SAGE GROUSE DECLINES IN WESTERN NORTH AMERICA: WHAT ARE THE PROBLEMS?

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ABSTRACT

Sage grouse (*Centrocercus urophasianus*) populations have declined throughout western North America. This species has been extirpated in five states and one province, all at the periphery of the original distribution. Breeding population size in each of 3 additional states and two provinces is estimated at less than 2,000 individuals. Declines in population size in Colorado have varied from 45 to 82% since 1980, depending upon area, and the range-wide estimate is at least 30% decrease since 1985. Major factors involved in the documented decreases in distribution and abundance are habitat loss (usually permanent), habitat fragmentation (usually permanent), and habitat degradation (usually short term, 2 to 30 years). No single factor is responsible for the observed declines and human-induced habitat changes are accentuated by periodic drought. No natural undisturbed habitats are known to exist and active management of sagebrush (*Artemisia* spp.) rangelands is needed on a management experiment basis.

INTRODUCTION

The original distribution of sage grouse in western North America included 16 states and three provinces (American Ornithologists' Union 1957, Aldrich 1963, Johnsgard 1973). This distribution closely followed that of sagebrush, primarily big sagebrush (*A. tridentata* subspecies *tridentata, vaseyana, and wyomingensis)* as identified by Beetle (1960). At the periphery of the known range, other species of sagebrush (*A. cana, A. filifolia, A. nova, A. tripartita*) predominated. The original distribution was not contiguous as habitats were naturally fragmented by forests and deserts which were disected by river valleys and mountain ranges (Patterson 1952, Rogers 1964).

Estimates of sage grouse abundance were mostly anecdotal prior to the late 1950's as there were no systematic surveys. Patterson (1952:13) presented the first rangewide estimate of abundance using the general terms of "common" and "uncommon". Early accounts (reported by Bent 1932) suggest that sage grouse were abundant in many areas of their original range from North Dakota west to Washington and south into Utah and northwest Colorado. Predictions of the extinction of sage grouse also appear early in the literature (Visher 1913, Hornaday 1916). By the 1920's and 1930's sage grouse were generally believed to be declining throughout their range (Bent 1932, Gabrielson and Jewett 1940, Rush 1942, Patterson 1952, Rogers 1964). State wildlife agencies responded to these concerns by

markedly reducing bag limits, reducing season length, and season closures (Patterson 1952). Closed seasons generally continued in most states until the early 1950's while bag and possession limits remained low until the mid to late 1960's. It is unclear what data were available to justify reopening of hunting seasons and liberalizing bag limits in most areas. However, the apparent consensus was that hunting mortality was compensatory and replacive (Braun and Beck 1985).

The dependence of sage grouse upon sagebrush was established in a series of early studies in Wyoming , Utah, Colorado, and Oregon (Girard 1937, Griner 1939, Dargan and Keller 1940, Batterson and Morse 1948). While these studies clearly identified the sage grouse:sagebrush relationship, well funded efforts were underway starting in the 1930's to control and reduce the amount of sagebrush on public and private lands throughout the west (Carhart 1954, Pechanec et al. 1954, Vale 1974, Wright et al. 1979, Young et al. 1979, Tisdale and Hironaka 1981, Blaisdell et al. 1982, Lancaster et al. 1987, Laycock 1987). Concern about the reduction in habitat available to sage grouse resulted in published resolutions concerning this issue by the Western Association of State Game and Fish Commissioners (1968, 1974) and culminated in publication of "Guidelines for maintenance of sage grouse habitats" (Braun et al. 1977). Despite the common belief that sagebrush increased after settlement, Vale (1975) documented that sagebrush was widely distributed prior to settlement of the west. At present probably no sagebrush rangelands have been unaltered by human manipulation. In some states, more than 70% of the original sagebrush-dominated rangeland has been converted to agricultural crops. It can be conservatively estimated that at least one-half of the original area occupied by sage grouse is no longer capable of supporting this species on an annual basis (Schneegas 1967, Braun et al. 1976, Braun 1995).

This paper describes the decline in the overall distribution and abundance of sage grouse, identifies the problems resulting in the described changes, and examines reasons for the observed long-term reductions in habitat and population size.

PROBLEM

The available evidence in the historical literature supports the conclusion that the abundance of sage grouse decreased after the early 1900's (Hornaday 1916) and remained low into the mid 1940's (Patterson 1952). This decrease in population size obviously paralleled decreases in distribution as sage grouse became extirpated in Arizona, British Columbia, Kansas, Nebraska, New Mexico, and Oklahoma (Table 1). All of these states (+1 province) were at the periphery of the species' range. The magnitude of the decrease in distribution in each state/province that currently retain sage grouse populations is unknown. In Colorado, Braun (1995:6) estimated a decrease in distribution of "more than 50% since the early 1900's".

Table 1. Sage grouse breeding population status, western North America, spring 1998.

Extirpated		500±	<2,000
Arizona	Nebraska	Alberta	North Dakota
British Columbia	New Mexico	Saskatchewan	South Dakota
Kansas	Oklahoma		
Washington			

<5,000	<15,000	<20,000	>20,000	
California	Colorado	Idaho	Montana	Wyoming
Utah	Nevada	Oregon		

Surveys of the abundance of sage grouse started in the late 1940's (Wyoming:Patterson 1952, Oregon:Willis et al. 1993) and early 1950' (Dalke et al. 1963, Eng 1963, Rogers 1964). Early surveys were affected by inadequate access, equipment, and personnel commitment, as well as a lack of understanding of sage grouse biology. Count protocols were not well established until scientific study (Jenni and Hartzler 1978, Emmons and Braun 1984). Thus, the accuracy of counts in the 1940's, 1950's, and into the 1960's is suspect. Further, not all leks in selected areas were surveyed each year.

Despite these problems, all available data indicate that number of males counted per lek decreased from the early 1950's, a decline that has continued to the present. Connelly and Braun (1997) reported decreases from prior to 1985 to after 1985 ranged from 17 (Wyoming) to 47% (Washington) and averaged 33% for 10 states (+1 province). In Moffat County, Colorado there was a decrease of 82% from 1978-80 to 1996-98 in number of males counted and 57% in active leks (Table 2). In Jackson County, Colorado, there was a decrease in total males counted in 1976-80 vs. 1996-98 of 44% and in number of males counted per lek of 55% between 1959 and 1998 (Fig. 1).

The present size of the breeding population of sage grouse in the 11 states and two provinces where the species exists is unknown. However, I estimate there are 500± breeding sage grouse each in Alberta and Saskatchewan based on counts of male sage grouse on leks in spring 1998 (C.L. Aldridge, pers. commun.), less than 2,000 breeding sage grouse each in North Dakota, South Dakota, and Washington, <5,000 in California, <15,000 each in Colorado and Utah, <20,000 in Idaho and Nevada, and >20,000 breeding sage grouse each in Montana, Oregon, and Wyoming (Table l). Thus, a reasonable range-wide estimate for spring 1998 is about 142,000 sage grouse.

Table 2. Sage grouse population trends, lower Moffat County, Colorado, 1978-98.

Statistic	1978-80[a]	1996-98[a]	Decrease (%)
Total males counted	2, 442	437	82
Total active leks	56	24	57
Males/active lek	43.6	18.2	58

[2]Three-year average.

It is reasonable to conclude that significant long-term changes in distribution and abundance of sage grouse have occurred throughout the original range of the species in western North America. Rich (1985) suggested that sage grouse populations may be cyclic. This hypothesis may be true as the data from Jackson County, Colorado (Fig. 1) indicate "high" counts of males on leks occurred in 1959, 1969, 1979, 1987, and 1998. Thus, the data support a hypothesis of cyclic highs at about 10-year intervals. Unfortunately, each high population level is lower than the preceding high. Further, examination of data from the Western States Sage Grouse Technical Committee (1995) indicates no sustained increases in sage grouse population levels within any portion of the range of this species.

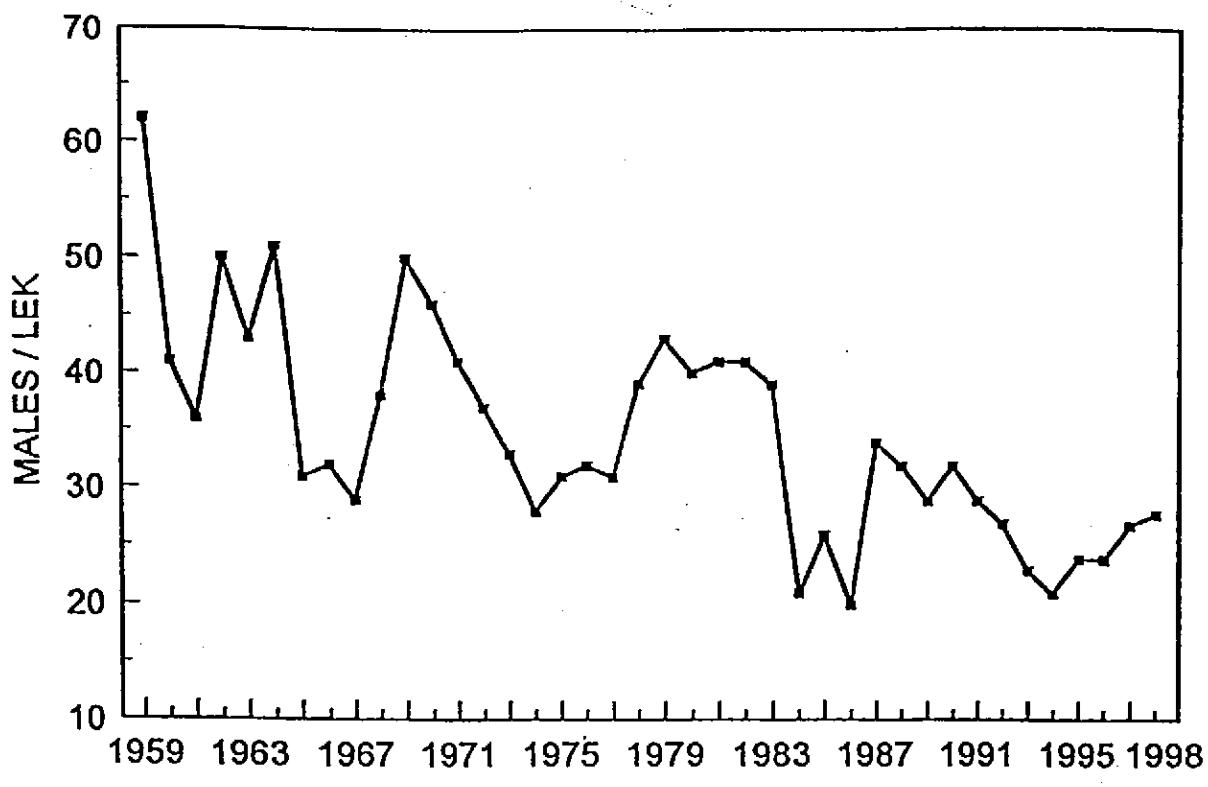

Figure 1. Trends in numbers of male sage grouse counted per lek, Jackson County, Colorado, 1959-98.

REASONS FOR CHANGES IN DISTRIBUTION/ABUNDANCE

Habitat Loss

Agriculture

Settlement of western rangelands was encouraged by a series of Homestead Acts starting in 1862 (Todd and Elmore 1997). Most land with agricultural potential was homesteaded and in private ownership by 1930. With advent of a series of low precipitation years, some lands were abandoned and reverted to public ownership. This occurred primarily at the periphery of sage grouse range. Much of the land originally homesteaded was plowed and planted to agricultural crops. Some areas could not support annual or biennial crop production and reverted to pastures or rangeland. The advent of irrigation projects, some as early as the 1880's, intensified land use (Todd and Elmore 1997) and resulted in additional loss of sage grouse habitat. Ploughing of private lands to convert rangeland to cropland continues, although at an extremely low rate. Swenson et al. (1987) documented decreases of sage grouse in Montana following ploughing of sagebrush steppe.

Mining/Energy Development

Development of mines and energy resources in western North America was initiated prior to 1900 (Robbins and Wolf 1994). Oil development intensified in the 1930's and 1940's while gas development continues to the present. Other major mining activity within sage grouse habitats has been for gold, uranium, trona, and especially coal.

The magnitude of the impacts of these activities on sage grouse and their habitat is largely unknown. Development of open pit mines (primarily for coal) and the associated roads, powerlines, noise, and increased human activities clearly negatively impacted sage grouse numbers and habitat in the short term. However, studies in Montana, Wyoming, and Colorado indicated some recovery of sage grouse populations after initial development and subsequent reclamation of mine sites, roads, etc. (Eng et al. 1979, Tate et al. 1979, Colenso et al. 1980, Scott and Zimmerman 1984, Braun 1986). Remington and Braun (1991) concluded that sage grouse were displaced by coal mining activities but returned to fluctuating predisturbance levels once mine activity ceased. Braun (1987) reported similar findings for sage grouse in areas impacted by oil development. In the area Braun (1987) studied in Jackson County, Colorado, oil development was initiated in the mid 1940's and reports of sage grouse in the oil field area decreased. By the mid 1970's, sage grouse again were present in the developed area and populations fluctuated with no large increases or decreases through 1998. The anecdotal evidence (1946-72) indicates the sage grouse population markedly decreased and then increased to at least one-half of predevelopment levels by 1973 and then maintained itself at the 1973-75 level with regular fluctuations through 1998. It is reasonable to conclude that as oil/gas developments mature and disturbed areas are reclaimed, similar to mined areas, sage grouse will repopulate the area. However, there is no evidence that population levels attain their previous size. Further, length of time to population re-establishment may be at least 20-30 years. Thus, there is both short-term and long-term (permanent facilities) habitat loss for sage grouse because of energy development and mining.

Ranches/Farm Sites

Placement of farm and ranch buildings was affected by availability of water, shelter, and building materials as well as access. Examination of abandoned and active farm/ranch sites within the distribution of sage grouse indicate that a high proportion are in areas that could be expected to be used by sage grouse. These developments would appear to affect about 1% of the original sage grouse range. However, because of their location in areas with better soils and water, it is reasonable to conclude that development of farm/ ranch sites negatively impacted more than 1% of the sage grouse population.

Reservoirs

Creation of reservoirs throughout the distribution of sage grouse in western North America has resulted in direct inundation of hundreds of kilometers of riparian habitats useful for sage grouse broods. In addition, adjacent upland habitats useful throughout the year and especially in winter have been eliminated by fluctuating water levels as well as associated recreation areas for water enthusiasts. No estimate of area impacted is available but reservoirs larger than 50 ha clearly negatively affect sage grouse through loss of brood habitat, lek sites, and winter habitat.

Roads/Highways

Settlement of western rangelands resulted in development of road/highway systems disecting sage grouse habitats. Most roads/highways were established without regard to important sage grouse use areas. Thus, roads/highways transect brood habitat, lek sites, winter habitat as well as migration corridors. In addition to loss of habitat, roads/highways cause direct mortality of sage grouse (especially high speed paved roads/highways) and may result in reduction of sage grouse use of leks within 1 km because of noise. No estimate of total direct or indirect habitat loss is available.

Town/Urban Sites

Selection of town sites during settlement resulted from a variety of factors including access, water, presence of building materials, safety, etc. Many sites clearly were sage grouse habitat and contained components that could be used for winter habitat, lek sites, and brood use areas. More recently, placement of residential dwellings and subdivisions in sage grouse habitats has become common. Some residences and subdivisions (ranchettes) are far removed from towns and have been placed within sage grouse winter and brood habitats as well as on lek sites. This trend is continuing and may result in complete extirpation of sage grouse in some fragmented populations. It is estimated that 3-5% of all historical sage grouse habitat in Colorado has been negatively impacted by town and urban development. In some counties, up to 50% of the available sage grouse habitat is under development for ranchettes.

HABITAT FRAGMENTATION

Fences

Historically, large expanses of sage grouse habitat were not fenced. Fences have been used to delineate property boundaries and to manage livestock. They vary from one to two to as many as five strands of wire with some including woven wire with varying mesh size. Originally, most posts were wood but many fences are now supported by metal posts. Thus, fences are not equal in their potential to divide habitats useful to sage grouse. Fence management frequently requires trail access along them and some may be brush beat on one or both sides. Fences with 1-3 strands of wire are normally not negative to sage grouse although sage grouse have been observed and documented flying into fences. Woven wire fences are more negative to sage grouse as they cannot quickly fly or travel through them. Fences with maintained trails adjacent to them are most negative for sage grouse as they are travel corridors for potential predators. Similarly, fences with wood posts provide perch sites for potential avian predators. Sage grouse in some areas in Colorado avoid fences, possibly because of predator activities. Thus, fences are capable of fragmenting useful habitats for sage grouse. There is no estimate of the area impacted by fences within the distribution of sage grouse.

Powerlines

Placement of powerlines within sage grouse habitats dates to the late 1800's to the advent of telegraph, telephone, and electrical systems. Sage grouse have been documented to be negatively impacted by powerlines through accidental contact while in flight and through use of powerline poles as perches by raptors (Graul 1980, Ellis 1984, 1987). Use of areas near powerlines by sage grouse, as measured by pellet transects, increases as distance from the powerline increases for up to 600 m (C.E. Braun, unpubl. data). Powerlines fragment habitats useful to sage grouse and reduce their security in linear strips up to >1 km in width. There is no estimate of the area impacted by powerlines available. It is possible to markedly reduce the impact of powerlines upon sage grouse through elimination of raptor perch sites.

Treatments

Management of sagebrush, usually to increase herbaceous forage for domestic livestock, has been and remains common throughout the distribution of sage grouse (Pechanec et al. 1954, Vale 1974, Laycock 1987). Treatments vary from short-duration livestock grazing to chemical and mechanical control of sagebrush. Depending upon type of treatment, sage grouse may alter their use or completely avoid treated areas (Braun et al. 1976, 1977 and many other references). Thus, treatments have altered sage grouse use of habitats throughout western North America. It is conservatively estimated that at least 50% of all western rangelands have been treated at least once with sage grouse use being slightly to heavily (complete avoidance) altered for periods of at least 2-3 years (minimum) to as much as 30 years.

Other Factors Fragmenting Habitats

Ranch/farm development, reservoirs, and roads/highways all fragment sage grouse habitats by making areas unsuitable for seasonal use. Fragmentation caused by reservoirs and roads/highways is linear while that caused by ranch/farm (and town/urban) development is circular. All of these factors negatively impact sage grouse habitats as sage grouse have been documented as landing (unable to cross large reservoirs) in reservoirs and drowning in May-August, being impacted by vehicles during all seasons, and avoiding (radio-marked birds) active farm/ranch and town sites in all seasons except the mid brood-rearing period. The amount of habitat impacted by these factors is unknown.

HABITAT DEGRADATION

Treatments

Sagebrush and associated habitats used by sage grouse have been altered since at least 1850-1860 by biological and mechanical treatments (livestock grazing and herding) and the late 1940's by applications of chemicals to control sagebrush. No areas used by sage grouse are known to have escaped treatment. Domestic livestock alone have grazed over most, if not all, areas used by sage grouse. Unlike historic use by wild herbivores of the vast area originally used by sage grouse, use by domestic livestock is repetitive with annual or biennial grazing periods of varying timing and length. Domestic livestock grazing has been shown to have ecological costs (Fleischner 1994, Robbins and Wolf 1994, Brown and McDonald 1995, Paine et al. 1996, Brown and McDonald 1997, Clements and Young 1997, Dudley 1997, Bork et al. 1998, Dobkin et al. 1998). Further, it has been demonstrated through exclosure studies that domestic livestock alter ecosystem processes by reducing water infiltration rates and cover of herbaceous plants and litter as well as disturbing and compacting soils and increasing soil erosion (reviewed by Belsky and Blumenthal 1997). Changes in herbaceous cover and litter coupled with control of fire can lead to establishment and expansion of pinyon (*Pinus spp.*) and juniper (*Juniperus spp.)* into sagebrush-dominated rangelands (Miller and Wigand 1994, Miller and Rose 1995, Davenport et al. 1998). Expansion of pinyon and juniper into habitats used by sage grouse reduces the use of these areas by sage grouse as they generally avoid areas with conifers, apparently because of predation pressure (Commons et al. 1998).

Fire, like domestic livestock grazing, can be considered a biological treatment of sagebrush-dominated habitats. Several species of sagebrush (*A. cana, A. filifolia*) resprout after burning suggesting they evolved with fire. Big sagebrush (*A. t. tridentata, A. t. vaseyana, A.t. wyomingensis*) is killed by fire and does not resprout after burning (Wright et al. 1979) suggesting it evolved where fire was infrequent. While wild fire was widespread in historic times and encouraged by native people, fire intervals are unknown but probably did not exceed 30 to 50 years (Bunting et al. 1987, Bunting 1994). Burning of rangelands at the sagebrush:pinyon/juniper interface was most likely responsible for controlling the spread of pinyon and juniper into sagebrush rangelands (Bunting 1994, Evans and Workman 1994). It is unlikely that fire burned areas uniformly and large areas were unburned for decades (Winward 1984, Braun 1987). Sage grouse may respond to fire by foraging on forbs within burned areas (Pyle and Crawford 1996) as burning can enhance forb production

(Cook et al. 1994). However, a clear positive response of sage grouse to burning has not been demonstrated (Benson et al. 1991, Fischer et al. 1996, Connelly and Braun 1997, Connelly et al. 1998). Prescribed fire has been promoted as a tool to improve sagebrush habitats (Winward 1991) for both livestock and wildlife. The total area burned by prescribed and wild fires at 10-year intervals within the distribution of sage grouse is unknown but appears to be increasing (Connelly and Braun 1997).

Mechanical treatments of sagebrush generally involve brush beating, disking, chaining, and railing (Pechanec et al. 1954). These practices were initiated in the 1930's and have continued at relatively low levels (because of costs) to the present. Brush beating in strips with untreated areas twice the width of treated strips appears to have potential benefits to sage grouse by improving herbaceous cover, forb production, and resprouting of sagebrush. Mechanical treatments, especially when coupled with reseeding of exotic grasses, in large (>100 ha) blocks has degraded sage grouse habitats by altering the structure and composition of the vegetation community (Blaisdell et al. 1982, Lancaster et al. 1987). The total area of sage grouse habitat involved with mechanical treatments is unknown.

Chemical control of sagebrush has been accomplished with 2, 4-D; 2, 4, 5 - T; and Tebuthiuron with 2, 4-D being most commonly used from the early 1960's until the late 1970's. Because of health concerns, use of 2, 4-D and 2, 4, 5 -T was curtailed in the 1980's but use of 2, 4-D is again increasing. Use of Tebuthiuron to control sagebrush began in the late 1970's and increased in the 1980's and 1990's until, at present, it is the preferred herbicide by both private individuals and public agencies. Response of vegetation to 2, 4-D is relatively well understood depending upon time of application and plant phenology. Tebuthiuron is a delayed-response herbicide and effectiveness is dependent upon soil characteristics, moisture, as well as application rates (Emmerich 1985). Sage grouse response to herbicide treatment is predictable (Braun et al. 1977) and depends upon extent of kill of forbs and sagebrush. Herbicide treatments in relatively narrow strips (<50 m) with non-treated strips of equal or greater width has not been shown to have positive or negative effects on sage grouse. All block treatments >200 ha in size have negatively impacted sage grouse (Braun and Beck 1996). Millions of hectares of sagebrush have been treated with herbicides to control sagebrush since the early 1960's, but total size of area treated is unknown but probably exceeds 20-25% of the total remaining sagebrush-dominated rangelands. Expected treatment life for sagebrush treated with herbicides has been widely debated but is no less than 15 years and probably not longer than 25-30 years.

Chemicals have also been used to control insects on sagebrush rangelands and adjacent areas. Insects of concern have primarily included grasshoppers, mormon crickets, and mosquitos. Little is known about the direct or indirect effects of insect control upon sage grouse although (Johnson and Boyce 1990) found that sage grouse chicks died of malnutrition if insufficient numbers of insects were available. Blus et al. (1989) documented sage grouse mortality attributed to use of orgnophosphorus insecticides used on cultivated crops. The extent of insecticide use in habitats seasonally used by sage grouse is unknown as is the size of the area involved. However, Johnson and Boyce (1990) reported that 5 million hectares of western rangelands were sprayed for grasshopper control between 1980 and 1985.

NATURAL CHANGES

Drought

Sagebrush-dominated rangelands are generally xeric with average annual precipitation ranging from 15 - 32 cm. Evaporation:transpiration ratios are generally high except in northern latitudes and effective moisture for plant growth is extremely variable. Drought commonly occurs either seasonally or for periods of several years and is normal within the distribution of sage grouse. If average moisture conditions are considered, generally one-half of each 10 or 20-year period will have less than average moisture (Palmer 1965). Thus, habitat management for average herbaceous production could result in improper use in 50% of the years. Declining sage grouse populations in the mid 1930's coincided with drought (Patterson 1952:68-69) throughout the west. A period of dry years in the late 1980's and early 1990's also seemed to coincide with apparent low sage grouse populations (Connelly and Braun 1997). Drought is believed to affect sage grouse populations through increased nest predation and early brood mortality caused by decreased herbaceous cover and forb availability which may also affect insect abundance (Klebenow and Gray 1968, Peterson 1970, Drut et al. 1994 *a* and *b*, Gregg et al. 1994, Fischer et al. 1996).

PREDATION

Predators are commonly believed to negatively impact sage grouse populations and, it is true, that every sage grouse will eventually be eaten. Thus, it does not matter whether death occurs in accidents (and the carcass is scavenged) or the bird is harvested (and eaten by humans) or the bird is captured and killed by a predator. Of most importance is the timing of death. Nest loss to predators is most important as potential production of young and recruitment may be seriously impacted. Removing predators has been documented to have a large positive effect on hatching success but was not significant in affecting breeding population size (Cote and Sutherland 1997). Sage grouse nest loss has been attributed to many types of predators (Batterson and Morse 1948, Patterson 1952, Braun et al. 1977, Autenrieth 1981). Gregg et al. (1994), Delong et al. (1995) and Sveum et al. (1998) suggest that nest success is related to herbaceous cover near the nest site. Taller, more dense herbaceous cover apparently reduces nest predation and likely also positively affects early brood survival. Predation of males at lek sites is also common but likely has little overall impact on breeding success or population size except in small populations (Commons et al. 1998). Predation during extreme winters with extensive and deep snow cover may negatively affect size of the breeding population. Generally, it is believed that quantity and quality of habitats used by sage grouse controls the importance of predation. Thus, predation would be expected to be most important as habitat size and herbaceous cover within live sagebrush decreases.

HUNTING

The effect of recreational harvest on subsequent sage grouse breeding population size is believed to be inconsequential as hunting mortality is thought to be replacive and compensatory. The available evidence (Braun and Beck 1985, Zablan 1993) indicates that direct recovery rates (= annual harvest rate) range from 3 to 11% which is well below

one-half of the annual mortality rate that Hickey (1955) believed could be harvested. Zunino (1987) suggested that hunting could negatively affect sage grouse population size. This may be possible depending upon which segment (i.e., brood hens vs. chicks vs. adult males) of the population incurs the highest harvest mortality. However, if hunting seasons are delayed to allow population mixing in fall and with conservative bag/possession limits (1/2, 2/4), it is unlikely that subsequent breeding population size could be affected by recreational hunting. (Braun and Beck 1985, 1996).

CONCLUSIONS

Distribution and abundance of sage grouse have markedly decreased since the advent of survey efforts. Overall distribution has decreased by an estimated 50% since settlement while apparent breeding population size has decreased from 45 - 80% since the early 1950's. Much of the decrease in population size has occurred since 1980. Declines in sage grouse abundance are mostly attributed to human-caused changes in sagebrush habitats with drought also implicated in short-term population fluctuations. The demonstrated declines in sage grouse populations are not attributable to one factor but instead have been caused by a complexity of factors. No undisturbed habitats occur within the distribution of sage grouse and active habitat management is needed on a landscape scale if populations are to remain viable, especially at the present periphery of the distribution. Conservation plans that are developed at the local community level appear to have the best opportunity for support and eventual success.

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REFERENCES

Aldrich, J.W. 1963. Geographic orientation of American Tetraonidae. J. Wildl. Manage. 27:529-545.

American Ornithologists' Union. 1957. Check-list of North American birds. 5th ed. Lord Baltimore Press, Baltimore, MD. 691 pp.

Autenrieth, R.E. 1981. Sage grouse management in Idaho. Idaho Dep. Fish and Game Wildl. Bull. 9. 238 pp.

Batterson, W.M., and W.B. Morse. 1948. Oregon sage grouse. Oregon Game Comm. Fauna Ser. 1. 29 pp.

Bent, A.C. 1932. Life histories of North American gallinaceous birds. Orders Galliformes and Columbiformes. U.S. Natl. Mus. Bull. 162:300-310.

Beetle, A.A. 1960. A study of sagebrush. The section Tridentatae of Artemisia. Univ. Wyoming Agric. Exp. Stn. Bull. 368. 83 pp.

Belsky, A.J., and D.M. Blumenthal. 1997. Effects of livestock grazing on stand dynamics and soils in upland forests of the Interior West. Conserv. Biol. 11:315-327.

Benson, L.A., C.E. Braun, and W. C. Leininger. 1991. Sage grouse response to burning in the big sagebrush type. Proc. Issues and Technology in the Management of Impacted Western Wildlife. Thorne Ecol. Inst. 5:97-104.

Blaisdell, J.P., R.B. Murray, and E.D. McArthur. 1982. Managing Intermountain rangelands - sagebrush-grass ranges. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. INT-134. 41 pp.

Blus, L.J., C.S. Staley, C.J. Henny, G.W. Pendleton, T.H. Craig, E.H. Craig, and D.K. Halford. 1989. Effects of organophosphorus insecticides on sage grouse in southeastern Idaho. J. Wildl. Manage. 53:1139-1146.

Bork, E.W., N.E. West, and J.W. Walker, 1998. Cover components on long-term seasonal sheep grazing treatments in three-tip sagebrush steppe. J. Range Manage. 51:293-300.

Braun, C.E. 1986. Changes in sage grouse lek counts with advent of surface coal mining. Proc. Issues and Technology in the Management of Impacted Western Wildlife. Thorne Ecol. Inst. 2:227-231.

_____. 1987. Current issues in sage grouse management. Proc. West. Assoc. Fish and Wildl. Agencies 67:134-144.

_____. 1995. Distribution and status of sage grouse in Colorado. Prairie Nat. 27:1-9.

_____, and T.D.I. Beck. 1985. Effects of changes in hunting regulations on sage grouse harvest and populations. Pages 335-343 *in* S.L. Beason and S.F. Roberson, eds., Game Harvest Management. Proc. 3rd Int. Symp. Caesar Kleberg Res. Inst., Kingsville, TX.

_____, and _____. 1996. Effects of research on sage grouse management. Trans. North Am. Wildl. and Nat. Resour. Conf. 61:429-436.

_____, M.F. Baker, R.L. Eng, J.S. Gashwiler, and M.H. Schroeder. 1976. Conservation
Dalke, P.D., D.B. Pyrah, D.C. Stanton, J.E. Crawford, and E.F. Schlatterer. 1963. Ecol

Committee report on the effects of alteration of sagebrush communities on the associated avifauna. Wilson Bull. 88:165-171.

_____, T. Britt, and R.O. Wallestad. 1977. Guidelines for maintenance of sage grouse habitats. Wildl. Soc. Bull. 5:99-106.

Brown, J.H., and W. McDonald. 1995. Livestock grazing and conservation on southwestern rangelands. Conserv. Biol. 9:1644-1647.

_____, and _____. 1997. Historical and cultural perspectives on grazing: reply to Dudley. Conserv. Biol. 11:270-272.

Bunting, S.C., B.M. Kilgore, and C.L. Bushey. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the northern Great Basin. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. INT-231. 33 pp.

_____. 1994. Effects of fire on juniper woodland ecosystems in the Great Basin. Pages 53-55 *in* S.B. Monsen and S.G. Kitchen, compilers. Proc. Ecology and Management of Annual Rangelands. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. INT-GTR 313 pp.

Carhart, A.H. 1954. Sagebrush is going! Audubon Mag. 56:200-204.

Clements, C.D., and J.A. Young. 1997. A viewpoint: rangeland health and mule deer habitat. J. Range Manage. 50:129-138.

Colenso, B.E., M.S. Boyce, and J. Tate, Jr. 1980. Developing criteria for reclamation of sage grouse habitat on a surface coal mine in northeastern Wyoming. Pages 27-31 in Proc. Symposium: Surface Mining Hydrology, Sedimentology, and Reclamation. Univ. Kentucky, Lexington.

Commons, M.L., R.K. Baydack, and C.E. Braun. 1998. Sage grouse response to pinyon-juniper management. Pages 1-2 *in* S.B. Monsen, R. Stevens, R.J. Tausch, R. Miller, and S. Goodrich, compilers. Proc. ecology and management of Pinyon-Juniper communities within the interior west. U.S. Dep. Agric., For. Serv. RM. In Press.

Connelly, J.W., and C.E. Braun. 1997. Long-term changes in sage grouse *Centrocercus urophasianus* populations in western North America. Wildl. Biol. 3:229-234.

_____, K.P. Reese, R.A. Fischer, and W.L. Wakkinen. 1998. Response of a sage grouse breeding population to fire in southeastern Idaho. Wildl. Soc. Bull. In Press.

Cook, J.G., T.J. Hershey, and L.L. Irwin. 1994. Vegetative response to burning on Wyoming mountain-shrub big game ranges. J. Range Manage. 47:296-302.

Cote, I.M., and W.J. Sutherland. 1997. The effectiveness of removing predators to protect bird populations. Conserv. Biol. 11:395-405

Dalke, P.D., D.B. Pyrah, D.C. Stanton, J.E. Crawford, and E.F. Schlattered. 1963. Ecology, productivity, and management of sage grouse in Idaho. J. Wildl. Manage. 27:811-841.

Dargan, L.M., and R.J. Keller. 1940. Survey of 1940/North Park, Jackson County, Colorado. Sage Grouse Surv. 2, Colorado Game and Fish Dep. Denver. 28 pp.

Davenport, D.W., D.B. Breshears, B.P. Wilcox, and C.D. Allen. 1998. Viewpoint: sustainability of pinon-juniper ecosystems - a unifying perspective of soil erosion thresholds. J. Range Manage. 51:231-240.

Delong, A.K., J.A. Crawford, and D.C. Delong. 1995. Relationships between vegetational structure and predation of artificial sage grouse nests. J. Wildl. Manage. 59:88-92.

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

Drut, M.S., J.A. Crawford, and M.A. Gregg. 1994a. Brood habitat use by sage grouse in Oregon. Great Basin Nat. 54:170-176.

_____, W.H. Pyle, and J.A. Crawford. 1994b. Diets and food selection of sage grouse chicks in Oregon. J. Range. Manage. 47:90-93.

Dudley, J.P. 1997. Paleontological and cultural perspectives on livestock grazing in southwestern rangelands: response to Brown and McDonald. Conserv. Biol. 11:267-269.

Ellis, K.L. 1984. Behavior of a lekking sage grouse in response to a perched golden eagle. West. Birds 15:37-38.

_____. 1987. Effects of a new transmission line on breeding male sage grouse at a lek in northwestern Utah. Trans. Western States Sage Grouse Workshop 15: Abstract.

Emmerich, W.E. 1985. Tebuthiuron - environmental concerns. Rangelands 7:14-16.

Emmons, S.R., and C.E. Braun. 1984. Lek attendance of male sage grouse. J. Wildl. Manage. 48:1,023-1,028.

Eng, R.L. 1963. Observations of the breeding biology of male sage grouse. J. Wildl. Manage. 27:841-846.

_____, E.J. Pitcher, S.J. Scott, and R.J. Greene. 1979. Minimizing the effect of surface coal mining on a sage grouse population by a directed shift of breeding activities. Pages 464-468 *in* G.A. Swanson, tech coordinator. The Mitigation Symposium: a national workshop on mitigating losses of fish and wildlife habitats. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-65.

Evans, S.G., and J.P. Workman. 1994. Optimization of range improvements on sagebrush and pinyon-juniper sites. J. Range Manage. 47-159-164.

Fischer, R.A., K.P. Reese, and J.W. Connelly. 1996. An investigation on fire effects within xeric sage grouse brood habitat. J. Range Manage. 49:194-198.

Fleischner, T.L. 1994. Ecological costs of livestock grazing in western North America. Conserv. Biol. 8:629-644.

Gabrielson, I.N., and S.G. Jewett. 1940. Birds of Oregon. Oregon State Coll., Corvallis. 650 pp.

Girard, G.L. 1937. Life history, habits, and food of the sage grouse, *Centrocercus urophasianus* Bonaparte. Univ. Wyoming Publ. 3. 56 pp.

Graul, W.D. 1980. Grassland management and bird communities. Pages 38-47 *in* R.M. DeGraff and N.G. Tilghman, compilers. Workshop Proc., Management of western forests and grasslands for nongame birds. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep.. INT-86.

Gregg, M.A., J.A. Crawford, M.S. Drut, and A.K. Delong. 1994. Vegetational cover and predation of sage grouse nests in Oregon. J. Wildl. Manage. 58:162-166.

Griner, L.A., 1939. A study of the sage grouse (*Centrocercus urophasianus*), with special reference to life history, habitat requirements, and numbers and distribution. M.S. thesis, Utah State Coll., Logan. 83 pp.

Hickey, J.J. 1955. Some American population research on gallinaceous birds. Pages 326-396 in A. Wolfson, ed. Recent studies in avian biology. Univ. Illinois Press, Urbana

Hornaday, W.T. 1916. Save the sage grouse from extinction, a demand from civilization to the western states. New York Zool. Park Bull. 5:179-219.

Jenni, D.A., and J.E. Hartzler. 1978. Attendance at a sage grouse lek: implications for spring censuses. J. Wildl. Manage. 42:46-52.

Johnsgard, P.A. 1973. Grouse and quails of North America. Univ. Nebraska Press, Lincoln. 553 pp.

Johnson, G.D., and M.S. Boyce. 1990. Feeding trials with insects in the diet of sage grouse chicks. J. Wildl. Manage. 54:89-91.

Klebenow, D.A., and G.M. Gray. 1968. Food habits of juvenile sage grouse. J. Range Manage. 21:80-83.

Lancaster, D.L., J.A. Young, and R.A. Evans. 1987. Weed and brush control tactics in the

sagebrush ecosystem. Pages 11-14 *in* J.A. Onsager, ed. Integrated pest management on rangeland: state of the art in the sagebrush ecosystem. U.S. Dep. Agric., Agric. Res. Serv. ARS-50.

Laycock, W.A. 1987. Grazing management systems and tactics in the sagebrush ecosystem. Pages 40-49 *in* J.A. Onsager, ed. Integrated pest management on rangelands: state of the art in the sagebrush ecosystem. U.S. Dep. Agric., Agric. Res. Serv. ARS-50.

Miller, R.F., and J. A. Rose. 1995. Historic expansion of *Juniperus occidentalis* (western juniper) in southeastern Oregon. Great Basin Nat. 55:37-45.

_____, and P.E. Wigand. 1994. Holocene changes in semiarid pinyon-juniper woodlands. Bioscience 44:465-474.

Paine, L., D.J. Undersander, D.W. Sample, G.A. Bartelt, and T.A. Schatteman. 1996. Cattle trampling of simulated ground nests in rotationally grazed pastures. J. Range. Manage. 49:294-300.

Palmer, W.C. 1965. Meteorological drought. U.S. Dep. Commerce Res. Paper 45. 58 pp.

Patterson, R.L. 1952. The sage grouse in Wyoming. Sage Books Inc., Denver, CO 341 pp.

Pechanec, J.F., G. Stewart, A.P Plummer, J.H. Robertson, and A.C. Hull. 1954. Control ling sagebrush on rangelands. U.S. Dep. Agric. Farmer's Bull. 2072. 36 pp.

Peterson, J.G. 1970. The food habits and summer distribution of juvenile sage grouse in central Montana. J. Wildlife Manage. 34:147-155.

Pyle, W.H., and J.A. Crawford. 1996. Availability of foods of sage grouse chicks following preseribed fire in sagebrush-bitterbrush. J. Range Manage. 49:320-324.

Remington, T.E., and C.E. Braun. 1991. How surface coal mining affects sage grouse, North Park, Colorado. Proc. Issues and Technology in the Management of Im pacted Western Wildlife. Thorne Ecol. Inst. 5:128-132.

Rich. T. 1985. Sage grouse population fluctuations: evidence for a 10-year cycle. U.S. Dep. Inter., Bur. Land Manage., Idaho State Office Tech. Bull. 85-1. 20 pp.

Robbins, W.G. and D.W. Wolf. 1994. Landscape and the intermountane northwest: an environmental history. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. PNW-GTR-

Rogers, G.E. 1964. Sage grouse investigations in Colorado. Colorado Dep. Game, Fish and Parks Tech. Publ. 16. 132 pp.

Rush, W.M. 1942 . Wildlife of Idaho. Caxton Printers Ltd., Caldwell, ID. 299 pp.

Schneegas, E.R. 1967. Sage grouse and sagebrush control. Trans. North Am. Wildl. and Nat. Resour. Conf. 32:270-274.

Scott, M.D., and G.M. Zimmerman. 1984. Wildlife management at surface coal mines in the northwest. Wildl. Soc. Bull. 12:364-370.

Sveum, C.M., W.D. Edge, and J.A. Crawford. 1998. Nesting habitat selection by sage grouse in southcentral Washington. J. Range Manage. 51:265-269.

Swensen, J.E., C.A. Simmons, and C.D. Eustace. 1987. Decrease of sage grouse *Centrocercus urophaianus* after ploughing of sagebrush steppe. Biol. Conserv. 41:125-132.

Tate, J., Jr., M.S. Boyce, and T.R. Smith. 1979. Response of sage grouse to artificially created display ground. Pages 459-463 *in* G.A. Swanson, tech. coordinator. The Mitigation Symposium: a national workshop on mitigating losses of fish and wildlife habitats. U.S. Dep. Agric., For. Serv. Gen. Tech. Rep. RM-65.

Tisdale, E.W., and M. Hironaka. 1981. The sagebrush-grass region: a review of the ecological literature. Univ. Idaho For., Wildl., and Range Exp. Stn. Bull. 33. 31 pp.

Todd, M., and W. Elmore. 1997. Historical changes in western riparian ecosystems. Trans. North Am. Wildl. and Nat. Resour. Conf. 62:454-468.

Vale, T.R. 1974. Sagebrush conversioin projects: an element of contemporary environmental change in the western United states. Biol. Conserv. 6:274-284.

_____. 1975. Presettlement vegetation in the sagebrush-grass area of the Intermoun tain West J. Range Manage. 28:32-36

Visher, S.S. 1913. Notes on the sage hen. Wilson Bull. 25:90-91.

Western Association of State Fish and Game Commissioners. 1968. Resolution No. 9. Preservation of sage grouse habitat./ Proc. West. Assoc. state Fish and Game Comm. 48:702

_____. 1974. Resolution No. 9. Guidelines for sage grouse rang. Proc. West. Assoc. state Fish and game Comm. 54:398-399.

Western States Sage Grouse Technical Committee. 1995. Status of sage grouse. West. States Sage Grouse Tech. Comm., Unpubl. Rep. San Diego, CA. Unnumbered.

Willis, M.J., G.P. Keister, Jr., D.A. Immel, D.M. Jones, R.M. Powell, and K.R. Durbin. 1993. Sage grouse in Oregon. Oregon Dep. Fish and Wildl. Wildlife. Res. Rep. 15. 56pp.

Winward, A.H. 1984. Fire in the sagebrush-grass ecosystem - the ecological setting. Pages 2-6 *in* K. Sanders and J. Durban, eds. rangelend fire effects, a symposium. U.S. Dep. Inter., Bur. Land Manage. Boise, ID.

_____. 1991. Management in the sagebrush steppe. Oregon Agric. Exp. Stn., Oregon State Univ. Spec. Re. 880. 7pp.

Wright, H.A., L.F. Neuenschwander, and C.M. Britton. 1979. The role and use of fire in sagebrush-grass and pinyon/juniper plant communities: astate of the art review. U.S. Dep. Agric., For. Serv. Gen Tech. Rep. INT-58. 48pp.

Young, J.A., R.E. Eckert, and R.A. Evans. 1979. Historical perspectives regarding the sagebrush ecosystem. Pages 1-3 *in* Proc. The sagebrush ecosystem: a symposium. Utah State Univ., Logan.

Zablan, M.A. 1993. Evaluation of sage grouse banding program in North Park, Colorado. M.S. thesis, Colorado State Univ., Fort Collins. 59pp.

Zunino, G.W. 1987. Harvest effect on sage grouse densities in northwest Nevada. M.S. thesis, Univ. Nevada, Reno. 41pp.

Braun, C.E. 1987. Current issues in Sage Grouse management . Proceedings of the Western Association of State Game and Fish Commissioners 67:134-144.

Braun, C.E. 1998. Sage-grouse declines in western North America: what are the problems?. Proceedings of the Western Association of State Game and Fish Commissioners 78:139-156.

Eng. R. L., and R. J. Mackie. 1982. Integrating grazing-range management practices with management of major wildlife species on rangeland in north central Montana. Proceedings of the Western Association Fish and Wildlife Agencies 62:112-119.

Autenrieth, R.E. 1981. Sage Grouse management in Idaho. Wildlife Bulletin No. 9, Boise, Idaho.

Craddock, G.W., and C.L. Forsling. 1938. The influence of climate and grazing on spring-fall sheep range in southern Idaho. Technical Bulletin 600. United States Department of Agriculture, Washington, DC.

Fulgham, K.O., M.A. Smith, and J.C. Malechek. 1982. A compatible grazing relationship can exist between domestic sheep and mule deer. pp. 458-478 *In* J.M. Peek and P.D. Dalke [eds]. Proceeding of the Wildlife-Livestock Relationships Symposim Idaho For., Wildl. and Range Exp. Sta. University of Moscow, Moscow, ID.

Klebenow, D.A. 1981. Livestock grazing interactions with sage grouse. pp. 113-123 *In* J.M. Peek and P.D. Dalke [eds]. Proceedings of the wildlife-livestock relationships symposium April 20-22. University of Idaho, Idaho Forest, Wildlife and Range Experiment Station, Moscow, ID.

Platts, W.S. 1981. Sheep and cattle grazing strategies on riparian-stream environments . Proceeding 10. pp. 251-270 *In* U.S. Dept. of Agriculture, and Forest Service [eds]. Proceeding of the wildlife-livestock relationships symposium . University of Idaho, Moscow, ID.

Nielsen, L.S., and C.A. Yde. 1981. The effects of rest-rotation grazing on the distribution of sharp-tailed grouse. University of Idaho Forest, Wildlife and Range Experiment Station, Moscow, Idaho .

Autenrieth, R., W. Molina, and C. Braun. 1982. Sage grouse management practices. Technical Bulletin No. 1. Western States Sage Grouse Committe, Twin Falls, ID.

Autenrieth, R.E. 1973. Sage grouse research in Idaho. Proceeding Western States Sage Grouse Workshop 8:51-52.

Autenrieth, R.E. and W. Molina, and C. Braun. 1982. Sage Grouse Managment Practice. Technical Bulletin #1. Western States Sage Grouse Committee , Twin Falls, Idaho .