 (from 4,373 to 5,904; Fig. 21; Colorado Oil and Gas Conservation Commission 2007*a*). Early 2007 APD statistics suggest that the number approved in 2007 could reach 6,350 (Colorado Oil and Gas Conservation Commission 2007*b*). This increase in permits dwarfs that seen in the energy boom of the early 1980s (Fig. 21). The majority of these permits are for new wells; in 2005, 99% of the permits were for new wells. In Garfield County (one of the counties overlaying the PPR GrSG population), drilling permit totals more than tripled from 2003 (566 APDs) to 2006 (1,844 APDs; Colorado Oil and Gas Conservation Commission 2006, 2007*a*). Many of these wells are likely to be developed within GrSG habitat.

In May, 2007, 2 new energy development-related bills were passed through the Colorado State legislature. Both are geared at finding a better balance between oil and gas development in the state and providing adequate protection for wildlife and natural resources. The first bill, HR1341, reorganized the COGCC to include 7 appointed members, including 3 members with expertise in the oil and gas industry, 1 member with substantial expertise and/or experience in wildlife or the environment, and 1 member with soil conservation and/or reclamation expertise. The intent was to balance representation on the committee that governs decisions regarding oil and gas development in the state. The second bill, HR 1298, The Colorado Habitat Stewardship Act of 2007, reaffirms the state's responsibility to plan and manage oil and gas operations in a manner that balances development with wildlife conservation. This bill directs the state to minimize or avoid adverse impacts to wildlife resources whenever possible, and mitigate impacts when they are unavoidable.

The 2005 Energy Act (Energy Policy Act of 2005, H.R.6, Section 369) included an emphasis on the development of domestic energy sources, and in particular, oil shale. The largest US deposits of oil shale are in the Green River formation, which includes the Piceance Basin in Colorado (Fig. 22), and 72% are owned by federal entities (Bartis et al. 2005). The new legislation removed earlier provisions that restricted large-scale development of oil shale, and required that public lands be made available for research, development, and demonstration (RD&D) leases for oil shale within 6 months. This legislation, along with higher oil prices and the advent of new oil shale in situ extraction techniques, has encouraged companies to pursue the development of oil shale resources. Five proposals for RD&D leases, all within Colorado, have been approved by the BLM (which included environmental analyses under NEPA). Commercial leasing could begin as early as July, 2008.

The majority of the high potential areas for oil shale development in Colorado are within the BLM's White River Resource Area (WRRA), in Rio Blanco County (Fig. 22). In 1997 the BLM (WRRA) identified approximately 223,860 acres of land available for oil shale leasing and development (of which 39,140 acres will be available for open pit development; Bureau of Land Management 1997). Although full-scale development of oil shale will be somewhat delayed by the need to develop the most economical extraction techniques, estimates are that full-scale production could occur within 20 - 30 years (Bartis et al. 2005).

An important note, from the GrSG perspective, is the considerable overlap in potential resources for oil and gas drilling and oil shale extraction (Fig. 23).

Coal is also increasing in demand and use as an energy source. Coal production in the United States reached record levels in 2005 (Freme 2005). The wide-ranging economic expansion experienced in China in 2004 drove world markets for many commodities into overdrive and helped to reestablish the United States into Asian coal markets (Energy Information Administration 2005). Colorado ranked 6th in U.S. coal production, which has increased dramatically since 1958 and reached 40 million tons produced in 2004 (Colorado Geological Survey 2004). Demand for coal is expected to remain high due to continued economic expansion and elevated natural gas prices (Freme 2005).

Colorado's coal is considered "clean coal" because it is low in mercury, arsenic, sulfur, and ash, making it in demand at power plants because it can be used without the added cost of washing (Colorado Geological Survey 2004). The largest coal reserves in the state also significantly overlap GrSG habitat and include large portions of the NWCO and PPR populations (Fig. 24). Note that coal reserves also overlap with potential oil, gas, and oil shale resources (Figs. 23 and 24).

The following information summarizes the evidence for impacts to GrSG from energy development and mining, including cumulative landscape-level impacts. We also identify the primary impact(s) for each type of energy development or mining (e.g., coal, uranium, gravel, sodium), and examine the potential for growth of each industry in specific GrSG population areas in Colorado. Infrastructure associated with energy and mineral development (e.g., powerlines, pipelines) is mentioned where relevant, but specific impacts are covered in more detail in a separate section (see "Infrastructure" issue section, pg. 170), as are impacts of roads (see "Roads" issue section, pg. 193).

For analysis and exploration of potential approaches to address the cumulative impacts of energy and mining development on GrSG, see the "Housing Development and Surface Mining" [pg.

217] and “Oil and Natural Gas Development” [pg. 223] sections of the Population Viability Analysis, “Energy and Mineral Development: Avoiding and/or Mitigating Impacts” [pg. 292], and “Energy and Mineral Development” strategy section [pg. 313].

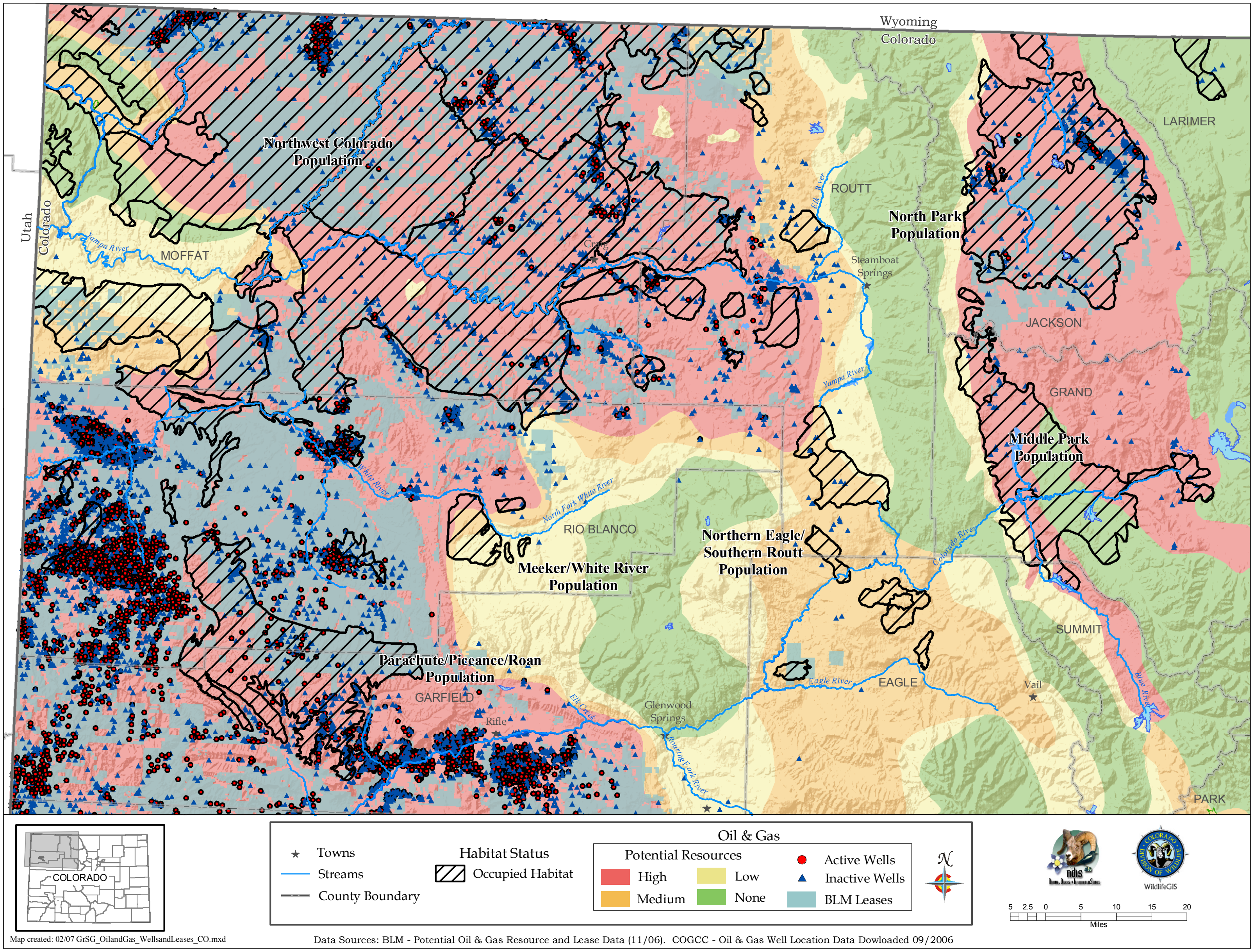

Fig. 20. Current and potential oil and gas development in Colorado GrSG population areas.

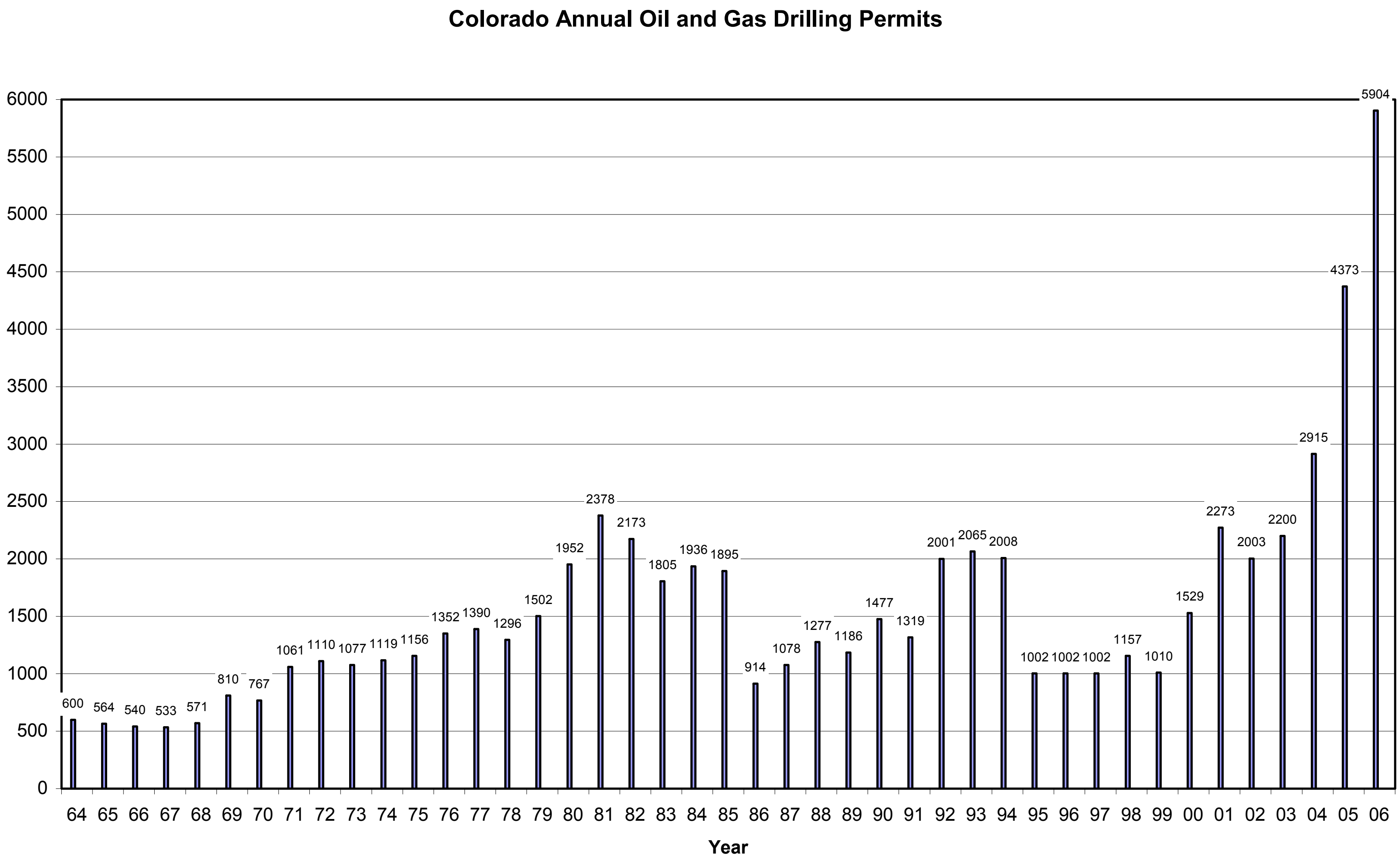

Fig. 21. Annual Colorado oil and gas drilling permits, 1964 – 2006 (COGCC 2002, 2003, 2004, 2005, 2006, and 2007a). Data are actual numbers of statewide permits except for 2002, which is an estimate.

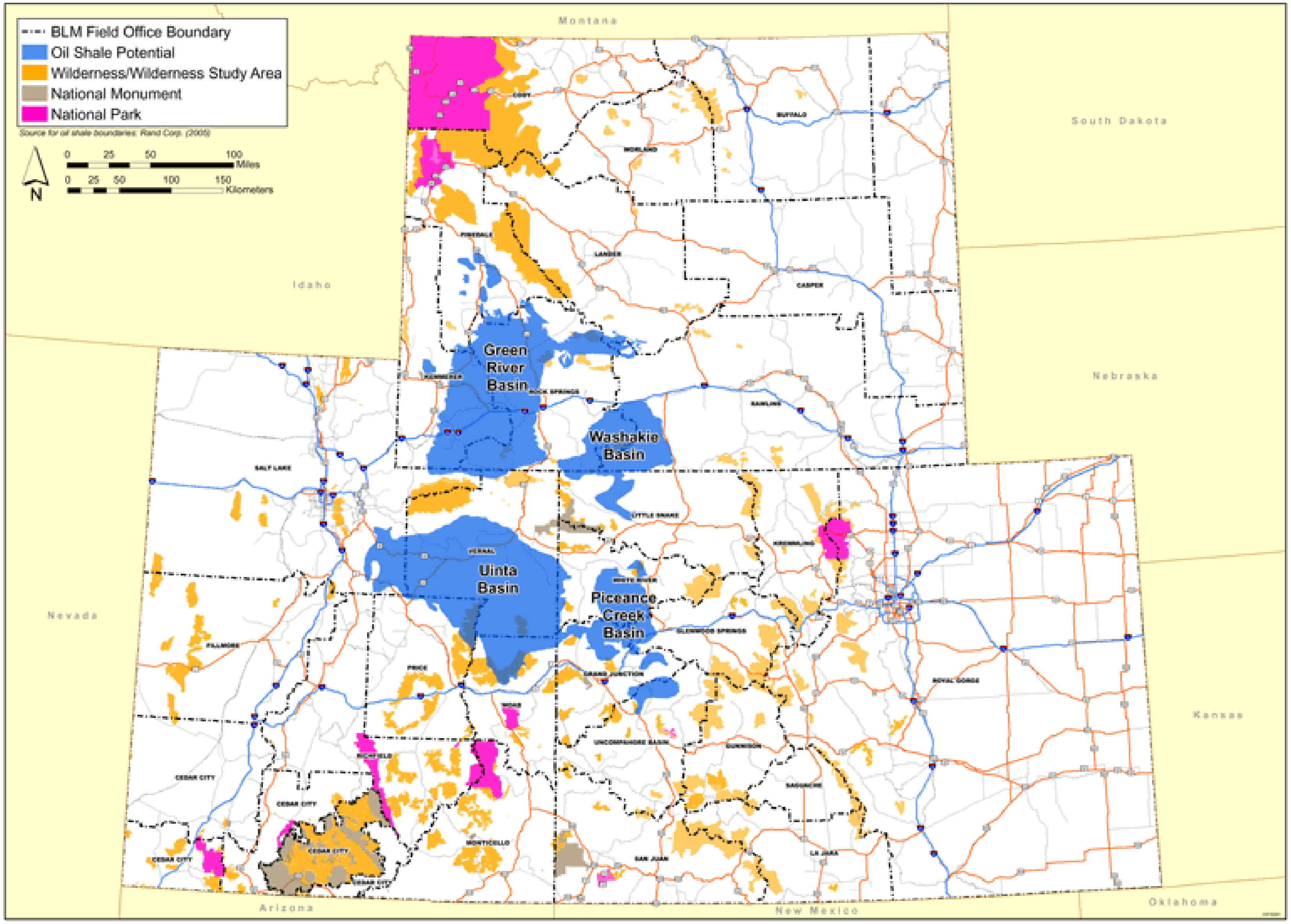

Fig. 22. Potential oil shale resources in Colorado and neighboring states (Bureau of Land Management 2006).

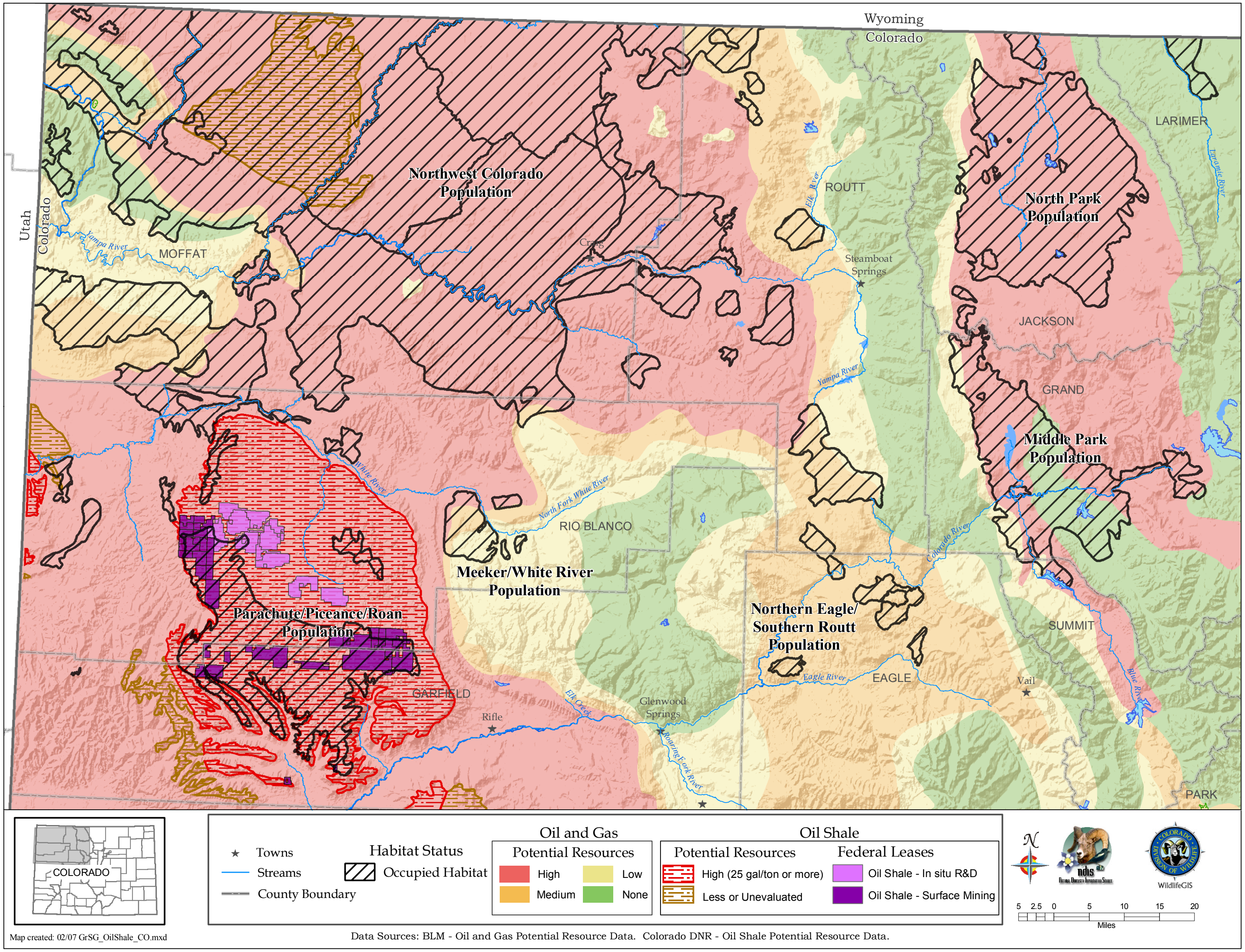

Fig. 23. Overlap in (1) potential oil shale and (2) potential and current oil and gas development in Colorado GrSG population areas.

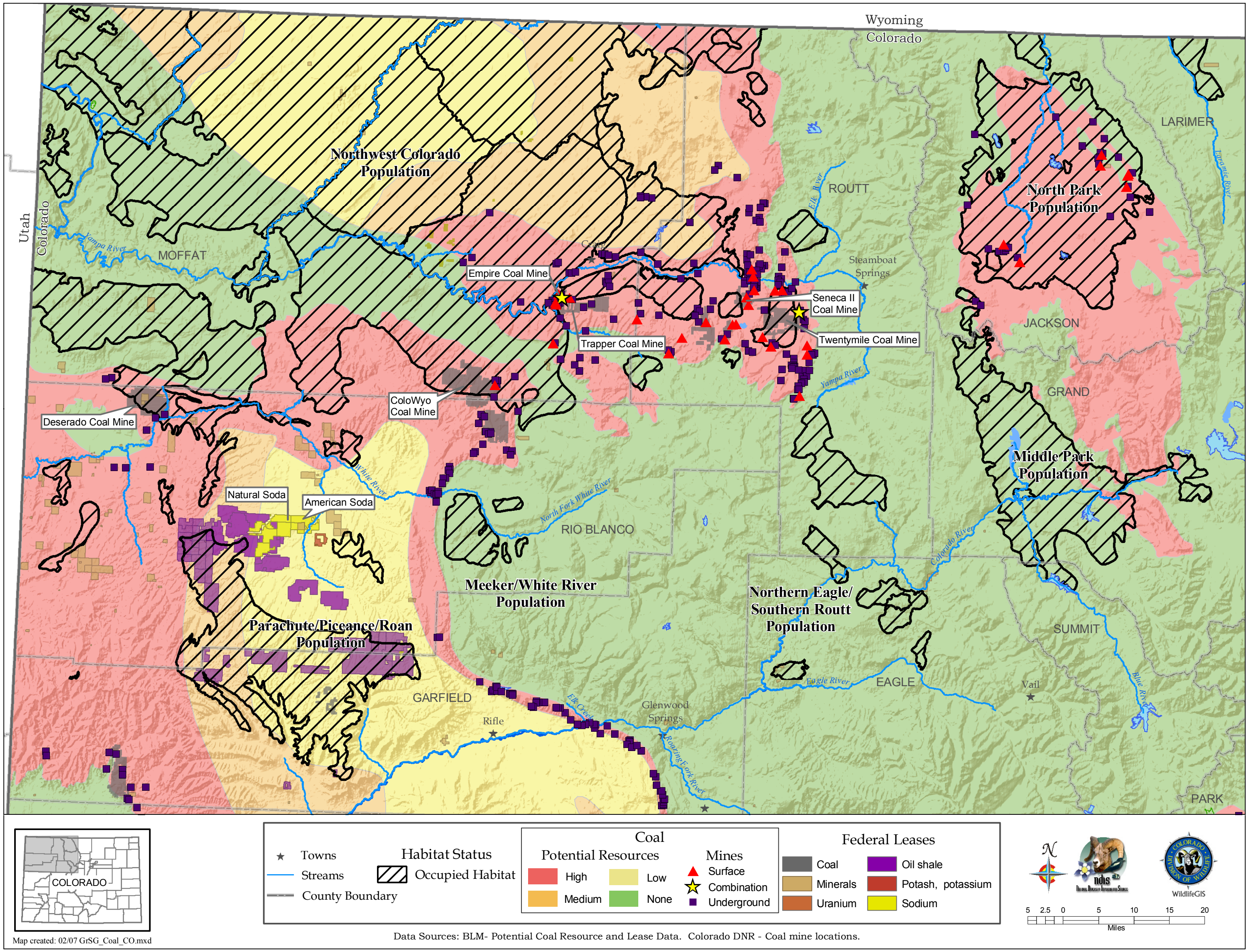

Fig. 24. Current and potential coal and other mining development in Colorado GrSG population areas.

Evidence of Energy and Mineral Development Impacts to GrSG and GrSG Habitat

Although the activities and structures covered in this section are not all related, their potential risks to GrSG are similar and can be grouped into 5 general categories: (1) direct disturbance, displacement, or mortality of grouse (this includes physiological stress to birds); (2) direct loss of habitat, or a decline in habitat suitability through fragmentation and reduced habitat patch size (see "Habitat: Fragmentation, Quality, and Quantity" issue section, pg. 151 and "Infrastructure" issue section, pg. 170); (3) increase in predation (see "Predation" issue section, pg. 183); (4) increase in invasive plant species and the potential for reduced habitat quality (see "Weeds: Noxious, Invasive, and Encroaching Plants" issue section, pg. 198); and (5) cumulative landscape-level impacts: the synergy of the first 4 listed factors may result in a greater impact to GrSG populations than the factors do individually. (For an additional summary of the literature on this topic, see Appendix H, "Literature Review: Oil and Gas Development Impacts on Prairie Grouse".)

Because many of the potential factors that can affect sage-grouse populations are correlated, it is unclear how individual components of development might impact GrSG populations.
There is currently no peer-reviewed published literature evaluating the effects of oil and gas development on GrSG specifically in Colorado. Research in Wyoming and Montana, conducted in the same ecoregion (Wyoming Basin) as many of Colorado's GrSG, represents the only published information available regarding how GrSG populations respond to gas development (Lyon and Anderson 2003, Holloran 2005, Kaiser 2006, Walker et al. 2007*a*, Doherty et al. 2008). Preliminary coal bed natural gas-related research from Montana and Wyoming offers the first landscape-level examination of cumulative impacts to GrSG from energy development (Walker et al. 2007*a*, *b*; Doherty et al. 2008). We acknowledge some limitations of any information that infers a treatment effect that is derived from a descriptive, non-experimental research approach. However, we also recognize that experimental research on oil and gas development impacts to GrSG is difficult to achieve. Nevertheless, GrSG conservation planning and management efforts need to move forward (see "Adaptive Management", pg. 10). Therefore, the SC supports the use of the only available information regarding energy development and GrSG, until better information is available.

(1) *Direct Disturbance, Displacement, or Mortality of Grouse*

Braun et al. (2002) reviewed hypotheses and preliminary data suggesting adverse impacts to sage-grouse from energy development. More recent studies have documented adverse impacts to sage-grouse by disruption of their behavior, resulting in displacement and demographic consequences (Lyon and Anderson 2003; Holloran 2005; Kaiser 2006; Walker et al. 2007*a*, *b*; Doherty et al. 2008). Some of the factors that could affect GrSG behavior include human activity during exploration, activity at wells and mines, collisions with vehicles, collisions with powerlines, increased raptor predation near powerlines, and road traffic, both during construction and during production (Holloran 2005, Walker et al. 2007*a*, Doherty et al 2008). There are often additional disturbances beyond an energy or mineral development site, including those at related access roads, surface facilities, rail spurs, temporary roads, and exploration drill holes. Increased human activity and noise associated with facilities (e.g., pumping, retorting, surface mining, compressor stations) may cause grouse to avoid an area or to be displaced, and may impact breeding activity (Braun et al. 2002, Lyon and Anderson 2003, Holloran 2005). Such effects might be expected to extend beyond the immediate site of development, depending on the degree of activity and noise.

Remington and Braun (1991) reported that GrSG lek attendance decreased on leks within 1.2 miles of coal mining activity relative to "control" leks, although overall population trends in the area did not change during this time. Whether or not disturbance will ultimately affect the larger GrSG population depends on the number and distribution of disturbed sites.

Holloran (2005) investigated GrSG in an area of intensive gas development in Wyoming and found that the number of males using leks declined where there were more than 5 producing wells within 1.8 miles of the lek. Noise, rather than the visual effects of drilling rigs appeared to impact lek attendance. However, Holloran's work suggested it was difficult to evaluate the impact of individual disturbance factors (such as noise) on GrSG; the cumulative effect of multiple factors associated with drilling appeared to be more important than any individual impact. Lyon and Anderson (2003) found that GrSG females in disturbed areas nested further away from leks, and had decreased nest initiation rates. Holloran (2005) showed increased mortality of GrSG females associated with wells.

In addition, Holloran (2005) reported that adult female GrSG showed high nest site fidelity, regardless of gas development levels, but yearlings selected nest sites further from main haul roads than did adult females. Brooding female survival was lower in areas with gas field development impacts than in control areas. Modeling exercises and population calculations suggested that these impacts will lead/have led to population declines in the area (Holloran 2005). Holloran concluded, for his study area with its high level of development, that existing BLM stipulations were inadequate to protect GrSG during lekking, nesting, and brood-rearing periods.

In Wyoming, Walker et al. (2007*a*) identified severe negative impacts of coal-bed natural gas development on sage-grouse breeding populations (as indexed by counts of displaying males), even after controlling for habitat loss and considering alternative explanations. Doherty et al. (2008) documented avoidance of coal-bed natural gas fields by sage-grouse in winter and showed that females were 30% less likely to use otherwise suitable habitat if it had coal-bed natural gas development.

Among sagebrush community species, sage-grouse might be particularly sensitive to disturbance, especially during the breeding season. Because sage-grouse gather on leks and breeding displays have an acoustic component, multiple sage-grouse can be affected at a single disturbance site, and a display arena might be particularly vulnerable to noise disturbance. Some disturbances may directly affect a small area, but if they impact leks they may have an exaggerated effect on the population because of the potentially large number of birds affected.

In general, oil and gas operations may produce excess water that is: (1) held in containment pits; (2) re-injected back into an injection well; or (3) hauled away via truck to an approved disposal facility. The quality of produced water varies, but open water pits could conceivably become mosquito breeding habitat where water was not previously present (Zou et al. 2006, Walker et al. 2007*b*). Sand and gravel pits are often left as open water ponds after completion of mining, also potentially enhancing mosquito habitat. Any increase in the distribution and numbers of mosquitoes could pose a risk to GrSG because these insects spread West Nile virus (see also "Disease and Parasites" issue section, pg. 103). However, open water pits resulting from energy or mineral development are not considered to be an issue for GrSG in Colorado at this time because generally excess water is re-injected or hauled away (see Appendix G, "Energy and Mining Leasing and Development Process").

In addition, if containment pits hold water not suitable for consumption or surface discharge, these areas could be detrimental to GrSG if a bird becomes trapped or attempts to access the water. These pits are protected from use by grouse and other birds through standard mitigation actions such as fencing, netting, or other methods to restrict their access.

Direct mortality of grouse from collisions with overhead power and telephone lines has been documented (Borell 1939, Ligon 1951, Sika 2006, J. Stiver, University of Nebraska, personal communication), but examples have been isolated and anecdotal. Although these incidents result in the death of individual grouse, there has been no evidence for population-level impacts. Grouse mortality could also be caused by collisions with wind turbines, communication towers (and associated guy wires), fences, and various structures in utility corridors. The USFWS has proposed a set of guidelines to minimize the danger of collision with wind turbines (Manville 2004). Although mortality of GrSG from road traffic has been observed (Holloran 2005), it is not expected to have a significant impact on populations (see "Roads" issue section, pg. 193).

(2) *Direct Habitat Loss*

Construction of any structure, or any surface-disturbing activity in sagebrush habitat will inevitably result in vegetation disturbance and removal, equating to habitat loss for sage-grouse. Surface mining operations (e.g., coal, oil shale) may remove large areas of habitat, and after mining it may take 15 - 30 years or more to reclaim the habitat to a condition deemed to be usable by GrSG (Bureau of Land Management 1991*a*, Monsen 2005). Furthermore, some reclamation efforts that are grass-dominated do not necessarily result in suitable sage-grouse habitat.

In other types of energy development or mineral extraction, the total amount of direct habitat loss may be a small percentage of the overall landscape because many of these structures and the resulting habitat loss are relatively small points (such as an individual well pad), and/or narrow and linear (such as roads, pipelines, and powerlines). Although the total amount of habitat lost may not be great, the impact these features have on habitat may extend beyond their immediate boundaries by fragmenting larger units of habitat, potentially making it less effective habitat for sage-grouse (constituting a "loss" of habitat; see "Habitat: Fragmentation, Quality, and Quantity" issue section, pg. 151). In addition, large-scale development of multiple industries (e.g., oil and gas, oil shale, coal) in a single area could result in a collectively large loss of habitat.

Pipeline corridors and buried powerlines represent a temporary habitat loss, if they are revegetated to appropriate shrub and understory species. However, frequent human use of, and activity in corridors may diminish the positive impact of revegetation efforts, resulting in effective habitat loss. Primary corridors congregate multiple lines and their resulting impacts, minimizing habitat loss. Overhead powerlines may have a long-term linear effect on native sage-grouse habitat by fragmenting habitat or through the creation of potential predator travel lanes.

(3) *Increase in Predation Pressure*

Elevated structures of various types may provide perch sites for raptors that prey on grouse, possibly resulting in increased predation (see also “Infrastructure” [pg. 170] and “Predation [pg. 183] issue sections). In addition, if grouse perceive a greater threat of harassment and/or predation, they might avoid areas with overhead structures, whether they are linear, such as powerlines, or not, such as drilling rigs or wind turbines. It is unknown how far elevated structures must be from sage-grouse to have no effects on the birds (e.g., behavioral changes, increased predation).

Research that clearly addresses this risk is limited. Ellis (1987) attributed changes in sage-grouse movements on a lek and a shift in lek location in northeastern Utah to construction of a 345-KV transmission line within 660 feet of the lek. Braun et al. (2002) suggested that increased avian predation associated with nearby powerlines may have contributed to lower growth rates in one Wyoming GrSG population. Walker et al. (2007*a*) found that, after controlling for habitat loss, probability of lek persistence declined with proximity to powerlines and with increasing area affected by powerlines within 4 miles of a lek. Negative effects of energy development (including powerlines) outweighed those of powerlines alone.

Another possible influence on predation rates is reduction in sagebrush cover in any energy or mineral development area. A substantial reduction in sagebrush canopy that serves as hiding cover for sage-grouse could increase the risk of predation. In addition, the presence of roads, or paths cleared under powerlines or for pipelines, that fragment previously contiguous habitat may change the behavior of terrestrial predators by providing easy travel lanes into sagebrush habitat (Chesness et al. 1968, Haensly et al. 1987, Mankin and Warner 1992). Habitat fragmentation could also force grouse to move across more open areas (less optimal habitat), potentially exposing them to predators more frequently than in contiguous sagebrush habitat. As noted earlier, above-ground power lines and transmission lines can result in a long-term linear effect to native habitat (habitat fragmentation and creation of potential travel lanes for predators), depending on the type of power line right-of-way and vegetative cover.

(4) *Increase in Invasive Plant Species and Habitat Quality Decline*

Construction and use of any substantial structure or road in previously contiguous habitat can facilitate invasion by noxious weeds and other invasive plants (Bureau of Land Management 1999; see also “Infrastructure” [pg. 170], “Roads” [pg. 193], and “Weeds: Noxious, Invasive and Encroaching Plants” [pg. 198] issue sections), and may increase deposition of dust on plants, potentially degrading GrSG habitat (Gelbard and Belnap 2003, Bergquist et al. 2007). Effects may be particularly pronounced in areas with high traffic volume and long-distance travel by vehicles. Reclamation efforts may also inadvertently introduce noxious or invasive weeds (Tyser and Worley 1992), thereby permanently and unpredictably altering the sagebrush community. Soil erosion, disruption, contamination of water sources, and lowering of water tables may result from activities associated with oil and gas drilling (Wyoming Game and Fish 2003, Bureau of Land Management 2004*a*); although these could affect sage-grouse habitat, it is likely that other impacts would affect GrSG populations earlier and more significantly.

(5) *Cumulative Landscape-level Impacts of Energy and Mining Development on GrSG*

The first 4 listed potential impacts may interact or combine in a way that creates overall greater consequences for GrSG populations. In fact, if there is synergy among the individual specific impacts, that cumulative effect could be the most important overall issue within energy and mineral development.

There has been less research on this topic than on the individual impacts listed earlier, (1) - (4), largely because of the difficulty in addressing such a broad issue. However, recent research in Montana and Wyoming has examined landscape-level impacts of energy development, without teasing out the specific proximate factors that might affect GrSG (Holloran 2005, Walker et al. 2007*a*, Doherty et al. 2008), such as direct disturbance, predation levels, or habitat fragmentation. Walker et al. (2007*a*) controlled for habitat loss and still found negative impacts on lek persistence by coal-bed methane development. Holloran (2005) found the total maximum number of males declined 51% on heavily impacted leks from the year prior to impact to 2004 (control leks declined 3% during the same time period). Further, the total maximum number of males on three heavily impacted leks situated centrally within the developing field declined 89%, and 2 of the 3 leks were essentially inactive in 2004. Research in the Powder River Basin, where 75% of the area is under federal mineral estates (Bureau of Land Management 2003, Bureau of Land Management and the State of Montana 2003) suggests that GrSG avoid otherwise suitable lek and winter habitat in areas where coal bed natural gas is being developed (Walker et al. 2007*a*, Doherty et al. 2008). This is even the case when lease stipulations and mitigation measures designed to protect GrSG and/or enhance habitat are in place (Walker et al. 2007*a*, Doherty et al. 2008).

The forecast for dramatic increases in oil and gas, oil shale, and coal development in Colorado, particularly within the PPR and NWCO population areas (see Figs. 23 and 24, pp. 115-116), suggests that the cumulative effects of all these facilities could have an adverse impact on sage-grouse.

For analysis and exploration of potential approaches to address the cumulative impacts of energy and mining development on GrSG, see the “Housing Development and Surface Mining” [pg. 217] and “Oil and Natural Gas Development” [pg. 223] sections of the Population Viability Analysis, and “Energy and Mineral Development: Avoiding and/or Mitigating Impacts”, pg. 292.

<u>Oil, Natural Gas, and Coal Bed Methane Development</u>

The primary risks to GrSG from oil, gas, and coal bed methane (CBM) development are elevated mortality due to collisions and WNV, disturbance of birds that may force them into suboptimal habitats with elevated predation rates (resulting in a decline in habitat suitability), and direct habitat loss. A detailed description of the oil and gas development process is provided in Appendix G, "Energy and Mining Leasing and Development Process".

The construction phase of well development (drilling and completion), which typically takes 1 - 2 months for a single drill bore (but can extend up to 14 months or more for a multiple drill hole well pad), is a period of high intensity human activity, noise, road and equipment use, and site disturbance. This period is considered one of high impact to sage-grouse, especially if it coincides with seasons when the birds might already be stressed (Bureau of Land Management 1991*a*). However, adverse impacts to GrSG may continue to occur following the construction phase, during normal operations (Holloran 2005 Walker et al. 2007*a*, Doherty et al. 2008).

Typical natural gas drill pads require an average of between 2 acres for single wells and 5 acres where multiple wells are drilled from 1 surface location. Drill pads with multiple wells may be as large as 10 acres, but may also house more than 20 wells at 1 site. Areas for drill pads are cleared of all vegetation using a bulldozer or other earth-moving equipment. Topsoil is typically removed and stored for use in reclaiming some of the site after construction is complete. When initial drilling results in a "dry hole" or a well becomes depleted, the well is plugged and reclamation occurs. Interim reclamation may occur on part of the well pad after well completion, and less area is required to maintain the well in production. Access roads have a driving surface of 16 to 18 feet wide, and an assumed total disturbed width of 35 feet. Directional drilling may be employed to reduce the amount of surface disturbance necessary to drill wells or to reach bottom-hole locations that may not be accessible from the surface with a straight hole. More than 1 well can be drilled from a single surface location using this technology. The distribution, or density, of well pads and associated infrastructure has a great influence on the potential development impact to sage-grouse. Holloran (2005) worked in an area with high density drilling (40 well pads/mi^2), and found evidence of demographic impacts to GrSG.

The BLM is responsible for managing oil, gas, and CBM development on federal lands and on lands where the federal government retained the minerals and patented the surface (termed a "split estate"). A large proportion of oil and gas development on GrSG habitat in Colorado is administered by the BLM. Typically, the BLM identifies lands available for leasing (and any stipulations designed to mitigate potential impacts from oil and gas development) through the Land Use Planning (LUP) process; CBM development follows the same process. At the site-specific level, the BLM is required to analyze potential impacts of a proposed exploration, development, or production activity through NEPA, and complete any necessary clearances or consultations, such as those required by the Antiquities Act or the Endangered Species Act.

There are some inherent problems with this approach. Current standard BLM stipulations to protect sage-grouse and sage-grouse habitat are limited to (1) permanent avoidance of surface disturbance within 0.25 miles of active sage-grouse leks to protect leks from disturbance (for discussion of the 0.25-mile buffer, see pg. B-5, Appendix B, "GrSG Disturbance Guidelines"); and (2) temporary restriction of activities, generally during the period from March through June, to protect sage-grouse nesting habitat from disturbance during the nesting period (or in winter habitat during the appropriate period).

Research in Wyoming and Montana (Holloran 2005; Walker et al. 2007*a*, Doherty et al. 2008) suggests that standard stipulations designed to avoid significant impacts to sage-grouse are not effective, at least in areas experiencing large-scale and intense energy development. These studies find that the current stipulations are inadequate to achieve the desired effect. The 3 studies document instances where disruption of sage-grouse breeding, increased mortality of sage-grouse, and declines in sage-grouse populations occurred as a result of energy development in locations where standard BLM timing and habitat avoidance stipulations were in full force and effect. Stipulations are placed on federal oil and gas leases at the time the lease is issued. There are few mechanisms to strengthen stipulations or add additional stipulations on an oil or gas lease after the lease is issued, even when existing stipulations prove inadequate or ineffective. In addition, industry may request waivers (permanent removal) or exceptions (case-by-case basis) of stipulations. Although waivers are rarely approved, both are evaluated by BLM, and exceptions are often granted if analysis determines the stipulation is not necessary or would not provide significant benefit to sage-grouse. If a waiver or exception is approved, the stipulation (and thus the intended protective measure) would not be applied to that location.

The COGCC has broad statutory authority to regulate oil and gas development in Colorado, including (1) the drilling, producing, and plugging of wells and all other operations for the production of oil or gas; (2) the perforating and chemical treatment of wells; (3) the spacing of wells; and (4) oil and gas operations so as to prevent and mitigate significant adverse environmental impacts on any air, water, soil, or biological resource resulting from oil and gas operations to the extent necessary to protect public health, safety, and welfare, taking into consideration cost-effectiveness and technical feasibility.

On non-federal lands with private mineral rights, COGCC is the only regulatory authority. The COGCC adopted a policy in 1996 that stated, "Whereas it is the policy of the Colorado Oil and Gas Conservation Commission that, consistent with fostering, encouraging and promoting the development of oil and gas resources in Colorado, oil and gas operations should be conducted so as to prevent and mitigate significant adverse environmental impacts to wildlife…" This resolution went on to describe a process of data collection efforts and analysis to assess wildlife impacts and encourage voluntary cooperation among oil and gas operators in preventing and mitigating impacts to wildlife. Adoption of new legislation in 2007 strengthens the commitment to balancing development with wildlife conservation, directing the state to minimize or avoid adverse impacts to wildlife resources whenever possible, and mitigate impacts when they are unavoidable.

Three of the basins in Colorado that have high oil and gas potential also encompass currently occupied habitat of GrSG populations (Fig. 20, pg. 112): (1) the Piceance Basin (PPR population); (2) the Sand Wash portion of the Greater Green River Basin (NWCO population); and (3) the North Park Basin (NP population). Potential areas for CBM development may overlap with other oil and gas operations.

The level of future development activity varies significantly among the 3 basins. When preparing a Resource Management Plan/Environmental Impact Statement (RMP/EIS), the BLM prepares a Reasonable Foreseeable Development (RFD) scenario of future oil and gas development (including CBM). The RFD usually includes an anticipated number of additional wells and associated surface disturbance, for impact analysis purposes. However, it should be noted that well numbers alone do not necessarily reflect the potential level of disturbance to wildlife in an area:

> "If oil and gas activities are scattered over a large area and outside of crucial habitat areas, the total disturbed acres in any given year would not, by itself, have a significant impact. If oil and gas activities were concentrated in a small area over an extended period, detectable significant impacts would be anticipated. Field development with a concentrated number of wells could cause significant direct and indirect impacts" (Bureau of Land Management 1991*a*:4-3).

The level of future development in the Sand Wash portion of the Greater Green River Basin is currently being analyzed in the Little Snake Field Office RMP Revision. An updated RFD has been prepared and an additional 3,031 wells (approximately 950 currently exist) are anticipated to be drilled during the next 15 - 20 years (Fred Conrath, Bureau of Land Management, personal communication). As part of the RMP revision process, mitigation measures to protect GrSG and their habitat are being considered.

Although the Piceance Basin is within the boundaries of 3 BLM field offices (White River, Glenwood Springs, and Grand Junction), occupied GrSG habitat predominately falls within the White River Field Office (WRFO) boundary. The WRFO is currently initiating a RMP/EIS oil and gas amendment to address future oil and gas development within the Piceance Basin. An updated RFD is currently being prepared. The Piceance Basin is one of 5 areas identified as highest priority for development potential by national energy policy (Energy Policy and Conservation Act). As such, the area overlapping the PPR GrSG occupied habitat expects to see more than a 3-fold increase in annual well drilling permits and continued production (current number of wells is approximately 4,000). As part of the RMP revision process, mitigation measures to protect GrSG and their habitat will be prepared.

The level of oil and gas development in the North Park Basin was analyzed in the Kremmling Field Office's (KFO) 1991 Oil and Gas RMP amendment (Bureau of Land Management 1991*b*). The RFD projected 100 wells during the life of the plan, and these numbers are still valid (approximately 250 wells exist today). As part of the 1991 RMP amendment, mitigation measures to protect GrSG and their habitat were prepared. Both KFO and the Glenwood Springs Field Office (GSFO) have initiated RMP revisions (2007) which will include estimates of future oil and gas development within their respective boundaries. If significant CBM resources are discovered in North Park, the number of anticipated wells may increase substantially. These additional wells could be drilled at tight spacings, similar to the development situation in the Powder River Basin studies by Walker et al. (2007*a*) and Doherty et al. (2008), and could have commensurate effects on greater sage-grouse. However, no geological information is currently available to determine how this area might be developed in the future.

We do not expect the NESR, MP, and MWR GrSG populations to be impacted by significant oil, gas, or CBM activity in the near future.

Oil Shale

The primary potential impacts to GrSG from oil shale extraction are loss of habitat, disturbance of grouse in areas adjacent to development, and introduction of invasive plant species. This is the case regardless of the method of oil shale extraction, whether by surface mining or by an in-situ retorting process.

Oil shale refers to any sedimentary rock that contains kerogen, which can be released as petroleum-like liquids when heated. Oil shale can be mined and processed (retorting process) to generate oil similar to conventional oil, but is more complex to recover. The largest deposits in the world are found in the Green River formation, in portions of Colorado, Utah, and Wyoming (Fig. 22, pg. 114). Not all oil shale resources are recoverable, but those that are of highest potential are located in the Piceance Basin in Rio Blanco County (Fig. 23, pg. 115), and interest in oil shale development is growing rapidly. More than 70% of the total oil shale acreage in the Green River Formation, including the richest and thickest oil shale deposits, are federally owned and managed lands.

Surface mining of oil shale has many of the same impacts of other surface mining operations (see following section), particularly large-scale disturbance of vegetation and topography. Although the in situ extraction technique being tested by Shell Oil company (Bartis et al. 2005) creates a smaller "footprint" than for surface mining of oil shale, extensive drilling at each individual site and added infrastructure (including transmission lines) may result in considerable habitat loss and/or could fragment sagebrush habitat. Large gas or coal-fired electrical power plants will be required to heat the underground shale to 700 degrees for 3 - 4 years, as well as to power the "freeze wall" around the perimeter of the extraction zone, which would prevent groundwater from entering the zone. The surface disturbance at oil shale sites may last for at least a decade (Bartis et al. 2005). One estimate for when oil shale development will be at initial commercial operations is 12 years, with full-scale (larger area) operations in place in 20-30 years (Bartis et al. 2005).

Oil shale development in Colorado would primarily overlap GrSG habitats in the PPR GrSG population, and would occur in areas that are already experiencing high natural gas development (Fig. 23), pg. 115, which is also expected to dramatically increase for the next 10 -15 years. The Washakie Basin (Fig. 22, pg.114) also contains oil shale which may someday be developed, and this overlaps with part of the NWCO GrSG area.

Mining

The primary risks to GrSG from surface mining are direct loss of habitat, disturbance to birds in the area surrounding mining activity, and introduction and spread of invasive plants. If a surface mine later becomes an underground mine, its potential impacts regarding habitat loss and disturbance to birds decline. Transport activities and infrastructure may continue to disturb grouse and habitat in a more limited area. Disturbance from underground mining is limited to surface facilities, access roads, rail spurs, small exploration pads, gas vent holes, and escape shaft(s). Surface effects from subsidence are minor and generally limited to shallow cracks, which close within a few weeks.

Surface mining includes primarily coal in northwestern Colorado, but potentially oil shale (see earlier discussion), sodium, and other minerals. It removes sage-grouse habitat by creating a “moving” open pit where the topsoil is removed and segregated. Overburden (the material overlying a useful mineral deposit) is removed to expose the deposit, and placed in a mined-out area. After mining, the area is graded to approximate original contours, topsoil is replaced, and the site is re-vegetated while mining continues in adjacent areas.

Coal mining and reclamation requirements in Colorado stem from the Colorado Surface Mining Reclamation Act (34-33-101 et seq. C.R.S.) of 1979 and subsequent regulations promulgated by the Colorado Division of Reclamation, Mining, and Safety. The statutes and regulations describe reclamation requirements, bonding requirements, performance standards, and statistical techniques for demonstrating the effectiveness of reclamation and require monthly inspection of each mine site. Reclamation requirements are developed individually for mine sites, but plant materials used must be compatible with other plant and animal species found in the area and generally include a woody plant component. Where wildlife habitat is a post-mining land use, plant materials are selected that can support and enhance wildlife habitat in the future and have nutritional and cover value for wildlife. The arrangement of reclamation is designed to optimize benefit for wildlife. It is important to note that mine reclamation does not necessarily result in restoration of suitable sage-grouse habitat. Previous reclamation for most mines in northwestern Colorado has not met state reclamation standards for woody vegetation. Success in replanting shrub species is relatively poor on lower elevation shrub steppe sites, and natural sagebrush stand regeneration may take 15 to 30 years, or longer (Bureau of Land Management 1991*a*, Monsen 2005).

Current coal mining operations overlap the NWCO GrSG population (Fig. 24, pg. 116). The Colowyo and Trapper mines near Craig have been operating for 20 years and will continue into the near future. Colowyo is currently disturbing 70 - 90 acres/year and reclaiming 125 - 150 acres/year, while Trapper is mining 50 - 100 acres/year and reclaiming 100 - 150 acres/year. Both mines will probably go underground in the next 10 years. Both companies are participating in a sage-grouse and sharp-tailed grouse study with CDOW. Telemetry data show that GrSG are not currently using the Colowyo and Trapper mine areas, but are using nearby suitable native habitats.

The Peabody mine is located southeast of Hayden, adjacent to NWCO GrSG habitat. It is ceasing operations in 2006, but has the potential for starting an underground operation. There is also a potential surface mine site in the Iles Mountain area in Moffat County, but operations here are not expected in the next 10 years. Some potential for a mine site in the Ninemile Gap area in Rio Blanco County has been identified, but should not impact existing GrSG habitat.

The NP population area is underlain by coal deposits, most of which are not considered mineable. Mining has occurred near Coalmont and east of Walden. Mining ceased in 1993 when the rail line from Laramie, Wyoming, was abandoned and removed. No potential for new mines has been identified. Reclamation activities in these areas have been fairly successful.

Underground coal mines currently occur in northwestern Colorado and have the potential to affect the NWCO and PPR GrSG populations. The 20-Mile mine near Hayden currently includes 475 acres of disturbed ground and will continue operations for the foreseeable future. Another underground mine is likely nearby as the 20-Mile deposit nears depletion. Empire mine (close to Trapper mine) has been idle since 1995 and has 422 acres of disturbed area. This mine is adjacent to, but does not overlap currently occupied sage-grouse habitat in the area. No other new mines are foreseen in the Green River Region. The Deserado mine east of Rangely began production in 1981 and will continue to operate in the foreseeable future. There is no potential for additional mines in the Rangely area.

Two sodium mines exist near the PPR GrSG population, but do not affect currently occupied habitat. Effects of sodium mines are similar to those of other surface mines. Natural Soda currently has 70 acres of disturbed land. Each well pad and access road impacts approximately 2.1 acres and the life of each well is 3 to 8 years. American Soda, currently idle, has disturbed 76 acres, including 22 acres for the 34 wells and access roads (approximately 1.5 acres per well and access road). American Soda’s 40-mile pipeline to Parachute disturbed 300 acres. This area has been re-vegetated, but not necessarily to suitable GrSG habitat. If American Soda resumes operation at the pre-shut-down production rate, they would need to add 8 - 10 new wells per year. Neither of these operations is located within GrSG habitat and should not directly affect the species.

Uranium leasing and mining have occurred in occupied GrSG habitat in Colorado. Uranium mining can occur in both underground and surface mining configurations. Uranium exploration and mining have been dormant in the MP and NWCO populations for a lengthy period, but there has been a recent increase in lease filings and exploration activities in both populations. Impacts to GrSG from prospecting, claim location, and exploration for uranium may occur without BLM or other land managers’ knowledge or oversight in several basins and areas that have metal potential and are not withdrawn from entry to mining. Only upon large-scale exploration or production mining will thresholds be triggered to allow for full NEPA analysis and for mitigation of impacts to occur.

Sand, gravel and other mineral mining activities may occur adjacent to existing river and stream channels, or in upland habitat areas. This type of mining may also be located close to towns or areas of impending development, potentially affecting GrSG seasonal habitats. Similar to other surface mines, these operations would directly remove existing habitat where they overlap and must be in close proximity to a well developed haul road to facilitate material transport.

Wind Energy Development

Wind energy is an alternative energy resource that has increased in development over the last 5 years. Typical wind farms include multiple wind turbines, ranging from 75 - 250 feet high, access roads, associated above-ground facilities and electrical stations, and access to sufficient transmission powerlines. Although no significant high wind potential areas overlap existing GrSG habitat in Colorado, individual wind turbines could be constructed in GrSG habitat, most likely on non-federal land.

The USFWS has proposed a set of guidelines to minimize the danger of collision with wind turbines (Manville 2004). The Colorado Public Utilities Commission has promulgated a rule requiring siting requirements, including (1) consultation with CDOW and certification of site-specific avian surveys conducted on proposed wind facility sites; and (2) verification that the surveys are used in design, placement and management of the facilities. Considerations include state and federally listed species, local bird migration pathways, critical habitat, and areas where birds or other wildlife are highly concentrated or considered at risk. 4 CCR723-3 (b) (c).

Conclusion

As is typical in many natural resources management scenarios, there is some uncertainty regarding the potential impacts of energy and mining on GrSG. Nevertheless, it is reasonable to assume that at some level of activity, energy and mineral resource development will adversely affect GrSG in surrounding habitat. Identifying that level of activity is difficult, in particular because of the interplay among multiple disturbance factors. Although there is a lack of conclusive replicated experimental research on this subject, the preponderance of evidence clearly quantifying and outlining impacts to GrSG from oil and gas development in several GrSG populations is surfacing. Because of (1) the potential for serious GrSG population impacts; and (2) the likelihood for extensive and intensive oil, gas, and mineral development in Colorado, caution should be used in energy development activities in sagebrush habitat. Using an adaptive management approach will allow managers to proceed in the face of uncertainty (see "Adaptive Management", pg. 10).

Fire and Fuels Management

Fire and Sage-grouse Habitat Components

The use of fire to remove sagebrush has been a popular tool for increasing forage production for livestock (Fischer et al. 1996*a*). Prescribed fire in sagebrush-grasslands is increasingly used for improving wildlife habitat, as well. Removing sagebrush by using fire may allow grasses and forbs to increase in abundance and productivity (Nelle et al. 2000), which may enhance sage-grouse nesting and brood-rearing habitats (Sime 1991). However, fire in sage-grouse winter range can decrease the capacity of areas to support sage-grouse (Sime 1991). Response of sage-grouse habitat to fire is variable because of site differences (Fischer et al. 1996*a*).

In the short-term (2 - 3 years), prescribed fire did not enhance brood-rearing habitat in xeric sites and resulted in a significant decrease in abundance of ants, an important food source for sage-grouse chicks (Fischer et al. 1996*a*). In more mesic sites, Martin (1990) found an increase in forbs following fire in eastern Idaho. Pyle and Crawford (1996) found a short-term increase in sage-grouse food supply for chicks on burned sites, in the form of increased forb cover and diversity, but cautioned that enough shrub cover needs to remain and be interspersed for protection of broods. The ideal size and pattern of burned sites for enhancement of foods for sage-grouse chicks remain unknown (Pyle and Crawford 1996).

The long-term impact (> 10 years) of fire on sage-grouse habitats was studied in southeastern Idaho (Nelle et al. 2000), in a predominantly mountain big sagebrush community. Fourteen years after burning, sagebrush had not returned to pre-burn conditions. The study concluded that burning created a long-term adverse impact on nesting habitat because sagebrush required over 20 years of post-fire growth for canopy cover to become sufficient for sage-grouse nesting requirements. In Wyoming big sagebrush communities, recovery to pre-fire conditions may take even longer (Bunting et al. 1987, Monsen 2005).

The short-term benefits of fire to sage-grouse in the form of increased forb cover may be offset by the delayed recovery of sagebrush canopy cover that meets nesting and wintering requirements. The ultimate effect of fire on sage-grouse habitat depends on site potential and condition, average precipitation, sagebrush types, and size and pattern of the burn (Miller and Eddleman 2000). The use of fire for sage-grouse habitat management should be cautiously approached (Connelly et al. 2000*b*, *c*; Baker 2006) and evaluated on a site-specific basis.

Sagebrush Species: Response to Fire

Prior to European settlement, the sagebrush landscape was a mosaic of different sagebrush species, in varying seral stages, occupying areas with different soil, topographic, and moisture conditions (Miller and Eddleman 2000). Fires historically occurred in many sagebrush communities on a regular basis. Estimates of fire frequency vary, depending on the sagebrush species and local factors (Young et al. 1979, Wright and Bailey 1982, Howard 1999, Miller and Eddleman 2000, Baker 2006). Recent research has suggested that fire rotation (time required to burn once through a given sagebrush landscape) ranges from 35 - 450 years, depending upon sagebrush species and local community conditions (Baker 2006). Earlier estimates of fire frequency have ranged from 10 - 100 years (Young et al. 1979, Wright and Bailey 1982, Howard 1999, Miller and Eddleman 2000). Fires spread in a patchy manner, especially in Wyoming big sagebrush, responding to the landscape mosaic and the amount and distribution of fuel in the understory (Howard 1999, Miller and Eddleman 2000). Natural fire regimes in sagebrush-dominated communities probably occurred on a variety of scales, from small to large.

How fire affects a sagebrush community depends on multiple local characteristics such as dominant sagebrush species, aridity, soils, topography, and disturbance (Bunting et al. 1987, Miller and Eddleman 2000). The primary sagebrush species present in GrSG habitat are Wyoming big sagebrush, mountain big sagebrush, black sagebrush, and basin big sagebrush. All 4 species are killed by fire, but can eventually reestablish (McMurray 1986, Bunting et al. 1987, Howard 1999, Johnson 2000, Miller and Eddleman 2000). Recovery time frames for return of sagebrush following fire vary, especially depending on environmental conditions (West 1979, Bunting et al. 1987, Maier 1999, Maier et al. 2001) and size and intensity of fire (Johnson and Payne 1968).

Wyoming Big Sagebrush

Wyoming big sagebrush reestablishes slowly from the seedbank, or from seed produced by plants surviving the fire or by plants adjacent to the fire (Bunting et al. 1987, Howard 1999), replacing themselves at infrequent intervals (West 1979, Maier 1999). New sagebrush seedlings seem to appear only short distances from mature plants. Consequently, Wyoming big sagebrush cannot rapidly re-enter large openings, indicating that surviving plants adjacent to large openings are of “no practical importance as a seed source for reinvasion” (Johnson and Payne 1968:212).

Additionally, adequate moisture for sagebrush seed germination is not present in all years or seasons, especially in the areas where Wyoming big sagebrush grows (Maier et al. 2001, Monsen 2005) because Wyoming big sagebrush occupies the most xeric sites of all big sagebrush subspecies (Winward 2004). Furthermore, the open aspect of many burned sites allows wind to move snow around, reducing moisture entrapment and further drying out the soil (Monsen 2005). Moisture availability is a key factor in initial survival of new seedlings (Johnson and Payne 1968). Maier et al. (2001) found seedling establishment of Wyoming big sagebrush is greatest in years with above-average winter (December-January) precipitation and speculated that winter snow cover is important to this subspecies. In some cases, Wyoming big sagebrush stands did not demonstrate cohort recruitment for as many as 15 consecutive years in central Wyoming (Maier 1999).

Mountain Big Sagebrush

Mountain big sagebrush can reseed from surviving plants or plants in adjacent habitat (Johnson 2000). Generally this species grows in sites with more reliable moisture (Winward 2004), aiding in seedling establishment, but individual populations vary in their fire tolerance (Monsen 2005).

Mountain big sagebrush stands in central Wyoming appear to recruit more regularly than Wyoming big sagebrush stands (Maier 1999) with shorter intervals between cohorts, although both species recruit in infrequent "pulse" events.

Basin Big Sagebrush

Basin big sagebrush, while not a predominant part of sage-grouse habitat, occurs on mesic sites with deep soils, where fuel loads are likely to accumulate. In addition, because moisture in these deep soils is available later into the summer months, the potential of these sites for grass and forb production is high. Much of the basin big sagebrush habitat has been lost to agricultural conversion, and it now occurs in Colorado only in scattered patches west of the Continental Divide (Winward 2004). Where it occurs, diversity and productivity of grasses and forbs is much greater than in Wyoming big sagebrush communities, and vegetation continues active growth longer into the growing season. Although this larger sagebrush (the tallest of the big sagebrush complex) is less palatable to sage-grouse than some other sagebrush species (Remington and Braun 1985), the understory productivity and large shrub canopies may provide some habitat for sage-grouse in critical periods. However, in the deeper, moister soils of basin big sagebrush sites, encroachment of deep-rooted perennial weed species is more likely. Prescribed fire is seldom needed in these stands. Consequently, should wildfire occur in basin big sagebrush stands, grass and forb production will be high only if exotic species are not allowed to dominate the system, and return of sagebrush to the site may be slow. Reseeding of sagebrush in these sites can be successful.

Black Sagebrush

Black sagebrush is a widespread species in Colorado, on shallow or claypan soils (Winward 2004). Understory production on black sagebrush sites is best where the restrictive soil layer is at least 12 inches below the surface (Winward 2004). These sites should be the most likely to support fire and to respond with greater herbaceous production following fire. Black sagebrush reseeds from off-site plants (McMurray 1986) and from the seed bank (Monsen 2005). Fire does not spread readily through black sagebrush because of its generally sparse vegetation (McMurray 1986), but in some cases cheatgrass has increased the fuel load and allowed fire to eliminate black sagebrush stands (Monsen 2005). Because black sagebrush is heavily browsed by wildlife, increased grass and forb production following fire may be short-lived if wildlife use is not monitored. This is also true in any sagebrush community where other resprouting, palatable browse species such as antelope bitterbrush, mahogany, and snowberry occur (Whisenant 2004).

<u>Altered Fire Regimes in Sagebrush Habitat</u>

Many new disturbance factors have been introduced to the sagebrush landscape since European settlement, including livestock grazing, aggressive alien plant species, cultivation, and multiple factors associated with an increased modern human presence on the landscape (Young et al. 1979, Miller and Eddleman 2000). The resulting altered landscape has experienced significant changes in fire frequency, distribution, and intensity. Two new scenarios have emerged in sagebrush habitats in the West that alter sagebrush community response to burning.

First, in sagebrush stands where aggressive alien weed species such as cheatgrass have become established, fire frequency may increase (Whisenant 1990, Billings 1994, Tirmenstein 1999, Miller and Eddleman 2000), eventually changing the shrubland community to an annual grassland (Young et al. 1979, Connelly et al. 2000*c*, Miller and Eddleman 2000). In areas of Idaho and Nevada, where large wildfires have occurred and exotic species are present, natural fire regimes and native landscapes have already been permanently altered. In most GrSG population areas in Colorado, cheatgrass is not currently a dominant component of the vegetation, even though it is often present, and it has not yet greatly affected fire regimes.

Second, where historic fire suppression has occurred, sagebrush communities can transition to dominance by piñon-juniper communities (Burkhardt and Tisdale 1969, Young and Evans 1981, Miller and Rose 1995, Miller et al. 2000). Fire suppression in some sagebrush areas in Colorado may have contributed to piñon-juniper encroachment (NESRCP 2004; see "Piñon-Juniper Encroachment" issue section, pg. 179). Fire suppression may also have caused a decline in GrSG habitat quality in Colorado.

<u>*Prescribed Fire*</u>

Prescribed burning can be used to open up large stands of late-seral sagebrush (Klebenow 1972), or to reduce advancing piñon-juniper in sagebrush habitat (Burkhardt and Tisdale 1969, Bunting et al. 1987, Miller et al. 2000). Baker (2006) recommends against using fire to "thin" sagebrush stands because the result is not thinning, but dead patches of sagebrush. However, great care must be taken to avoid exacerbating existing problems and to ensure weed invasion does not occur (Connelly et al. 2000*c*, Nelle et al. 2000, Monsen 2005, Baker 2006). Removal of shrubs by fire can result in exposure of nutrient-rich sites where shrubs once stood, favoring subsequent entry of exotic annuals (Hassan and West 1986, Halvorson et al. 1997). In instances where sagebrush habitat has become fragmented and limited, there is potential for fire to eliminate the existing sagebrush seed source, reducing the likelihood of natural regeneration via seedling recruitment of shrubs. In areas where fire has been suppressed and exotic weeds are absent, the goal should be to re-introduce fire in a way that most closely reflects natural fire at the landscape scale and that meets the needs of GrSG. When woody species (including piñon-juniper and Douglas fir) are encroaching on sagebrush habitat, mechanical treatments may be more effective than prescribed fire in keeping treatment areas small.

In addition to reducing the density of woody vegetation, prescribed fire can also improve native forb and grass understory growth, and nutritional quality (Bunting et al. 1987, Miller and Eddleman 2000, Wirth and Pyke 2003) if sufficient moisture is available for regrowth following fires. Sage-grouse use of burned habitat has been the subject of debate, but it appears that sage-grouse will use burned sites as long as the sites provide appropriate cover and food resources during the season of use (Slater 2003).

Favorable response of vegetation to fire for improved herbaceous production is limited by our inability to anticipate favorable moisture availability after the burn. Because sagebrush ecosystems have a highly variable precipitation regime, it is especially difficult to obtain desired results using prescribed fire. In sagebrush stands at higher elevations, greater moisture availability allows more effective use of fire and large sagebrush types usually provide sufficient fuel to carry fire (Whisenant 2004). If small openings and reduced density of shrubs is the goal, alternate management tools, such as mowing or spraying, may be preferable to use of fire.

Genetics: Small Populations

Small populations face 3 primary genetic risks: inbreeding depression, loss of genetic variation, and accumulation of new mutations. In this section we discuss each of these threats to population viability, and their relevance to Colorado GrSG populations.

There has been much concern about the genetic viability of GuSG populations (Oyler-McCance 1999, Oyler-McCance et al. 1999), but not as much concern about GrSG, and there is less information available regarding GrSG. The persistence of a population is typically influenced more by demographic processes than by environmental or genetic effects (Lande 1988, Caughley 1994, Soulé and Mills 1998). But when the number of individuals in a population declines to a low level, genetic factors combine with demographic and environmental factors (i.e., "extinction vortices") and become increasingly important (Gilpin and Soulé 1986, Lande 1988, Soulé and Mills 1998).

Inbreeding Depression

In geographically isolated populations, inbreeding is inevitable because individuals will become increasingly related. The genetic consequence of inbreeding is increased homozygosity (Falconer 1981). This increase in homozygosity can have individual and population consequences (Fig. 25), either by increasing the phenotypic expression of recessive, deleterious alleles (Charlesworth and Charlesworth 1987), or by a reducing in the overall fitness of individuals in the population, assuming there is increased fitness in being heterozygous (i.e., the heterozygote advantage; Wright 1977), or both (Kimura and Ohta 1971).

INBREEDING →	GENETIC CONSEQUENCES→	INDIVIDUAL CONSEQUENCES→	POPULATION CONSEQUENCES
	Increased homozygosity; increased potential for expression of recessive deleterious alleles, or loss of heterozygosity	Increased susceptibility to disease; physical deformity; reduced reproduction, increased mortality	Decreased recruitment; declining population growth rate; greater probability of extirpation or extinction

Fig. 25. Diagram of consequences of inbreeding.

Available evidence suggests that inbreeding is virtually universal (however, see Ralls et al. 1984), but inbreeding depression is rare and has highly variable effects (see Lynch and Walsh 1998, Crnokrak and Roff 1999, and Hedrick and Kalinowski 2000, for reviews). In a survey of 36 mammalian species, Ralls et al. (1988) estimated that a degree of inbreeding equivalent to parent-offspring mating reduced viability in captivity by 33%. Crnokrak and Roff (1999) reviewed 35 studies of inbreeding depression in the wild and found that 141 out of 157 populations showed reduced fitness in inbred individuals. In addition, Crnokrak and Roff (1999) found that inbreeding depression in the wild was substantially stronger than in captivity. This agrees with experimental work showing inbreeding depression to be stronger in more stressful environments (Miller 1994). However, the effect of inbreeding on fitness differs widely among species (Price and Waser 1979, Ralls and Ballou 1983, Ralls et al. 1988, Laikre and Ryman 1991).

There is no demographic evidence of inbreeding or inbreeding depression in sage-grouse. However, studies of greater prairie chickens in Illinois showed that fertility and hatching success of greater prairie chickens were correlated with a reduction in genetic variation, due to a population bottleneck caused by habitat loss (Bouzat et al. 1998*a*, *b*; Westemeier et al. 1998). However, there was no evidence that inbreeding depression was the mechanism creating the loss of genetic variation or the loss in fitness.

It is likely that the deleterious effects of inbreeding will occur faster in small populations than in large ones (Frankham 1995). In a randomly mating, geographically closed population, with discrete generations and modest variation in reproductive success, the average inbreeding coefficient (F_t) increases according to

(1) $$F_t = 1 - \left(1 - \frac{1}{2N_e}\right)^t$$

where t is the number of generations and N_e is the genetic effective population size (Hedrick 2000). Inbreeding occurs much faster in a population of 20 than a population of 500 individuals (Fig. 26). More specifically, the initial rate of increase is 25 times faster in a population of 20 than 500. This illustrates that avoiding small population size, even for a few generations, is essential for avoiding inbreeding and reducing the potential for inbreeding depression.

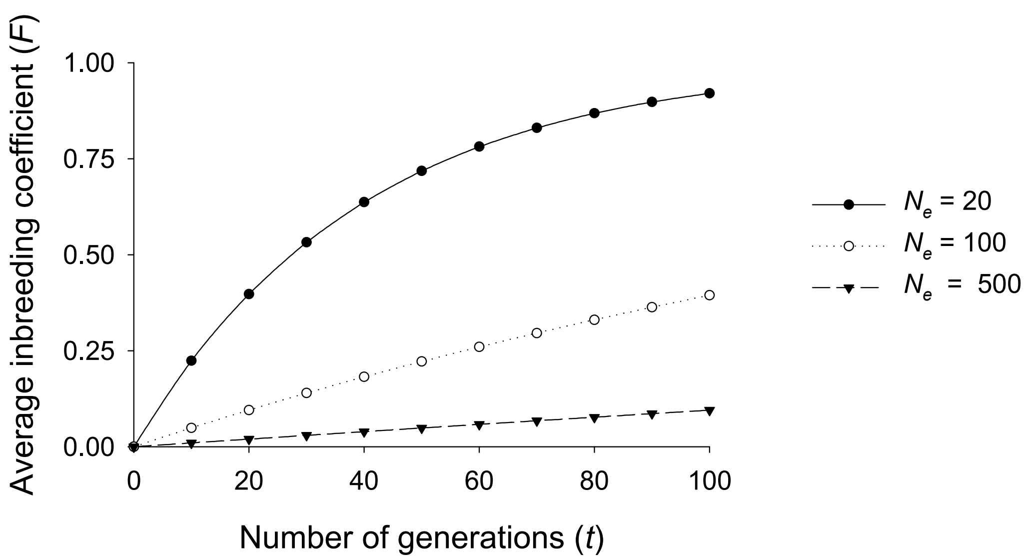

Fig. 26. The increase of average inbreeding coefficient as a function of genetic effective population size and the number of generations of breeding.

There is no consensus on how large a population must be to avoid biologically significant inbreeding depression, and there is little reason to believe that a single critical size or threshold exists. When inbreeding depression was first recognized as a threat to managed populations, Franklin (1980) and Soulé (1980) suggested that 500 individuals should be sufficient to avoid biologically significant inbreeding depression. This rule-of-thumb was based on anecdotal evidence that domesticated animals seemed to tolerate this level of inbreeding. Subsequent experimental inbreeding (in house and fruit flies), however, has shown that populations with a genetic effective size of 500 individuals often have substantial extinction rates (Latter et al. 1995, Bryant et al. 1999, Read and Bryant 2000). Although Franklin's (1980) and Soulé's (1980) guideline of 500 individuals has been shown to be too small, no larger size has emerged as a replacement guideline.

Although inbreeding depression is considered a potential threat to small populations, we have no information to evaluate the relative threat of inbreeding to GrSG. In addition, we do not have reliable information from smaller GrSG populations to test whether there are any impacts on demographic rates (e.g., nest success, hatchability, juvenile or adult survival), to determine whether inbreeding depression is of concern. Inbreeding in small populations does not necessarily increase the likelihood of extinction (Caro and Laurenson 1994, Caughley 1994). Furthermore, it is possible that natural selection may purge deleterious alleles from the species thereby eliminating the threat of inbreeding depression (Templeton and Read 1983, Lacy and Ballou 1998).

Loss of Genetic Variation

The loss of genetic variation, both within individuals and among populations, has the potential to reduce individual fitness and disrupt locally adapted populations ("outbreeding depression"). Adaptation to changes in the environment over time is more likely to occur with greater genetic variation among individuals in a population. In principle, populations with large amounts of genetic variation will have a greater chance of coping with climate change, exotic diseases, or other stresses. For example, O'Brien and Evermann (1988) found low variation in the major histocompatibility complex (an antigen-producing gene complex that plays a key role in the production of antibodies) in cheetahs, and documented 50 - 60% mortality in cheetahs over a 3-year period due to a corona virus. They advocate that genetically depauperate populations face enhanced susceptibility to infectious disease or parasitic agents.

There have been many proposed mechanisms that introduce genetic variation into a population, including mutation. However, there is no evidence of how existing levels of genetic diversity arose in sage-grouse. Natural and sexual selection work to eliminate deleterious alleles and retain favorable alleles. Genetic drift changes allele frequencies randomly, which leads to a net loss of genetic variation. For neutral loci, average heterozygosity (H) in a population declines according to

$$H_{t+1} = H_t\left(1 - \frac{1}{2N_e}\right) \qquad (2)$$

where t indicates the generation and N_e is the genetic effective size of the population. Note the similarity to Equation (1).

There is no consensus on how large populations must be in order to retain a level of genetic diversity that maximizes evolutionary potential. This question has been interpreted as how large a population must be in order for the processes of mutation and genetic drift to be balanced. Presumably, such a population would maintain its potential to adapt to local changes in the environment. Unfortunately, answering this question with confidence requires a more detailed understanding of mutation and heritability than is now available. Estimates currently range from 500 to 5000 individuals (Franklin 1980, Lande and Barrowclough 1987, Lande 1995*a*), and these guidelines should be considered approximate.

GrSG have higher genetic diversity than GuSG (Oyler-McCance 1999, Oyler-McCance et al. 1999), but the consequences of this, regarding threat of extinction, are not well understood. While genetic theory and empirical evidence suggest the loss of genetic diversity can have deleterious effects on reproductive fitness of individuals, the effect on the probability of extinction of a species can only be theoretically modeled. It has never been demonstrated that a population, much less a species, has gone extinct solely because of the loss of genetic diversity but rather by the interplay of demographic and genetic factors (Caro and Laurenson 1994).

Accumulation of New Mutations

Both genetic drift and natural selection change allele frequencies. The strength of natural selection is independent of population size, and the consequences of genetic drift are stronger in small populations than in large populations. One consequence of this is if a population is small enough, slightly deleterious alleles behave as if they are neutral, and are almost as likely to increase as to decrease in frequency. When this is the case, slightly deleterious alleles can become fixed in the population. More specifically, alleles with selection coefficients less than 1/2 N_e will respond to genetic drift in a manner similar to alleles that are selectively neutral (Kimura 1983).

Consider a population or species with a large number of individuals that then becomes reduced in size. Before population decline, deleterious alleles arise by mutation and are eliminated by selection. However, if the population declines in size enough, some deleterious mutations will become fixed. This accumulation of deleterious alleles may lead to extinction of the population, and this process is frequently called “mutational meltdown.” The deleterious alleles responsible for mutational meltdown can be divided into 2 types: deleterious alleles existing at the time of population size reduction, and those that are new mutations. The adverse impact of deleterious alleles existing at the time of population size reduction is essentially inbreeding depression. The mutational meltdown scenario predicts that in small populations the consequences of inbreeding depression will become magnified.

Mutational meltdown is probably the most controversial genetic threat to small populations. There is no doubt that genetic drift will cause mildly deleterious alleles to increase in frequency in small populations, but estimates for how large populations will have to be in order to prevent mutational meltdown vary dramatically. For example, Lande (1995*b*), Lynch et al. (1995), and Charlesworth et al. (1993) suggested that populations will need to have a genetic effective population size of 1000, 100, and 12 individuals, respectively, to avoid accumulating mutations. The wide discrepancy among these estimates is due to uncertainty regarding mutation rates. The process of mutation accumulation is slow when measured on a time scale relevant to most conservation applications. Even if mutational meltdown is a threat to small populations, it is expected to take hundreds to thousands of generations to occur.

Conclusions

Although there is no consensus on how large populations must be to avoid genetic problems associated with small population size, Shaffer (1987) states that populations smaller than a few hundred individuals warrant careful scrutiny in this regard. As noted earlier, it is strongly debated whether reduced genetic variation reduces the viability of a population.

Small populations, regardless of the amount of genetic variation, are at risk of extinction because of demographic fluctuations (Gilpin and Soulé 1986, Caughley 1994). Because of such factors, Lande (1988) and Caughley (1994) argued that, for conservation plans, demographic and behavioral concerns should be a higher priority than genetic concerns.

Small GrSG populations face many threats to their persistence, and these risks may interact. For example, climate change and exotic diseases may stress GrSG populations in the future, and populations with more genetic variation should be able to deal with these stresses better than populations with less genetic variation (e.g., Keller and Waller 2002 and references therein). The low levels of genetic diversity are not apparent in Colorado GrSG populations, and there is currently no evidence of inbreeding depression.

Grazing

Introduction

Potential impacts of herbivory on sage-grouse and their habitat include (1) long-term effects of historic overgrazing on sagebrush habitat; (2) sage-grouse habitat changes due to herbivory; (3) direct effects of herbivores on sage-grouse, such as trampling of nests and eggs; (4) altered sage-grouse behavior due to presence of herbivores; and (5) impacts to sage-grouse and sage-grouse behavior from structures associated with grazing management. This assessment relies heavily on information available for GrSG distributed over a large geographic range of sagebrush systems. When available, more local and specific data regarding habitat use by a given GrSG population should take precedence over generalities stated here.

Herbivory is an integral part of sagebrush ecosystems in the West, although large ungulate use differs with each site. As Wambolt et al. (2002) observe, "…most of the research on sage-grouse habitat needs took place, and continues to take place, on habitats that are grazed. We can see from the range of data that grouse and grazing coexist in many, if not most, areas so we know with reasonable certainty that grouse and livestock are not mutually exclusive."

Terminology

The grazing factor that has greatest impact on vegetation and wildlife is "stocking rate" (Guthery 1996). Stocking rate (the measure of number of animal units per land unit area) provides a measure of the use to be expected over an entire year or grazing season, and is useful in comparing different grazing management systems. "Stocking density" (the number of animal units per unit land area at a given instant in time) can also be helpful in understanding potential direct impacts such as trampling, because it provides records of animal concentrations at the time of use, and it describes the animal-to-land relationship (Heady and Child 1994). "Grazing pressure" suggests relationships of animals to weight of available forage, and may not indicate trampling potential and animal distributions in the same way as stocking density and stocking rate.

Variation in Sagebrush Ecoregions in Colorado

There is considerable variety in sagebrush ecosystems; while some sagebrush communities have well-developed mixes of herbaceous understory species, others are relatively lacking in native herbs by virtue of the soils and climate within which these plant communities occur. Variability in annual precipitation, temperature, position in the landscape, elevation, and soils dictate a site's potential to produce desirable GrSG habitat conditions. Goodrich (2005) provides a clear delineation of the capabilities of many sagebrush communities to produce sage-grouse habitat, based on the habitat characteristics provided by Connelly et al. (2000*c*). A site's response to ungulate grazing may also be influenced by the site's individual characteristics, as well as by the natural selection processes with which the plant community evolved.

Recently, a group of interagency and private enterprise representatives developed a statewide ecosystem classification system for Colorado, based in part on R.G. Bailey's Descriptions of the Ecoregions of the United States (Bailey 1995). In this classification system there are 3 "Level III Ecoregions" in GrSG range in Colorado: Colorado Plateau, Wyoming Basin, and Southern Rockies (Fig. 27, Chapman et al. 2006). These ecoregions stratify the environment by its probable response to disturbance (Bryce et al. 1999). Designation of these ecoregions is useful for consistent structure and implementation of ecosystem management strategies across agency and non-governmental organizations (Omernik et al. 2000).

The 3 Colorado ecoregions differ, but due to terrain, many characteristics separating the ecoregions may overlap. In general, the Colorado Plateau has drier sagebrush sites and higher temperatures, limiting potential for habitat conditions that favor GrSG (West 1983*a*, *b*; Winward 2004; Goodrich 2005). However, within this ecoregion there are extreme elevation changes, and some sagebrush sites have lower temperatures, more moisture, and higher potential for more favorable GrSG habitat conditions. The Wyoming Basin ecoregion, found in the northwestern part of the state (Fig. 27) also varies considerably in temperature, moisture, and site potential. The majority of the portion of this region in Colorado is more mesic than the Colorado Plateau, with higher potential for favorable GrSG habitat. The Southern Rockies ecoregion includes the high elevation NP and MP areas (Fig. 27), and is generally higher and moister than the other 2 regions. There is more variation in climate and habitat potential in this ecoregion than in the other ecoregions, because elevations range from 6,000 feet to over 14,000 feet (Chapman et al. 2006).

In addition to a site's potential to support (produce) desirable GrSG habitat, another important factor determining a site's response to grazing is the amount of evolutionary exposure to herbivory that the area has experienced. Large herbivore abundance in the Colorado Plateau, and to some extent the Wyoming Basin, is thought to have been relatively low compared to other ecoregions to the north and east (Miller et al. 1994, Dorn 1986). With less evolutionary exposure to large animal herbivory, it is expected these areas have less resistance to grazing. A conclusion could be that drier GrSG habitat sites with less evolutionary exposure to grazing are impacted more by herbivory than other sites. Due to larger and deeper root systems than the forbs and grasses, shrubs have an advantage in utilizing the limited moisture on these sites.

It is thought that fire was the major disturbance on many of these sites. After fire, forbs and grasses become dominant in the plant community. As succession progresses, the shrubs re-establish and, due to their competitive advantage for moisture, become dominant in the plant community. The degree of shrub dominance depends on site potential, period since last significant disturbance, and management. Often the community will develop into a steady-state community with shrubs being dominant for a relatively long period of time. These steady-states are resistant to change except for extraordinary events such as fire, long term drought, wet periods, or human intervention. Grazing that selects for forbs and grasses can hasten the transition to a steady-state shrub community, although with proper use, forbs and grasses can remain a significant part of the plant community over a long period of time.

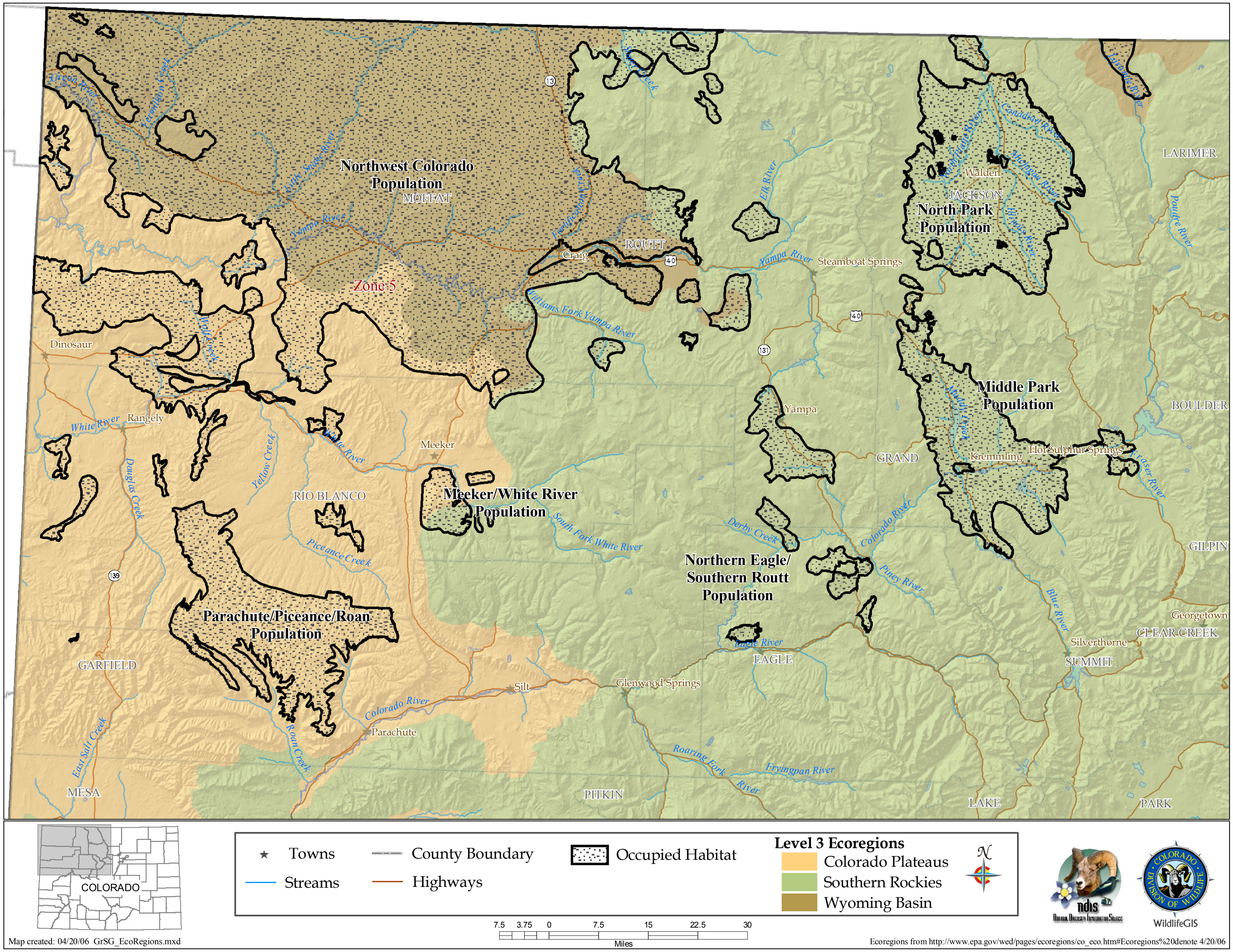

Fig. 27. Level III ecoregions and Colorado GrSG population areas (Chapman et al. 2006).

Challenges in Assessing the Impacts of Grazing on Sage-grouse

The evidence for impacts of herbivory on sage-grouse is greatly debated. The impacts of grazing by domestic stock on sagebrush ecosystems have been examined in many studies (Laycock 1967, Vale 1974, Laycock 1978, Owens and Norton 1992, Archer 1994, Miller et al. 1994, West 1999, Belsky and Gelbard 2000, Jones 2000, Anderson and Inouye 2001). However, it is difficult to separate grazing impacts on sage-grouse from other compounding factors such as climatic events, site-specific vegetative and historic use, presence of exotic weeds, and wildlife use (Rowland 2004). Few studies attempt to separate other factors from grazing impacts on sage-grouse, and no experimentally replicated manipulative studies have been conducted to separate grazing from other confounding factors (Braun 1987, Guthrey 1996, Beck and Mitchell 2000, Connelly et al. 2000*c*, Rowland and Wisdom 2002, Wambolt et al. 2002, Rowland 2004). Additionally, because response of grouse populations is often slow and lags behind vegetative manipulations (Crawford et al. 2004), sage-grouse may show little response for several years, making the ties between vegetation manipulations (e.g., habitat grazing, sagebrush treatment projects) and sage-grouse populations less obvious. Even with improvement in range management and grazing systems, the impacts of domestic herbivory are not easily uncoupled from annual climatic variation, and other wildlife use (e.g., Holloran 1999, Kuipers 2004).

An example of the difficulties encountered in identifying grazing impacts on sage-grouse is the interplay between forbs and drought. Sage-grouse appear to be sensitive to forb abundance, and forbs are especially responsive to precipitation. Fluctuations in forbs and other herbaceous species may vary greatly among years, irrespective of grazing management, and some recent studies of herbivory impacts on habitat have been compromised because of drought years. Drought is a natural condition in western rangelands and should not be considered abnormal, even though drought may stress populations that are already at risk. Such confounding factors make interpretation of sage-grouse response to grazing particularly difficult. Obtaining a clear understanding of the impacts on sage-grouse requires attention to such detail.

In addition, information that is available is derived from different ecosystems, usually from studies of short duration (Crawford et al. 2004). As mentioned earlier, responses of sagebrush communities to herbivory will vary depending on the community and site characteristics; assuming the response might be uniform across sagebrush communities does a disservice to meaningful communication and effective management. There are several reviews available that consider the impacts of domestic livestock grazing on sagebrush-steppe and bird communities (Entwistle et al. 2000, Wambolt et al. 2002, Knick et al. 2003, Connelly et al. 2004, Crawford et al. 2004, Rowland 2004). However, since these authors attempt to discuss range-wide impacts to sage-grouse, they tend to blend critical differences in geographic variation in the sites studied, the level of wildlife populations in the area, and species and stocking rate differences. For example, rotational grazing systems may be helpful in sagebrush ecosystems in northern areas that have sufficient moisture to respond favorably following use, but rotation may be less helpful in dry areas where historic topsoil losses and insufficient moisture limit vegetative recovery. In addition, different stocking rates, timing (season and rotational patterns), and herbivore species (e.g., cattle, bison, sheep, elk) will affect vegetative response differently.

Ultimately, the goal of management to benefit wildlife species should be healthy, sustainable ecosystems that support a variety of species, rather than targeting individual wildlife species. Until more clear documentation of sage-grouse response to herbivory is available for a given site, the best assessment of impacts may derive from a focus on site-specific details of soils, vegetation, use history, and climate. Current efforts (Pellant et al. 2005) to develop detailed descriptions of rangeland "ecological sites" are focused on potential for soil erosion and species composition on a site-specific basis, and serve as a tool to incorporate the level of detail that Goodrich (2005) recommends. Application of ecological site condition could aid in sorting out the response of sage-grouse to management efforts by providing a standardized tool for comparing multiple scientific studies. It is also useful in providing a standardized tool for communication about management. Ecological site condition enhances communication among range managers who understand and can apply management to help achieve specific goals where habitat development for sage-grouse may be most effective and feasible.

Historic Use by Domestic Livestock

The vegetation in many sagebrush ecosystems has clearly been altered and topsoil erosion has increased as a result of historic overgrazing, introduction of exotic species, and early attempts at cropping (Young et al. 1976, Miller et al. 1994, National Research Council 1994). However, the timing of historic overgrazing coincided with an era when sage-grouse numbers are presumed to have been high, making assessment of impacts of domestic livestock on sage-grouse populations unclear. Because it is impossible to identify and quantify the relative impact of all independent factors affecting sage-grouse populations and habitat during the period of initial sage-grouse population declines, we are unable to attach causal relationships of historic grazing to sage-grouse populations.

In addition, changes in ecosystems due to historic impacts of over-use will not be reversed in a time frame that is meaningful to the more immediate sage-grouse population needs. Reversal of historic damage would require broad-scale intervention to alter current ecosystems in a manner that is not feasible over extensive land areas. So, although most land managers acknowledge that historic grazing and climatic events altered the systems within which sage-grouse now remain (Vale 1974, Owens and Norton 1992, Vavra et al. 1994, West 1999, Clifford 2002), a focus on current grazing management is the most fruitful approach to integrating grazing and effective sage-grouse management.

Current livestock stocking rates are substantially lower than historic levels (Council for Agricultural Science and Technology 1974, Bureau of Land Management 1990), and for this reason it is important to distinguish impacts of historic overgrazing from impacts of herbivory (including by wild ungulates) under more recent, improved management and reduced stocking rates (Crawford et al 2004).

Indirect Effects of Grazing on Sage-grouse Via Habitat Alteration

Sage-grouse response to domestic herbivory can range along a gradient from negative, to neutral, to positive, depending upon context (Guthery 1996, Beck and Mitchell 2000). Although this section is intended to describe adverse impacts of grazing on sage-grouse habitat, it is important to include positive and neutral impacts of grazing on sage-grouse habitat because they often differ from adverse impacts only as matter of degree in level or timing of grazing. Beck and Mitchell (2000) consider grazing impacts to be a function of grazing system, animal type and movement, timing, and stocking rates.

Habitat Alteration: Adverse Impacts

In general, habitat manipulations that reduce sagebrush cover, grass, and forb availability, or are tied to increased predator numbers are considered indirect impacts of herbivory on sage-grouse. Indirect impacts are surmised by assessing habitat alterations, nest success, and bird mortality via predation. Rowland (2004:17-18) notes that “many studies imply negative effects of livestock grazing on sage-grouse by noting that grazing systems must be designed such that adequate herbaceous and shrub cover for nesting or brood rearing are maintained (e.g., Gregg et al. 1994, DeLong et al. 1995, Sveum et al. 1998[*b*])”. The examples of indirect grazing influences upon vegetation are much more common than are instances of direct impacts. However, as noted earlier, evidence of vegetative changes derived specifically from grazing is limited by confounding factors of climatic conditions, site differences, predation, and wildlife use.

In Wyoming, nesting densities of sage-grouse were considerably lower in areas heavily grazed by domestic sheep (10 nests/247 acres), than in adjacent sites with moderate grazing (28 nests/247 acres) (Patterson 1952). Heavy grazing by sheep limits shrub cover more than does use by cattle (Heady and Child 1994).

Heath et al. (1998) compared sage-grouse nesting and breeding success at 3 ranches with different grazing operations and levels of predator control in Wyoming. They found that, despite heavier livestock use (removal of >50% of annual herbaceous production, and grazing by both sheep and cattle) and long-term predator control on 1 ranch, nesting and breeding success of sage-grouse did not differ substantially among the 3 sites. Chick survival to 21 days was, however, greater on the ranch with lighter grazing pressure, suggesting that predator control did not fully compensate for the greater reductions in herbaceous production (Heath et al. 1998). Further, hens were documented leaving the more heavily grazed ranch to nest elsewhere, but returning to that ranch to rear broods (Heath et al. 1998).

In a similar study, Holloran (1999) examined sage-grouse habitat use and productivity in relation to grazing management strategies at 4 ranches in southeastern Wyoming. He found no differences in nest success, brood survival, or numbers of chicks fledged among the ranches. Some differences in habitat use by sage-grouse were found among the ranches; however, these could not be ascribed to differences in grazing pressure, but were ascribed to differences in soil types and precipitation patterns (Holloran 1999). Above-average precipitation during the study, however, may have obscured any potential differences in habitat suitability for sage-grouse among sites. In follow-up work, Kuipers (2004) examined the same ranches during dry years and found only minor differences in grazing systems. Favorable response of forb availability to summer rotation were attributed to reduced spring grazing and lower stocking rates rather than to the grazing system. Kuipers (2004) suggests that grazing systems did not improve sage-grouse habitats over a rested area and that stocking rates and season of use are more important to sage-grouse habitat. Neither Holloran's (1999) nor Heath et al.'s (1998) studies of grazing influence on breeding success employed control sites or replication.

Crawford et al. (2004) suggest that moderate to light livestock grazing in mid- to late-summer, fall, or winter, maintains perennial grasses and forbs in sagebrush habitat based on examination of several studies (Pechanec and Stewart 1949, Mueggler 1950, Laycock and Conrad 1967, Gibbens and Fisser 1975, Laycock and Conrad 1981, Miller et al. 1994, Bork et al. 1998). Cool-season (C-3) herbaceous species are vulnerable to defoliation during late spring and early summer. However, heavy grazing pressure (approximately 60% or greater utilization by weight) during this time (1) decreases the vigor, yield, and cover of late-seral grasses and forbs; (2) may increase early-seral species, annual grasses and sagebrush density; and (3) may increase shrub cover (Craddock and Forsling 1938, Pechanec and Stewart 1949, Mueggler 1950, Laycock 1967, Bork et al. 1998). The transition of sagebrush uplands to higher ecological status may be slowed (Mueggler 1950, Laycock 1967, Eckert and Spencer 1986).

In nesting and brood-rearing habitats, Rowland (2004) suggests it is important to ensure that grazing does not reduce herbaceous understory cover below levels that (1) deter predation of eggs and chicks (Connelly et al. 2000*c*, Hockett 2002); and (2) support insects and forbs that are important in diets of pre-laying hens and chicks (Johnson and Boyce 1990, Barnett and Crawford 1994, Drut et al. 1994b). DeLong et al. (1995) found that predation rates on sage-grouse nests in Oregon were inversely related to cover of tall grass and medium-height shrubs. Klebenow (1982) examined sage-grouse habitat use in relation to grazing at the Sheldon NWR in Nevada, where sheep and cattle had grazed for >130 years. He found that meadows heavily grazed by livestock were avoided by sage-grouse, except when the grouse sought free water. In Nevada, sage-grouse habitat in wet meadows was degraded through overgrazing by domestic livestock and altered system hydrology (Oakleaf 1971, Klebenow 1985; as reported by Beck and Mitchell 2000).

Habitat Alteration: Positive Impacts

Because meadows and riparian areas have greater moisture availability than uplands, the potential for grouse to be limited by dense standing organic material is most likely in these sites. In sagebrush systems where grasses may become too dense and decadent, grazing may be used to remove grass and forb cover, or to increase shrub cover and enhance sage-grouse habitat. Rowland (2004:18) notes "When cattle were introduced into a meadow with residual grass, sage-grouse initially preferred the grazed openings, which had an effective cover height (sensu Robel et al. 1970) of 5 to 15 cm, compared to 30 to 50 cm in the lightly grazed surrounding areas. Grouse avoided dense, ungrazed basin wildrye meadows but were observed in adjacent wildrye that was grazed". One 90-acre meadow that was lightly grazed by cattle was used throughout the summer by sage-grouse and had more sage-grouse (100) than any other meadow on the refuge (Rowland 2004).

In systems where there is potential for shrub cover to limit grass and forb production, grazing may either further reduce grasses and forbs and favor shrubs, or reduce shrub cover. Examples are in sheep bedding grounds becoming leks (Hulet 1983), and improving herbaceous species abundance with grazing (Vale 1974). When feeding and bedding of livestock occurs in dense sagebrush stands, the cover of shrubs can be greatly reduced. Sheep bed grounds on ridges destroyed sagebrush stands used by sage-grouse in heavy snow, causing grouse to abandon this habitat (Rasmussen and Griner 1938). Removal of brush essential for grouse nesting or wintering cover can adversely impact grouse reproduction and survival, but brush treatments in less critical or degraded grouse habitat may increase habitat capability (Giesen and Connelly 1993, Giesen 1998, Connelly et al. 2000*c*). These openings may be considered favorable during breeding because grouse seek open areas for leks. Reduced cover of sagebrush overall can be derived from use by sheep or wildlife that target shrub species, but lek habitat is seldom considered limiting (Schroeder et al.1999). Vegetation can also become too dense for use as cover and for chick movement in summer (Wambolt et al. 2002). Light grazing in meadows can enhance habitat for sage-grouse (Neel 1980). Evans (1986), as reported in Beck and Mitchell 2000) also found that grazing by cattle stimulated production of forb species used by sage-grouse in upland meadows in Nevada. In these systems, herbivory can improve quality of sage-grouse habitat.

Habitat Alteration: Grazing Rotation, Intensity, and Timing Effects on Grazing Impact to GrSG Habitat

Rowland (2004:19) noted research specifically investigating different grazing methods: "Research on upland meadows in Nevada showed that pastures under a rest-rotation system provided better production of those forb species eaten by sage-grouse than did pastures that were not rested, but sage-grouse also used a pasture not grazed by cattle for 10 yr (Neel 1980)". Moderate use equates to a 4-inch residual stubble height for most grasses and sedges and 2-inch for Kentucky bluegrass (Mosley et al. 1997, Clary and Leininger 2000). Shrub utilization should not exceed 50 - 60% during the growing season, and at least 50% protective ground cover (i.e., plant basal area + mulch + rocks + gravel) should remain after grazing (Mosley et al. 1997). While hydrophytic shrubs may not directly serve as sage-grouse habitat, they do impact the stability of riparian and meadow habitats important to sage-grouse (Winward 2000). The length of time livestock have access to meadows may be more important than the level of utilization; it has been suggested that livestock access be limited to 3 weeks (Myers 1989, Mosley et al. 1997).

Timing of grazing can greatly influence the subsequent vegetative response (Crawford et al. 2004). Meadows and riparian areas are particularly vulnerable in late summer (Crawford et al. 2004) when excessive grazing and browsing may damage shrubs, reduce availability of herbs (Kovalchik and Elmore 1992), and cause deterioration of riparian function over time (Klebenow 1985). In spring, early summer, or winter, moderate grazing pressure is sustainable in non-degraded mesic sagebrush habitat (Clary et al. 1996, Mosley et al. 1997). On uplands, spring grazing by sheep can lead to increased sagebrush and decreased herbaceous cover (Bork et al. 1998). Degraded riparian and meadow habitat may require rest from grazing for recovery (Clary and Webster 1989). Rest is often useful in brood-rearing habitat before the nesting season (Beck and Mitchell 2000, Hockett 2002). Rowland (2004) suggests that stocking rates and season of use are especially important to avoid habitat degradation on recently sprayed or burned sites.

Management control over herbivory (timing, species, numbers, and movements) is much greater with domestic stock than with wildlife species (Heady and Child 1994). Well-managed livestock can be used to manipulate vegetation where needed much more effectively than can wild herbivores whose movements are not controlled and whose populations are inherently variable. Consequently, managers of sage-grouse habitat must consider level and timing of herbivory for all animal species. Rest or rotation systems for livestock use may be rendered ineffective if wildlife populations in the area are high.

Habitat Alteration: Removal of Herbivores

Commonly, managers interested in restoring damaged habitat suggest removal of herbivores to restore waning habitat quality, even in systems that evolved with herbivory. Because we can more easily control movement and numbers of domestic stock, it is most tempting to remove domestic livestock. This approach does not acknowledge the potential impacts of removing livestock on wildlife and vegetation. Much of the sagebrush ecosystem has already been altered by the loss of topsoil and entry of exotic species with historic use. Removal of domestic stock amounts to removing the herbivore over which we have the most control, and leaving herbivores over which we have least control. Subsequent use by rapidly increasing wildlife populations can result in even higher levels of herbivory.

Furthermore, removal of all domestic livestock may have no effect if competitive interactions between plant species have been altered such that desired grass and forb species cannot recover (Friedel 1991, Laycock 1994). In shrublands where woody species attain dominance, recovery of herbaceous species is greatly limited (Archer 1994). Once exotic weeds enter shrubland systems, they may increase in prevalence with reduced herbivory, and subsequent fire intervals may be greatly shortened. As a result, little advantage is derived by native herbaceous species. In more productive sagebrush-grass communities, return of sagebrush seedlings, high levels of forb production, and germination of exotic annuals are highly variable and primarily result from climatic events rather than from domestic stock presence (Laycock 1994, Hild et al. 2001, Maier et al. 2001).

Removal of domestic herbivory is also problematic when managers and the public anticipate that vegetation will return to “pristine” condition. The inaccuracy of this assumption has been repeatedly demonstrated (Laycock 1994), especially in woody plant systems (Archer 1994). Because of (1) historic overuse; (2) loss of topsoil; (3) loss of native species; (4) loss of vigor of remaining natives; (5) altered fire regimes; (6) introduction of exotic weeds; and (7) shifts in competitive balance between woody and herbaceous native species, removal of livestock seldom accomplishes a return to original vegetation. Rules of vegetative recovery have changed and removal of domestic stock may actually harm the system, allowing increased exotics, shortened fire intervals, slowed nutrient cycling, or increased public expectation that sage-grouse populations will increase.

Nest Trampling and Desertion

Direct impacts of domestic stock on sage-grouse are demonstrated in a few examples in the literature as damage to nests and eggs, or nest abandonment. Of 161 nests examined in Utah, 2 were trampled by livestock (1 sheep, 1 cattle), and 5 were deserted due to disturbance by livestock (Rasmussen and Griner 1938). In addition to trampling, nest desertion and reduced nesting have been documented in areas with heavy sheep grazing in Wyoming (Patterson 1952). Nest desertion caused by migrant bands of sheep also was documented (Patterson 1952). Danvir (2002) reported 2 instances of nest abandonment in northern Utah over 7 years of observation, (1 with presence of cattle and 1 with sheep). Jensen et al. (1990) demonstrate the impact of increased stocking density and days of exposure on the cumulative percentage of nests trampled. Overall, direct impacts seem to derive from high stocking densities (Bryant et al. 1981) that concentrate many animals together in sage-grouse habitat at the time of sage-grouse use. Many of these losses could be minimized by observance of critical periods of sage-grouse habitat use and avoidance of high stocking densities in these sites during these times.

Altered Sage-grouse Behavior on Leks and in Winter Habitat

Sage-grouse behavior on leks did not appear to be altered by the presence of cattle grazing (Danvir 2002), or with sheep grazing in Idaho (Hulet 1983). Autenrieth (1981), however, cautioned that grazing sheep in sage-grouse winter habitat, as well as livestock drives in sage-grouse habitat, could be detrimental to sage-grouse. These cautions suggest avoiding high stocking densities. Low stocking densities in the same habitat seem to be less problematic (Autenrieth 1981).

Structures and Activities

Structures and activities associated with grazing management can have multiple and variable effects on sage-grouse and sage-grouse habitat. Fences, corrals, windmills, and other structures related to livestock grazing can cause mortality of grouse from collisions, and provide perches that raptors and ravens may use, which could increase avian predation on grouse or their nests (Call and Maser 1985). Grazing structures, such as fences or stock tanks, also influence livestock distribution, which may have a positive or adverse effect on sage-grouse and their habitat, depending on the resulting livestock distribution. Many activities beyond livestock management, such as small acreage residences, energy development, and road and highway construction have greatly augmented structural development in sagebrush habitat in Colorado (Maestas et al. 2002).

Water developments may alter existing sage-grouse habitat by congregating livestock use in previously unused upland habitat, or by lowering water tables associated with riparian areas. However, water developments can also be used to improve overall riparian habitat condition by drawing livestock and wild ungulates away from previously degraded areas.

Wild Ungulate Effects on Sage-grouse

The effect of wild ungulates on sage-grouse and their habitat has been raised as an issue that requires greater understanding. Direct physical confrontation between sage-grouse and pronghorn antelope, elk, or mule deer is probably not a major concern, although an instance has been observed of an elk consuming sage-grouse eggs in Wyoming (Holloran and Anderson 2003). Indirect impacts to GrSG because of wild ungulate use of herbaceous species and browse use of sagebrush and other shrub species are more likely. Note that herbivory by non-ungulate wildlife, such as prairie dogs also occurs, but there are no data regarding its potential impacts on, or benefits to, GrSG.

Elk impact herbaceous species, especially grasses, in spring and fall when production may be limited (Wisdom and Thomas 1996). Both elk and mule deer use sagebrush-steppe as transitional range in fall and spring. Both mule deer and pronghorn prefer forbs when available (Yoakum et al. 1996), and because pronghorn populations are high, they may limit forb availability in the Wyoming Basin in the spring. Hobbs et al. (1996) documented a decline in available dead perennial grasses and early spring live perennial grasses as elk densities increased. They further noted a small increase in quality of the forage as elk densities increased, due to the increased digestibility and nitrogen content of new forage. They suggested that competition for forage between elk and domestic livestock will primarily only be a concern during heavy snowfall years, when wild ungulates are concentrated in large densities on lower elevation winter ranges (Hobbs et al. 1996). These conditions could adversely impact nesting cover for sage-grouse in extreme situations. Forage made available to wildlife with rest and rotation systems may result in little habitat improvement if wildlife populations in the area are high. Ultimately, impacts on nutritional quality of plants, forb production, and reduction of standing organic biomass can be accomplished by any herbivore (domestic or wild). Controlled use levels are more feasible with domestic livestock than with wildlife populations. Research should be conducted to fully understand the effects of wild ungulate grazing on sage-grouse.

Conclusions

It is apparent in the examples discussed that the nature of the sage-grouse habitat (nesting, brood-rearing, wintering), the level of herbivory (light, moderate, or heavy stocking rates), and the ability of the vegetation to respond to herbivory (e.g., dry Colorado Plateau ecoregion versus more mesic Southern Rockies ecoregion), determine the degree to which grazing has adverse, neutral, or positive impacts on sage-grouse habitat. For these reasons, site-specific management is needed.

Grazing by domestic and wild ungulates plays an important role in shaping and maintaining vegetative communities in sage-grouse range. Some sagebrush communities in the Colorado Plateau are incapable of producing ideal GrSG nesting cover, irrespective of grazing. Even in more productive sagebrush-grass communities, return of sagebrush seedlings, herbaceous cover, and exotic annual germination are highly variable and primarily result from climatic events rather than domestic stock absence. Reduction or removal of domestic grazing may not improve sage-grouse habitat in most years. Decreased use by domestic stock may be replaced by wildlife use, negating intentions to rest a particular area for improved sage-grouse habitat.

Domestic stock in high stocking densities may cause direct damage to nests and cause abandonment of other habitat, but such events are probably rare. High stocking rates and stocking densities may reduce herbaceous cover, potentially increasing predation on grouse. Low to moderate stocking densities, or effective timing of grazing can reduce direct damage via trampling and nest abandonment. In settings where grass height and density restrict grouse movement and limit herbaceous production and nutritional quality, and where openings in dense sagebrush stands are needed, domestic livestock grazing can be used as a tool to maintain and improve seasonal habitats for sage-grouse.

Wise consideration of timing and low to moderate stocking rates can be used to favorably alter vegetation and enhance sage-grouse habitat. Enough is known about GrSG habitat requirements to make reasonable recommendations to maintain and improve habitat. However, any effort to manage defoliation of vegetation must consider all herbivores, domestic and wild, grazers and browsers (and ideally, below-ground herbivores as well, such as small mammals). Developing grazing systems and management plans that would achieve desired vegetation composition and structure, including shrubs, forbs, and grasses, should benefit both GrSG and domestic and wild ungulates.

Habitat: Fragmentation, Quality, and Quantity

Background

No single topic affects GrSG conservation more than habitat. Sage-grouse are closely tied to and dependent upon various sagebrush habitats. "Habitat" itself is a broad category encompassing or touching on many individual issues that might affect the survival of GrSG.

The fields of landscape ecology and conservation biology recognize 3 primary aspects of habitat that affect a species: (1) habitat quality (how closely the habitat matches the needs of the species); (2) habitat quantity (the amount of habitat necessary to support a given number of individuals); and (3) habitat configuration (how the areas of habitat are arranged relative to one another). These 3 aspects of habitat are inextricably linked and grade into each other, depending on one's perspective (Forman and Godron 1986, Fahrig 1997, Ortega and Capen 1999, Caley et al. 2001, Franklin et al. 2002).

For instance, one could consider habitat quantity and configuration to be components of habitat quality (Turner 1989, Fahrig 1997). That is, if a habitat patch is not large enough, or is arranged in a particular way, it may not meet the needs of the species, and thus is not of adequate quality for the species. In another twist, if habitat quality (in this case, perhaps referring to inappropriate vegetation characteristics) declines to the point where the habitat is unusable to a species, the result could be considered habitat loss. Furthermore, when patches of habitat are destroyed, habitat is not only lost, but is also inevitably reconfigured, resulting in habitat "fragmentation" (Turner 1989, Fahrig 1997). Both the loss and the reconfiguration, or "fragmentation", can independently affect a species' ability to survive.

Sometimes these general and broad conservation biology terms regarding aspects of habitat are used to refer to specific issues potentially affecting a species. For instance, it might be said that "habitat quality" is an issue for a population, meaning more specifically that the habitat quality in a given area is "poor", often as a result of a more specific factor, such as piñon-juniper encroachment into sagebrush habitat. In another case, a different broad term might be used to describe the same specific issue: habitat fragmentation might also be said to occur when there is piñon-juniper encroachment into sagebrush habitat blocks.

If one tries to classify individual issues on the basis of which aspect of habitat they affect, additional confusion ensues. For example, invasive weeds may cause a decline in habitat quality by reducing the vegetation upon which a species depends. If weeds completely overtake a habitat and convert it to a different cover type, one might consider that there is habitat loss, which may in turn fragment other intact habitat blocks.

How Habitat Issues are Addressed in the CCP

Although it is generally believed that areas of high habitat quality are better for the persistence of a species than are areas of lower habitat quality, it is difficult to find for a species the appropriate response variable or population parameter that changes in response to changes in habitat quality.

Density of individuals in a habitat area does not necessarily reflect the habitat's quality (Van Horn 1983). Often, some measure of productivity is recommended as an index to habitat quality.

Few studies have rigorously evaluated the relationship between habitat quality and GrSG populations. Most research is correlative and observational in nature, although Huwer (2004) found a relationship between chick growth and quantity of forbs in the understory. Our approach regarding habitat quality includes identifying research needed to more firmly establish the relationship between habitat quality and GrSG populations (see "Research" strategy, pg. 411). In addition, the "Conservation Assessment" (pg. 30) provides a summary of current knowledge of GrSG habitat, in the form of a description of habitats used by GrSG during different life stages and seasons (see "Habitat Requirements", pg. 35). Appendix A ("GrSG Structural Habitat Guidelines" provides guidelines to habitat structure that would provide for productive sage-grouse populations of GrSG in Colorado. The guidelines offer specific ranges of measurements of vegetation that are appropriate for GrSG, serving as a guide (which is flexible and should be frequently updated with new research) to evaluating GrSG habitat quality. The "Habitat Enhancement" strategy section (pg. 349) outlines appropriate steps to take when managers consider whether and how to improve habitat for GrSG.

Although data exist on the composition and structure of habitat used by GrSG, information regarding the minimum habitat patch size required to sustain an individual GrSG, or a GrSG population, is lacking. Nor is there research regarding how habitat configuration affects GrSG populations. Despite the uncertainty about these issues and sage-grouse, there is still a need to address the possibility of their impacts on GrSG. There is clearly a point at which habitat becomes too fragmented, or the amount of available habitat has declined so much, that a GrSG population will not survive. If it is when we reach one of those thresholds that we finally understand the relationship between habitat fragmentation/quantity and GrSG populations, it is too late. This is a classic situation for adaptive management, when managers must respond to potential issues for a species, without having complete information about how the issue might affect the species (see "Adaptive Management", pg. 10).

Thus, we have identified key research that will address the uncertainty regarding GrSG habitat quantity and configuration (see "Research" strategy, pg. 411). In addition, we offer a GIS analysis that identifies potential linkages that may serve to link habitat within and between populations (see "GrSG Habitat Linkages in Colorado", pg. 287), and strategies to pursue regarding this issue ("Habitat Linkages" strategy, pg. 352). Regarding habitat quantity, our approach is to analyze 2 key causes of habitat loss and degradation: (1) energy and mineral development; and (2) housing development. An analysis of future housing development identifies GrSG habitat areas that are at highest risk of future housing development, and prioritizes areas for protection measures (see "Predicted Future Housing Development and GrSG Habitat Protection", pg. 268). We also estimate the amount of GrSG habitat lost to roads in "Habitat Loss: Roads in Colorado", pg. 284). Another GIS analysis identifies "core areas" consisting of relatively large and important areas of existing GrSG habitat, that may be considered for exemption from energy and mining development for some period of time (see "Energy and Mineral Development: Avoiding and/or Mitigating Impacts", pg. 292). The

"Energy and Mineral Development" strategy (pg. 313) also has strategies that identify potential habitat protection measures.

Although we don't know exactly how much habitat a GrSG population requires to be persistent, or how that habitat should be arranged, we are poised to begin answering some of those questions, while offering tools to protect existing habitat. This approach will help maintain GrSG in Colorado until it is more clearly understood how development of various kinds may be able to proceed without harm to the species' long-term persistence. Recent research in Wyoming is beginning to answer questions about GrSG landscape-level needs (Walker et al. 2007*a*, Doherty et al. 2008).

Housing Development

Problem Definition

There is no other issue more fundamental to the long-term preservation of GrSG than protection of sagebrush habitat and other seasonal habitats on which they depend. Human development results in permanent habitat loss, degradation, and fragmentation. In addition, it results in indirect impacts from associated factors (e.g., roads, fencing, powerlines, increased human activity; see "Infrastructure [pg. 170] and "Roads" [pg. 193] issue sections), and may facilitate introduction of novel predators and noxious weeds (see "Predation" [pg. 183] and "Weeds: Noxious, Invasive and Encroaching Plants" [pg. 198] issue sections).

Colorado has been experiencing substantial increases in human population in recent years. Of all 50 states, Colorado ranked third in population growth from 1990-2000, based on U.S. Census data (CensusScope 2006). Of 63 counties in Colorado, Eagle (NESR) and Summit (MP) are ranked 4th and 6th in growth, respectively (CensusScope 2006). Grand (MP), Garfield (PPR), and Routt (NESR) counties are also ranked in the top 1/3 of all Colorado counties, with population increases exceeding 35% from 1990-2000 (CensusScope 2006). This growth has resulted in conversion of agricultural lands to residential land-uses, and impacts of development have spread onto nearby public lands (Theobald 2003).

Riebsame et al. (1996) described a changing pattern in residential development in Colorado which began in the 1970s and continues today: a significant amount of home building now occurs in subdivisions and large lots far from existing townsites (termed "exurban development"). Exurban development for primary population growth and for second homes has been a significant cause of loss of sagebrush habitats. Within GrSG range, ski resorts such as Vail, Breckenridge, and Steamboat Springs have driven much of the second home development and have also created a demand for lower-cost housing for ski industry employees, away from resort communities. This has resulted in increases in development of "bedroom" communities, which are most often closer to or within existing sage-grouse habitats than are the resorts themselves. Examples include the area from Steamboat Springs to Craig, and from Steamboat Springs to Yampa (Fig. 5, pg. 49).

Regulatory and Other Relief

Habitats on publicly owned and managed lands appear to be already protected from permanent loss. Although it is not common, some public land parcels are slated for land trades, essentially eliminating them from the "protected" category. More importantly, habitat on public land may need to be protected from degradation resulting from land-uses such as overgrazing, energy development, and intensive recreation. Also, public lands adjacent to (or within close proximity of) private lands that are being developed are experiencing increased day-use by people, dogs, feral cats, and vehicle traffic.

Protection of habitat from permanent loss on private land is much more problematic. Authority for regulating land-use on non-federal lands was delegated to the 63 counties in Colorado in 1974. All units of local governments, including counties, cities, and towns, were given authority to regulate land-use within their jurisdictions (C.R.S. 29-20-101).

In Colorado, the CDOW is required by statute (C.R.S. 106-7-104) to (1) provide counties with information on "significant wildlife habitat"; and (2) provide technical assistance, if requested, in establishing guidelines for designating and administering such areas. Counties may, but are not required to, protect land from activities that would cause immediate or foreseeable material danger to significant wildlife habitat, or endanger a wildlife species. Normally, conversion of land zoned as agricultural from one agricultural use to another (e.g., native pasture containing sagebrush converted to cropland), would not come before a county zoning commission; typically habitat loss of that nature is not regulated. State statute exempts from regulation all parcels of land of a size 35 acres or more with 1 house, so county zoning laws can only restrict developments with housing densities greater than 1 per 35 acres (C.R.S. 30-28-101).

Where development is a likely issue for GrSG populations, other protections such as easements or fee-title acquisition of important habitats will be necessary to protect the land for the long-term. Maintaining sustainable rural economies (where traditional land-uses compatible with sage-grouse are profitable) can significantly reduce impacts associated with subdivisions.

Private property owners have a right to develop their land. Long-term and community-based planning to direct growth and development to appropriate areas, along with compensations for restrictions on developments in important areas, are the most efficient means to accomplish conservation. For an analysis of predicted future housing development in GrSG habitat in Colorado, see "Predicted Future Housing Development and GrSG Habitat Protection", pg. 268.

Hunting

Prior to the 20th century most wildlife harvest in the United States was associated with subsistence or market (commercial) hunting. Most wildlife conservation efforts were directed at the prohibition or restriction of harvest because, as Leopold (1933: 208) stated, "As long as game shortage prevails, the purpose of hunting controls is obviously to limit the kill of each species…" At the start of the 20th century, once wildlife (game) populations were at sustainable levels following conservation efforts, the concept of "sport hunting" was more formally introduced. Leopold (1933: 208) stated that once the "…game shortage has been corrected by management, the purpose may extend beyond mere limitation. It may become necessary to enlarge the kill in order to bring the game into a desirable relationship to farm, or forest crops…" The question of when and if "game shortages" have been "corrected" has been a point of much discussion and research, continuing into the 21st century.

Harvest Theory

In the first game management textbook, Leopold (1933) ushered in modern-day wildlife management. Research projects investigated sport harvest in the 1940s and 1950s and continued into the later half of the century. The major question under investigation was the evaluation of the harvestable surplus in wildlife populations (i.e., the portion of the population that can be harvested without impacting the persistence of the population). Harvest management has operated under the auspices of 2 primary conceptual theories: (1) additive mortality; and (2) compensatory mortality (Anderson and Burnham 1976, Bergerud 1988*b*). Each theory uses winter mortality and resultant spring population as benchmarks.

According to additive mortality theory, every individual harvested in a population represents a mortality in addition to those individuals lost to other factors such as disease, starvation, predation, and accidents. The result is a lower spring breeding population than would be present if the population was not harvested. In contrast, compensatory theory considers harvest to be completely compensatory to other factors. Compensation theory suggests that the spring breeding population is unaffected by sport harvest, and that those individuals harvested in the population would have otherwise died from the aforementioned limiting factors.

It is likely that sport harvest is neither entirely additive nor compensatory, but instead falls along a continuum between predictions of the 2 theories, and may vary by year and/or population. Newton (1998) suggested that hunting is compensatory to some certain threshold, and beyond that threshold any harvest is additive. Robertson and Rosenberg (1998) concluded that harvest mortality is typically situated between the extremes of completely additive or completely compensatory, while Anderson and Burnham (1976) agreed that partial compensation could occur in hunted populations.

Allen (1947) and Allen (1974), using the ring-necked pheasant as an example for many upland gamebirds, argued that hunting can replace natural loss. Allen (1974) further suggested that if hunting did not occur, natural limiting factors would compensate for what the hunter did not harvest. Compensatory harvest theory and how it might apply to a number of upland bird species has been examined (Gullion 1984, Ellison 1991, Small et al. 1991, Hudson and Dobson 2001, Roy and Woolf 2001, Willebrand and Hornell 2001, Otis 2002, Williams et al. 2004).

The issue of compensatory versus additive mortality and the theoretical "threshold" upon which compensatory harvest mortality becomes additive has been discussed for sage-grouse. Crawford (1982) evaluated GrSG harvest with respect to season lengths and daily bag and possession limits in Oregon. He concluded that the number of hunters and amount of harvest in Oregon could be predicted and controlled, and that sage-grouse could be harvested consistently and efficiently. Braun and Beck (1985) argued that season lengths and bag limits (from 1973-1983) in the north central Colorado population only resulted in a 7 - 11% harvest rate of the fall population, and they concluded that this harvest rate never approached additive levels. They concluded that 20 - 25% of the fall population of sage-grouse in Jackson County, Colorado could be harvested without hunting mortality reaching the additive level (Braun and Beck 1985). In a subsequent, but different analysis of the same Jackson County, Colorado population data (between 1973-1995), Johnson and Braun (1999) used population viability and regression analyses, and hypothesized that hunting losses in this population may be additive to over-winter mortality; they did not suggest a threshold above which compensatory mortality might become additive.

In the last 20 years, it has been suggested that some GrSG harvest rates may be exceeding the theoretical harvest "threshold" where compensatory mortality becomes additive. Bergerud (1988*b*:702) argued that, "Although hunting mortality is clearly additive to overwinter mortality, it is probably not additive to the mortality that occurs in the breeding season." Bergerud (1988*b*:697-701) suggested that there are three "irrefutable" tests to evaluate whether harvest is additive to overwinter mortality, including the (1) annual mortality rate of marked birds between differing harvest regimes; (2) rate of change of populations that are at different densities; and (3) natural mortality rates of birds in intensively hunted populations compared to expected mortality rates based on the size of the clutch.

Over a decade later, additional evidence (Connelly et al. 2000*a*, 2003*a*) was presented about sage-grouse sport harvest that may lend credence to the additive mortality theory. Connelly et al. (2000*a*) suggested that larger proportions of sage-grouse mortalities in Idaho were related to sport harvest. They reported that 42% and 15% of radio-marked sage-grouse adult female and male mortalities were caused by sport harvest, respectively. Later, Connelly et al. (2003*a*) reported on a spatially modified sport harvest season structure in Idaho. Three season lengths (7 and 23 days, and closed), 2 daily bag and possession limits (1 bag/2 possession and 2 bag/4 possession), and 2 environmental conditions (higher precipitation mountain valleys and drier lowland areas) were evaluated. Although Connelly et al. (2003*a*) acknowledged that they had "little evidence to suggest that hunting caused population declines…" they suggested that their data support the concept that hunting may be additive to overwinter mortality by depressing spring breeding populations. There has been criticism (Sedinger and Rotella 2005) of the Connelly et al. (2003*a*) study based on the correlative nature of the study, combined with statistical issues that make the distinction between the additive and compensatory theories impossible. Reese et al. (2005) disagreed with Sedinger and Rotella (2005), and raised fundamental concerns with their critique.

The primary dependent variable tracked in the Connelly et al. (2003*a*) study was the number of males counted on a sample of strutting grounds located along lek routes in the spring; no population demographics were evaluated in the treatment areas. Connelly et al. (2003*a*) assumed that the counts of males on leks along lek routes have a level of precision that is sensitive enough to detect or discern rather modest changes in spring breeding populations (both males and females) among treatments. Although counting male sage-grouse on strutting grounds in the spring has been a standard technique and used as an index to spring populations for over 50 years (Jenni and Hartzler 1978, Emmons and Braun 1984), there have been past (Beck and Braun 1980) and recent (Walsh et al. 2004) criticisms of lek counts and whether or not they can serve as an accurate index to spring breeding populations (see "Abundance", pg. 50). In addition, the research treatments in Connelly et al. (2003*a*) were not replicated or randomly assigned, therefore making inferences regarding the results difficult. Lastly, this study would be categorized as a quasi-experiment (Campbell and Stanley 1966, Williams et al. 2002), and not "experimental" as Connelly et al. (2004:9-5) suggested.

Although the results of the aforementioned studies are intriguing, and may generally appear to support the additive mortality theory, they also do not conclusively reject the compensatory mortality theory. Understandably, applying the uncertain harvest theory literature to harvest management has been problematic. Connelly et al. (2004:9-6) stated that, "No studies have demonstrated that hunting is a primary cause of reduced numbers of greater sage-grouse", and that "An appropriate harvest rate has not been determined for greater sage-grouse populations." However, this statement conflicts with Connelly et al. (2000*a*), who suggested that sport harvest rates should not exceed 10% of the estimated fall population. Interestingly, the 10% harvest rate cited by Connelly et al. (2000*c*) is derived from Connelly et al. (2000*a*), but after a thorough review of the cited literature in Connelly et al. (2000*a*), it is unclear how the 10% guideline was derived. For example, Connelly et al. (2000*a*) did not evaluate annual survival rates or estimate fall sage-grouse populations, both of which would be necessary to determine an appropriate harvest rate. Furthermore, although Connelly et al. (2004) recognized the lack of support for a specific harvest rate, they nevertheless later suggested a "…5 - 10% harvest rate" might be appropriate, although they note that fall population size must be known to make this approach effective (Connelly et al. 2004:9-6).

In conclusion, it is apparent that the best available literature is unclear regarding (1) whether or not sport harvest of GrSG is additive or compensatory to over-winter mortality; and (2) what an appropriate harvest rate is for GrSG. Even if a recommended harvest rate of 5 - 10% (Connelly et al. 2004) were accepted in good faith, and were applied by state management agencies, managers would need to be able to annually estimate fall population levels in order to apply that harvest rate, and to adjust annual harvest. To date, techniques to estimate fall populations do not exist.

Colorado Seasons, and Bag and Possession Limits, and Harvest

As noted earlier, in the early 1900s there was disagreement between groups that promoted hunting seasons and those that desired wildlife protection. The first law that ultimately protected grouse in Colorado was enacted in 1877 and it established the first sport harvest season (Rogers 1964). In 1904 and 1906 the Colorado Game and Fish Commissioner noted an abundance of "sage chicken" and other game birds, and the Colorado legislature officially sanctioned the first licensed sage-grouse season in 1905 (Rogers 1964:9).

However, after the seasons were set, there was a perceived population decline, and an early opening date was believed responsible for the decline. Hornaday (1916) called on western citizens to save the sage-grouse from "complete annihilation" and called on western states (including Colorado) to restrict their aggressive seasons. He considered Colorado's liberal daily bag limit and season beginning on 1 August a "double crime!" (Hornaday (1916:187). Legislative action was required to make season changes, but no action was taken until 1917, when the Colorado legislature modified daily bag and possession limits in response to the apparent population decline, and delayed the opening date to 15 August. Season opening dates and daily bag and possession limits were repeatedly manipulated by subsequent legislatures (Rogers 1964).

Starting in 1905, statewide season lengths and bag limits were set biennially (Rogers 1964). Hunting seasons and bag limits could be more restrictive in individual counties if county commissions deemed it necessary (Rogers 1964). More standardized seasons were established in 1937 when the Colorado Game and Fish Commission (CGFC) was created (Rogers 1964). The CGFC immediately closed the season on sage-grouse, which was not reopened until 1944 (Rogers 1964). Since the first sage-grouse season in 1905, season lengths have varied from 1 to 62 days (along with some closed seasons), the bag limit has varied from 1 to 25 with possession limit ranging from 2 to 50, and season start dates have ranged from 1 August to mid-September (Table 18). Historically, season length, and bag and possession limits have varied greatly by GrSG population, but recently (since 1998) season lengths and bag and possession limits have become more restrictive, stable, and consistent across the state.

Hunting increases interest, awareness, and appreciation of sage-grouse, and provides a sustainable economic return to local communities. It also provides an incentive for GrSG conservation. The recent standard season is 7 days of harvest (one weekend), a daily bag limit of 2, and a possession limit of 4. Harvest data for Colorado since 1968 are presented in Table 19. For a modeling exercise exploring how harvest might affect GrSG population persistence, see "Harvest" in the population viability analysis, pg. 220.

Currently, there is another hunting season in addition to the firearm season. The additional season is for falconry. The 2006 season occurred from September 1 through March 31. The bag and possession limits are 2 and 2, respectively. It is thought that falconers have little influence on the total number of GrSG harvested, even though they have a 7-month season. There are currently approximately only 160 falconers in Colorado, and it is generally believed that they are much less efficient in harvesting GrSG than are firearm hunters.

Table 18. Colorado GrSG hunting season details, 1905-2005.

YEAR	HUNTING SEASON DATES	DAYS	BAG LIMIT	POSSESSION LIMIT	AREA
1905 - 1906	1 September – 20 October	50	25	50	Statewide
1907	1 August – 1 October	62	25	50	Statewide
1908 - 1912	1 September – 20 October	50	25	50	Statewide
1913 - 1916	1 August – 1 September	32	20	30	Statewide
1917 - 1920	15 August – 1 September	18	10	15	Statewide
1921 - 1922	15 August – 1 September	18	5	5	Statewide
1923 - 1924	15 August – 1 September	18	3	3	Statewide
1925 - 1931	1 August – 15 August	15	8	8	Statewide
1932	1 August – 15 August	15	3	3	Statewide
1933	15 August – 20 August	6	3	3	Statewide
1934 - 1936	1 August – 15 August	15	3	3	Statewide
1937 - 1943	Closed	N/A	N/A	N/A	Statewide
1944	1 – 2 September	2	3	3	Statewide Chaffee County Closed
1945	1 September	1	3	3	Statewide Yuma and Kit Carson Counties Closed
1946 - 1952	Closed	N/A	N/A	N/A	Statewide
1953	20 September	1	2	2	Open west of U.S. 87
1954	19 – 20 September	2	2	2	Open west of U.S. 87
1955	18 – 19 September	2	2	2	Open west of U.S. 87 Gunnison and Saguache Counties (18 September only)

Table 18. Colorado GrSG hunting season details, 1905-2005.

YEAR	HUNTING SEASON DATES	DAYS	BAG LIMIT	POSSESSION LIMIT	AREA
1956	15 – 16 September	2	3	3	Open west of U.S. 87
1957	13 – 14 September	2	2	2	Open west of U.S. 87 Moffat County Closed
1958	13 – 15 September	3	2	2	Open west of U.S. 87 Mesa and Garfield Counties Closed
1959	22 – 24 September	3	3	3	Open west of U.S. 87
1960	20 – 21 September	2	3	3	Only Moffat, Dolores, Montezuma, and West Routt Counties
	17 – 20 September	4	3	3	Statewide except for counties listed above
1961	19 – 20 August	2	3	3	Moffat and East ½ of Routt County
	16 – 18 September	3	3	3	Statewide except Moffat, Routt, Grand, Summit, and Eagle Counties
1962	15 – 17 September	3	2	4	All of the state west of U.S. Highway 85-87, except those portions of Moffat and Routt counties that were opened for an earlier season.
1963	Data Unavailable				
1964	12 – 14 September	3	2	4	All of Sate west of U.S. Highway 87
1964	15 – 20 September	6	2	4	All of Rio Blanco County and that part of Moffat County southwest of Yampa River starting at Utah line, following Yampa River to Lily Park County road #24, to Cross Mountain, and that part of Moffat County in White River drainage.
1965	11 September	1	2	2	All of state west of Interstate 25

Table 18. Colorado GrSG hunting season details, 1905-2005.

YEAR	HUNTING SEASON DATES	DAYS	BAG LIMIT	POSSESSION LIMIT	AREA
1965	11 – 13 September	3	2	4	Routt County east of State 131 and south of U.S. 40; all of Grand County; Eagle County south of Colorado River; Garfield County south of U.S. 6 and east of State 82; Pitkin County north of Sate 82; and Laramie River area east of Medicine Bow Range, north of Fall Creek, west of Laramie River and west of Sand Creek and Chimney Rock roads.
1965	11 – 19 September	9	2	4	All Rio Blanco County; that part of Eagle County west of Colorado River; that part of Garfield County – U.S. 50 – State 141 and north of Dolores River; and those parts of Moffat County north of Sate 10 and west of Sate 318, and south of the Green and Yampa Rivers and west of County Road 24 and the divide between the White and Yampa drainages
1966	10 – 11 September	2	2	4	All of the state west of U.S. Interstate 25 except: Elk River drainage in Routt County north of Steamboat Springs; all of Rio Blanco, Garfield and Pitkin counties; Mesa County north and east of U.S. Highway 6 and U.S. Highway 50; Eagle and Summit Counties south of U.S. Highway 6.
1966	10 – 18 September	9	3	6	Rio Blanco and Garfield Counties west of State Highway 13 and U.S. Highway 6; Moffat County south of Yampa River, west of County Road 143, south of U.S. Highway 40 and west of County Roads 23 and 57.

Table 18. Colorado GrSG hunting season details, 1905-2005.

YEAR	HUNTING SEASON DATES	DAYS	BAG LIMIT	POSSESSION LIMIT	AREA
1967	9 – 10 September	2	2	4	All of state west of U.S. Interstate 25 except: Mesa County east of U.S. 6 and 50; Garfield County east of US Highway 6 and State Highway 13; Rio Blanco County east of State Highway 13; Eagle County south of US Highway 6; Summit County south of US Highway 6; all of Pitkin County.
1967	9 – 17 September	9	2	4	In: Snake River drainage; Rio Blanco and Garfield counties west of State Highway 13, and US Highway 6. Moffat County west of State Highway 13, north of County Highway 9, west of County Highway 7, of U.S. Highway 40, and west of State Highway 57.
1968	14 – 16 September	2	1/2/3 Selected Units	2/4/6 Selected Units	Small game management units 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15, 16, 17, 18, 19, 20, 24.
1968	14 – 22 September	9	1/2/3 Selected	2/4/6 Selected Units	Unit 5 in Snake River drainage and units 7 and 8.
1969	13 – 16 September	4	2	4	
1969	17 – 30 September	13	3	6	
1970					
1971	Data Unavailable				
1972					
1973		3	2	4	Jackson County + ??
1974	14 – 16 September	3	2	4	Jackson County +??
1975	13 – 21 September	9	2	4	Jackson, and +??

Table 18. Colorado GrSG hunting season details, 1905-2005.

YEAR	HUNTING SEASON DATES	DAYS	BAG LIMIT	POSSESSION LIMIT	AREA
1975		3	2	2	Grand County
1976	11 – 19 September	9	3	6	Jackson County only
1976		3	2	4	Rest of the state
1977	10 – 25 September	16	3	6	Jackson County
1977		7	3	6	Rest of the state
1978	9 – 24 September	16	3	6	Jackson County
1978		7	3	6	Elk River Drainage and east of Colorado Highway 131
1978		9	3	6	Rest of the state
1979		9	3	6	Eastern Moffat, Western Routt, and Grand Counties
1979	8 – 23 September	16	3	6	Rest of the state
1980		16	3	6	Grand and Jackson Counties
1980	13 September – 4 October	25	3	6	Moffat and Grand Counties
1981		16	3	6	Moffat and Grand Counties
1981	12 September – 4 October	23	3	6	Jackson County
1982	11 September – 10 October	30	3	6	Jackson County
1982		16	3	6	All of Moffat County, except Cold Springs and Grand County
1982		7	3	6	Cold Springs only
1983		30	3	6	Jackson County
1983	10 – 25 September	16	3	6	Rest of state
1984	8 September - 7 October	30	3	6	Jackson and Larimer County

Table 18. Colorado GrSG hunting season details, 1905-2005.

YEAR	HUNTING SEASON DATES	DAYS	BAG LIMIT	POSSESSION LIMIT	AREA
1984	8 – 23 September	16	2	4	Rest of state
1984	8 – 23 September	16	1	2	Cold Springs only
1985	14 September – 6 October	23	3	6	Jackson and Larimer County
1985	14 – 29 September	16	3	6	Rest of the state
1986	13 September – 5 October	23	3	6	Rest of the state
1986	13 September – 5 October	23	1	2	Cold Springs only
1987	12 September – 4 October	23	3	6	Rest of state
1987	12 September – 4 October	23	1	2	Cold Springs
1988	10 September – 2 October	23	3	6	Rest of state
1988	10 September – 2 October	23	1	2	Cold Springs
1989	9 September – 8 October	30	3	6	Entire state
1990	8 September – 7 October	30	3	6	Entire state
1991	7 September – 6 October	30	3	6	Entire state
1992	1 September – 4 October	34	3	9	Entire state
1993	1 September – 3 October	33	3	9	Entire state
1994	1 September – 2 October	32	3	9	Entire state
1995	1 – 17 September	17	2	4	Jackson County and Blue Mountain
1995	1 – 17 September	17	1	2	All but above
1996	1- 22 September	22	2	4	Jackson County and Blue Mountain
1996	1 – 22 September	22	1	2	Entire state except where noted
1997	13 – 28 September	16	2	4	Jackson County and Blue Mountain
1997	13 – 28 September	16	1	2	Entire state except where noted

Table 18. Colorado GrSG hunting season details, 1905-2005.

YEAR	HUNTING SEASON DATES	DAYS	BAG LIMIT	POSSESSION LIMIT	AREA
1998	12 - 27 September	16	2	4	Jackson County
1998	12 – 18 September	7	2	4	Western Moffat and Grand County,
1998	Closed	N/A	N/A	N/A	Eastern Moffat and Western Routt Counties
1999	Data Unavailable				
2000	9 – 15 September	7	2	4	Units 3, 6, 10, 11, 16, 17, 18 (except east of Colo. 125 in Grand County), 27, 28 (except north and east of Grand Co. Rd. 50 or Church Park Road), 37, 161, 171, 181, 201, 211
2001	8 – 14 September	7	2	4	Units 3, 6, 10, 11, 16, 17, 18 (except east of Colo. 125 in Grand County), 27, 28 (except north and east of Grand Co. Rd. 50 or Church Park Road), 37, 161, 171, 181, 201, 211
2002	14 – 20 September	7	2	4	Units 3, 6, 10, 11, 16, 17, 18 (except east of Colo. 125 in Grand County), 27, 28 (except north and east of Grand Co. Rd. 50 or Church Park Road), 37, 161, 171, 181, 201, 211
2003	13 – 19 September	7	2	4	Units 3, 6, 10, 11, 16, 17, 18 (except east of Colo. 125 in Grand County), 27, 28 (except north and east of Grand Co. Rd. 50 or Church Park Road), 37, 161, 171, 181, 201, 211

Table 18. Colorado GrSG hunting season details, 1905-2005.

YEAR	HUNTING SEASON DATES	DAYS	BAG LIMIT	POSSESSION LIMIT	AREA
2004	11 – 17 September	7	2	4	Units 3, 6, 10, 11, 16, 17, 18 (except east of Colo. 125 in Grand County), 27, 28 (except north and east of Grand Co. Rd. 50 or Church Park Road), 37, 161, 171, 181, 201, 211
2005	10 – 16 September	7	2	4	Units 3, 6, 10, 11, 16, 17, 18 (except east of Colo. 125 in Grand County), 27, 28 (except north and east of Grand Co. Rd. 50 or Church Park Road), 37, 161, 171, 181, 201, 211

Table 8. Colorado GrSG harvest statistics, 1968 – 2005, by county.

Table 19. GrSG harvest in Colorado, by county.

Year	Eagle	Garfield	Grand	Jackson	Larimer	Mesa	Moffat	Pitkin	Rio Blanco	Routt	Summit	Total Harvest
1968	419	396	1,520	1,861	-	144	2,175	-	92	1,493	-	8,100
1969	570	1,008	1,513	3,398	-	87	7,300	-	22	2,719	-	16,617
1970	217	724	1,260	2,172	-	58	4,939	-		2,506	-	11,876
1971	491	597	968	1,962	-	172	5,050	-	13	1,339	-	10,592
1972	537	1,134	677	2,846	-	577	7,822	-	-	2,369	-	15,962
1973	620	584	876	2,007	-	36	2,481	-	-	1,387	-	7,991
1974	1,059	295	987	2,509	-	126	3,379	-	158	1,678	292	10,483
1975	103	275	514	1,973	-	103	3,081	103	460	1,832	-	8,444
1976	785	97	1,154	1,287	-	34	3,569	-	336	1,102	59	8,423
1977	23	46	704	1,621	23	115	2,645	115	171	1,974	153	7,590
1978	226	72	441	1,753	119	198	4,337	68	1,456	1,324	174	10,168
1979	270	68	1,578	3,262		182	6,882		61	1,433	352	14,088
1980	1,324	938	1,445	3,482	-	559	9,083	30	308	1,413	127	18,709
1981	608	110	788	2,089	508	36	7,624	-	1,182	1,920	108	14,973
1982	264	290	818	2,849	33	-	4,489	-	572	1,185	67	10,567
1983	1,575	339	1,562	4,530	501	351	4,579	-	1,586	1,975	155	17,153
1984	Data Unavailable			3,614	Data Unavailable							3,614
1985				1,657								1,657
1986	1,100	614	971	501	48	230	3,627	40	429	825	58	8,443
1987	2,040	294	1,047	2,004		33	7,612	-	691	360	262	14,343
1988	1,180	954	651	1,537	648	67	11,222	-	1,374	827	134	18,594
1989	1,025	265	398	2,876	133	188	9,104	-	711	1,992	144	16,836

Table 8. Colorado GrSG harvest statistics, 1968 – 2005, by county.

Table 19. GrSG harvest in Colorado, by county.

Year	Eagle	Garfield	Grand	Jackson	Larimer	Mesa	Moffat	Pitkin	Rio Blanco	Routt	Summit	Total Harvest
1990	452	211	949	1,472	96	1,520	10,176	415	668	1,068	-	17,027
1991	416	208	-	1,559	205	312	7,472	-	208	618	624	11,622
1992	740	234	2,933	1,029	-	-	4,034	273	1,784	586	640	12,253
1993	345	181	637	1,059	-	117	3,743	-	91	928	-	7,101
1994	438	-	198	1,396	25	151	2,997	124	354	685	-	6,368
1995	51	-	25	458	76	254	721	-	76	51	-	1,712
1996	104	346	104	1,125	-	83	1,125	-	1,090	488	-	4,465
1997	95	-	856	571	71	143	1,466	-	119	71	-	3,392
1998	14	17	235	103	-	-	533	-	116	9	27	1,054
1999	99	-	25	176	-	-	278	-	67	39	18	702
2000	-	-	13	212	-	-	325	-	107	7	4	668
2001	-	-	25	280	-	30[a]	391	-	29	29	-	784
2002	-	-	4	137	-	-	158	-	2	3	3	307
2003	-	-	33	246	-	4[a]	140	-	2	2	-	427
2004	-	-	152	948	-	-	471	-	75	77	8	1,731
2005	-	-	58	461	-	-	518	-	33	14	31	1,115

[a] Data in the table result from surveys of hunters; in some cases hunters are mistaken about the county where they harvested birds, resulting in harvest being reported in counties where the season is closed.

Infrastructure

This section discusses the potential impacts to GrSG from infrastructure that is associated with various types of human development, including housing, energy, and minerals (see "Energy and Mineral Development [pg. 109] and "Housing Development" [pg. 154] issue sections). Infrastructure refers to powerlines, pipelines, fences, and communication towers. Roads are addressed in a separate section (see "Roads" issue section, pg. 193). For positive effects on GrSG resulting from fences, see "Grazing" issue section (pg. 139).

The primary infrastructure-related issues for GrSG are increased risk of predation (see also "Predation" issue section, pg. 183), avoidance, disturbance, collision mortality of birds, and introduction and spread of invasive weeds leading to habitat degradation (see also "Weeds: Noxious, Invasive, and Encroaching Plants" issue section, pg. 198). Although habitat loss does occur in this category, it is generally distributed as linear or small patch changes in habitat, so total amount of habitat loss is relatively minimal (however, see "Habitat Loss: Roads in Colorado" GIS analysis, pg. 284). The wide distribution of these smaller habitat disturbances does, however, fragment formerly intact habitat (see "Habitat: Fragmentation, Quality, and Quantity" issue section, pg. 151) and may result in the impacts mentioned, such as an increase in predation risk and invasive weeds.

Elevated structures of various types may provide perch sites for raptors that prey on grouse, possibly resulting in increased predation. Known raptor predators of GrSG include golden eagles, red-tailed hawks, ferruginous hawks, Swainson's hawks, northern harriers, gyrfalcons, northern goshawks, Cooper's hawks, American kestrels, merlins, and great-horned owls (Schroeder et al. 1999). In addition, if grouse experience or perceive a greater threat of harassment and/or predation, they might avoid areas with overhead structures. Most raptor predation will be on juveniles and older age classes, while other avian predators (e.g., common ravens, American crows and black-billed magpies) will mainly affect clutches. It is unknown how far elevated structures must be from sage-grouse to have no effects on the birds (e.g., behavioral changes, increased predation).

However, there are few studies in peer-reviewed research that clearly address this risk. Ellis (1987) attributed changes in sage-grouse movements on a lek and a shift in lek location in northeastern Utah to construction of a 345-KV transmission line within 660 feet of the lek. Braun et al. (2002) reported that a sage-grouse population in Wyoming that used 40 lek areas within 0.25 miles of power lines had a significantly lower growth rate than a sage-grouse population using lek areas farther away. Increased avian predation was the suggested cause of the lower growth rate.

Although raptors that prey on adult sage-grouse (e.g., golden eagle, red-tailed hawk), chicks (e.g., American kestrel), and eggs (e.g., common raven) typically increase following power line construction (Stahlecker 1978, Knight and Kawashima 1993, Steenhof et al. 1993, Oles 2007), such changes have not yet been linked to population-level impacts on sage-grouse. Oles (2007) also found that new perch deterrents reduced raptor numbers.

A recent study in Nevada examined the effects of new transmission lines on sage-grouse in relation to avian predators (Collopy and Lammers 2004), and had different conclusions. This preliminary progress report concluded that the numbers of avian predators documented during surveys did not change significantly after construction of the new powerline (Collopy and Lammers 2004). Perch deterrents used on new and existing powerlines did not prevent raptor perching, but there was evidence that the amount of time raptors spent perching (for all species) was reduced (Collopy and Lammers 2004).

Grouse have anti-predator behaviors, such as crouching low or seeking cover under vegetation in the presence of predators, or flying in the opposite direction of attack from avian predators (Hartzler 1974, Schroeder et al. 1999). Ellis (1984) described a morning when a golden eagle apparently altered the strutting behavior of GrSG on a lek in Utah after it flew near the lek and eventually landed on an oil well pump; most males eventually resumed strutting.

The presence of paths cleared under powerlines, that fragment previously contiguous habitat, may change the behavior of terrestrial predators by providing easy travel lanes into sagebrush habitat. Studies have indicated that the rate of predation for grassland birds is highest in small, linear patches of nesting habitat, and some have suggested that the linear nature of the habitat allows it to serve as a travel lane for predators (Haensly et al. 1987, Mankin and Warner 1992). Above-ground power lines and transmission lines can result in a long-term linear effect to native habitat (habitat fragmentation and creation of potential travel lanes for predators), depending on the type of power line right-of-way and vegetative cover. Burying powerlines and transmission lines, however, can result in greater ground disturbance and more regular maintenance in seeding and weed prevention. In addition, because of the inherent limitations with burying power lines, this approach could only apply to certain project scenarios and line voltages.

Direct mortality of grouse from collisions with overhead power and telephone lines has been documented (Borell 1939, Ligon 1951, Sika 2006, J. Stiver, University of Nebraska, personal communication), but examples have been isolated and anecdotal. Although these incidents result in the death of individual grouse, population-level impacts of collisions have not been studied. Grouse mortality is also caused by collisions with communication towers (and associated guy wires), fences, and various structures in utility corridors (reviewed across grouse species by Bevanger 1998).

Roads provide an avenue for the spread of exotic plants (Bureau of Land Management 1999, Trombulak and Frissell 2000, Gelbard and Belnap 2003, Bergquist et al. 2007), and powerline or pipeline corridors could also do so. Some roadside introductions have come from revegetation efforts that included alien species (Tyser and Worley 1992), also a risk in utility corridors that are revegetated. Even if exotic weeds are not introduced, disturbed ground may be colonized by native invasive species (e.g., broom snakeweed, wooly mullein).

Lek Viewing

It has been suggested that lek viewing may have an adverse impact on GrSG during the lekking season by interfering with normal lek behavior. Male and female sharp-tailed grouse flushed from active leks when disturbed by human presence and leashed dogs, and females were also disturbed by multiple other types of disturbance (Baydack 1986, as cited in Sime 1999). Of 5 different recreation-user groups at a wildlife refuge in Florida, photographers were the most disruptive, since they were most likely to stop, leave their vehicles, and approach wildlife (Klein 1993, as cited in Knight and Gutzwiller 1995).

Profera (1985) studied the distance at which GrSG stopped displaying or flushed in response to human activity associated with guided and self-guided public viewing tours. She found that even on self-guided tours little disturbance occurred during the duration of the study. Grouse reacted sooner when approached by people on foot than in a vehicle. It was suggested that females flushed at longer approach distances to disturbance than did males, and that male response to disturbance was inversely correlated to the number of females present (Profera 1985). Aldridge (2000) found that males flushed from the lek would not return until the following day. Although not documented, it was postulated that continual disturbance would result in site abandonment and even have a detrimental effect on the population status (Aldridge 2000). Boyko et al. (2004) evaluated how GrSG responded to the avian predator, the golden eagle. If GrSG see humans as predators, then viewers' presence at a lek could cause the same adverse response as do predators.

With limited experimental research on the topic, it is important to evaluate and monitor lek sites that are already experiencing lek-viewing. A GrSG lek in the NP GrSG population, Coalmont lek, was opened for viewing in 1987. Birdwatchers and wildlife enthusiasts were referred to this lek by both the CDOW and BLM. Evaluation of lek counts from the Coalmont lek (Fig. 28) from 1973 to 2005 demonstrates annual fluctuations in numbers, with long-term stability. This stability suggests that lek viewing at this lek, which was open for self-guided viewing, did not have an adverse impact on GrSG.

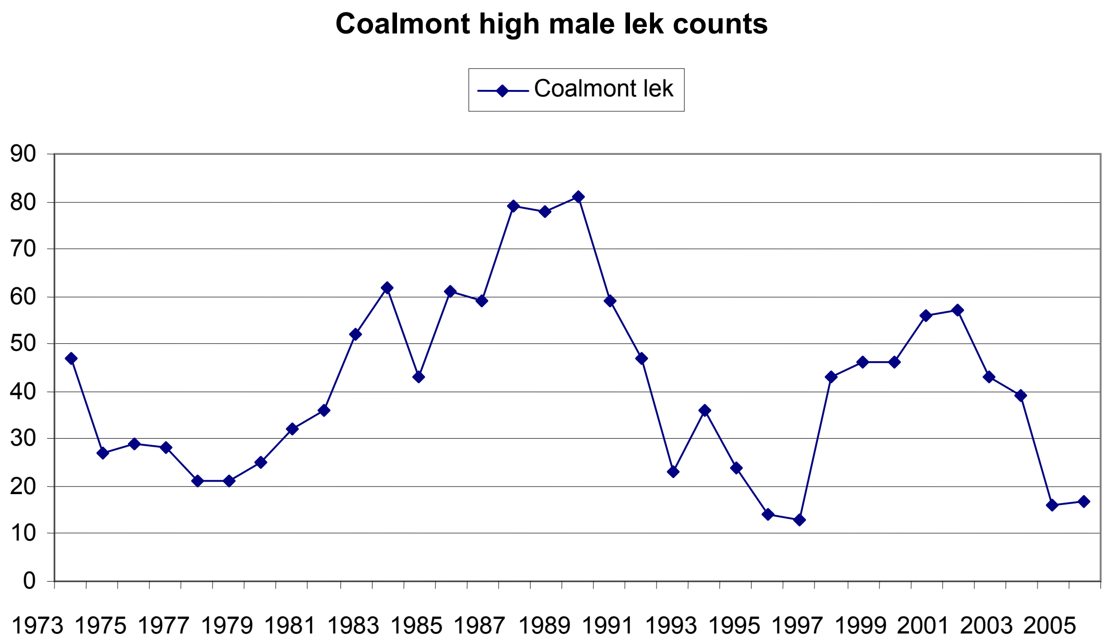

Fig. 28. High male lek counts at Coalmont lek in NP population area. Self-guided lek viewing occurred from 1973 to 2005.

A second lek that has regular visitors is the Boettcher lek (Fig. 29), also in the NP GrSG population area. The local Chamber of Commerce has been offering commercially guided 2-day viewing tours from late April to early May since 1999, occurring 2 to 3 times per lekking season. Boettcher lek counts have increased, over all, since the tours began in 1999 (Fig. 29).

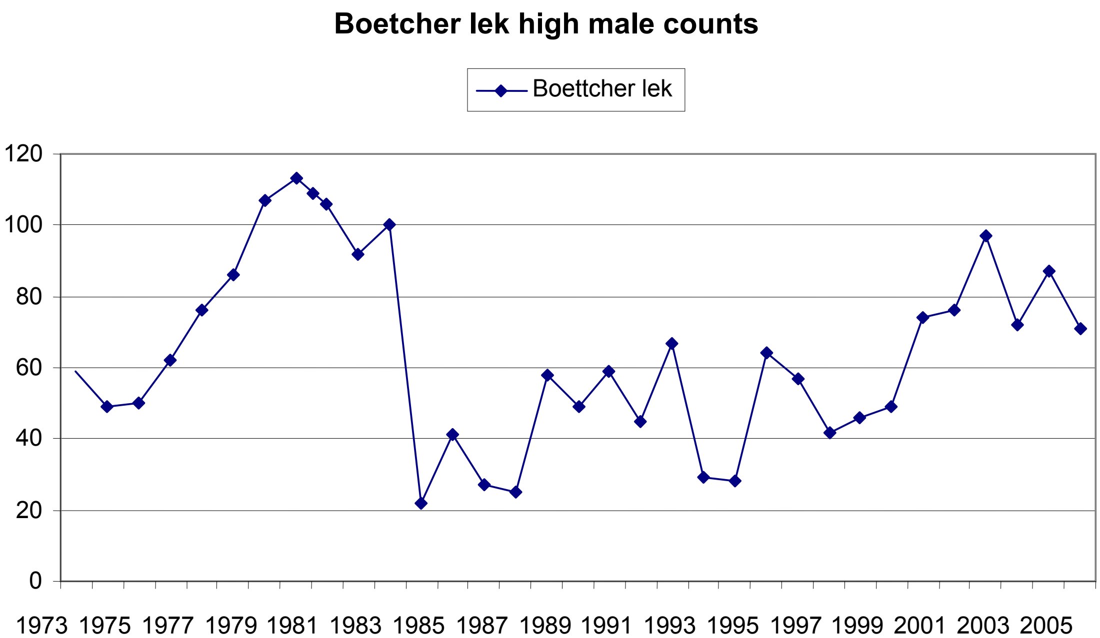

Fig. 29. High male lek counts at Boettcher lek in NP population area. Guided lek viewing tours have been conducted since 1999.

Although guided and self-guided viewing tours may not have an impact on GrSG, it has been found that vehicle disturbance and high-volume traffic is disruptive to GrSG (Mattise 1995, Trombulak and Frissell 2000, Holloran 2005). Leks that can be viewed from the road or a parking area may be vulnerable to vehicle traffic disturbance, if the viewing experience is not managed properly. On the Wuanita lek near Gunnison, Colorado, great efforts have been made to regulate the viewing that occurs on the public lek. Patrons are asked to arrive before sunrise and remain in their vehicles until all of the birds have left the lek for the day. The lek has a volunteer or temporary employee on site everyday during the mating season, in an effort to keep viewers in compliance with the viewing rules/suggestions.

The economic boost wildlife viewing brings to rural economies is significant, but unless the value of ethical viewing of wildlife is enforced and regulated, then there is potential for the wildlife to be impacted (Loft 1998). In 2001, the USFWS found that 2.1 million people participated in wildlife-associated recreation in Colorado (e.g., anglers, hunters, and wildlife watchers), and 73% of them were wildlife watchers (Caudill 2003). Of the 1.6 million wildlife watchers who participated in wildlife watching in Colorado, 1.1 million of them were residents. In total, these wildlife watchers spent a total of $624 million dollars on expenditures specific to viewing, with 67% of that relating to the viewing trip. It was also found that Colorado has 1.1 million people who classify themselves as wild bird watchers, with 61% of them being trip-takers.

There is little research that focuses specifically on the short-term responses of GrSG to human activity at lek sites, and there are no studies on the potential long-term impacts. An inclusive, long-term, controlled study of impacts would require great amounts of time, money, and personnel. This type of project would need to monitor all other factors that affect lek attendance and GrSG populations, and should incorporate data from several sage-grouse populations over numerous years. The impact of 1 year of viewing should not be assumed as the cause if the next year's recruitment of males is low. Factors to be evaluated would include, but should not be limited to, current lek attendance, and from the previous year: lek attendance, mating success, nest success, chick survival, juvenile recruitment, and weather conditions. All of these factors, however, are not yet fully understood and until then the impacts of viewing must continue to be measured with short-term disturbances. These studies, although inconclusive, have only focused on daily responses of grouse to human disturbances. These types of studies could guide the creation of a viewing lek protocol to prevent possible actions that would deter the grouse from returning to the lek.

Conclusion

Lek viewing while on-foot, or without using blinds or vehicles is likely to disturb GrSG. Broader-level impacts of recreational viewing on GrSG, however, have not been studied.

Pesticides

Pesticides may impact GrSG indirectly, by altering habitat and food sources, or directly, through accidental consumption or exposure. Both insecticides and herbicides have the potential to affect sage-grouse.

Insecticides

The pesticides used to control insects (insecticides) are those most likely to affect sage-grouse. Insects are generally a minor diet item for adult sage-grouse, but the importance to chicks has been well-documented (Patterson 1952, Klebenow and Gray 1968, Johnson and Boyce 1990, Fischer et al. 1996*a*). Insects, especially ants (Hymenoptera) and beetles (Coleoptera), can comprise a major proportion of the diet of juvenile sage-grouse (Patterson 1952), and are important components of early brood-rearing habitats (Drut et al. 1994*a*). Fischer et al. (1996*a*) found that insect abundance was greater at brood-rearing areas than at non-brood sites. Johnson and Boyce (1990) reported that survival and growth rates of sage-grouse chicks were proportional to the amount of insect material in the diet. Early brood-rearing habitats are generally close to nesting habitat and are often relatively open areas with abundant herbaceous cover (Sveum et al. 1998*a*). These areas may include farmlands and irrigated croplands adjacent to sagebrush habitats.

Impacts of insecticide spraying to sage-grouse may be direct or indirect, and are dependent on the type of insecticide used, timing of insecticide spraying, and site-specific factors affecting use by sage-grouse, such as crop types and proximity to sagebrush cover. Direct (acute) toxicity of insecticides to sage-grouse occurs through consumption of animal or plant materials with sufficiently high amounts of insecticide residue to kill them, dermal absorption, or vapor inhalation through the mucosa of the respiratory tract (Smith 1987). Indirect (sub-acute) impacts are the disruption of neuronal and endocrinological systems affecting immune function, development, and behavior. Another important indirect impact is the reduction of an important food supply for chicks.

Insecticide use for agricultural pests in GrSG range in Colorado is limited primarily to control for grasshoppers, Mormon crickets, and mosquitoes. Alfalfa weevil and Russian wheat aphid are present in GrSG range, but usually not to the extent that the use of pesticides is needed. The principal method of control in 2003-2004 for grasshoppers was aerial applications of Dimilin (not an insecticide, but a growth regulator) applied in strips 50-feet wide adjacent to 50-feet wide strips of no treatment. Canola oil is used in the treated strips as a pheromone attractant. This method achieves up to 80% control but only applies product on half the ground (C. J. Muclow, Routt County Extension Service, personal communication). Timing of treatment is critical, because Dimilin only works on molting grasshoppers when they are in the 4th or earlier instars. It prevents chitin formation, preventing the exoskeleton of the grasshopper from hardening, resulting in death by exposure. Because mammals and birds do not have chitin, Dimilin is not toxic to them.

Carbaryl and Malathion are also recommended for grasshopper control, usually for backyard and small rural acreage. These areas are not typically inhabited by GrSG, but occasional exposure to these products is possible. Malathion has a short half-life (2 days) and moderate-low toxicity to birds. Carbaryl has a moderate half-life (7 - 28 days) and low toxicity to birds. Both products are not bioaccumulants and ingestion of treated insects soon after treatment would be necessary for lethal doses to GrSG.

Mormon cricket outbreaks are controlled with pesticides in Moffat County and in parts of western Rio Blanco County. As with grasshoppers, outbreaks requiring treatment are not predictable, nor do they occur every year. Treatments include aerial and bait treatments with Malathion, Carbaryl, and Astro (Permethrin). The same treatment using Dimilin for grasshoppers has also been used for Mormon crickets. Permethrin does bioaccumulate, but its toxicity is so low for birds that there is little risk of direct mortality to GrSG. Indirect effects of bioaccumulated Permethrin on GrSG are unknown.

The arrival of WNV in GrSG range presents an additional potential problem with insecticides. Infection with WNV could threaten GrSG populations, but use of insecticides to control mosquitoes which transmit the virus could have detrimental effects on sage-grouse. Use of larvicides such as Bti (*Bacillus thuringiensis israelensis*), which have extremely low toxicities to vertebrates, can greatly mitigate risks (Rose 2004). Available adulticides include synthetic pyrethroids such as permethrin, which are applied at low concentrations and have low vertebrate toxicity (Rose 2004). Organophosphates such as malathion have been used at low rates to kill adult mosquitoes in and near urban areas for decades, and are judged relatively safe for vertebrates (Rose 2004). Throughout GrSG range in Colorado, all 3 of these pesticides have primarily been used in and around urban areas.

Herbicides

In GrSG range different combinations of herbicides (pesticides applied to plants) and seasons of applications have been developed to remove sagebrush, other unwanted woody shrubs, and weedy annual and perennials from western rangelands (Tueller and Evans 1969, Evans and Young 1975, Evans and Young 1977). The use of herbicides has the potential to directly and indirectly impact GrSG. The impacts can be through direct contact (Ward et al. 1942, Post 1951, Blus et al. 1989), or through modification of components of the habitat (indirect contact). These modifications can include the removal of sagebrush (Carr and Glover 1970, Klebenow 1970) and the reduction of forbs or insects (Eng 1952). The most common herbicides used are 2,4-D, Tebuthiuron (Spike), Sulfonylureas (Escort), Glyphosate (Roundup), Picloram (Tordon), Dicamba (Banvel), and Curtail. All have low toxicity to birds and ingestion would have little direct effect on GrSG.

The substantial risk to GrSG from herbicide application is the indirect impact of altering habitat. Herbicides are powerful tools that have been used to both enhance and inadvertently degrade GrSG habitat. Applications of 2,4-D or Tebuthiuron are commonly used to kill sagebrush, leaving standing dead skeletons of the shrubs with low risk of soil erosion. Historically, large blocks of sagebrush were treated with little regard to impacts on sage-grouse habitat. Critical habitat areas were not avoided and impacts to forbs were not considered to be important. Recently, with the emphasis on GrSG habitat in the region, treatment areas have been smaller, and have considered critical habitat areas and impacts to the forb component of the plant community. With proper timing and application rates 2,4-D can be used to reduce sagebrush densities to a desirable level and have little effect on forbs. More recently, thinning of sagebrush density by Tebuthiuron, rather than sagebrush removal from large areas, has been the focus of some treatments (Emmerich 1985, Olson and Whitson 2002). However, due to the long period of effectiveness, it is much harder to control impacts to forbs by Tebuthiuron.

Most other herbicides used in GrSG range, such as Roundup, Escort, Curtail, and Banvel, are used to control noxious and invasive weeds in both agricultural and development settings. Many of the targeted weeds these chemicals are designed to control are forbs, and impacts to desirable forbs are often unavoidable. Using spot treatment applications, adjusting timing of application, using herbicides with short half-lives and low adsorption to soil particles can be help to minimize impacts to desirable forbs and shrubs.

Piñon-Juniper Encroachment

Problem

Loss of habitat within GrSG range in Colorado can be attributed in some areas to piñon-juniper expansion and encroachment into sagebrush communities. Although the amount of sage-grouse habitat lost due to piñon-juniper conversion in Colorado is unknown, a significant portion of the sagebrush-steppe in the West has been affected. Miller and Wigand (1994) estimated that over 8 million acres of sagebrush-steppe are in different stages of conversion to juniper woodlands. Miller and Tausch (2001) stated that the increase in piñon-juniper woodlands has been among the most pronounced vegetation changes that have occurred in the Intermountain West during the past 130 years.

In addition to loss of habitat, conversion of shrub-steppe communities to piñon-juniper results in alterations in habitat suitability for wildlife (Miller et al. 1999). Commons et al. (1999) reported that Gunnison sage-grouse avoid piñon-juniper areas during breeding and summer periods. A similar study on GrSG has not been done, but field observations suggest such avoidance also occurs with GrSG, because GrSG are almost never observed in areas with a piñon-juniper overstory. Doherty et al. (2008) reported strong avoidance of conifers by female sage-grouse during winter.

Mechanism

Piñon-juniper expansion in the West began during the late 1800s (Eddleman 1987, Miller and Rose 1995), peaked during the early 1900s, and is continuing to increase across the intermountain region (Miller and Tausch 2001). Piñon-juniper expansion has been attributed to the simultaneous occurrence of 3 primary factors: (1) a mild and wet climatic period between 1870 and 1920; (2) introduction of domestic livestock; and (3) a reduction in fire intervals (Tausch et al. 1981, Miller and Wigand 1994, Miller and Rose 1995).

Miller and Rose (1999) found support for the 3-factor hypothesis in a study in southern Oregon, in which they examined tree ring data, historic grazing records, fire history, and vegetation characteristics and measurements. Climate during the late 1800s and early 1900s was mild, with an increase in precipitation above long-term averages (LaMarche 1974, Graumlich 1987). Miller and Rose (1999) reported an increase in growth ring widths during this period, suggesting wetter conditions. Expansion of western juniper coincided with domestic livestock introduction (Archer 1994, Miller and Rose 1999). Numbers of cattle, sheep and horses rapidly increased from 1870 and peaked at the turn of the century (Oliphant 1968, Young et al. 1976). Grazing by livestock may have enhanced piñon-juniper expansion by reducing fine fuels, changing the plant community structure, and reducing competition with herbaceous species (Ellison 1960, Burkhardt and Tisdale 1976, Wright et al. 1979, Madany and West 1983, Archer 1994, Miller et al. 1994). Under heavy grazing and reduced fire events, sagebrush cover generally increases and becomes dominant over grasses, providing safe sites for juniper seedling establishment (Miller and Rose 1995).

Fire played a major role in suppressing expansion of piñon-juniper into shrub-steppe communities prior to 1880 (see "Fire and Fuels Management" issue section, pg. 129). Young juniper trees are easily killed when they are less than 4 feet in height (Wright et al. 1979) and less than 50 years in age (Burkhardt and Tisdale 1976, Young and Evans 1981). Fire return intervals of 30 to 40 years are reported to be frequent enough to limit establishment of western juniper (Burkhardt and Tisdale 1976). The fire return interval prior to 1871 in southeastern Oregon was an average of 7.7 years (range of 1 - 19), and the fires were relatively extensive (Miller and Rose 1999). Fire frequency declined after 1870, a full 60 years prior to effective human fire suppression efforts. During the late 1800s accumulation of fine fuels was limited by livestock. Studies in California, Oregon, and eastern Nevada reported decline in fire frequency after introduction of livestock, due to an associated reduction in fine fuels (Burkhardt and Tisdale 1976, Young and Evans 1981, Savage and Swetnam 1990, Gruell et al. 1994, Miller and Rose 1999).

Piñon and juniper establish into new areas through seed dispersal, facilitated primarily by birds and rodents (Chambers et al. 1999). Jays and nutcrackers are the primary avian seed dispersers; both establish shallow seed caches. Distances of seed dispersal vary by avian species. Scrub jays, a solitary species, seldom disperse seeds more than 0.6 miles, piñon jays carry seeds slightly farther, and Clark's nutcrackers can carry seeds as far as 13 miles (Chambers et al. 1999). While jays usually place only one seed per cache, nutcrackers stash up to 10 seeds per cache (Chambers et al. 1999). Ligon (1978) estimated a flock of 250 piñon jays could cache up to 4.5 million Colorado piñon seeds in a 5-month period. The favorite seed storage sites of piñon jays in New Mexico were on open ground and in areas cleared of piñon-juniper by chaining (Ligon 1978), essentially replanting treated sites.

The role of mammals in dispersal of piñon-juniper seeds has probably been underestimated (Chambers et al. 1999). Mammals such as coyotes, cottontail rabbits, and jackrabbits are dispersers of piñon-juniper seeds and usually deposit seeds in interspaces between vegetation (Schupp et al. 1999). Mammals may be more apt to create piñon-juniper invasions into grasslands than are birds because of the need of birds to remain near perches. In Utah, movement of juniper seeds into a grassland community by rabbits was recorded as far as 160 feet (Schupp et al. 1999)

Piñon pines have short-lived seeds, whereas juniper seeds are long-lived (Chambers et al. 1999). Tests of stored juniper seeds showed that 45-year old Utah juniper seeds still had 17 percent germination. Due to this longevity, junipers have highly persistent seed banks (Chambers et al. 1999), and can establish in areas long after seed dispersal has occurred.

Colorado GrSG Habitat Areas Experiencing Piñon-Juniper Encroachment

Piñon-juniper encroachment into occupied GrSG habitat in Colorado is most significant in the NESR, NWCO, and PPR populations (Fig. 30).

Piñon-juniper is expanding into sage-grouse habitat in the NESR population (area 10, Fig. 30). Specifically, piñon-juniper encroachment is in the Eagle zone of the population, in the Colorado River-Eagle River drainage area near Burns and State Bridge. Habitat in this area is at a lower elevation and is drier than in the Routt Zone. The Sunnyside area near Burns has young piñon-juniper growing in previously open sagebrush areas. A recently discovered lek site is in the middle of a small piñon forest. Piñon-juniper is also a factor in the occupied areas around State Bridge. Piñon-juniper is not widely established in the Routt Zone (Yampa-Toponas area) of the population. Piñon-juniper treatment is listed as a conservation action in the local plan (NESRCP 2004), and has been identified as a priority for CDOW biologists.

The NWCO population has the largest areas of piñon-juniper communities, primarily in the western part of the occupied habitat. Areas most affected by piñon-juniper encroachment are numbered in Fig. 30 as follows:

(1) The east and south side of Blue Mountain (east end of Blue Mountain).
(2) The Winter Valley/Elk Springs area all the way to Cross Mountain. The south side of Cross Mountain is a large area experiencing piñon-juniper encroachment. There have been some major fires in the last 15 years that have knocked the piñon-juniper back but there are still encroachment areas.
(3) The area around Greystone (NWCO Zone 2) and to the North up through Sheephead Basin. This area has limited known use by grouse, which could be due, in part, to the piñon-juniper encroachment.
(4) Seven Mile Ridge, west of Little Snake River in NWCO Zone 2.
(5) East of Cross Mountain in the northwest corner of NWCO Zone 5 (Peck Mesa) and the southwest corner of NWCO Zone 3A (Simsberry Draw).
(6) Axial Basin. This area, however, is experiencing a lesser level of encroachment than in other areas.
(7) Brown's Park (southern and eastern portions of NWCO Zone 1).
(8) West of the Green River in the middle of NWCO Zone 7.

The Piceance Basin portion of the PPR population (area 9, Fig. 30) is also strongly affected by piñon-juniper encroachment. Many of the ridge tops are relatively flat, and due to heavy encroachment sagebrush has become more of an understory to piñon-juniper than a predominant community type. Piñon-juniper encroachment is not a concern in the occupied habitat located in the Parachute – Roan portion of population; elevation and precipitation are both too high for piñon-juniper establishment on these ridge tops. However, piñon-juniper encroachment is occurring in potential habitats mapped in Roan Creek and lower elevation areas to the south and west of DeBeque.

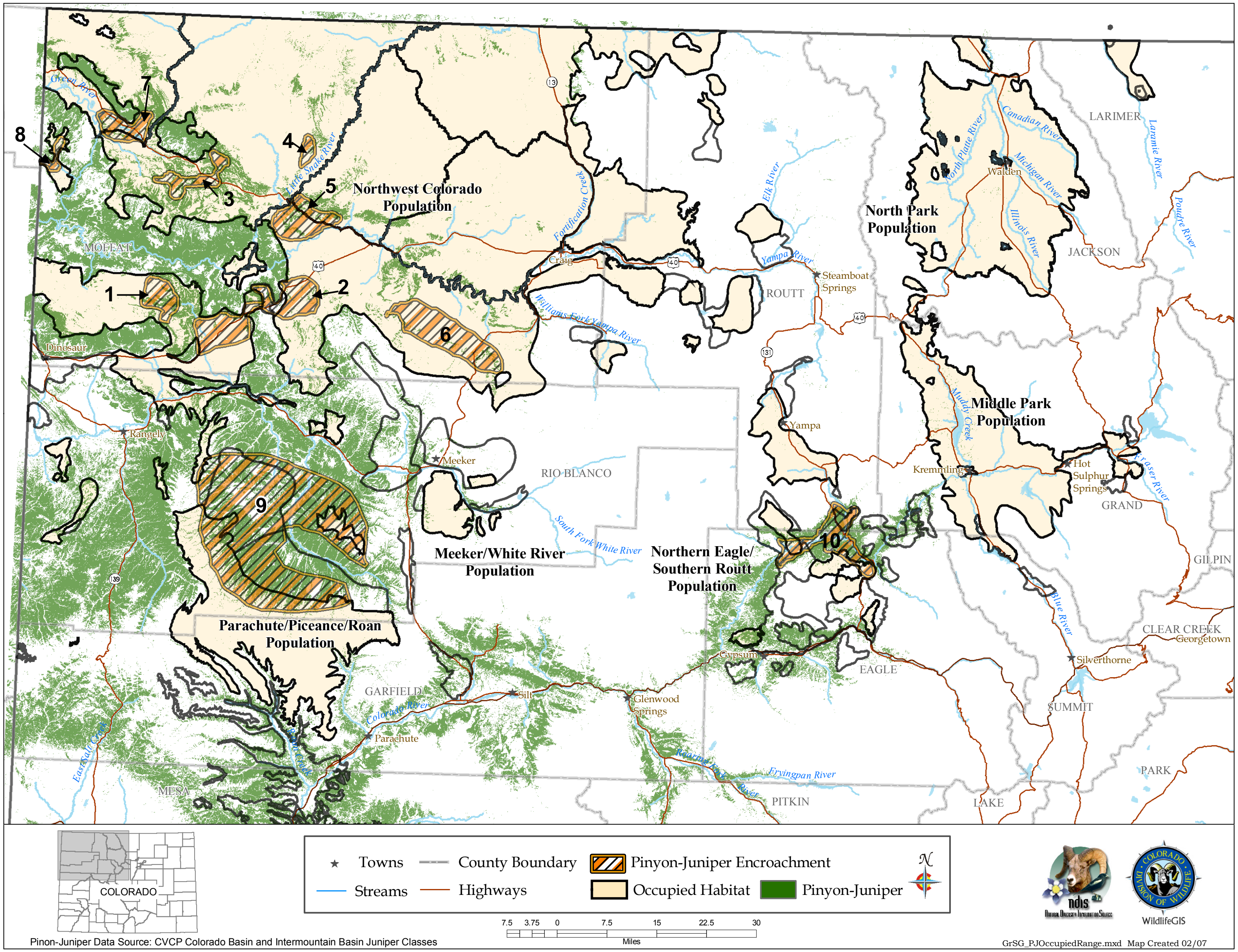

Fig. 30. Areas where piñon – juniper is encroaching in sagebrush habitat with GrSG population areas in Colorado.

Predation

Sage-grouse and Predators

Predation is a major cause of mortality in sage-grouse (Bergerud 1988*a*, Schroeder et al. 1999, Connelly et al. 2000*c*). Predation rates vary seasonally. The period of highest mortality for yearling and adult males occurs during the lekking (breeding) season, for yearling and adult females during nesting and brood-rearing, and for juveniles during the first few weeks after hatch (Patterson 1952, Schroeder et al. 1999, Schroeder and Baydack 2001).

However, the effect of predation on the fluctuations and viability of sage-grouse populations has never been investigated (Connelly and Braun 1997, Connelly et al. 2000*c*, Schroeder and Baydack 2001). Schroeder and Baydack (2001) suggest that nest predators have an important impact on sage-grouse population dynamics given the high variation in nest success. Nest predation may be higher, more variable, and have a greater impact on small, fragmented populations. Predation is an important factor in juvenile mortality, but nutrition, habitat quality, and environmental conditions also affect juvenile mortality (Pyle and Crawford 1996, Sveum et al. 1998*a*, Burkepile et al. 2002, Gregg et al. 2007). The population viability analysis suggests that GrSG juvenile female survival is almost as important as adult female survival for population growth (see "Sensitivity Analysis", pg. 217).

Sage-grouse have evolved with native predators, and consequently have developed traits to survive with high predation pressure. For example, both yearling and adult females nest, lay moderately large clutches, and attempt to re-nest if nests are destroyed by predators (Svedarsky 1988, Schroeder 1997). Sage-grouse plumage is extremely cryptic, and grouse often remain motionless (especially while on nests) instead of flushing (Schroeder et al. 1999). Grouse have also adapted anti-predator behaviors such as crouching low or seeking cover under vegetation in the presence of predators, or flying in the opposite direction of attack from avian predators (Hartzler 1974, Ellis 1984, Schroeder et al. 1999). Females perform displays (e.g., erratic movements or dragging their wings on the ground) to distract predators from nests and broods (Schroeder et al. 1999). GrSG females have also been documented defending their nests from ground squirrels (Schroeder 1997), and Girard (1937) observed females attacking predators in the defense of their broods. Nevertheless, at low GrSG population levels, these adaptations may not be sufficient to prevent serious predation consequences for the population.

Predator Community and Interactions

The effect of predation on sage-grouse populations will depend on the composition of the predator community. Predators of GrSG have been well documented (Schroeder et al. 1999). Predators that depredate juvenile and adult GrSG include avian predators such as golden eagles, red-tailed hawks, ferruginous hawks, Swainson's hawks, northern harriers, gyrfalcons, northern goshawks, Cooper's hawks, American kestrels, merlins, and great-horned owls; and mammalian predators such as coyotes, red foxes, weasels, and bobcats. Predators that depredate eggs include avian predators such as common ravens, American crows, northern harriers, common grackles, and black-billed magpies; mammalian predators such as badgers, ground squirrels, raccoons, red fox, striped skunks, and elk; and reptilian predators such as gopher snakes and prairie rattlesnakes.

The composition and density of predator communities can vary greatly across space and time (Greenwood 1986, Johnson et al. 1989, Sargeant et al. 1993, Sovada et al. 1995). The effect of predation on the demographic structure and population fluctuations of GrSG is unknown, but will likely depend on the composition of the predator community. Avian predators, primarily corvids, were major predators of GrSG nests in Idaho (Autenrieth 1981) and Washington (Vander Haegen et al. 2002), while ground squirrels and badgers were major nest predators in Colorado (Gill 1965) and Wyoming (Patterson 1952). Giesen (1995) documented poor nesting success in North Park, Colorado, in 1993 and 1994 (22% of 42 nests and 27% of 20 nests, respectively). Most nest loss (87%) was due to depredation, primarily by Richardson's ground squirrels. It is possible that most mammalian predation will be on eggs. Only coyotes and red foxes are likely to prey on all grouse life stages. Most raptor predation will be on juveniles and older age classes, while other avian predators (e.g., common ravens, American crows, and black-billed magpies) will primarily affect clutches.

Increasing residential development and/or energy and mineral development have been identified in most GrSG local conservation plans as risks to GrSG (see "Housing Development" [pg. 154] and "Energy and Mineral Development" [pg. 109] issue sections). Development of all kinds can contribute to increased populations of predators (e.g., red foxes, American crows, and common ravens) that are frequently associated with altered landscapes that provide (1) additional denning or nesting sites; (2) additional food resources from agricultural household garbage, waste grain, landfills, or gut piles left by hunters; or (3) easier access to previously contiguous sagebrush habitat via linear features such as roads and powerlines. Housing development increases the likelihood that feral cats and dogs will affect local GrSG populations. Any kind of human development (including housing, energy, and minerals) that produces infrastructure, such as powerlines, communication towers, and roads, presents additional risk to sage-grouse populations. One of the potential risks of these structures is increased predation on GrSG (Ellis 1984, Braun et al. 2002). It is unknown how far elevated structures must be from sage-grouse to have no effects on the birds (e.g., behavioral changes, increased predation). These issues are addressed in more detail under the "Energy and Mineral Development" (pg. 109), "Infrastructure" (pg. 170), and "Roads" (pg. 193) issue sections.

Andelt (2003) investigated the relative abundance of avian and mammalian predators, and the diets of coyotes, red fox, and bobcat in both fragmented and contiguous habitats in Moffat County. In these preliminary surveys, red fox were more abundant in the fragmented habitat than in the more contiguous habitat (Andelt 2003). Golden eagles and common ravens were observed frequently in both study areas. In addition, Andelt (2003) found no GrSG feathers in 141 coyote, 26 red fox, and 4 bobcat scats. Andelt's results may have been affected by predator control efforts (primarily coyote) that took place in the months before his study was conducted (D. Moreno, USDA, personal communication).

There are other complex ecological consequences associated with predation that must also be addressed before specific management strategies can be recommended. These include the behavioral and spatial interactions of predators with GrSG and with other predator species.

Removing predators from a specific area can lead to a functional and/or numerical response by other predators. Predators compensate for predator removal by either moving into vacated areas (functional response; Sargeant 1972, Gese et al. 1989), or by producing larger litters that typically have higher survival rates (numerical response; Knowlton 1972). The reproductive and movement characteristics of predators such as red foxes (Allen 1983), raccoons (Fritzell 1978) and striped skunks (Greenwood and Sargeant 1994) make it possible for these species to rebound quickly following predator removal programs.

Furthermore, it has been argued that removing dominant predators from an ecosystem can result in increased populations of lower trophic-level predators (i.e., "mesopredators") such as red foxes, raccoons, ground squirrels, and feral pets (Soulé et al. 1988, Rogers and Caro 1998, Crooks and Soulé 1999, Mezquida et al. 2006). The increased population densities of lower trophic-level predators may compensate for the removal of dominant predators such that overall predation rates are not affected (Parker 1984, Greenwood 1986). Predator control programs that focus on removing coyotes can lead to increased populations of red foxes (Sargeant et al. 1987, Voigt and Earle 1983). Red foxes may have a more profound effect on sage-grouse populations than coyotes. In prairie ecosystems, red foxes are a major predator of grassland birds (Sargeant et al. 1984, Greenwood et al. 1987, Johnson et al. 1989) and have a greater impact on nest success of grassland birds than do coyotes (Johnson et al. 1989). Both coyotes and red foxes are territorial and red foxes avoid areas with coyotes (Voigt and Earle 1983). Areas with high densities of coyotes have low densities of red foxes and higher overall nest success (Sovada et al. 1995). Therefore, behavioral and spatial interactions among predator species are complex, and compensatory predation may undermine predator control programs that focus on a single predator species. It is possible that attempts to control multiple mammalian predators to allow more sage-grouse to fledge in the short-term, may ultimately lead to increased predation by avian predators (Mezquida et al. 2006).

Predator Control - Background

Predator control studies in prairie ecosystems have had variable success in increasing waterfowl nest success or productivity (Greenwood 1986, Sargeant et al. 1995). The variability may be partly due to restrictions on the methods allowed (Sargeant et al. 1995), but may also be due to compensatory predation from predator species not included in the control program, or by a numerical and/or functional response by predators included in the program. Predator removal was most successful in small (< 1,236 acres), intensively managed waterfowl nesting areas (Balser et al. 1968, Chesness et al. 1968, Duebbert and Lokemoen 1980, Greenwood 1986, Sargeant et al. 1995). Moderate improvements in nest success and brood production have been documented for predator removal programs that used multiple methods over relatively larger (<64,247 acres) areas (Balser et al. 1968, Schranck 1972, Duebbert and Kantrud 1974, Duebbert and Lokemoen 1980, Garrettson et al. 1996). However, increases in nest success as a result of predator removal programs tend not to last beyond the duration of active predator removal (Chesness et al. 1968, Duebbert and Kantrud 1974) and generally have not resulted in significant recruitment or population growth in prey populations over time (Cote and Sutherland 1997).

Legal restrictions on predator control techniques (e.g., trapping and poisoning) may influence a predator control program. In Colorado, it is unlawful to kill wildlife by trapping or poison unless a landowner can provide evidence of ongoing damage to livestock or crops and that other methods not prohibited by law have failed (Colorado Constitution, Title 33: Article 6; note, there are some exemptions under Amendment 14). Even then, trapping is allowed only for a 30-day period each year. Some poisons, such as sodium monofluoroacetate (1080), have been used to kill predators that feed on a carcass that has poison placed in it. This use has been banned on federal lands since 1972, due to a lack of evidence that poisons such as 1080 effectively controlled predator populations (particularly coyote populations), and because non-target animals (e.g., badgers, eagles, livestock, and pets) were often unintentional victims. The compound may still be used in livestock protection collars, which target only predators that kill and feed on livestock.

Before control of raptors or other migratory birds is considered for sage-grouse management, multiple federal laws must be considered.

The Migratory Bird Treaty Act of 1918 (16 U.S.C. 703-712; Ch 128; July 13, 1918; 40 Stat. 755) as amended, implemented the 1916 Convention between the United States and Great Britain (for Canada), for the protection of migratory birds. This act established a federal prohibition, unless permitted by regulations, to "pursue, hunt, take, capture, kill, attempt to take, capture or kill, possess, offer for sale, sell, offer to purchase, purchase, deliver for shipment, ship, cause to be shipped, deliver for transportation, transport, cause to be transported, carry, or cause to be carried by any means whatever, receive for shipment, transportation or carriage, or export, at any time, or in any manner, any migratory bird, included in the terms of this Convention…for the protection of migratory birds…or any part, nest, or egg of any such bird" (16 U.S.C. 703). This prohibition applies to birds included in the respective international conventions between the United States and Great Britain, the United States and Mexico, the United States and Japan, and the United States and Russia.

The Bald Eagle Protection Act (16 U.S.C. 668-668dd, 54 Stat. 250), as amended, provides for the protection of bald and golden eagles. This act prohibits, except under certain specified conditions, the taking, possession, and commerce of such birds. The Airborne Hunting Act, Public Law 92-159, approved November 18, 1971 (85 Stat. 480) prohibits shooting or attempting to shoot, or harassing any bird, fish, or other animal from aircraft, except for certain specified reasons, as authorized by a federal- or state- issued license or permit. The Endangered Species Act of 1973 (16 U.S.C. 1531-1544, 87 Stat. 884) may also apply to raptors or other wildlife that may depredate sage-grouse.

Predator Control – Methods

A variety of lethal and nonlethal predator control methods have been developed (Lokemoen 1984, U.S. Department of Agriculture 1994). Occasionally, multiple methods are used to increase the effectiveness of predator control programs, but typically methods are designed for specific predator species in localized areas and are limited by budget and personnel constraints

(U.S. Department of Agriculture 1994). Most methods focus on controlling mammalian nest predators, but some target avian nest predators.

Lethal predator control methods are the most traditional and controversial of predator management programs (U.S. Department of Agriculture 1994). These methods include both species-specific chemical toxicants (e.g., zinc phosphide for rodents, sodium cyanide for canids, and DRC-1339 for blackbirds) and non-target strychnine- or arsenic-based toxicants (U.S. Department of Agriculture 1994). They also include methods such as shooting (e.g., aerial gunning of coyotes), kill-traps, catch and kill techniques (i.e., shooting predators after capturing them in leg-hold traps, snares, or box traps), killing offspring in dens (used mostly for coyotes and red foxes), or destruction of nests/eggs/hatchlings of avian predators (U.S. Department of Agriculture 1994).

Non-lethal predator control strategies can be divided into small-scale (intensive) methods or relatively large-scale (extensive) methods. Small-scale predator control methods are typically designed to repel predators from well-defined important areas (e.g., a small block of dense nesting habitat). One type of small-scale method involves building fences (predator exclosures) around small blocks of nesting habitat (Lokemoen et al. 1982, Lokemoen 1984, Greenwood et al. 1990) or around individual nests (Sargeant et al. 1974). These barriers can be effective, but are often expensive.

Scare tactics are another type of small-scale method that attempt to disrupt predators from their normal hunting behavior and potentially repel them in important areas. Scare tactics can include distress calls (or calls from avian predators that are designed to ward off other avian species, such as common ravens and American crows), strips of flagging attached to fence lines, bright lights (spotlights) or loud noises (e.g., propane exploders, gunfire, pyrotechnics, or ultrasonic devices) that are triggered by a predator, or scarecrows. Scare tactics are relatively inexpensive; however, many predators (particularly canids) are quick to adapt to the tactics. Some tactics such as bright lights and loud noises may be more annoying to people than to predators.

Another small-scale nonlethal predator control strategy involves altering predator behavior through aversion techniques (Nicolaus et al. 1982, 1983; Nicolaus 1987; Conover 1989, 1990). The techniques attempt to train individual predators to either avoid prey items such as eggs or to avoid important areas. Chemically treated eggs are placed where they will be commonly encountered by a predator. The method works only if the predator associates the eggs with the chemical's taste; otherwise predators will continue to disturb nests and destroy eggs to determine if they contain the chemicals (Conover 1989). Other aversion techniques include repellents broadcast over an important area (U.S. Department of Agriculture 1994). Repellants are typically nontoxic, aversive chemicals applied to trees or fence posts. Scent stations are also used to repel predators, but are used only for territorial predators such as canids. Chemical repellants are regulated by the Federal Insecticide, Fungicide and Rodenticide Act as administered by the Environmental Protection Agency. Aversion techniques have not been demonstrated to be consistently successful and are relatively expensive and labor-intensive (Greenwood and Sovada 1996).

Another nonlethal approach is to inhibit reproduction of predators through sterilization (U.S. Department of Agriculture 1994). It is argued that inhibiting reproduction will reduce predation rates since parents will have fewer offspring to feed and ultimately, the predator population size will decline as a result of lower recruitment. However, any gains from the approach are likely to be offset by compensatory predation from other species and by a functional response by predators (i.e., untreated predators from adjacent areas move into the treated area in response to decreased population density).

Habitat Management as Predator Control

Habitat management, as a nonlethal approach to predator control, is receiving increasing attention. A variety of habitat-related techniques have been suggested for predator control, including: (1) managing the composition and configuration of habitats at landscape scales; (2) small-scale restoration and management of vegetation structure for cover from predation; (3) managing habitats to enhance (or diminish) the presence of alternative prey; and (4) removing den or nesting sites, and perching sites from important habitats.

The quantity of nesting habitat in the landscape has been correlated to the nesting success of grassland birds and has often been linked to the rate of predation (Kirsch, 1974; Greenwood et al. 1987, 1995; Connelly et al. 1991; Andren 1992; Ball 1996). Furthermore, the composition and configuration of habitats in the landscape can influence the movement patterns and ability of predators to find nests of grassland birds (Kuehl and Clark 2002; Phillips et al. 2003, 2004). Large blocks of nesting habitat in landscapes with alternative habitat types, such as pastures that have food resources attractive to predators (Greenwood et al. 1999), decrease the foraging efficiency of mammalian predators in grassland ecosystems (Phillips et al. 2003, 2004). The fragmentation of important habitat is considered an important mechanism in the decline of many avian populations (Wilcove 1985; Johnson and Temple 1986, 1990) and has been correlated to the type and density of the predator community (Robinson et al. 1995, Yahner 1996, Vander Haegen et al. 2002). It is argued that habitat fragmentation increases predation by decreasing the amount of cover habitat for birds while increasing the amount of habitat easily traveled and searched by predators (e.g., edge habitat). Studies have indicated that the rate of predation is highest in small, linear patches of nesting habitat (Chesness et al. 1968, Haensly et al. 1987, Mankin and Warner 1992). Management of sagebrush habitat at the landscape scale to maintain large, undisturbed blocks of sagebrush habitat may be a cost-effective way to reduce the effect of mammalian predation on GrSG.

Habitat with adequate shrub and grass structure may provide sage-grouse and sage-grouse nests some protection from predators (DeLong et al. 1995, Sveum et al. 1998*b*). It is suggested that dense vegetation structure will prevent predators from detecting nests. Several studies in prairie ecosystems have reported high nest success for grassland birds in areas with dense vegetation (Schranck 1972; Duebbert and Lokemoen 1976; Livezey 1981; Cowardin et al. 1985; Sugden and Beyersbergen 1986, 1987). The success of the approach may depend on patch size as well as the predator community. Mammalian predators that use olfactory cues to search for prey may not be affected as much by vegetation structure as avian predators that rely more on visual cues.

One possible management tool that has been suggested for controlling predators is managing habitat (or supplementing food resources) so that there is greater abundance of alternative prey (or food resources) either in, or adjacent to, areas of important nesting or brood-rearing habitat. The assumption is that predators will alter their behavior and search for prey items (i.e., alternate prey such as rodents and lagomorphs) that are more abundant or require less energy to find and consume than nests or broods. That is, predation rates may be greater for grouse if alternate prey are scarce. However, the few studies that have addressed the question have not been conclusive. Nest success of grassland birds has either improved (Angelstam et al. 1984, Crabtree and Wolfe 1988), shown no response (Greenwood et al. 1998), or declined in the presence of alternative prey (Vickery et al. 1992). Supplemental feeding may artificially increase predator population levels, leading to higher overall prey consumption and the danger that when supplemental feeding ceases, predation on the target species (i.e., GrSG) would be higher than before feeding was initiated (D. Moreno, USDA, personal communication). Conflicting results may be due to complex predator-prey population dynamics such that temporal or spatial population fluctuations of alternative prey may be too erratic for a predictable predator response.

It has been suggested that predator populations (both the species and population abundance) may be controlled by removing den sites, such as abandoned farmsteads, and nesting or perching structures, such as powerlines and fences (Fleskes and Klaas 1991, Herkert 1994, Greenwood et al. 1995, Larivierre et al. 1999). However, there has been no research on the influence of these structures on predator or sage-grouse populations.

Manipulating habitat to influence predator communities may be the most cost-effective long-term predator control method. However, habitat manipulation will take time and it may not be feasible to reverse the trends in habitat loss and fragmentation for some populations (e.g., in areas of residential development). GrSG populations that are small and embedded in highly fragmented and developed landscapes, intensive predator control should be considered as a short-term management tool where legally feasible. An integrated program that includes both intensive and extensive predator control methods may be the most effective but will likely be costly. Any predator control program must include long-term monitoring of both predator and GrSG populations in order to evaluate the effectiveness and validity of the program.

Conclusions

Before a predator control program is implemented, it is recommended that research be conducted to: (1) evaluate the demographic status of GrSG populations; (2) eliminate other contributing factors to population fluctuations, especially those most amenable to management; (3) address the behavioral and spatial interactions of predators and sage-grouse; (4) identify the extent of predation pressures and contributing predator community; (5) identify the most important predators for each life stage; and (6) evaluate the role of predation on the long-term viability of sage-grouse populations.

The development of an effective predator management program is problematic given the complexity of the ecological and socioeconomic consequences, lack of reliable information, and public resistance to lethal predator control (Messmer et al. 1999). However, predator control may be necessary under some circumstances for GrSG populations that are small, isolated, and/or fragmented. In these cases, a predator control program should be designed for a specific GrSG population, since the relevant predator community varies for each population. An integrated program that includes both intensive and extensive (lethal and nonlethal) predator control methods may be the most effective, but will likely be costly. Predator control may be warranted only if nest success and/or female (or brood) survival is exceptionally low and predators are known with certainty (e.g., red fox in Strawberry Valley, Utah). The population viability analysis indicates a higher extinction probability for populations with <30 breeding males (see results for MWR population, Appendix K, "Population Viability Analysis Report", pg. K-14).

If predator control is used, the quantifiable objectives within a specific time-frame must be specified, and long-term monitoring of both predator and prey communities (sage-grouse as well as other prey species), is necessary in order to objectively evaluate the success of the program. All predator management plans in Colorado will follow directives of the Colorado Wildlife Commission Mammalian Predator Management Policy and be submitted to the Wildlife Commission and the Director of the Division of Wildlife for review and approval.

Recreational Activities

Human recreational activities can impact wildlife, including GrSG, through 4 primary routes: (1) exploitation; (2) disturbance; (3) habitat modification; and (4) pollution (Knight and Gutzwiller 1995). Exploitation means death by hunting, trapping, or scientific collection (see "Hunting" issue section, pg. 156). Disturbance results from activities such as birdwatching, wildlife photography, hiking, biking, or motorized use through an animal's territory, which can cause unintentional disturbance. Recreationists can modify vegetation, soil, water, and even microclimates, which in turn can impact species associated with these affected habitat components. Some wildlife species are indirectly affected by pollution, such as human trash, including food and plastic objects. Recreation on lands managed by the BLM is a significant land-use (Connelly et al. 2004), and recreation use on national forests has increased 76% since 1977 (Rosenberg et al. 2004).

Disturbance is the aspect of recreational activity most likely to impact GrSG. Most studies on wildlife species have documented immediate, rather than long-term responses to disturbance (Knight and Gutzwiller 1995). Some of these responses are behavioral changes including nest abandonment, change in food habits, and physiological changes, such as elevated heart rates.

Wildlife viewing has the potential to adversely affect wildlife. Avid birders sometimes intentionally seek out rare or spectacular species, such as GrSG. Because viewing activities sometimes occur during sensitive times of year (e.g., strutting and nesting), they have the potential to adversely affect wildlife behavior, if not managed properly (also see "Lek Viewing" issue section, pg. 172). Of 5 different recreation-user groups at a wildlife refuge in Florida, photographers were the most disruptive, since they were most likely to stop, leave their vehicles, and approach wildlife (Klein 1993, as cited in Knight and Gutzwiller 1995).

Dispersed recreational activities, such as off-road vehicle use, backpacking, hiking, cross-country skiing, and horseback riding have increased dramatically in recent years. These activities are extensive in nature and have the ability to disrupt wildlife in many ways, particularly by displacing animals from an area. Most documented responses have been behavioral and short-lived (Knight and Gutzwiller 1995). Dispersed recreational activities may have substantial impacts in some Colorado GrSG populations, especially the NESR population, due to resort development and the associated increase in human populations in Eagle and Routt Counties. The BLM manages large portions of northern Eagle County, and the majority of these areas are currently open to motorized travel. Several of the high motorized use areas historically had sage-grouse use, but are no longer occupied.

Disturbance during an animal's breeding season may affect an individual's productivity. Wildlife may respond to disturbance during the breeding season by abandoning their nests or young, leading to reproductive failure. Human activity can also alter parental attentiveness (increasing the vulnerability of the young being preyed upon), disrupt feeding patterns, or expose young or eggs to adverse environmental stress.

Studies on human disturbance during the lekking season for sharp-tailed grouse (Baydack 1986, as cited in Sime 1999) tested different forms of disturbance on lekking birds, including parked vehicles, snow fencing, propane "bangers", scarecrows, radio sounds, human presence, and leashed dogs. Male grouse tolerated all experimental disturbances and continued to display, except when disturbed by visible human presence and leashed dogs. With human presence, males flushed from the lek but generally remained within 1/4-mile of it and returned within 5 minutes following cessation of the disturbance. In contrast, female sharp-tailed grouse showed more sensitivity to disturbance, being displaced from leks by all tested disturbances. Unfortunately, it is not known whether the females returned to the lek after the disturbance stopped, because they were not monitored in this study. However, because females attend leks for only a brief period of time, there is a possibility that disturbance could influence nesting chronology and fecundity for a local grouse population.

One extension of human recreation in wildlife habitats is the effect of disturbance, harassment, displacement, or direct mortality of wildlife due to domestic dogs that accompany recreationists. Authors of many wildlife disturbance studies concluded that dogs with people, dogs on-leash, or loose dogs provoked the most pronounced disturbance reactions from their study animals (Sime 1999). Dogs extend the zone of human influence when they are off-leash. Potential consequences of dogs off-leash are primarily harassment, due to the predator instinct of dogs to chase/hunt animals. Harassment by dogs can lead to physiological stress, destruction of nests or chicks, separation of adult hens from young, or flushing of incubating birds from nests. Displacement, whether caused by dogs or humans, also has the potential to increase predation by the natural predators, as well, by increasing the vulnerability of adults and young.

Roads

Roads have multiple impacts on wildlife in terrestrial ecosystems, including (1) increased mortality from collision with vehicles; (2) changes in behavior; (3) loss and alteration of habitat; (4) spread of exotic species; and (5) increased human access, resulting in facilitation of additional alteration and use of habitats by humans (Jackson 2000, Trombulak and Frissell 2000). The literature on road effects in terrestrial systems is dominated by work in forest systems, followed by grasslands (see review by Trombulak and Frissell 2000); research on the effects of roads on sagebrush systems is more limited (Gelbard and Belnap 2003, Lyon and Anderson 2003, Holloran 2005). In addition, research has generally focused more on paved and other improved roads (e.g., Clevenger and Waltho 2000, Forman and Deblinger 2000, Parendes and Jones 2000), rather than less developed roads such as graded and four-wheel drive roads.

Collision Mortality

Direct mortality through collisions with vehicles is perhaps the most obvious adverse impact of roads on wildlife, and is well-documented (Trombulak and Frissell 2000). However, data specific to collisions between sage-grouse and vehicles is limited.

At a Wyoming study site, despite the fact that 2 GrSG leks were partially located on main haul roads, direct grouse mortalities from vehicle collisions were rarely observed (Holloran 2005). GrSG collisions with vehicles were recorded during a wildlife crossing study in Teton County, Wyoming, although the number of mortalities was not reported (Biota Research and Consulting, Inc. 2003). There was a collision mortality of a Gunnison sage-grouse reported in the San Miguel, Colorado population (A. D. Apa, CDOW, personal communication). Patterson (1952) reported that sage-grouse collisions with vehicles were more likely to occur during summer when hens with broods increased movements. There are anecdotal reports of GrSG mortality due to vehicle collisions (e.g., Sika 2006, D. Naugle, University of Montana, unpublished data). Clearly, collisions with vehicles may cause individual grouse mortality, but population-level impacts have not been studied.

Behavior Changes

Some wildlife species tolerate roads, or may even benefit from them, but many species avoid roads or reside at lower densities near roads (Stoms 2000). Hunted species may exhibit a greater avoidance of road-related disturbances than related, unhunted species (Jalkotsy et al. 1997). The effect of roads on wildlife may extend for some distance from the road itself (Stoms 2000).

Holloran (2005) investigated GrSG population response to different aspects of natural gas development in Wyoming, including responses of breeding populations to main haul roads. Main haul roads were defined as roads accessing ≥ 5 producing wells, and secondary roads were those accessing <5 wells. The number of vehicles using haul roads within certain distances from leks was measured with pneumatic counters. Results revealed that the number of GrSG males on leks within 1.8 miles of a main haul road declined significantly relative to the number of males on control leks located > 3.7 miles from main haul roads. Results did not show a significant decline in lek attendance on leks located greater than 1.8 miles from main haul roads. In addition, male lek attendance rates appeared related to traffic volume on nearby roads.

Lyon and Anderson (2003) examined the effect of vehicular activity from natural gas development on GrSG nest-site selection and productivity. They termed leks that were within 1.8 miles of gas development (well pads or roads) "disturbed", and leks further from development as "undisturbed". The reasoning behind stratifying the data at the 1.8-mile distance was not provided. Results indicated that hens captured at disturbed leks nested nearly twice as far from the lek of capture as did females from undisturbed leks. The authors hypothesized that hens from "disturbed" leks moved further to nest because of "light" road traffic (1 - 12 vehicles/day) within 1.8 miles of the lek. In addition, the study found a lower nest initiation rate in females from the disturbed leks than in those from undisturbed leks.

If roads are movement barriers for a species, they may fragment populations (National Research Council 2005). However, roads do not effectively serve as barriers to sage-grouse movement because, although GrSG could choose to avoid roads, they are physically able to cross any type of road.

Spread of Exotic Plant Species

Roads provide an avenue for the spread of exotic plants (see also "Weeds: Noxious, Invasive, and Encroaching Plants" issue section, pg. 198), particularly in arid and semiarid environments of the West (Bureau of Land Management 1999). Substrate disturbance in roadside areas facilitates establishment of exotic species, thus providing seed sources for further dispersal into adjacent vegetation communities (Tyser and Worley 1992). Roadside introductions have come from both accidental transport of alien seeds by vehicles, as well as from reintroduction through revegetation efforts that included alien species (Tyser and Worley 1992). Road use and roadside management may also encourage the proliferation of exotic species (Gelbard and Belnap 2003, Bergquist et al. 2007).

The type of road influences its effect on native vegetation, with paved and improved roads (e.g., gravel) corresponding to increasing cover of exotic species in roadside verges, and four-wheel-drive roads showing relatively lower exotic species cover (Gelbard and Belnap 2003). This can be explained in part due to intensity and frequency of disturbance, but also to the amount of area impacted; wider roadsides create more disturbed habitat conducive to exotic weed invasion. However, the impact of the more improved roads is noticeable even beyond the roadside verge, as exotic species spread into undisturbed native habitat. In addition, the facility of invasion is affected by site characteristics such as soil depth and type (Gelbard and Belnap 2003).

Increased Alteration and Use of Habitats by Humans

Roads facilitate increased human use and development of areas by providing easy access, sometimes to formerly remote areas. This may lead to increased recreational use of an area and associated human disturbances (Massey 2001, Wyoming Game and Fish Department 2003). Increasing use by humans can include activities such as hunting, recreation, and changes in land-use.

Increased access into sage-grouse habitats can increase hunting and recreation opportunities such as off-road vehicle use, hiking, and camping (see “Hunting” [pg. 156] and “Recreational Activities” [pg. 191] issue sections). Consumptive recreational activities are known to have an impact on abundance, distribution, and demographics of some wildlife populations (Wood 1993). Nonconsumptive activities can have similar effects by increasing mortality, reducing productivity, and displacing individuals or populations (Knight and Cole 1995).

Roads often are built to promote extraction industries (see “Energy and Mineral Development” issue section, pg. 109), housing or commercial development (see “Housing Development” issue section, pg. 154), and agriculture (Trombulak and Frissell 2000; see also “Grazing” issue section, pg. 139). Such changes in land-use result in persistent adverse effects on the native ecosystem. For example, the addition of a road that increases residential development can cause cumulative impacts due to fragmentation, degradation, and loss of wildlife habitat (Theobald et al. 1997; see also “Habitat: Fragmentation, Quality, and Quantity” issue section [pg. 151]). Theobald (2003) found that houses were more likely to be located near roads and less likely to be distant (>0.6 mile) from roads.

Other Road Effects on Habitat

Roads may affect wildlife species by fragmenting habitat (National Cooperative Highway Research Program 2002, National Research Council 2005), or by causing a decline in habitat quality and/or quantity (National Cooperative Highway Research Program 2002, Marsh and Beckman 2004; see also “Habitat: Fragmentation, Quality, and Quantity” issue section, pg. 151). Fragmentation of habitat appears most important for species that are area-sensitive (i.e., require large areas of contiguous habitat for survival). Roads also may affect the quality of surrounding habitat by introducing greater movement of predators and nest parasites into remaining habitat (Thogmartin 1999, Gucinski et al. 2001, Shochat et al. 2005); this is sometimes considered an effect of habitat fragmentation.

Habitat loss is not always mentioned as a potential impact of roads on wildlife species (Trombulak and Frissell 2000), probably because other impacts are so much greater (see “Habitat Loss: Roads in Colorado” analysis, pg. 284). For instance, the loss of habitat may be insignificant relative to the impact roads have on remaining habitat, especially in forest ecosystems where roads introduce edge habitat that fragments and degrades the quality of the remaining forest (National Cooperative Highway Research Program 2002, Marsh and Beckman 2004).

Weather

Weather patterns within GrSG range in Colorado can be unpredictable and extreme. The variability and unpredictable nature of severe weather can pose problems to wildlife managers, and one severe winter or dry spring may impact populations for many years.

The 1983-84 winter is believed to have been a factor in the decline of GrSG populations in Colorado. Heavy snows, particularly when combined with high winds and extreme temperatures may (1) harden snow and affect the ability of GrSG to burrow into snow for thermal cover; (2) reduce availability of sagebrush for winter feed; (3) affect over-winter survival; and (4) affect lek attendance and/or reproduction when snow lingers into the spring. Dry, cold winters may reduce the ability of GrSG to burrow into snow, and also may affect over-winter survival rates. Snow burrows are important since they provide a warmer micro-environment than the surrounding ambient air temperatures. Temperatures under 8 inches of snow were between 10 - 27 ° F when ambient air temperature was as low as -31 ° F (Gullion 1970, as cited in Northeastern Nevada Stewardship Group, Inc. 2004). Severe winter range (habitat used when general winter range is not available, due to weather conditions) may only be crucial 1 year out of many, but the identification and protection of these areas is important for the long-term survival of sage-grouse.

Habitat used by pre-laying hens is a subset of breeding habitat. These areas should provide a diversity of forbs high in calcium, phosphorus, and protein; the condition of these areas may greatly affect nest initiation rate, clutch size, and subsequent reproductive success (Barnett and Crawford 1994, Coggins 1998). A dry spring may reduce forbs, and therefore impact nesting factors. A spring that is wet may produce adequate forbs, but a late spring snow may reduce chick survival rates. Cool spring weather may limit insect availability for chicks and therefore increase mortality. It is important to identify and provide good brood habitat to mitigate the uncontrollable nature of weather patterns. Maintaining areas with reliable forb and insect production during dry years is one method to assist with chick survival rates.

Poor weather conditions in the spring may influence sage-grouse production because chicks rely on plant growth and insects for a high percentage of their diet (Connelly et al. 2000*c*). Due to the poor insulating quality of downy feathers, young chicks are susceptible to wet, cold springs if severe weather occurs near hatching (Wallestad 1975). Nesting cover and nest success depend on residual grass and new growth for screening around sagebrush plants (Holloran et al. 2005). In dry years, or consecutive drought years, the lack of screening grasses can impact nest success. An early, dry fall can cause sagebrush habitats to desiccate, causing grouse to move to more mesic sites (Connelly et al. 1988, Fischer et al. 1996*b*). A hot, dry summer may cause chicks to make early, longer-ranging moves, causing stress and a potentially higher risk of predation than a long, wet fall providing more forage areas in a closer range.

The variability of weather patterns in GrSG range can provide for high or low nest success, as well as influence chick survival. This is one factor that cannot be controlled by wildlife managers, but it can be planned for by maintaining populations at sizes sufficient to withstand unpredictable changes in climate (e.g., long-term drought). The factors that can be planned for are to (1) identify quality nesting and brood rearing habitats; (2) mitigate for dry periods with strategically placed water developments, while considering water development design to reduce

WNV risk to GrSG; (3) define general winter ranges as well as severe winter ranges for sage-grouse; and (4) develop plans to work with willing landowners to enhance and restore sagebrush in these areas.

Weeds: Noxious, Invasive, and Encroaching Plants

Noxious and invasive weeds are considered a serious threat to rangeland health in much of GrSG habitat. Noxious and/or invasive plants have the potential to degrade GrSG habitat, primarily by increasing the fire return frequency (see also "Fire and Fuels Management" issue section, pg. 129), decreasing plant diversity, and changing structure of plant and insect communities.

Colorado weed law defines a noxious weed as an alien plant that has been designated by rule as being noxious, or that has been declared a noxious weed by a local advisory board and meets one or more of the following criteria: (1) aggressively invades or is detrimental to economic crops or native plant communities; (2) is poisonous to livestock; (3) is a carrier of detrimental insects, diseases, or parasites; or (4) the direct or indirect effect of the presence of the plant is detrimental to the environmentally sound management of natural or agricultural ecosystems (Code Title 35 (Agriculture), Article 5.5 (Noxious Weed Act), 103 (Definitions); Colorado Department of Agriculture 2007*b*). Invasive and encroaching plants include most noxious weeds, but also can include native species that have competitive traits which allow them to become established, and at times dominant, in areas where they are not desired. At least 14% of Colorado flora can be considered invasive species (Hartmann and Nelson 2001).

Increased presence of annual plants such as cheatgrass, annual wheatgrass, bulbous bluegrass, and many annual forbs, can, depending on the sagebrush community type, reduce mean fire return interval (MFRI) from an estimated normal 20 - 100 years, to 5 - 10 years (Miller and Eddleman 2000). Shorter fire return periods can effectively eliminate sagebrush from plant communities by preventing recruitment of new sagebrush plants (Connelly et al. 2000*c*). In former sagebrush sites on the Snake River Plain in Idaho, there is evidence that secondary weed invasions can become an added problem (Laio et al. 2000). There, invasion by deep-rooted exotic perennial weeds, such as rush skeletonweed, have the potential to alter soil moisture availability such that sites may be almost impossible to return to shrublands.

At the other end of the spectrum, fire suppression efforts have increased MFRI and allowed plants such as juniper and serviceberry (see "Piñon-Juniper Encroachment" issue section, pg. 179) to become dominant in plant communities typically dominated by sagebrush (Miller and Rose 1999). This change in plant community composition can make habitat less desirable for GrSG by providing perches and cover for predators, and crowding out more desirable plants such as sagebrush and perennial forbs.

Other noxious weeds, often introduced species from Eurasia, such as Dalmatian toadflax, leafy spurge, whitetop and houndstongue, possess attributes that allow them to become dominant in the plant community. Their dominance reduces plant diversity and excludes many native plants (Hobbs and Huenneke 1992) that are essential for GrSG food and cover. The same characteristics that allow them to become dominant also can severely hamper habitat restoration efforts. Many noxious weeds have physiological characteristics that give them a competitive advantage over native plants during drought conditions and in disturbed areas.

Within GrSG range in Colorado the primary weed threats in drier, lower elevation sagebrush communities are cheatgrass, annual wheatgrass, bulbous blue grass, and various annual mustards. Most of these annuals are not on county noxious weed lists and are a problem in western Moffat and Rio Blanco counties in association with dry Wyoming big sagebrush plant communities. Cheatgrass is a species that thrives in disturbed, and especially burned, areas (Vallentine 1989, Whisenant 1990). A cheatgrass invasion into sagebrush habitat can lead to an eventual conversion of sagebrush/grass (perennial) community to sagebrush/grass (annual) or annual grass rangeland (Connelly et al. 2000*c*, Miller and Eddleman 2000). Sage-grouse food sources vary through the year and include primarily sagebrush, forbs, and insects, but not grasses (Schroeder et al. 1999). In dry sites where cheatgrass is present, an unusually wet year can allow increased dominance of annual bromes, such as cheatgrass, into even the driest shrublands originally thought to be resistant to invasion (Meyer et al. 2001).

In some cases, cheatgrass invasion encourages other exotic species such as knapweed and thistle (Grahame and Sisk 2002). In Colorado and the Wyoming Basin, Russian knapweed and Canada thistle (both deep-rooted, re-sprouting, perennial weed species) may replace the shrub component and form large monocultures following disturbance (Watson 1980). Little is known about the effects of noxious and invasive weeds on insect communities, which are an important food source for young sage-grouse.

No literature specifically addresses how sage-grouse use exotic invasive plants as food, but sage-grouse sometimes use plants in the same families as some invasive species. Some species used for food by sage-grouse are in the Asteraceae and Brassicaceae families (Monsen 2005), which also contain a large proportion of invasive species found in sagebrush-steppe. For example, of the 15 forbs listed as “high” food value (Monson 2005:207-208), 4 are non-native to sagebrush-steppe (alfalfa, dandelion, salsify, and clover). Additionally, other exotic species on the food forb list are the invasive genus, *Lepidium* (pepperweed), flax, small burnet, and some fleabane (*Erigeron*) species.

Juniper and piñon encroachment into sagebrush communities on deeper soils is occurring in parts of Garfield, Moffat, Rio Blanco, and Eagle counties (see “Piñon-Juniper Encroachment” issue section, pg. 179). In the same counties, at mid- and higher elevations, some rangeland areas typically dominated by sagebrush are becoming co-dominated by serviceberry and Gambel oak. Houndstongue is becoming very abundant in the Parachute – Piceance – Roan population area in Garfield and Rio Blanco Counties. Rio Blanco County has had large infestations of leafy spurge, which has the potential to reduce desired plant diversity. Toadflax is increasingly occurring on rangeland in Moffat, Rio Blanco, and Routt Counties.

Each county in GrSG range in Colorado has an official list of noxious weeds (Table 20; Colorado Department of Agriculture 2007*a*). Many of the weeds occur in agricultural situations that have little current or potential impact on sage-grouse habitat. However, any ground-disturbing action (e.g., such as that associated with oil and gas development, or housing development) that occurs in or near sage-grouse habitat has the potential to initiate weed establishment that could impact sage-grouse habitat (see “Energy and Mineral Development” [pg. 109], “Housing Development” [pg. 154],“Infrastructure” [pg. 170], and “Roads” [pg. 193] issue sections.

Table 20. County noxious weed lists for Colorado GrSG counties (based on Colorado Department of Agriculture 2007*a*). Weeds that have invaded or have greater potential to invade and significantly degrade sage-grouse habitat are in italics.

Eagle County (NESR Population)	
Canada thistle	*leafy spurge*
chamomile, scentless	musk thistle
common burdock	plumeless thistle
hoary cress (whitetop)	scotch thistle
houndstongue	toadflax, Dalmatian
knapweed, diffuse	toadflax, yellow
knapweed, Russian	wild caraway
knapweed, spotted	
Garfield County (PPR Population)	
Canada thistle	musk thistle
chicory	oxeye daisy
common burdock	plumeless thistle
hoary cress (whitetop)	purple loosestrife
houndstongue	Russian olive
jointed goatgrass	scotch thistle
knapweed, diffuse	tamarisk (saltcedar)
knapweed, Russian	*toadflax, Dalmatian*
knapweed, spotted	*toadflax, yellow*
leafy spurge	*yellow starthistle*
Grand County (MP Population)	
black henbane	*knapweed, spotted*
Canada thistle	*leafy spurge*
chamomile, mayweed	musk thistle
chamomile, scentless	orange hawkweed
field bindweed	oxeye daisy
hoary cress (whitetop)	scotch thistle
houndstongue	*toadflax, Dalmatian*
knapweed, diffuse	*toadflax, yellow*
knapweed, Russian	*yellow starthistle*

Table 20. County noxious weed lists for Colorado GrSG counties (based on Colorado Department of Agriculture 2007*a*). Weeds that have invaded or have greater potential to invade and significantly degrade sage-grouse habitat are in italics.

Jackson County (NP Population)	
bull thistle Canada thistle chamomile, corn dame's rocket Dyer's woad *hoary cress (whitetop)* *houndstongue* *knapweed, diffuse* *knapweed, Russian*	bull thistle Canada thistle chamomile, corn dame's rocket Dyer's woad *hoary cress (whitetop)* *houndstongue* *knapweed, diffuse* *knapweed, Russian*
Moffat County (NWCO Population)	
knapweed, diffuse *knapweed, Russian*	*knapweed, diffuse* *knapweed, Russian*
Rio Blanco County (NWCO; PPR; MWR Populations)	
black henbane Canada thistle common burdock common mullein field bindweed *halogeton* *hoary cress (whitetop)* *houndstongue* knapweed, black *knapweed, diffuse*	*knapweed, Russian* *knapweed, spotted* *leafy spurge* musk thistle perennial pepperweed plumeless thistle scotch thistle *toadflax, Dalmatian* *toadflax, yellow*
Routt County (NESR Population)	
hoary cress (whitetop) *houndstongue* *knapweed, diffuse* *knapweed, Russian*	*knapweed, spotted* *leafy spurge* *toadflax, Dalmatian* *toadflax, yellow*

Table 20. County noxious weed lists for Colorado GrSG counties (based on Colorado Department of Agriculture 2007*a*). Weeds that have invaded or have greater potential to invade and significantly degrade sage-grouse habitat are in italics.

Summit County (MP Population)	
bull thistle	*knapweed, Russian*
Canada thistle	*knapweed, spotted*
chamomile, mayweed	*leafy spurge*
chamomile, scentless	musk thistle
Chinese clematis	oxeye daisy
coast tarweed	perennial pepperweed
common tansy	plumeless thistle
dame's rocket	*toadflax, Dalmatian*
hoary cress (whitetop)	*toadflax, yellow*
houndstongue	*yellow starthistle*
knapweed, meadow	

The Colorado Noxious Weed Act (Title 35 Article 5.5 101-119 C.R.S. (2003)) outlines responsibilities for weed control in Colorado [Code Title 35 (Agriculture), Article 5.5 (Noxious Weed Act), 103 (Definitions)]; (Colorado Department of Agriculture 2007*b*). The state assigns responsibility for weed control on private and state unincorporated lands to county governments through the county commissioners. Each county appoints a local advisory board that identifies noxious weeds in the county that will by rule be subject to integrated management. Weed control on incorporated land is the responsibility of the municipality governing board. The local governing bodies of all counties and municipalities are authorized to enter into cooperative agreements with federal agencies for the management of noxious weeds on federal lands (Colorado Department of Agriculture 2007*b*).

The State Agriculture Commissioner classifies weeds into 3 categories: List A, for rare noxious weed species that are subject to eradication wherever detected statewide; List B for noxious weed species with discrete statewide distributions that are subject to eradication, containment or suppression in portions of the state designated by the State Agricultural Commissioner in order to stop the continued spread of the species; and List C, for widespread and well established noxious weed species which control is recommended but not required by the state, although local governing bodies could require management. The State weed list can be accessed at http://www.ag.state.co.us/CSD/Weeds/statutes/weedrules.pdf.

Landowners are required to manage (eradicate) weeds on List A , weeds on list B that are designated for eradication, and any other weeds listed by the local governing bodies as noxious and requiring management. Prescribed management techniques for these species are mandatory and can be found in Colorado Department of Agriculture Publication 8-CCR-1203-19, Rules Pertaining to the Administration and Enforcement of the Colorado Noxious Weed Act. The local governing body does have the right, under certain circumstances, to enter either public or private lands to inspect for noxious weeds and if necessary oversee management practices at the expense of the landowner.

Threats Summarized by ESA Listing Factor

Evaluating the potential relative impact of the various issues affecting GrSG is a complicated task. Nevertheless, this topic has been considered at the federal, state, and local levels.

A species may be warranted for listing as threatened or endangered under the ESA due to 1 or more of 5 limiting factors described in section 4(a)(1) of the Act. The USFWS published in the Federal Register (U.S. Fish and Wildlife Service 2005) a 12-month status review finding for GrSG that evaluated and summarized threats, or potential threats, under each of the 5 factors. In a separate document (Deibert 2005; Appendix L, "Threats Ranking for GrSG"), the USFWS provided a table that depicts the relative impact of each threat to the species (as determined by an expert panel) in 3 different aspects of GrSG range: (1) the entire range; (2) the east portion of the range; and (3) the west portion of the range.

The CCP SC identified and ranked potential threats to GrSG in Colorado, for each population, and for each management zone in the NWCO population (Tables 21 and 22). Not all potential threats were considered in this exercise; instead we chose those for which (1) enough information exists to potentially evaluate the threat using a population viability analysis (see pg. 210); or (2) the interest and concern among stakeholders is high. Each potential threat was ranked as high, moderate, or low. The SC also identified whether the threat was increasing, stable, or decreasing in its potential impact to GrSG in each population/zone.

The completed local work group plans (MPCP 2001, NPCP 2001, NESRCP 2004) and the nearly completed plans for NWCO (NWCOCP 2006) and PPR (PPRCP 2008) list issues that may be affecting GrSG, but do not provide a ranking of importance of these issues to the given GrSG population. The MP and NWCO plans specifically address the 5 ESA listing factors using local information (MPCP 2001:Appendix E; NWCOCP 2006). Table 23 summarizes issues that were listed in each local work group plan by listing factor. Issues may have been named differently in each plan but were grouped into a common naming convention in this table. The NWCO and PPR plans are currently in draft stage (NWCOCP 2006, PPRCP 2008).

Here we give a general summary of the threats to GrSG from all these sources, grouped by ESA listing factors described by the USFWS (U.S. Fish and Wildlife Service 2005).

Listing Factor A: The present or threatened destruction, modification, or curtailment of the species' habitat or range.

Threats identified under this listing factor by the USFWS (U.S. Fish and Wildlife Service 2005) included habitat conversion, habitat fragmentation, infrastructure (powerlines, fences, pipelines, communication towers, roads, and railroads), grazing, mining, energy development, fire, invasive species and noxious weeds, piñon-juniper expansion, and urbanization. The USFWS, using an expert panel, ranked threats in highest importance to the east portion (Colorado included) of the range. These were: oil and gas development, infrastructure as related to energy development and urbanization, invasive species/noxious weeds, wildfire, grazing, habitat conversion due to agriculture, urbanization, coal/strip mining, and piñon-juniper (conifer) invasion (Deibert 2005; Appendix L, "Threats Ranking for GrSG").

The SC identified several of these threats as of high potential for impact in some Colorado populations (Table 21). These included grazing, urbanization (housing), and oil and gas development. Of those three, only housing and oil and gas development were considered to be an increasing threat in some GrSG populations. Oil and gas development was the only threat identified as 'increasing exponentially'; but only as such in 2 populations (PPR and NWCO).

The local work group plans for MP, NP, NWCO, NESR, and PPR identified and addressed issues pertaining to listing factor A that included habitat fragmentation, infrastructure, and grazing (Table 23). Four of the local plans also addressed invasive plant/weeds (MP, NWCO, NESR, PPR) and urbanization (MP, NP, NWCO, NESR). Three plans identified habitat conversion as an issue of concern (MP, NWCO, NESR).

Listing Factor B: Overutilization of the species for commercial, recreational, scientific, or educational purposes.

Threats identified under this listing factor by the USFWS (U.S. Fish and Wildlife Service 2005) include hunting, and scientific and recreational use. Scientific use is further described to include research studies that involve capture and handling of the species. This category also includes translocations. Under recreational use, lek viewing, general wildlife viewing and photography are identified as having possible effects on GrSG. The expert panel utilized by the USFWS did not identify hunting as a primary threat factor for the species (U.S. Fish and Wildlife Service 2005). The USFWS also concluded that overutilization for scientific and recreational use is not a factor that is threatening GrSG in a significant portion of its range (U.S. Fish and Wildlife Service 2005).

The SC identified both recreation activities and hunting as having potential affects in Colorado GrSG populations (Tables 21 and 22). Hunting is currently allowed only in MP, NP, and NWCO populations. Only NP is considered 'increasing' for the level of threat to the population. The 3 populations are all ranked as having a low effect on GrSG from hunting.

All completed local work group plans listed hunting, lek viewing, and recreational use as being a potential issue to their GrSG populations (Table 23). However, NESR recognized that hunting is currently not occurring in the NESR population. Only the NWCOCP (2006) identified a concern over effects of scientific research and translocations on their populations.

Listing Factor C: Disease or predation affecting the species.

Threats identified under this listing factor by the USFWS (U.S. Fish and Wildlife Service 2005) include both disease and predation. Under disease, infectious diseases, bacterial, fungal, and viral pathogens, and parasites are discussed. In these subcategories, only West Nile Virus was identified as being a particular concern, but not a large enough to justify it being a major threat that could lead to an increase in the risk to GrSG extinction. The predation section listed numerous predators whose relative impact to GrSG varies depending on the sex and age of the bird and the time of year. The section also associates increasing predation with agricultural and human development, landscape fragmentation, and decreases in habitat quality. Predators listed as most commonly causing direct mortality on GrSG include coyotes, bobcats, foxes, weasels, hawks, and eagles. Other predators are listed for specific time of the year and life stage of GrSG and include corvids, badgers, ground squirrels, other raptors, and domestic dogs and cats. The USFWS expert panel did not identify predation as being a limiting factor to GrSG except in areas experiencing habitat degradation and loss (U.S. Fish and Wildlife Service 2005).

The SC discussed including the threat of disease, particularly WNV, in the threat matrix. However, insufficient information is available to understand the effects of this potential threat in a PVA model. Hence, it was not included in Table 21 and 22. Predation was included in Tables 21 and 22, but was ranked as having only a low or moderate impact in Colorado GrSG populations. It was also thought to be a stable threat in all populations; neither increasing nor decreasing in its impact on GrSG at this time.

All local work group plans addressed predation as an issue to their GrSG populations (Table 23). The NESR, NWCO, and PPR plans addressed disease (Table 23). NESR and NWCO are the only 2 areas where WNV mortalities among radio-marked birds have been documented.

<u>*Listing Factor D*</u>: The inadequacy of existing regulatory mechanisms to protect the species.

The USFWS (U.S. Fish and Wildlife Service 2005) grouped discussion under this factor into 3 categories that are pertinent to Colorado: local laws and regulations, state laws and regulations, and federal laws and regulations. Under local laws, the USFWS recognized that county or city governed activities have the potential to influence GrSG habitats and that these entities can utilize their authority to protect GrSG habitats through avenues such as appropriate zoning and land-use planning. The USFWS states that they are not aware of any county or city protections currently in place specifically for GrSG or their habitats. Under state laws and regulations summary, the USFWS focuses on the management of hunting seasons by state wildlife agencies, as well as management of state owned lands which may have value to GrSG. State Wildlife Agencies also have the legal authority to protect lands through avenues such as conservation easements and fee title purchase and have the lead for developing conservation plans for the species and their habitats. The section under federal laws is lengthy and includes synopsis of authorities related to GrSG species and habitat protections for the BLM, USFS, NWRS, Department of Army, and NRCS. Avenues for protection lie within land-use and resource management plans, oil and gas leasing stipulations, grazing standards, and through NRCS managed programs. The USFWS concludes in the summary of this factor that existing regulatory mechanisms do not endanger or threaten GrSG throughout all or a significant portion of its range.

The SC did not address lack of existing regulatory mechanisms in Tables 21 and 22. For a detailed description of existing management and legal authorities for the protection of GrSG pertaining to Colorado see “Management and Legal Authorities” (pg. 21). The CDOW has authority for setting hunting seasons and possession limits and for enforcement against poaching and harassment. County and local governments have the authority through state statutes to regulate use of land as it affects significant wildlife habitats identified by the CDOW (see "Counties", pg. 23). However, the CDOW does not have authority for protecting against habitat loss except on lands that it owns or controls. Federal land management agencies have authority through several different laws, rules, and regulations to provide for protection of GrSG and their habitats. However, neither the CDOW nor the federal land management agencies has authority to protect against habitat loss or other impacts on private land. Mechanisms for addressing GrSG issues on private land exist within city and county governments to some extent (see "Counties" management authority section, pg. 23).

Local work group plans did not specifically state that regulations in federal, state, or local governing bodies were inadequate. However, they did address needs in conservation strategies for changes to hunting seasons (state), modifications to county land-use plans (local), and changes in management on federal lands (federal) that would benefit GrSG and their habitats. (Table 23).

Listing Factor E: Other natural or manmade factors affecting the species' continued existence.

Threats identified under this listing factor by the USFWS (U.S. Fish and Wildlife Service 2005) included pesticides, contaminants, non-consumptive recreational activities, drought/climate change, and life history traits that affect population viability. Discussed under pesticides were the direct mortality of individuals and reduction in available food sources (insects) that may contribute to sage-grouse mortality. Also discussed in this section are herbicide applications that can kill sagebrush and forbs needed by GrSG. The contaminant discussion lists many sources that potentially occur as a result of various human activities ranging from agricultural practices, energy development, pipeline operations, and transportation of materials along roads and railways. Non-consumptive recreational activities included hiking, camping, pets, and off-highway vehicle (OHV) use. Primary impact to GrSG from these activities was disturbance related, but impacts to vegetation and soils and spread of noxious weeds also were mentioned. The discussion within life history traits centered on low reproductive rates of GrSG and their polygamous mating system and how those may affect population growth rates.

The SC did include recreational activities within the threat matrix (Tables 21 and 22), and ranked this threat as being a low impact to GrSG in all populations, however, it was recognized to be an increasing threat with greater potential for impact in the future.

Four local work group plans addressed impacts from pesticides and weather/drought changes in their conservation strategies (MP did not; Table 23). All plans mentioned impacts to GrSG from non-consumptive recreational uses (Table 23). NWCO also addressed contaminants as an issue (Table 23).

Summary

The USFWS (50 CFR Part 17) summarized that none of threats listed in the five listing factors was significantly affecting current numbers of sage-grouse. They did, however, specifically mention that sagebrush habitat continues to be lost and degraded in parts of its range, but at a lower rate than that historically observed.

The expert panel convened by the USFWS for evaluation of listing factors did identify the threats they considered as having the most influence on GrSG populations across its range and then proceeded to rank their relative importance of each threat to GrSG (U.S. Fish and Wildlife Service 2005). The threats considered of having the highest impact to GrSG rangewide were: invasive species, infrastructure as related to energy development and urbanization, wildfire, agriculture, grazing, energy development, urbanization, strip/coal mining, weather, and piñon-juniper expansion. In the eastern portion of GrSG range (Colorado's population), oil and gas development was seen as being the highest threat to GrSG, followed by infrastructure as associated with energy development and urbanization.

The SC ranked the relative level of threats to GrSG in Colorado (Table 21). In conducting this exercise it was apparent that the highest threats varied by population. For instance, the only threat of high ranking for the PPR population was oil and gas development, whereas in MP, the highest ranked threat was housing development.

Of the 3 completed local work group plans, issues possibly affecting GrSG were identified and conservation strategies were developed, but no plan ranked the relative importance of each issue to the future of their GrSG populations (MPCP 2001, NPCP 2001, NESRCP 2004).

Table 21. Threat matrix for greater sage-grouse populations in Colorado. Ratings are judgments made by the SC, based on biology. See text for further process description (pg. 204).

Threat	MWR	MP	NP	NESR	NWCO	PPR
Improper Grazing	Moderate; stable	Moderate; stable	Moderate; stable	High; decreasing	High (both); stable to decreasing	Moderate; stable
Housing	Moderate; increasing	High; increasing	Low; increasing	High; increasing	Low; increasing	Low; stable
Hunting	N/A	Low stable	Low Increasing	N/A	Low; stable	N/A
Oil/Gas	Low; stable	Low; stable	Low; increasing (potential)	Low; stable	Moderate; increasing exponentially	High; increasing exponentially
Surface Mining (Coal, etc.)	Low; stable	Low; increasing	Low Stable	Moderate; increasing	Moderate; increasing	Low; increasing (potentially)
Predation	Moderate; stable	Low; stable	Low; stable	Moderate; stable	Low; stable	Low; stable
Recreation	Low, increasing	Low, increasing	Low, increasing	Low, increasing	Low, increasing	Low, increasing

Table 22. Threat matrix for greater sage-grouse in NWCO by zones. Ratings are judgments made by the SC, based on biology. See text for further process description (pg. 204).

NWCO Zone	Improper Grazing	Housing	Hunting	Oil/Gas	Surface Mine	Predation	Recreation
Zone 1	High, stable	Low, stable	High, stable	Moderate, increasing	Low, stable	Low, stable	Low, stable
Zone 2	Moderate, stable	None	None	High, increasing greatly	Low, stable	Low, stable	Moderate, increasing
Zone 3A	Moderate, decreasing	Low, stable	Low, stable	Moderate, stable	Low, stable	Low, stable	Low, stable
Zone 3B	High, stable	Low, increasing	Moderate, stable	High, increasing	Low, stable	Low, stable	Low, stable
Zone 3C	Moderate, stable	Low, increasing	None	Moderate, stable	Low, increasing	Moderate, stable	Low, stable
Zone 4A	High, stable	Low, stable	None	Moderate, increasing	Low, stable	Low, stable	Low, stable
Zone 4B	Same as 3C	Moderate, increasing	None	Moderate, increasing	High, increasing	Moderate, stable	Low, stable
Zone 5	Moderate, stable	Low, stable	Low, stable	Low, stable	Moderate, increasing	Low, stable	Low, stable
Zone 6	Moderate, stable	Low, stable	High, stable	Moderate, increasing	Moderate, stable	Low, stable	Low, stable
Zone 7	N/A Same as Utah	N/A Same as Utah	N/A Same as Utah	N/A Same as Utah	N/A Same as Utah	N/A Same as Utah	N/A Same as Utah

Table 23. List of issues addressed in local plans, organized by listing factor. Individual issues may have been more detailed in the local plans (i.e., sub-issues), but were placed into appropriate more generalized issue categories for this table. Issues listed in local plans but not addressed in strategies were not included. Local plan citations are MPCP 2001, NPCP 2001, NWCOCP 2006 (first draft completed, final draft expected in 2008), NESRCP 2004, and PPRCP 2008 (a first draft of the PPR local plan will be completed in early 2008).

Listing Factor A	**Population**				
ISSUE	**MP**	**NP**	**NWCO**	**NESR**	**PPR**
Habitat Conversion	X		X	X	
Habitat Fragmentation	X	X	X	X	X
Infrastructure	X	X	X	X	X
Grazing	X	X	X	X	X
Mining			X		X
Energy Development			X		X
Fire			X		X
Invasive plants/weeds	X		X	X	X
PJ Expansion			X		X
Urbanization	X	X	X	X	
Listing Factor B	**Population**				
ISSUE	**MP**	**NP**	**NWCO**	**NESR**	**PPR**
Hunting	X	X	X	X	X
Lek Viewing	X	X	X	X	X
Recreational Use	X	X	X	X	X
Scientific Use			X		
Listing Factor C	**Population**				
ISSUE	**MP**	**NP**	**NWCO**	**NESR**	**PPR**
Disease			X	X	X
Predation	X	X	X	X	X
Listing Factor D	**Population**				
ISSUE	**MP**	**NP**	**NWCO**	**NESR**	**PPR**
Inadequate regulations - local	X	X	X	X	
Inadequate regulations - state		X			
Inadequate regulations - federal	X	X			
Listing Factor E	**Population**				
ISSUE	**MP**	**NP**	**NWCO**	**NESR**	**PPR**
Pesticides		X	X	X	X
Contaminants			X		
Recreational activities – non consumptive	X	X	X	X	X
Drought/Climate Change		X	X	X	X