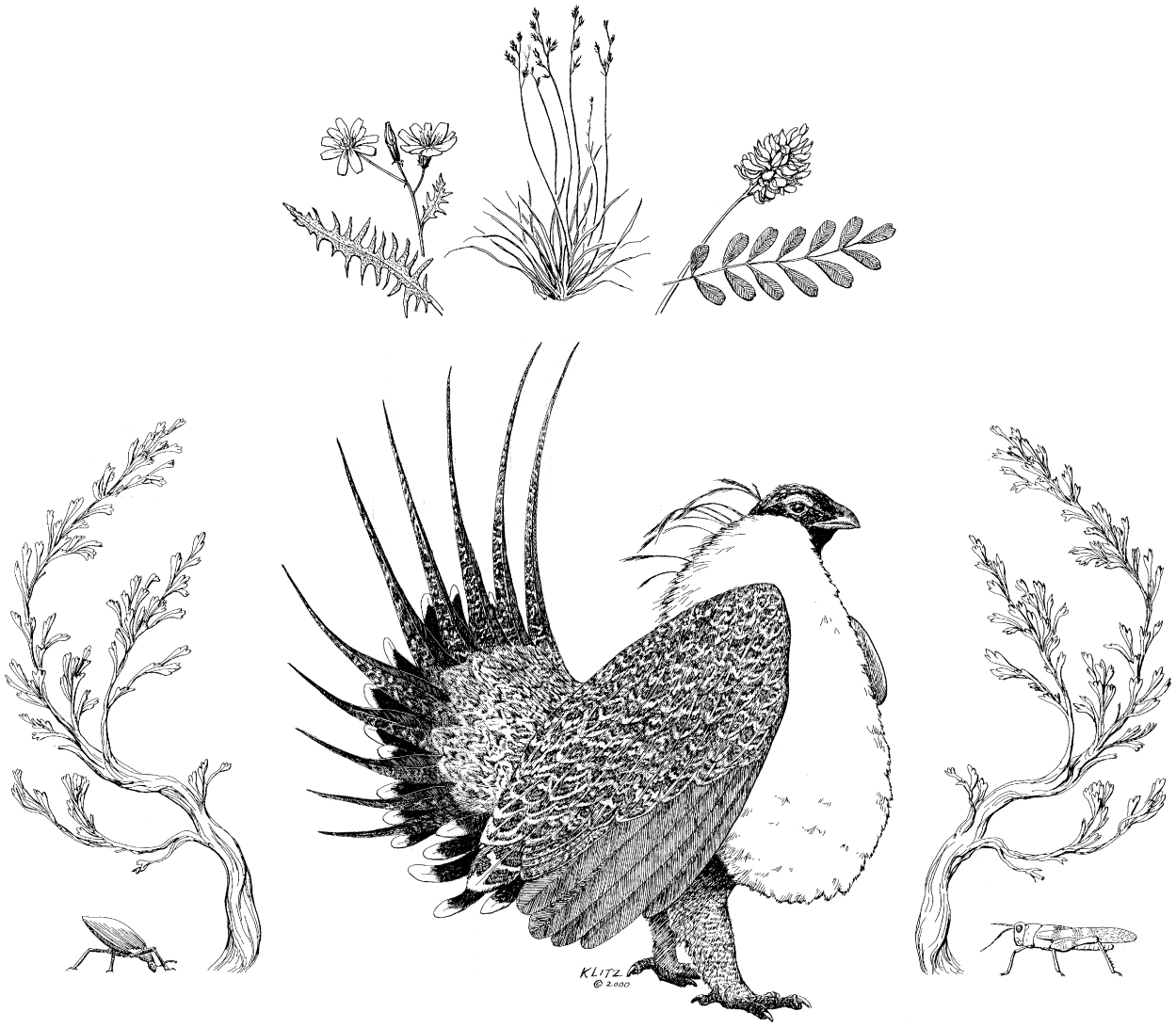

Status Review and Petition to List the Greater Sage Grouse (*Centrocercus urophasianus)* as Threatened or Endangered under the Endangered Species Act

American Lands Alliance

SENT CERTIFIED U.S. POSTAL EXPRESS MAIL

December 22, 2003

Assistant Director of Endangered Species
U.S. Fish and Wildlife Service
1849 C Street NW, Room 3242
Washington, D.C. 20240

Regional Director
U.S. Fish and Wildlife Service
P.O. Box 25486
Denver, Colorado 80225

Regional Director
U.S. Fish and Wildlife Service
911 NE 11th Avenue
Portland, Oregon 97232

Re: Petition to List Greater Sage Grouse (*Centrocercus urophasianus*) under the Endangered Species Act

The following petitioners hereby petition to list the Greater Sage Grouse (*Centrocercus urophasianus*) (sage grouse) as "threatened" or "endangered" under the Endangered Species Act (ESA) (16 U.S.C § 1531 *et seq.*) and the Administrative Procedures Act (5 U.S.C. § 551 *et seq.*).

- **American Lands Alliance**
- **Biodiversity Conservation Alliance**
- **Center for Biological Diversity**
- **Center for Native Ecosystems**
- **Forest Guardians**
- **The Fund for Animals**
- **Gallatin Wildlife Association**
- **Great Old Broads for Wilderness**
- **Hells Canyon Preservation Council**
- **The Larch Company**
- **Northwest Ecosystem Alliance**
- **Northwest Coalition for Alternatives to Pesticides**
- **Oregon Natural Desert Association**
- **Oregon Natural Resources Council**
- **Predator Defense Institute**
- **Sierra Club**
- **Sinapu**
- **Western Fire Ecology Center**
- **Western Watersheds Project**
- **Wild Utah Project**
- **Wildlands CPR**

This submittal is not intended to supplement any previous petition the U.S. Fish and Wildlife Service (Service) has received to list sage grouse under the Endangered Species Act (ESA), but is submitted as a wholly new petition for the species.

Please use the following address for all correspondence regarding this petition.

Mark Salvo
American Lands Alliance
2224 W. Palomino Drive
Chandler, Arizona 85224
mark@americanlands.org

While previous petitioners have contended that Greater Sage Grouse are two subspecies—an "eastern" and a "western" subspecies—this petition recognizes only one species of sage grouse, consistent with preliminary findings by Benedict et al. (2003),[1] with the possible exception of a genetically distinct Mono Basin species/subspecies/population segment in southwestern Nevada/eastern California.[2]

[1] Benedict, N. G., S. J. Oyler-McCance, S. E. Taylor, et al. 2003. Evaluation of the eastern (*Centrocercus urophasianus urophasianus*) and western (*Centrocercus urophasianus phaios*) subspecies of Sage-grouse using mitochondrial control-region sequence data. Cons. Genetics 4: 301-310.

[2] *See* Benedict, N. G., S. J. Oyler-McCance, S. E. Taylor, et al. 2003. Evaluation of the eastern (*Centrocercus urophasianus urophasianus*) and western (*Centrocercus urophasianus phaios*) subspecies of Sage-grouse using mitochondrial control-region sequence data. Cons. Genetics 4: 301-310; R. Webb. 2001. Status Review of the Mono Basin Distinct Population Segment of the Greater Sage Grouse (*Centrocercus urophasianus phaios*). Institute for Wildlife Protection. Eugene, OR.

Status Review and Petition to List the Greater Sage Grouse (*Centrocercus urophasianus)* as Threatened or Endangered under the Endangered Species Act

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EXECUTIVE SUMMARY

Sage grouse have inhabited the western United States and southern Canada since the Pleistocene epoch. The sage grouse was discovered by Lewis and Clark in 1806 and was assigned its scientific name, *Centrocercus urophasianus* (Latin for "spiny-tailed pheasant"), in 1831.

Sage grouse perhaps once numbered in the millions. Huge flocks of sage grouse were reported to "blacken the sky" as recently as the late 1800s. Their historic range closely conformed to the distribution of tall and short sagebrush on the prairie sagebrush steppe (the "Sagebrush Sea") covering what became sixteen western states and three Canadian provinces. However, since 1900 the distribution of sage grouse has been reduced with extirpation of populations at the periphery of their range. Sage grouse no longer occur in Arizona, British Columbia, Kansas, Nebraska, New Mexico, and Oklahoma.

The sage grouse population has declined as much as 45-80 percent over the past 20 years due to habitat destruction, degradation and fragmentation. The current breeding population is estimated at 140,000 individuals, representing only about eight percent of historic numbers. These birds are sparsely distributed over vast tracts of degraded habitat, often in isolated sub-populations.

Sage grouse are valued as an historical icon of the West and a charismatic ambassor for the Sagebrush Sea. Prior to the arrival of white settlers, American Indians utilized the sage grouse for food and created dances and costumes to mimic their strutting behavior. Today, birdwatchers delight in the species fascinating mating ritual in early spring, and hunters pursue the grouse in autumn. Scientists marvel at the sage grouse's ability to survive in its harsh, arid environment.

Sage grouse are a key focal species for the Sagebrush Sea. Because they depend on large expanses of healthy sagebrush habitat, conserving the species will also benefit other sagebrush obligates, such as the sagebrush vole (*Lagurus curtatus*), sage sparrow (*Amphispiza belli*), sagebrush lizard (*Sceloporusgraciosus*), and the pygmy rabbit (*Brachylagus idahoensis*).

The Endangered Species Act sets forth five criteria for listing, and requires the U.S. Fish and Wildlife Service to list species as "threatened" or "endangered" if they meet one or more of the criteria. This petition carefully and systematically documents how the Greater Sage Grouse meet not just one, but all five criteria.

A. Present or threatened destruction, modification, or curtailment of habitat or range.

Sage grouse habitat has been fragmented, damaged, and destroyed by domestic livestock grazing; agricultural and urban conversion (including suburbanizations and "ex-urbanization," or the establishment of new communities far outside of existing settlement); invasive species; application of herbicides and pesticides; altered fire regimes; oil and gas development (including coalbed methane development); off-road vehicle use; and the placement and construction of utility corridors, roads and fences. At least 80 million acres of sagebrush habitat have been lost in the past 200 years.

B. Overutilization for commercial, recreational, scientific or educational purposes.

Sage grouse are hunted in nine states, and incidents of poaching are evident. Experts now believe hunting of isolated, local populations has negatively impacted the species and can slow population recovery. Recreationists and birdwatchers can flush sage grouse on leks, disrupting breeding activity. Scientific study of sage grouse, specifically the use of radio transmitters, is known to cause mortality in sage grouse chicks and adults.

C. Disease or predation.

Sage grouse suffer periodically from a variety of parasites and disease, including coccidiosis. Disease outbreaks have been associated with contaminated water and drying water holes, where sage grouse are crowded together. West Nile encephalitis virus has also killed sage grouse.

Construction of powerlines, fences, and oil and gas wells, and encroaching juniper trees serve as raptor perches and may increase predation on sage grouse chicks and adults. Habitat degradation also unnecessarily exposes sage grouse to ground predators.

D. Inadequacy of existing regulatory mechanisms.

Federal, state, and local governments have failed to reverse the decline in sage grouse populations. Current regulatory regimes allow, and even prioritize harmful land uses over sage grouse conservation. Agency natural resource planning has been "captured" by local special

interests in many cases. Agency science and scientists that support sage grouse conservation have also been censored in favor of political and economic concerns.

Present conservation efforts are disjointed and lack leadership. The BLM's newly devised conservation framework would rely on local sage grouse working groups to conserve the species. These groups are often paralyzed by discord, lack of resources, and conflicting goals.

E. Other natural or man-made factors affecting the species' continued existence.

Drought in the West continues to stress both sage grouse and sagebrush ecosystems. New federal energy and livestock grazing policies issued by the current administration threaten to eliminate vast areas of habitat from sage grouse use. These factors combined with the myriad other threats described in this petition will further fragment and isolate sage grouse populations, leading to extirpation of local and regional populations.

Status Review and Petition to List the Greater Sage Grouse (*Centrocercus urophasianus)* as Threatened or Endangered under the Endangered Species Act

PETITIONERS

American Lands Alliance

American Lands works with grassroots groups and individuals to protect forest, grassland, desert and aquatic ecosystems; preserve biological diversity; restore landscape and watershed integrity; and promote environmental justice in connection with these goals.

American Lands Alliance
2224 W. Palomino Drive
Chandler, Arizona 85224
503-757-4221

Biodiversity Conservation Alliance

Biodiversity Conservation Alliance (BCA) is a Laramie, Wyoming based conservation organization dedicated to protecting and restoring native plants and animals in the Rocky Mountain Region and Northern Great Plains. Using outreach, education, science, comments, administrative appeals, and litigation, BCA works to protect and restore biodiversity, prevent the loss of native species and their habitat, and raise the threshold of public knowledge and appreciation of biodiversity and ecological health.

Biodiversity Conservation Alliance
P.O. Box 1512
Laramie, Wyoming 82073

Center for Biological Diversity

The Center for Biological Diversity is a national conservation organization based in Tucson, Arizona with over 7,500 members. Combining conservation biology with litigation, policy advocacy, and an innovative strategic vision, the Center for Biological Diversity is working to secure a future for animals and plants hovering on the brink of extinction, for the wilderness they need to survive, and by extension for the spiritual welfare of generations to come.

Center for Biological Diversity
P.O. Box 710
Tucson AZ 85702-0710

Center for Native Ecosystems

Center for Native Ecosystems (CNE) is an advocacy organization dedicated to conserving and recovering native and naturally functioning ecosystems in the Greater Southern Rockies and Plains. CNE values clean water, fresh air, healthy communities, sources of food and medicine, and recreational opportunities provided by native biological diversity. CNE uses the best available science to forward its mission through participation in policy, administrative processes, legal action, public outreach and organizing, and education.

Center for Native Ecosystems
P.O Box 1365
Paonia, Colorado 81428

Forest Guardians

Forest Guardians seeks to preserve and restore native wildlands and wildlife in the American Southwest through fundamental reform of public policies and practices. Forest Guardians' endangered species campaign prioritizes the protection of focal species to maximize biodiversity protection. Forest Guardians has 1,250 members, who recreate, photograph wildlife, and support and benefit from environmental conservation throughout the western United States.

Forest Guardians
312 Montezuma Avenue, Suite A
Santa Fe, New Mexico 87501

The Fund for Animals

The Fund for Animals was founded in 1967 by prominent author and animal advocate, Cleveland Amory. Created to “speak for those who can’t,” The Fund is one of the most active organizations dedicated to the cause of animals throughout the world. The Fund pursues a varied agenda that includes legal action, humane education and legislative efforts.

The Fund for Animals
200 West 57th Street
New York, New York 10019

Gallatin Wildlife Association

The Gallatin Wildlife Association (GWA) is a wildlife conservation organization that represents concerned hunters and anglers in southwest Montana and elsewhere. An affiliate of the Montana Wildlife Federation, GWA is comprised of dedicated volunteers working to protect fish and wildlife habitat in order to conserve hunting and fishing opportunities for present and future generations.

Gallatin Wildlife Association
P.O. Box 5276
Bozeman, Montana 59717

Great Old Broads for Wilderness

Great Old Broads for Wilderness (GOB) is a nationwide public lands, public interest group dedicated to the preservation and protection of wildlife habitat and roadless public lands in America. Bringing the voices of elders to the conservation debate, GOB members use wisdom, passion and humor to work for a legacy of protected wild places for future generations.

Great Old Broads for Wilderness
P. O. Box 2924
Durango, Colorado 81302

Hells Canyon Preservation Council

Hells Canyon Preservation Council (HCPC) is a rurally-based environmental organization that works to protect and restore the Hells Canyon-Wallowa and Blue Mountain ecosystems, including the plants and animals that depend on the varied habitats of this region of northeast Oregon, southeast Washington, and east-central Idaho. HCPC has existed for over 35 years and represents members from across the United States. HCPC uses a variety of advocacy tools to educate the public and advance sound policy as well as legal compliance for the benefit of natural ecosystem values.

Hells Canyon Preservation Council
P.O. Box 2768
La Grande, Oregon 97850

The Larch Company

The Larch Company is a for-profit, non-membership conservation organization specializing in environmental policy, advocacy and litigation.

The Larch Company
1213 Iowa Street
Ashland, Oregon 97520

The Northwest Coalition for Alternatives to Pesticides

The Northwest Coalition for Alternatives to Pesticides (NCAP) is dedicated to protecting people and the environment from hazardous pesticides. NCAP has been a strong progressive force since 1977, promoting alternatives to pesticide use by government agencies on public forests, grasslands and deserts.

Northwest Coalition for Alternatives to Pesticides
P.O. Box 1393
Eugene, Oregon 97440

Northwest Ecosystem Alliance

Northwest Ecosystem Alliance (NWEA) and its 8,000 members are dedicated to the protection and restoration of biological diversity in the northern Pacific region. NWEA conducts research and advocacy to promote the conservation of sensitive and endangered wildlife and their habitat in the region.

Northwest Ecosystem Alliance
1208 Bay Street, Suite 201
Bellingham, Washington 98225

Oregon Natural Desert Association

Oregon Natural Desert Association is a public interest organization with approximately 1500 members. ONDA's mission is to promote the preservation, protection, and restoration of Oregon's deserts and the native fish and wildlife species that depend on those ecosystems, and to educate the general public on the values of preserving natural arid-land environments.

Oregon Natural Desert Association
16 NW Kansas Avenue
Bend, Oregon 97701

Oregon Natural Resources Council

Oregon Natural Resources Council (ONRC) is a regional conservation organization centered in Oregon, and with a membership of more than 5000. ONRC is involved in federal lands issues with an emphasis on forests, old growth, wilderness and wildlife habitat. ONRC aggressively defends and restores wildlands, wildrivers, and wildlife to be an enduring legacy.

Oregon Natural Resources Council
5825 N. Greeley Avenue
Portland, Oregon 97217

Predator Defense Institute

Predator Defense is a conservation organization founded by professionals from the business and scientific community who are concerned about the humane treatment of wildlife, and the effective management of public and private ecosystems that support wildlife and provide clean air, water and soil for Americans.

Predator Defense
P.O. Box 5446
Eugene, Oregon 97405

Sierra Club

The 750,000 members of the Sierra Club make up America's oldest and largest grassroots conservation organization. Founded in 1892, Sierra Club's mission is to explore, enjoy and protect the wild places of the Earth; practice and promote the responsible use of the Earth's ecosystems and resources; educate and enlist humanity to protect and restore the quality of the natural and human environment, and; use all lawful means to carry out these objectives.

Sierra Club
85 Second Street, 2nd Floor
San Francisco, California 94105

Sinapu

Sinapu, named after the Ute word for wolves, is dedicated to the restoration and protection of native carnivores and their wild habitat in the Southern Rockies, and connected high plains and deserts. Sinapu is based in Boulder, Colorado and has approximately 1,000 members.

Sinapu
4990 Pearl East Circle, Suite 301
Boulder, Colorado 80301

Western Fire Ecology Center

The Western Fire Ecology Center, a project of the American Lands Alliance, works to protect public wildlands, conserve native biodiversity, and restore forest ecosystems through research, analysis, and education advocating the restoration of wildland fire ecology processes, and the reform of federal fire management policies and practices.

Western Fire Ecology Center
P.O. Box 51026
Eugene, Oregon 97405

Western Watersheds Project

The mission of Western Watersheds Project (WWP) is to protect and restore western watersheds and wildlife through education, public policy initiatives and litigation. In 10 years, the progressive conservation group has greatly expanded the scope of its efforts and geographic range of its work, with offices in Idaho, Montana, Utah, and Wyoming, and activities in eight western states.

Western Watersheds Project
P.O. Box 1770
Hailey, Idaho 83333

Wild Utah Project

The Wild Utah Project provides biological analysis and computer mapping support for the conservation community in the intermountain region. Experts in regional ecosystem planning, Wild Utah Project also develops habitat assessment methods for rangelands based on the best conservation biological knowledge.

Wild Utah Project
68 S. Main Street, Suite 400
Salt Lake City, Utah 84101

Wildlands CPR

Wildlands CPR revives and protects wild places by promoting road removal, preventing new road construction and limiting off-road vehicles. Wildlands CPR serves as a national network and clearinghouse, providing scientific, strategic and legal information about road and off-road vehicle impacts as well as road removal opportunities. Wildlands CPR is based in Missoula, Montana, and has 500 members.

Wildlands CPR
P.O. Box 7516
Missoula, Montana 59807

Status Review and Petition to List the Greater Sage Grouse (*Centrocercus urophasianus)* as Threatened or Endangered under the Endangered Species Act

This status review and listing petition and is excerpted from *STATUS REVIEW OF THE EASTERN SUBSPECIES OF THE GREATER SAGE GROUSE (Centrocercus urophasianus urophasianus),* except for *italicized* portions, which are inserted from *STATUS REVIEW OF THE WESTERN SUB-SPECIES OF THE GREATER SAGE GROUSE (Centrocercus urophasianus phaios).* A complete bibliography for the Petition is enclosed.

Webb, R. 2002. Status Review of the Eastern sub-species of the Greater Sage Grouse (*Centrocercus urophasianus urophasianus*). Publ. No. 186-02. Institute for Wildlife Protection. Eugene, OR.

Webb, R. 2001. Status Review of the Western sub-species of the Greater Sage Grouse (*Centrocercus urophasianus phaios*). Publ. No. 024-02. Institute for Wildlife Protection. Eugene, OR.

Introduction

In historical times, sage grouse were so numerous that their flocks used to darken the skies (Patterson 1952c, p. 19). Vast clouds of the birds extended for miles. Today, the bird has been extirpated from 5 states, and is "at risk" in 6 other states (Bradley 1999; Nevada State Office, BLM 2000a, p. 1) and only remnant populations exist even in the center of the range. Existing populations are highly fragmented, and population trends are downward even among the largest populations. All remaining habitat has been degraded. Sage grouse inhabit the sagebrush shrub-steppe areas of North America, a little-loved landscape that has been severely damaged by a wide variety of threats. Vast areas of the public's land has been converted to pasturage with exotic plant species, water pipes and troughs, and electric pumps – the infrastructure of industrial agriculture needed to support livestock management. Agriculture occupies 41% of the areas from which sage grouse have been extirpated in the interior Columbia River basin (Wisdom, Wales, et al. undated, p. 12) – this simple statistic illustrates the extreme effect of agro-industrial infrastructure on sage grouse.

* * * This Status Review incorporates by reference all citations in the Bibliography (Webb and Salvo 2001), as well as the citations in the references themselves. The Service

recognizes that it must examine "information submit[ted] with or referenced in the petition" (Deibert 1999b). The Bibliography consists of the literature cited and selected references, which are intended to help the Service in its evaluation of the plight of this species.

Taxonomy

The two species of sage grouse, the Gunnison sage grouse, *Centrocercus minimus*, and the Greater sage grouse, *Centrocercus urophasianus* (Bonaparte 1827), are referred to the Phasianidae (formerly to the family Tetraonidae), in the order Thwaites 1959.

Common Names

The standardized common names are Gunnison sage grouse and Greater sage grouse, but the species have also been referred to variously as sage hen, sage cock, spiny-tailed pheasant, spine-tail grouse, fool hen, cock of the plains, tétras des armoises (French), Beifusshuhn (German) or sage chicken (Coues 1893; Girard 1937; Patterson 1952c; Jewett, et al. 1953; Johnsgard 1973, p. 155; Johnsgard 1983, p. 109). Lewis and Clark used the term "Cock of the Plains" (Terres 1980). Male sage grouse have been called toms, mountain cocks, master-of-the-plains, old toms, bustards, prairie turkeys, heath cocks, sage fowls, turkey gobblers, sergeant-at-arms, and turkey buzzards, while females have been called brush hens, battle hens, and heath hens (Girard 1937). Together with sharp-tailed grouse (*Tympanuchus phasianellus*), sage grouse are sometimes popularly termed prairie grouse. Various Native Tribes and language groups used a number of different names to refer to sage grouse, including such phonemic Anglicizations as Kop-te, Ko-pah-te, Hoo-dze-hah, Oo-jah, Se-chah, Witch-ah, See-yook, and more (Merriam 1979). The standard AOU (American Ornithologists' Union) code for the Greater sage grouse is CEUR [309].

Affinities of Higher Taxa

Centrocercus is a designated subgenus (AOU 1998). Bonaparte (1827) first described a single species as *Tetrao urophasianus*, and the genus was revised to *Centrocercus* in 1831 (Patterson 1952c). Short (1967) recognized a Subfamily, Tetraoninae, containing sage grouse and allied species. Sibley and Monroe (1990, p. 11) followed Short's general sequence of species in the Phasianidae. The AOU recognizes the Tetraoninae, following Ellsworth, et al. (1995, 1996).

Hudson, et al. (1964) proposed that sage grouse were most closely related to species of forest grouse, rather than to sharp-tailed grouse or other prairie dwelling birds. Johnsgard (1973) followed Holman (1964) in suggesting that speciation in these taxa followed increasing aridity, and that *Centrocercus* is most closely related to a genus of forest dwelling grouse, *Dendragapus*. This assertion was supported by the mt-DNA work of Ellsworth, et al. (1995). This scheme differs somewhat from that of Short (1967) who proposed that sage grouse are most closely related to *Dendragapus obscurus*, the Blue Grouse. Lumsden (1968) supported this view based on behavioral similarities, and Johnsgard (1973) supported it based on adult and downy plumage characteristics. The taxonomic affinities assigned by these studies roughly parallel those of Sibley and Monroe (1990, 1993). Interestingly, the mating systems of sage grouse and other grouse appear to have evolved independently (Ellsworth, et al. 1995, p. 498).

The oldest fossils of the Galliformes date from the middle Eocene (Kuz'mina 1992). The Phasianids are the largest family in the order and are predominately found in tropical and sub-

tropical areas (Kuz'mina 1992). Tetraoninae are endemic to the Holarctic with 18-21 widely distributed species (Kuz'mina 1992). Mayr (1946) and Short (1967) ascribed the origin of the Tetraoninae to North America. However, the greatest diversity of Phasianids is in southern Asia, and a total of about 160 species are assigned to the family. There are 10 species of grouse in North America (Braun, et al. 1994).

DNA hybridization techniques and electrophoretic analyses of egg albumins show a close relation of grouse and pheasants, with a possible divergence during the Miocene (del Hoyo, et al. 1992).

Sage grouse hybridize rarely with sharp-tailed grouse (*Tympanuchus phasianellus*) and blue grouse (*Dendragapus obscurus*) (Johnsgard 1983; Aldridge, et al. 2001). The Greater sage grouse is the largest grouse in North America, and except for the Eurasian Capercaillie species, the largest grouse on Earth (Johnsgard 1983).

Use of Information on Sage Grouse species

All available data indicate that the ecological traits and habitat needs of Gunnison sage grouse are virtually identical to those of Greater sage grouse (J. R. Young 1994b, p. 44). This review will thus use data on the Gunnison species for those issues. J. R. Young (1994b, p. 44) identified only two habitat type and ecological traits differing between the species: Gunnison sage grouse are more tolerant of trees during the nesting and brooding stages, and Gunnison females have a lower rate of renesting than do female Greater sage grouse (thereby increasing the threat of population extinction from individual nest failure). The tolerance of trees by Gunnison sage grouse may reduce the impact of juniper invasion on this species; however, it might also merely be a response to severe habitat loss, thus exposing the Gunnison females to even higher mortality and nest failure. The latter seems likely as the birds in Young's study were affected by "heavy grazing and drought" and production of young was low (J. R. Young 1994b, p. 45).

Hereinafter, this Status Review will use the term "sage grouse" to refer to both or either species, unless otherwise noted.

* * *

Description

Sage grouse are large, robust birds, characterized by considerable sexual dimorphism. In the Greater sage grouse, the body mass of females ranges from 1 to 2 kg, with lengths from 48 to 58 cm, while the body mass of males ranges from 2 to 3 kg, with lengths from 66 to 76 cm (Crunden 1963, Beck and Braun 1978).

* * *

Sexual Dimorphism

During the breeding season, considerable color dimorphism exists between the sexes in both species (Johnsgard 1983, Braun 1991a, Patterson 1952c). Males have blackish brown throats that are separated from a dark "V" shaped pattern on the neck by a narrow white band. Males have expansive white breast feathers that conceal two large, frontally directed gular sacks of olive green skin, which the male inflates and deflates during sexual display (Dunn, et al.

1987). Short white feathers with stiffened shafts are located on the margins of the gular sacks and grade into softer and longer white feathers, and finally into a number of long black filoplumes. These hair like structures are erect during sexual display. Females lack these display features, have buffy throats with black markings, and have blackish brown barring on their lower throats and breasts. Additional accounts of sexual dimorphism are given by Honess and Allred (1942), Clark, et al. (1942), Crunden (1963), and Beck and Braun (1978). General descriptions can be found in standard guides such as Udvardy (1977), National Geographic Society (1987) and Harrison (1978), and in Dunn, et al. (1987), Girard (1937), Jewett, et al. (1953), Johnsgard (1973), among others.

Description of Life History Stages

Eggs are elliptical, semi-glossy, and pale olive to olive-buff with numerous small, dark-brown spots (Harrison 1978). Eggs weigh 38 to 41 grams, are 53 to 60 mm in length, and 36 to 41 mm wide (Patterson 1952c, O. C. Nelson 1955, Rothenmaier 1979).

Chicks are precocial with a mottled combination of black, brown, buff, and white feathers (Johnsgard 1973). The head is whitish and spotted with black and brown, while the underparts vary from grayish white to buff and brown, with a buff and brown band on the chest (Johnsgard 1973, Harrison 1978). Chicks have a black bill (Harrison 1978), black spots on the cheek and nostrils (Short 1967), and black spots on the lores (Harrison 1978). The downy plumage has a "salt and pepper" dorsal pattern (Johnsgard 1983).

Juveniles are distinguished by overall size and morphology, and more specifically, by the presence or absence of juvenile primaries 1 and 2, the condition of primaries 1, 2, 9, and 10, and the difference in length between primaries 2 and 3, depending on the stage of molt (Tirhi 1995). Juveniles also bear a sac-like structure on the dorsal surface of the cloaca, the bursa fabricii (Patterson 1952c). Sage grouse acquire full juvenile plumage between 6 and 8 weeks of age, at which time they resemble adult hens (Patterson 1952c). Juveniles are streaked on their upper body, and have brown and white wing coverts with white tips (Petrides 1942). The middles of the tail feathers are white as are the fringes (Ridgeway and Friedmann 1946).

Juveniles molt their wing and tail feathers 2 to 3 weeks after attaining juvenile plumage, and molt continues throughout the summer. The two outer primaries are maintained until after the mating season of the second year, but all other feathers are molted the first year. Juveniles can be identified by their frayed outer primaries. Sage grouse attain adult plumage after the first molt and molt to partial mating plumage in their first fall, reaching complete mating plumage the following spring.

Distinctiveness

Sage grouse are the only species of Phasianid living in desert shrub (Johnsgard 1983, p. 6). Sage grouse are uniquely adapted to the sagebrush shrub-steppe. The relationship to sagebrush is obligate and sage grouse require sagebrush for food. Sage grouse possess unique physiological and biochemical adaptations for the digestion and detoxification of sagebrush (Wambolt, et al. 1987; Welch, et al. 1989). These detoxification mechanisms make sage grouse of considerable importance for biomedical and genetic engineering research, particularly since monoterpenoids have bacteriostatic and bactericidal properties, and have been studied for use as prophylactic agents (Welch, et al. 1989). Another interesting physiological aspect of sage grouse is that they may face limits on energy production or protein metabolism caused by the need to detoxify sagebrush – limits on digestive rates of wildlife species have been suggested as

important factors in metabolism (Karasov and Diamond 1985).

Sage grouse are extremely habitat specific, and one report states that "no other bird is so habitat specific to one particular plant type [sagebrush] in meeting annual life requirements" (Gunnison Basin Sage Grouse Conservation Plan, GBCP 1997, p. 38). The size of sagebrush habitat and lack of fragmentation of that habitat is crucial to the species because sage grouse … move seasonally to different areas within the sagebrush shrub-steppe (GBCP 1997, p. 38). Barriers to movement will cut the birds off from critical habitat. Sage grouse are unable to adjust to patterns of land use that eliminate or adversely affect large tracts of sagebrush (GBCP 1997, p. 39).

Sage grouse provide a great deal of aesthetic enjoyment to bird watchers, recreationists, and hunters, and were relied on as a food source by many Native American tribes, who incorporated various rituals relating to the bird into their culture, including dances (Patterson 1952c, p. vii). The birds' renowned lekking behavior has occasioned a great deal of interest by behaviorists and evolutionary theorists, and the spectacular aural and visual displays of mating males have provided endless wonderment and amusement to the general public. The large number of publications in the popular literature testifies to the level of public interest in the species – recent examples include Fergus (2000) and Anonymous (2000b). Indeed, the species has even served as the inspiration for a Dixieland Jazz composition (Watters 1987).

Locomotion

Sage grouse are weak flyers and often prefer to walk to reach usable habitats except when snow cover increases their conspicuousness (GBCP 1997, p. 48; San Miguel Basin Conservation Plan, SMBCP 1998, p. 22). Especially for hens with broods, walking is the preferred means of locomotion (BLM 1999f). As BLM puts it: “roads, agricultural conversion, oil and gas development and seedings that do not result in the appropriate habitat in the appropriate place, all become barriers to grouse movement” (BLM 1999f). Sage grouse flight is slow, low, and laborious. Sage grouse spring into the air with some difficulty, particularly for the heavier bodied males (Johnsgard 1983). Less than half a minute is typically spent airborne – after 5 to 8 wing beats, sage grouse glide for 23 to 32 m, and then repeat this cycle (Girard 1937). The average distance covered during a flight bout is 575 m for males and 221 m for females (Girard 1937). Sage grouse are incapable of lengthy sustained flight – birds have been found dead in large reservoirs because of their inability to fly over them (Braun 1998a). Birds usually fly at heights of 14 m (females) and 23 m (males) (Girard 1937) but fly close to the ground when crossing ridges. This physiological performance explains the propensity for walking, and emphasizes the threat of habitat fragmentation to the bird.

Food Requirements

The importance of sagebrush in the diet of adult sage grouse is impossible to overestimate. However, it is incorrect to conclude that sage grouse can survive solely on sagebrush: forbs (wildflowers), insects, and probably grasses are both necessary and important for various life-history stages and at various times of the year.

Sage grouse lack a muscular gizzard and cannot grind and digest seeds: they must consume soft-tissue foods (Wallestad 1975a). This distinguishes sage grouse from many other grouse and related taxa, and limits them to the consumption of relatively soft food. Sage grouse possess an enlarged caecum, which functions to extract additional nutrients from the food, and depend on microbial digestion of cellulose (Leopold 1953).

Energy demand is likely greatest during the breeding season, during the pre-breeding season for females (during the period of egg production), and during winter. Besides male display (considered elsewhere in this review), a major source of energetic demand is thermoregulatory stress during winter. Energy demands increase when effective temperatures are below the lower critical temperature (T_{lc}), which is about –0.6 ^{o}C for winter acclimated birds (Sherfy and Pekins 1994). Effective temperature is not the same as air temperature; rather, effective temperature is an index that seeks to integrate the thermal effects of air temperature, wind speed, and solar radiation. For example, a sage grouse exposed to air temperatures of 5 ^{o}C and moderate or high wind speeds might experience increased energetic demand even though the air temperature is above the T_{lc}. The construction of effective temperature indices are non-trivial, and laboratory, field, and modeling exercises and have not been conducted for sage grouse. Nonetheless, some physiological studies have been conducted on the effects of wind on sage grouse (Sherfy and Pekins 1995). These studies show that even relatively low wind speeds can substantially increase energetic demand at any air temperature below freezing. For example, even a relatively low wind speed of 2.7 m/s increases energetic demand by a factor of about 2.5 x the standard metabolic rate (SMR) of 0.6 ml O2 g^{-1} hr^{-1}. This means that food requirements will increase substantially if adequate shelter from the wind cannot be found. Under some conditions, birds may be in immediate danger of hypothermia (i.e. they will die because they are unable to produce enough metabolism to stay warm in the cold, even when they have adequate food). Degradation of winter habitat can thus have strong effects on sage grouse. Even outside of winter, sage grouse select areas that minimize wind from both vegetation (Connelly, et al. 1994a, 1994b) and topographic features (Hupp 1987a, Hupp and Braun 1989).

Nutrition affects the productivity of all grouse and ptarmigans, and can be particularly important during the breeding season (Moss, et al. 1975). Females with better nutrition put more nutrients into eggs (Jenkins, et al. 1963), have larger clutch sizes and improved chick survival (Jenkins, et al. 1963; Eastman and Jenkins 1970). Nutrient deficiency is known to reduce egg and chick production in birds generally by reducing eggshell thickness (Gutowska and Parkhurst 1942, Taylor, et al. 1962; Ellis and Labisky 1966). More general reviews of the effects of nutrition of hens on offspring are given by Robbins (1983), King (1972), and the various publications by the Romanoffs – Romanoff (1934, 1960, 1967, 1972) and Romanoff and Romanoff (1949).

Nutritive issues are of extreme import to sage grouse declines because widespread habitat degradation severely affects nutrition, and hence productivity, throughout the species range. Food scarcity can affect energy intake, crude protein levels or amino acid balance, and intake of minerals and vitamins. Sage grouse diet and food availability presents interesting issues in nutritional ecology because the mechanism of resource depletion, cattle grazing, and associated "range treatments," differentially affects preferred food plants of sage grouse. This can easily lead to specific nutritional deficits, as well as general energy balance problems. These problems were previously thought unlikely in wild animals (King and Murphy (1985) but appear ubiquitous in sage grouse. * * *

Among minerals, deficiencies of calcium are more likely than are those of selenium or manganese because of organismal needs coupled with mineral availability in different portions of the continent (Robbins 1983). Other minerals are likely of intermediate availability relative to their requirements in sage grouse. Vitamin A is known to affect reproduction and growth in quail (Robbins 1983, p. 69). Vitamin A deficiencies can also have important but difficult to detect sub-

lethal effects. For example, Vitamin A affects vision and hence predator detection and mortality rates. Vitamin A is not found in plants (Robbins 1983, p. 73), thus the spraying of pesticides in sage grouse habitat or grazing that sufficiently depletes food supplies or vegetation structure needed for insect populations will also impact sage grouse. Vitamin C is known to be required in excess of organismal synthetic capacity in at least some game birds, especially during growth or when subjected to pesticides or other stress (Robbins 1983, p. 93). Vitamin C is also not as widespread in foodstuffs as other water-soluble vitamins.

Historically, clutch sizes as large as 26 eggs have been reported, but today clutch sizes average only 7 to 9 eggs (Schroeder 2000f). Although anecdotal, the historical reports are suggestive when contrasted with present day data. Also, annual variation in clutch size supports the hypothesis of nutrient limitation (Schroeder 2000f). Nutrient deficiencies are often reflected in reduced clutch size, reduced provisioning of each egg, and consequent poor survival and growth of young chicks. These are precisely the end effects suggested by Crawford and Gregg (2001) as one bottleneck affecting sage grouse in Oregon. The nutritional status of pre-laying hens is related to forb abundance and nutritive value, and decreases in average brood size tracks decreases in forb abundance (Barnett and Crawford 1994). Blood analyses show that female sage grouse in Oregon experience protein deficits during the pre-breeding season (Wagner, personal communication). This is likely due to inability to find adequate forbs and insects during this period. Effects on chicks are likely even more important. Chick survival appears to be related primarily to productivity of forbs and insects (Drut, et al. 1994b). It is likely that one major effect of habitat degradation by livestock grazing is that sage grouse are literally being starved across their range.

Sagebrush

Numerous studies have documented the year-round use of sagebrush by sage grouse (Beck 1975a, 1975b; Call 1979; Call and Maser 1985; Klebenow 1972; Patterson 1952c; Schneegas 1967; Sime 1991; Wallestad 1975a; Wallestad, et al. 1975). A Montana study, based on 299 crop samples, showed that 62 percent of total food volume over the year was sagebrush. Between December and February sagebrush was the only food item found in all crops. Only between June and September did sagebrush constitute less than 60 percent of the sage grouse diet (Wallestad 1975a). Sage grouse are incapable of digesting most seeds or other hard foods as they lack a muscular gizzard (Johnsgard 1983).

Sage grouse differentially choose certain sagebrush species, and this preference apparently relates to protein levels and monoterpene concentrations in different species (Remington and Braun 1985, Myers 1992). Sage grouse generally prefer big sagebrush to other species (Eberhardt and Hoffmann 1991, Tirhi 1995). However, sage grouse in Antelope Valley, California, browsed black sagebrush more frequently than the more common big sagebrush (Schneegas 1967). Among the big sagebrush sub-species, basin big sagebrush is less nutritious and higher in terpenes than either mountain or Wyoming big sagebrush. Sage grouse prefer the other two sub-species to basin big sagebrush (Autenrieth, et al. 1982). Welch, et al. (1991) found that sage grouse preferred mountain big sagebrush, Wyoming big sagebrush, and basin big sagebrush, in order from most preferred to least preferred. Remington and Braun (1985) found that Wyoming big sagebrush was preferred over mountain big sagebrush; however, their sagebrush samples were from different areas. Sage grouse will also eat other sagebrush species to a lesser extent than big sagebrush, including Alkali sagebrush (*A. longiloba*), black sagebrush (*A. nova*), low sagebrush (*A. arbuscula*), and half shrub fringed sagebrush (*A. frigida*) (Barnett and Crawford 1994; Patterson 1952c; Remington and Braun 1985; Rogers 1964;Wallestad, et al.

1975).

During winter, sage grouse have been observed selecting plants with high protein levels (Remington and Braun 1985). Vegetation high in nitrogen is preferred by sage grouse (O. Myers 1992). Sage grouse require high quality foods in winter (Welch, et al. 1988).

Forbs

Apart from sagebrush, the adult sage grouse diet consists largely of herbaceous leaves, which are consumed primarily in late spring and summer. Sage grouse are highly selective consumers, choosing only a few plant genera. Dandelion (*Taraxacum* spp.), legumes (Fabaceae), yarrow (*Achillea* spp.) and wild lettuce (*Lactuca* spp.) account for most of their forb intake (Autenrieth, et al. 1982; Sime 1991). Tirhi (1995) lists salsify (*Tragopogon* spp.), and the legumes clover (*Trifolium* spp.) and milkvetch (*Astragalus* spp.) as important forbs in sage grouse diets. Martin (1970a) found that from July to September, dandelion comprised 45 percent of sage grouse intake; sagebrush comprised 34 percent. Collectively, dandelion, sagebrush, and two legume genera (*Trifolium* and *Astragalus*) contributed more than 90 percent of the sage grouse diet.

Forbs are critical for egg productivity and nutritional status of hens during the pre-laying period and are taken selectively over sagebrush (Barnett 1992, Barnett and Crawford 1994). Gates (1983, p. 63) found that hens used forbs most both before and after incubation. Lack of forb availability during the pre-laying period reduces nest initiation rates and nutrient content of eggs (Crawford 2000c). Sagebrush is a negligible constituent (1%) of the diet for young sage grouse up to 11 weeks of age (Peterson 1970b, Pyrah 1971). Instead, forbs constitute more than 50% of juvenile diets up to 11 weeks of age (Klebenow and Gray 1968, Peterson 1970b). Lack of forbs and insects reduces the nutritional condition of chicks that do hatch and reduces recruitment of juveniles into the fall population (Crawford 2000c). This occurs even when sagebrush is still available (Crawford 2000c). Forbs density has been "greatly diminished by a long-term history of livestock grazing and invasive competitors" (Altman and Holmes 2000, p. 25).

Older chicks switch to forbs, with sagebrush gradually assuming primary importance. In a Utah study, forbs composed 54 to 60 percent of the summer diet of juvenile sage grouse, while the diet of adult birds was 39 to 47 percent forbs (Trueblood 1954). Martin (1976) found that the diet of juveniles was 76% plant material, 24% animal. Common dandelion and common salsify were the two most important plant items in the diet, occurring in 55 and 63 percent, respectively, of the 127 crops analyzed.

Insects

Overall, insects are a minor diet item for adult sage grouse but are nonetheless necessary and extremely important dietary components depending upon seasonality and life history stage. Martin, Zim, and Nelson (1951) reported that insects comprised 2 percent of the adult sage grouse diet in spring and fall and 9 percent in summer. Sagebrush made up 71 percent of the year-round diet. Females are known to consume cicadas (Sime 1991, p. 27). It is likely that gravid females have increased nutrient demands (Robbins 1983), and may require increased amounts of micro-nutrients, protein, and lipids. Also, high density foods such as insects have a disproportionate amount of nutrients relative to their proportion of dietary composition. Some insects are obligates on certain kinds of sagebrush and some specialize on certain leaf types (Winward 1991a). The degree to which sage grouse may specialize on various insect species or morphs is unknown.

Insects are a necessary food item for sage grouse chicks. In their first week of life, sage

grouse chicks consume primarily insects, especially ants and beetles (Patterson 1952c). Insects can constitute up to 75% of the diet of juvenile sage grouse (Patterson 1952c).

Even as adults, sage grouse do not eat an entirely plant based diet. Patterson (1952c) found that sagebrush constituted 77% of the diet, and plant materials overall constituted 95.7% of the diet. Though small, the remainder may nonetheless be important for micronutrients or particular amino acid constituents. Martin, et al. (1951) reported that sagebrush composed 71% of the adult diet, and that animal material ranged from 9% in summer, to 2% in spring and fall. Only between June and September does sagebrush constitute less than 60% of the diet (Wallestad 1975a). Animal material in the adult diet could be crucial for proper nutrition because it may serve as a vital source of particular amino acids or micro-nutrients. Rodriguez (1988) suggested that sage grouse select sagebrush on the basis of micronutrient content.

Water Requirements

Sage grouse apparently do not require open water for day to day survival if succulent vegetation is available. They will use free water if it is located in meadow vegetation (Savage 1968). Hens with broods avoid water surrounded by bare ground, such as areas trampled by livestock (Klebenow 1982). In some areas, sage grouse distribution may be seasonally limited by moisture gradients as expressed in riparian vegetation. In summer, sage grouse in true desert regions occur only near streams, springs, and water holes (Howard 1996). However, this may be due to dependence on succulent vegetation rather than on any need for free water. Physiological studies of water conserving ability and osmoregulatory function have apparently not been conducted.

In winter in Eden Valley, Wyoming, sage grouse have been observed visiting partially frozen streams to drink from holes in the ice (Call 1979). Sage grouse have been observed frequenting wet meadows and riparian areas in some studies (*Oakleaf 1971*, Pederson 1982; Willis, et al. 1993) but not in others (Cadwell, et al. 1994). Water has been considered a key component of summer and fall habitat by some (Carr 1967a, 1967b; Savage 1969a; Call and Maser 1985) but this may be merely an epiphenomenon of more succulent vegetation occurring near water, as others have not found that sage grouse prefer sites close to open water (Wallestad 1975a; Autenrieth 1981; Cadwell, et al. 1994). Without samples of vegetation water content, this issue is unlikely to be resolved – moreover, spatial analysis of habitat degradation and conversion is a substantially higher research priority. It is important to exclude cattle from wet meadow areas (Jones and Braun 1994).

Because there were far more sage grouse before the period of Euro-American settlement of the West than are extant currently, there is no reason to suppose that water developments associated with livestock operations provide any net benefit to sage grouse (Schroeder, et al. 1999a, p. 16). Indeed, water "catchments or guzzlers have not been shown to benefit sage grouse populations" (Braun 1998c, p. 4). Instead, such water developments lower water tables and channel water away from succulent vegetation areas such as wet meadows that sage grouse do require. Another negative impact is that such developments may serve to concentrate sage grouse, increasing the likelihood of disease transmission (Schroeder, et al. 1999a, p. 17). Sage grouse do not require free water and do not benefit from guzzlers, water tanks, stock ponds, or other water sources independent of riparian vegetation (Braun 2001e).

Demographics and Life History Events

Sage grouse are long lived birds (BLM 1999c) and may live up to 10 years in the wild

(Dalke, et al. 1963; Wallestad 1975a; Tirhi 1995, citing Braun, personal communication), but a more common lifespan is probably 2 to 3 years (Wallestad 1975a). However, 4 and 5 year old birds are not unusual (BLM 1999c). Elman (1974) found average life spans of only 1 to 1.5 years, while Drut (1993) indicated that a typical lifespan was 2 to 4 years. Returns of marked birds returning to the strutting grounds one year later ranged from 5% to 21% over a 3 year study (Dalke, et al. 1963). Annual mortality rates have been reported as 50% to 60% in two studies (Braun 1975, Tirhi 1995, citing Connelly, personal communication). However, Schroeder (1994a, 1994b) reported annual mortality rates of 29%. The Service reported annual mortality rates of 50% to 55% (FWS 2001d, 66 Fed. Reg. 22984, 22985).

Sex ratios, determined mainly from hunting data, typically range from 1:1 (Girard 1937) to 1.5 (Rogers 1964) for all sage grouse age classes. For juveniles, sex ratios were reported as 1:1.1 in Colorado (Braun 1984) and 1:1.2 and 1:2.3 in Wyoming (Patterson 1952c). Braun also reported sex ratios of 1:1.6 for yearlings and 1:2.6 for adults. Most of these reported sex ratios do not support the 1:2 male to female ratio assumed in the various conservation agreements for the Gunnison sage grouse (see below). In Colorado and Wyoming, populations were composed of 51% and 58% juvenile birds, respectively (Patterson 1952c, Rogers 1964). Sex ratios in both states were about 40% males.

Different stressors act at different seasons on different age classes and sexes. Breeding and nesting periods are energetically demanding: sage grouse experience a negative energy balance at these times and lose weight (Beck and Braun 1978).

Poor nesting success and mortality of young chicks are the most common factors acting to reduce population size and prevent population increase (Braun 1999a, p. 1). In some years, over-winter mortality is most limiting (Braun 1999a, p. 1).

Lekking

Leks are traditionally used sexual display grounds where males concentrate and cluster spatially (Beehler and Foster 1988) allowing females to observe large numbers of male displays, and exercise mate choice. The term was apparently first used by Selous (1906-1907). Leks are usually located in areas where females travel between wintering and nesting areas (Gibson 1996b). Males on leks utter unusual vocalizations (Welch, et al. 1995) and engage in visual displays that are "one of the most complex stereotyped motor patterns found among birds" (Wiley 1973b). The vocalizations apparently serve to attract females (Gibson 1989), as do the visual displays. Male mating success is correlated with display rate (Gibson, et al. 1991). Leks can range in area from 0.04 to 40 hectares and from several males to about 50 males; however, leks contained much larger numbers of males historically – accounts suggest 400 or more males at single leks (Scott 1942; Call 1979; Call and Maser 1985; Trimble 1989, p. 104). There appears to be a minimum viable number of males for a lek – there are numerous reports of leks being abandoned and apparently coalescing into a smaller number of larger leks (see, e.g. the Washington Population Assessment section). This is consistent with contemporary theories of female choice and supra-stimuli displays for mating (see the numerous papers by Gibson and by Wiley in the Bibliography), but also points up the danger of assuming that lek use will continue as population level decline. Males seek lekking areas with high quality habitat, and with large numbers of males and females present (Bradbury, et al. 1989a). Thus, as the number of individuals at a lek becomes smaller, it will eventually be abandoned at some threshold size. Such factors will contribute to Allee effects in sage grouse.

Males gather on the lek in late February to April, as soon as the lek area is relatively free

of snow. Yearling males arrive somewhat later (Eng 1963, Rothenmaier 1979). Sage grouse are highly conservative in moving to new leks, and in retaining use of traditional leks. Only a few dominant males, often only two, breed. Females typically gather on the lek beginning in mid-March, although this varies with weather conditions. Sage grouse mating behaviors, which are complex, are summarized by Johnsgard (1973). Older males establish lek territories earlier than younger males and exclude the latter; males with territories near the center of a lek have higher mating success (Davis 1978). Thus, younger males have significantly reduced mating success. Males employ vocalizations and visual displays that attract females and either repel or antagonize other males (Hjorth 1970, Hartzler and Jenni 1988). All adult males repel subadult males from leks (Thorvilson 1969).

Auditory elements of the display are generated by the rapid inflation and especially deflation of the ventral air sacs, and possibly by wing movements. Dr. Clait Braun noted that the auditory display of the Greater sage grouse sounds like the a "poik, poik." This vocalization is apparently the result of 2 pops of the air sac in the Greater species (J. R. Young, et al. 1994). Males employ 16 or more elements in the strutting sequence (Welch, et al. 1995). Displays typically occur at dawn and dusk (Dalke, et al. 1963; Johnsgard 1973; Wallestad and Schladweiler 1974); however, on cloudy days, displays continue through the middle of the day. Thus, exclusion of humans from lek areas only at dawn and dusk will not offer adequate protection of the lek area.

Males deplete lipid reserves during courtship, indicating that lekking activities are energetically demanding for them (Hupp and Braun 1989a). The holding of center territories entails even more energetic demand (Beck and Braun 1978). The cost of display in males is often 13.9 to 17.4 times BMR, basal metabolic rate (Vehrencamp, et al. 1989). Male display is thus an extremely demanding activity, far exceeding the instantaneous power demands of thermoregulation, and nearing or exceeding the 8x to 15x BMR of flight (Rayner 1982, Webb 1990). Moreover, lipid reserves are influenced by winter snowfall and air temperature (Hupp and Braun 1989a), showing that exposure caused by inadequate winter habitat cover or winter food could affect breeding activities, and hence fitness and population persistence, even if the effect was too small to affect individual survival.

Of particular importance for the analysis of population viability is that a very small proportion of males obtain nearly all matings – typically, only 1 or 2 males per lek (Scott 1942; Patterson 1952c; Lumsden 1968; Hjorth 1970; Johnsgard 1973; J. R. Young 1994b, p. 33). Thus, effective population sizes (N_e) are significantly smaller than actual population sizes, and consequently, the effects of genetic stochasticity and demographic stochasticity are highly magnified in these birds. Older, established males are known to repel subadults from leks (Thorvilson 1969, p. 2). Copulations outside of the very small "territories" (0.01 hectare) defended by males are often interrupted by other males, usually before sperm transfer is effected (Gibson and Bradbury 1986, p. 385). Thus, counting of copulations per se may overpredict mating success. Even if copulations are obtained by younger males (which often lack central lek "territories") they are likely to be ineffective.

Another effect on extinction dynamics is caused by the lekking habit. Hoglund (1996) suggested that lekking affects both distribution and local extinction risk.

Pre-Laying Period

During the period before a hen lays her clutch (and possibly including much of the lekking period), protein balance is critical for successful reproduction by hens. Hens require a

diet with at least 18% crude protein (J. Craig, personal communication). However, sagebrush provides only 14-16% crude protein, so a diet rich in forbs is crucial (Barnett and Crawford 1994; J. Craig, personal communication). Forbs are also higher in calcium and phosphorus than is sagebrush (Barnett and Crawford 1994). Forbs contribute 20% to 50% of the diet for pre-laying hens, and lack of forbs in the diet will cause reductions in the number of eggs and fledglings (Barnett and Crawford 1994). Poor nutritional status in female sage grouse is known to reduce reproductive success (Barnett and Crawford 1994). It is also well established in related species that chick survival is related to the physiological condition of the female before laying (Moss, et al. 1975; Riley, et al. 1998; Eastman and Jenkins 1970; Hudson, et al. 1994).

Egg formation and nesting are known to be energetically demanding periods for female sage grouse (Beck and Braun 1978). The same is true for many, and perhaps most, other species of birds (King 1972, 1974; Robbins 1983). Thus, females likely accumulate fat stores during winter and the lekking season to last throughout the breeding season. If they are unable to do so, or if they must squander these energetic resources in long distance movements, breeding will fail. Likewise, if habitat near the lek is not suitable for nesting, then females must move long distances. This effect has been noted in studies by Autenrieth (1981) and Crawford, et al. (2000). Such long distance movements deplete energy and nutritive reserves and expose females to predation.

Nesting

Nest success is usually cited as the main factor affecting population dynamics of sage grouse (summarized in Schroeder, et al. 1999a, p. 15). Nest success is strongly influenced by habitat characteristics, such as tall and thick grass and forb cover in sagebrush shrub. There are "substantial" data "correlating rates of nest success" with these habitat characteristics (Schroeder 2001a, 2000f, summarizing numerous studies). Grazing and fire strongly influence these vegetative characteristics. Survival of juveniles and adult over-winter survival are also frequently cited as perilous life history stages for sage grouse. However, little has been done to manage habitat for any of these life history stages. Consequently, populations have plummeted throughout the West.

After mating, the hen leaves the lek for the nesting grounds. The hen builds a nest, which is concealed under sagebrush and in grass and forb cover (Jarvis 1974). Shrubs as well as forb and grass cover are essential components of quality nesting habitat (Sveum 1995). The nest is a shallow depression slightly lined with grass, twigs, or sage leaves (Girard 1937, Rasmussen and Griner 1938, O. C. Nelson 1955, Autenrieth 1981). Standard guides provide comparative information, as well as color photographs and drawings of nests, eggs, and chicks (Ehrlich, et al. 1988; Harrison 1978; Harrison 1979).

Laying occurs 7 to 10 days after mating (Petersen 1980b, Autenrieth 1981). Yearling females lay later than do adults (Petersen 1980b). Hens typically lay 1 egg per 1 to 2 days (Petersen 1980b, Johnsgard 1983). Hornaday listed the clutch size as 13 to 17 (Hornaday 1916, p. 193; Willett 1906; Patterson 1952c). Modern accounts give clutch sizes averaging 7 to 8 eggs, ranging from 6 to 13 eggs (O. C. Nelson 1955; Autenrieth 1981; Johnsgard 1973, 1983; Schroeder 2000f). This suggests that sage grouse may now be experiencing reduced clutch sizes, probably due to poor nutrition of females caused by habitat degradation. Schroeder, et al. (1999a) suggested that these historically larger clutches might have been the result of egg dumping; however, brood parasitism has never been noted in sage grouse, and the lower clutch sizes now commonly seen may be a result of the widespread habitat degradation found

throughout the range.

Incubation time is 25 to 27 days (Harrison 1978). An incubation time of 27 to 28 days is listed for the Gunnison sage grouse (GBCP 1997, p. 3). Eggs are olive, yellowish, or greenish, and finely dotted with brown tones. They are oblong and about 2.2" (55 mm) in diameter (Ehrlich, et al. 1988; Harrison 1978; Harrison 1979).

Males do not participate in nesting, incubation, or brooding (Wallestad 1975a, Autenrieth 1981). Consequently, the female must leave the nest unattended to forage. O. C. Nelson (1955) and Girard (1937) reported that excursions off the nest last about 15 to 25 minutes, about twice a day during incubation. Girard (1937) reported that excursions from the nest were bimodal, occurring from about 9:30 to 11:30 am, and from 2:00 to 3:00 pm. Such excursions are consistent with biophysical analyses indicating that shading of the eggs from radiative exposure during the middle of the day is necessary (Webb 1993a, 1993b). The timing of nest absences to late morning and early afternoon is consistent with temporal periods of hypothermic environments early and late in the day, as found by Webb and King (1983a) for other species.

Reduced forb and grass cover near the nest negatively impacts the nest microclimate (Autenrieth 1981, Call and Maser 1985, Webb 1993b). The amount of grass cover over 18 cm. in height near the nest differentiates successful from unsuccessful nests (Gregg 1992; Gregg, et al. 1994). Call (1979) developed management recommendations for sage grouse habitat, and a series of recommendations and guidelines have been issued by the Western States Sage Grouse Technical Committee (WSSGTC 1999). As discussed elsewhere in this review, however, the WSSGTC guidelines are incomplete.

Nest productivity is very low in sage grouse. A substantial proportion of birds do not attempt to nest, and of the ones that do, hatch rates are low. Consequently, "it takes sage grouse longer to rebound from low population levels than any other game bird" in Idaho (Eustace 1995 quoting J. Connelly, personal communication).

Sage grouse have high rates of nest desertion and nest predation (Gregg, et al. 1994; Johnsgard 1973). Summarizing data from several sage grouse studies, Gill (1966b) found a range of nesting success from 23.7 to 60.3 percent, with known predation accounting for 26% to 76% of lost nests, and averaging 47.4% across the 503 nests in the summary. Bergerud (1988c) also reviewed this literature and found nesting success to average 35% in 699 nests over 12 studies, with the predation rate averaging 50%. This is the lowest nesting success in any grouse reviewed by Bergerud and the highest predation rates (Bergerud 1988b, p. 593, Table 15.2 and p. 601, Fig. 15.10). In Idaho, supposedly a stronghold of sage grouse, nesting success is even lower (44%) (Apa 1998). Bergerud (1988b) also found sage grouse to have the greatest reduction in nesting success of yearlings relative to adults of any grouse reviewed. Sage grouse are not determined nesters (GBCP 1997, p. 3). Sage grouse are known to readily abandon nesting attempts when disturbed. Disturbances need not be in close proximity to the nest. For example, one radio-marked hen abandoned her nest when a fencing crew was working on a fence 300 yards away, even though the nest was within two or three days of hatching (Eustace 1995, p. 26 citing J. Connelly, personal communication).

The primary cause of nest loss is predation (DeLong, et al. 1995). Sage grouse nests experience significantly higher predation when more densely spaced (Niemuth 1992, Niemuth and Boyce 1995). Thus, habitat fragmentation, degradation, or conversion, which concentrates nesting females into smaller areas, will cause higher mortality at this critical time in the life history.

Renesting is low in sage grouse (Connelly, et al. 1993, p. 1042; Hanf, et al. 1994) and

may be further inhibited by moisture and vegetation conditions (GBCP 1997, p. 3). Renesting may be limited by male reproductive condition (Eng 1963). Of the hens losing their nests, only 15% will renest (BLM 1999c). Subsequent nests, if attempted at all, have few eggs and reduced success (Hulet 1983). Clutch sizes of second nestings are reported to be only 4 to 7 eggs (GBCP 1997, p. 3). These findings point out the importance of preventing disturbance to nesting sage grouse. Bergerud (1988b) also reviewed two studies on renesting rates in sage grouse, finding it to average 42%. Other studies have found renesting rates to be about 10% (Patterson 1952c, Autenrieth 1981). Finally, Bergerud (1988b, p. 606, Fig. 15.13) found that higher densities of males were related to lower juveniles per adult in sage grouse. This effect has conservation implications: as birds are crowded into smaller and smaller habitat fragments, population productivity can be expected to decline.

Brooding

Females typically produce only a single brood per year. Development is precocial, and the chicks are mobile and down covered (Patterson 1952c). The female tends the young and shows them food and foraging sites. Hens cover chicks to protect them from severe weather and use frequent vocalizations for contact enhancement (Girard 1937, Patterson 1952c).

Chicks fly by 2 weeks of age, although their movements are limited until they are 2 to 3 weeks old (Wallestad 1975a). They can sustain flight by 5 to 6 weeks of age. Juveniles are relatively independent by the time they have completed their first molt at 10 to 12 weeks of age (Girard 1937, Patterson 1952c, Johnsgard 1983). The hen and her chicks mix with other sage grouse on the summer ranges (Patterson 1952c).

Juvenile mortality is high in sage grouse, and most juvenile mortality takes place in the first 2 weeks after hatching, before the chicks are able to fly (Patterson 1952c, Autenrieth 1981). Some studies have found that most chick mortality takes place in the first 4 weeks of life (Coggins 1998). During the pre-flight period, chicks respond to predators by freezing – their cryptic coloration provides good pattern matching, so long as adequate vegetation is available for cover (Patterson 1952c). The major predators on chicks are corvids, raptors, and various mammals (Autenrieth 1981, Presnall and Wood 1953). Ready availability of food and cover is crucial to juvenile survival (Klebenow 1972, 1985). Hickey (1955) reported early brood mortality ranging from 32% to 54% in three studies. Ricklefs (1969) has analyzed the significance of high egg and juvenile mortality in a population and evolutionary context. Bergerud (1988b, p. 618, Table 15.6) reviewed mortality rates for various grouse species and found that nest mortality rates for sage grouse were 59%, and chick mortality rates were 29%, with mortality rates of adult females being 37%. Other reports of chick mortality rates range from 40% to over 60% (Wallestad 1975a, Braun 1975). Mortality of chicks caused by wet weather during the brood-rearing period is not sufficient to account for population size during the following year (Jenkins, et al. 1967; Bergerud 1970; Bendell 1972a, 1972b; Myrberget 1972; Watson and Moss 1979 in Rich 1985a).

During the first week of life, chicks may be obligate insectivores (Klebenow and Gray 1968, Johnson and Boyce 1990, 1991), and depend on ants, weevils, and beetles, later adding grasshoppers to the diet (Patterson 1952c). Drut, et al. (1994b) identified three families of insects as major sources of food for young chicks: Scarabaeidae, Tenebrionidae, and Formicidae. Where insects and forbs are depleted, sage grouse survivorship will decline: in an area with higher grouse productivity, forbs and invertebrates composed 80% of dietary mass; however, in an area with lower productivity, chicks consumed primarily (65%) sagebrush (Drut, et al. 1994b).

As the chick grows, the proportion of insects in the diet steadily drops, being about 75% in the first few weeks, to about 10% in the later part of the juvenile period. Forbs constitute a high proportion of the diet for juveniles (Klebenow and Gray 1968). Trueblood (1954) reported that juveniles strongly preferred forbs and showed an aversion to grasses. Although sage grouse are found in alfalfa fields, they apparently seek out dandelion and salsify which are readily available in alfalfa fields (Peterson 1970b). Late in summer, as forbs become less available, juveniles shift to sagebrush and fringed sagewort (*Artemisia frigida*). The latter, a relative of sagebrush, may constitute a transitional food for juveniles (Peterson 1970b). The observation of sage grouse in alfalfa and other agricultural fields results from several factors: they are easier to see in alfalfa than in sagebrush areas, the richest natural foraging habitats have been converted into alfalfa fields leaving the birds nowhere else to go, and alfalfa is fairly nutritious and will be eaten so long as the birds are not too far from sagebrush cover for predator escape. That habitat conversion to alfalfa fields is not good for sage grouse follows from the obvious result that as large areas have been converted to alfalfa, sage grouse numbers have declined, not increased.

Martin (1970a) found that sage grouse diets during summer were composed of 34% sagebrush, and 45% dandelion (*Taraxacum* spp.). Together with forbs from two other genera (*Trifolium* and *Astralagalus*) these constituents totaled 90% of the diet. Other studies have also found forbs to be important dietary components (Leach and Hensley 1954, Leach and Browning 1958). Other highly used forbs during spring and summer include clover (*Trifolium* spp.), salsify (*Tragopogon* spp.), milkvetch (*Astragalus* spp.), and prickly lettuce (*Lactuca* spp.) (Peterson 1970b, Pyrah 1971, Johnsgard 1983).

Summer & Autumn

In late summer, Girard (1937) reported that sage grouse roost until about 6:00 am, forage until about 10:00 am, rest during the middle of the day, forage again from about 3:00 pm to 8:00 pm, and roost at about 9:00 pm.

Males and hens without broods, which typically form small gender-based flocks in the spring, move to summer ranges in the following order: males, broodless hens, and last, hens with broods (Schoenberg 1982; Connelly, et al. 1988). Young males typically flock with females that are segregated from male flocks (Patterson 1952c, Dalke, et al. 1960; Dunn and Braun 1986a). Movements to wintering areas are initiated by decreases in temperature and reductions in forb availability (Patterson 1952c; Dalke, et al. 1963). Female habitat selection and movement patterns are directly linked to forb cover (Gregg, et al. 1993) which in turn is determined by livestock grazing, recovery from strip mining, and other threats. Generally, populations will decline if the number of chicks produced by each hen is less than about 2.3 in the autumn (Nevada State Office, BLM 2000a, p. 3, citing Connelly and Braun 1997, Edelmann, et al. 1998; Compton and Connelly, unpubl. data).

Over-wintering

Sage grouse form unisexual winter flocks (with immature males associating with females). In the past, these flocks sometimes ranged upwards of 1,000 birds during severe weather, while in more moderate weather flocks typically ranged from 50 to 300 birds (Dalke, et al. 1963). In winter, birds do not migrate long distances, and survival over winter depends on adequate cover and food. Grouse have little metabolic resistance to winter fasting and must feed regularly to maintain energy balance (Thomas 1987). Sagebrush is consumed almost exclusively during winter, and also provides cover for the birds from the very high wind speeds common in

their winter range. Of particular concern is that the birds must not only survive the winter but also need to emerge from the winter season with sufficient lipid stores for male mating displays (Hupp and Braun 1989a; King 1972) and perhaps for female egg production (King 1972, Robbins 1983). Older birds carry larger lipid stores than do yearlings (Remington and Braun 1988), reinforcing the conclusion that yearlings are less likely to mate and breed successfully. Bergerud (1988a) suggested that the reason that not all sage grouse females ovulate and nest was because of yearling females in the population. This is consistent with physiological limits from overwintering stress, but could also result from inexperience, or delayed maturation.

Sage grouse show some site fidelity to wintering areas. Berry and Eng (1985) observed hens in Montana moving to known wintering areas before the onset of heavy snowfall, suggesting fidelity to specific wintering areas. Thus, sage grouse will be particularly susceptible to destruction or degradation of traditional wintering areas. Winters also fluctuate in severity. For example, Dr. Braun has stated that a severe winter will occur at 7 to 10 year intervals in North Park, Colo. (Summary of North Park Working Group Meeting 1999, p. 5). Even with operation of the proposed conservation plans, such winters would "certainly [cause] decreases in population" (id., p. 6). Even if birds are not directly killed during a winter, severe winters are known to alter lek behavior (Gibson and Bradbury 1987).

Seasonal Movements

Sage grouse often move from summering to wintering areas seasonally, although the movement distances vary dramatically depending upon the distances between areas of adequate quality habitat, weather, and other factors (Connelly, et al. 1988), perhaps including knowledge of habitat areas by experienced individuals in the population. Intermittent stream drainages are often used as migration routes (Hupp 1987a; Lyon 2000, p. 5). Some groups of sage grouse move substantial distances among nesting, lekking, brooding, and wintering areas, while others are nearly sedentary, perhaps because of loss of habitat corridors. Additionally, some lowland wintering areas may not be used at all until years of severe weather (Stiver, personal communication, 2000), increasing the likelihood of sharp population decreases in years with severe winters, even when populations may appear healthy.

Sage grouse occupying low elevation areas often do not migrate (Wallestad 1975a). Of the populations that do migrate, movements are typically on the order of a few dozen kilometers or less. Longer movements have been reported, but there is no doubt a bias to report such extreme events, as neither journals nor individual scientists consider typical movements of much note. Patterson (1952c) summarized the early literature on seasonal movements. Seasonal movements are often somewhat greater than 16 km (Berry and Eng 1985). Within the wintering range, Colorado sage grouse moved an average of 1.5 km per day, then dispersed an average of 27 km to the spring leks (Schoenberg 1982, p. 24). Longer distance movements, ranging from 80 to 160 km have also been reported anecdotally (Pyrah 1954, Connelly and Markhamer 1983, Berry and Eng 1985). Much shorter distance movements are more common (Bradbury, et al. 1989a).

Fall movements to wintering areas are driven by weather conditions and usually occur gradually. After late winter or spring lekking activity, sage grouse may move to higher elevations or down to irrigated valleys for nesting and feeding. Most broods moved only a few km from nesting areas to summer ranges, but a few moved up to 13.4 km (Gates 1983). In contrast, movements from summering areas to wintering areas may be 50 km in Colorado, Wyoming, Idaho and Montana (Dalke, et al. 1960; Martin 1976; Beck 1977; Connelly, et al. 1988). Sage

grouse may move only short distances, not at all, or distances in excess of 75 km between wintering, breeding, and summer ranges (Dalke, et al. 1963; Braun, et al. 1977; Connelly, et al. 1988; Fischer, et al. 1993a). These long distance movements may well be a response to habitat fragmentation in modern times.

A closer examination of these disparate movement distances is required. Schlatterer (1960) reported that in southern Idaho, brooding grounds were 13 to 27 miles (21-43 km) from the nesting grounds (see also Hulet, et al. 1986). In the Gates (1983) study, most males remained within 1.5 km of leks and only a few ventured as far away as 9 km, even though seasonal movements by flocks ranged up to 13.4 km. Movements by males probably have greater import for gene flow and sub-population cohesion because seasonal movements may merely represent flocks moving to different use areas and then back to familiar lek sites for breeding rather than interchange among different lek complexes.

Anecdotal evidence suggests that males may be capable of moving long distances over the seasons. During winter in Wyoming, Patterson (1952c) recovered a male sage grouse 75 air miles (120 km) from where he had banded it the previous summer. However, it is not known if the captured male moved purposefully, or was merely blown off course by the very strong winds common in Wyoming winters. Yearling males are much more likely to move long distances than are adult males, and some of the movements reported in the literature are the result of destruction of sagebrush by chemical sprays (Wallestad and Schladweiler 1974, Wallestad 1975b, Martin 1976). The Gunnison Basin Sage Grouse Conservation Plan reported movements by both sexes exceeding 20 miles to locate foraging and roosting areas (GBCP 1997, p. 5). No data support such long distance movements by adults outside of the winter season. Moreover, the movements that did occur by Gunnison sage grouse and by grouse in Washington are likely extreme responses to the very low availability of habitat in those areas. Radio telemetry data indicate that males typically stay within 1.5 km of leks, although a few males were located up to 9 km away (Gates 1983). Movements from wintering areas to leks in the Gunnison Basin generally followed river valleys, and did not exceed 35 km even after a severe winter (Hupp 1987b, p. 62). After the breeding season, males in the Gunnison Basin remained within a few km of leks, and females remained within a few km of their nest sites throughout the summer (Hupp 1987b, p. 67).

Although limited, the best available scientific data indicate that birds typically move relatively short distances unless forced to move greater distances due to habitat limitations. Typical movements are only a few km, substantially shorter than the few anecdotal reports of long distance movements, and the latter may have been made by young birds. In some isolated areas, birds may habitually engage in longer distance movements. It is likely that mortality risk increases substantially as movement distances increase. Crawford reports that birds in Oregon may move up to 100 km but suggested this may occur because of vast expanses of severely degraded habitat (John Crawford, personal communication, March 14, 2000). Long distance movements may well be a response to extremely low food productivity in recent decades. For example, net primary productivity of grasses and forbs in some stands has fallen from 800 pounds/acre to only 100 pounds/acre (Winward 1991a). Moreover, once birds undertake a long distance movement from one seasonal area to another, smaller scale vegetation factors may determine within patch movements, which are often made by walking (John Crawford, personal communication, March 14, 2000).

It is important to distinguish seasonal movements by flocks of birds from movements between demes by individuals, and to distinguish both those movement patterns from movements between feeding, breeding, and roosting areas within the home range (Wallestad

1971). In analyzing movement data to assess gene flow and hence population size, what is important is not whether birds can move long distances, but whether birds do move long distances and breed sufficiently frequently for gene flow to overcome drift and other deleterious genetic and demographic aspects of small population size. For example, one female moved 106 air miles among different nesting, summering and wintering areas, but then nested within 25 meters of her previous nest (Hulet, et al. 1986). Such long distance movements, coupled with lek and site tenacity, must not be confused with dispersal and subsequent gene flow. Dispersing individuals must successfully find appropriate habitat conditions and a mate, be sexually mature and active, be able to merge into the existing social structure, and successfully breed and raise those offspring to breeding status (Wiens 1976, p. 89). Dalke, et al. (1963) noted that movements of birds between leks were rare, both within a single season, and from year to year. Movements of males among leks ranged from 500m up to only 4.3 miles, and appeared to involve subordinate, rather than dominant males (Dalke, et al. 1963). Gibson and Bradbury (1986) note that movements among leks by yearlings are common, while movements by older males are merely "occasional." Yearlings are least likely to obtain matings. The data on older birds includes second year males and all non-yearlings, but since only 1 or 2 of the most experienced birds obtain nearly all matings at a lek, using inter-lek movement data will over-predict gene flow. Thus, gene flow among leks, and especially among different complexes of leks will be quite low.

Very large movements by sage grouse require the protection of vast amounts of acreage. In contradistinction, where sage grouse are relatively sedentary, gene flow among demes is reduced, increasing extinction risk.

Summary of Life History and Habitat Needs

J. R. Young (1994, p. 44) suggested that two habitats and life history periods critically limited Gunnison sage grouse: the density and height of sagebrush in winter, and the abundance of forbs and grasses in the summer early or late brooding periods. Braun (personal communication) feels that no specific life history stage or habitat type used is limiting across the entire range, and, instead, that certain habitat types will be limiting in certain areas, and others in other areas. When fluctuations in rainfall, snow pack and other variables are added, this would lead to a very complex landscape management prescription.

Even individual sage grouse need habitat blocks sufficiently large that they can stay 1.4 km from any trees (J. R. Young 1994b, p. 45, citing Schneider and Braun 1991). This means that any habitat smaller than about 3 km across is essentially unusable by sage grouse if the edges are defined by trees, poles or other suitable raptor perches.

Population Mechanisms and Vulnerability

Sage grouse possess certain physiological, anatomical, behavioral and population characteristics that render them more vulnerable to various environmental effects in terms of extinction risk. A variety of studies have identified increased vulnerability to extinction due to the following factors: small population size, low population density, isolation of sub-populations (demes), ineffectiveness of dispersal, large body size, large home range size, concentration of individuals (e.g. lekking), non-random mating system, and low fecundity, among others (Ehrenfeld 1970; Terborgh 1975, 1976; Pimm, et al. 1988; Primack 1993). These characteristics and the others discussed throughout this review constitute threats to the species within the purview of the ESA.

One such characteristic is large body size. Sage grouse are the largest grouse in North America, and large body size increases metabolic rate and food requirements. Space needs, such as foraging area, are increased as a consequence. Sage grouse are diet and habitat specialists, and this high dependence on particular habitat and food types increases the likelihood of extinction should those habitats become degraded.

Additionally, the "principal demographic properties contributing to" status as a "threatened or endangered species" are "a low maximum breeding population size and a high coefficient of variation in that size" (Ehrlich and Wilson 1991, citing Pimm, et al. 1988).

An important concern is that extinction probabilities among birds are more closely related to population density than to the area occupied (Bolger, et al. 1991). This is of particular importance to sage grouse, which range across large areas, but are extremely sparsely distributed across those areas. Moreover, Pimm, et al. (1988) showed that extinction risk was correlated with variation in population size – another significant concern for a species such as this, which often fluctuates in population size. These problems are exacerbated by the low intrinsic rate of increase in sage grouse, which also results in higher extinction risk (Pimm, et al. 1988, p. 760). Although the range of the species is large, it has been greatly reduced. Soule (1983) found that such range reductions are the time at which conservation efforts should be concentrated, as species may be inevitably doomed in the periods of decline following range reductions. Sage grouse posses many of the biological traits that are known to increase extinction risk based on both ecological and paleontological studies: a specialized diet, low fecundity, relatively long lifespan within its taxon, complex behavior, low mean abundance, and high variation in abundance (McKinney 1997, Table 1, p. 499)

The lekking habit can also enhance the spread of disease and parasites because it concentrates large numbers of birds in small areas. The fact that lekking reoccurs in the same areas year after year permits disease organisms, vectors, and parasites to easily reinfect birds if they can over-winter in a cyst, egg, or other resting stage. Sage grouse are restricted to particular types of nest sites, thus increasing their susceptibility to degradation or destruction of those type sites. The same is true for winter habitat and brooding habitat.

Population Recovery

Sage grouse have a relatively low reproductive rate and the ability to recover from population reductions is low (BLM 1999c). Sage grouse have low fecundity, low adult survivorship, and very low productivity. Their recovery time when threats are removed is slow, as is that of their habitat. As Connelly, et al. (2000e, p. 981) put it, sage grouse "populations that have thus far survived extensive habitat loss may still face extinction because of a time lag between habitat loss and ultimate population collapse."

Time lags may be common for birds in shrub-steppe habitat, and they have been noted in a number of avian population studies in sagebrush shrub-steppe (Rotenberry and Wiens 1978; Wiens and Rotenberry 1985; Wiens 1985a; Wiens, et al. 1986; Wiens 1989b, II, p. 114 (summarizing)). Once degraded, sage grouse habitat may not recover for many years, even if cattle grazing is halted (Coggins 1998). Besides these time lags in habitat responses *per se*, time lags also occur in species responses after habitat is fragmented (Cowlishaw 1999, Rosenberg and Raphael 1986). The rebounds in sage grouse populations in the 1930's in Colorado and some other states are not comparable to potential rebounds in the future – habitat is more degraded, populations are more fragmented, and virtually all threats are much more severe and imminent than previously. Moreover, sage grouse now face range-wide threats from climate change which

were not a significant factor half a century ago.

Time to extinction is not the metric of interest in an endangerment analysis; instead, the time until the species is unrecoverable is the most important concern. If the species declines to a point at which it cannot be recovered, it must inevitably become extinct at some time. For species which have difficulty in increasing their numbers from small populations – such as sage grouse – the differences between these two time periods is significant. Once the species, sub-species, or distinct population segment is no longer recoverable, extinction is inevitable. The Service should estimate the time remaining until populations of sage grouse are so small as to be unrecoverable. Dr. Clait Braun, perhaps the most acknowledged expert on sage grouse throughout their range, believes that if spring counts decline below about 50 to 100 birds, then the population will be unrecoverable (Braun 2001h).

The Service has recognized the important effects on extinction risk of demographic stochasticity, environmental stochasticity, natural catastrophes (such as fire and drought), and genetic stochasticity (Shaffer 1981). At the time of publication, Dr. Shaffer was a FWS biologist in the Office of Migratory Bird Management (Shaffer 1981, footnote, p. 131). The effects of these and other factors on population viability have been addressed in modeling exercises with varying degrees of empirical testing and validation. Boyce (1992) and later Beissinger and Westphal (1998) have summarized various population viability model (PVA) categories and discussed their data requirements. Viability analyses that do not estimate lower confidence intervals, or that fail to consider the effects of rare, but severe episodic events will be "unduly optimistic" in their assessment of population viability (Ludwig 1999). For example, when two known severe population declines were excluded from a data set, the probability of extinction calculated was "quite small;" however, the declines greatly increased extinction probabilities (Ludwig 1999, p. 304). There is always variance around any measurement of population phenomena, and additional variance around any model estimate – consequently, the Service should err on the side of conservation in considering both data and model outputs. Importantly, the Dept. of Interior has noted that population declines have exceeded estimates of the rate of decline in past recovery efforts (Pattee 1995, Fig.).

Small Population Size

Sage grouse are now typically found in small populations, and small population size is itself a threat to such species, even if no trend towards even lower numbers is seen. It has long been known that demographic and genetic stochasticity are important determinants of extinction risk (Shaffer 1981). Both these risk factors increase in small populations. The Service recognizes that stochastic perturbations can "extinguish populations even in an environment that, on average, is favorable for their growth and persistence" (Shaffer 1981, p. 131) and must take this crucial factor into account when evaluating a potential listing. The Service cannot assume that an increase in population size removes extinction risk, unless the populations are sufficiently large that stochastic effects are negligible. As Poethke, et al. (1996) note, virtually all models of population dynamics predict geometrically decreasing persistence time of a population as population size decreases. This is true of traditional birth and death demographic models, as well as Markovian chain approximations and Monte Carlo simulation approaches (Poethke, et al. 1996, p. 83). Simple analytical models are inadequate for assessing population extinction probabilities, and generally underestimate the risk of extinction (Shaffer and Samson 1985). Deterministic models, in general, also underestimate extinction risk (Beddington and May 1977, Caswell 1989). As one example of the rapidity of extinction in ground dwelling birds, the Heath

Hen (*Tympanuchus cupido cupido*) was given an island refuge and predators were controlled. Yet, the species became extinct in only 14 years, although over 800 individuals were present in the population (Shaffer 1981, p. 131). The Population Assessments section, below, discusses examples where grouse became extirpated without downward trends in population size.

Small populations are at high risk of extinction for several reasons, including loss of genetic variation through inbreeding or genetic drift, demographic fluctuations (such as variation in births, deaths, or age classes), and environmental fluctuations (such as variations in predation rate, disease or parasitism rates, climate, episodic weather events, competition, food supply and a host of other abiotic or biotic factors). Inbreeding depression, and perhaps other factors, show up preferentially in fitness characters such as fecundity, juvenile mortality, and age at first breeding, because those characters typically display dominance or over-dominance (Frankel and Soule 1981, p. 65). Inbreeding depression can affect all individuals in a population (Hedrick and Kalinowski 2000).

Until the early 1990's, classic population genetics theory had not often been expanded to consider the effects of weak selection, environmental fluctuations, strong population subdivision, different aspects of inbreeding, and cumulative weakly deleterious mutational loads (Loeschcke and Jain 1994a, p. 87-88). As analysis of population viability has expanded to incorporate additional factors, population persistence estimations have decreased. For example, when environmental fluctuations are added, persistence times increase only linearly with population size (Shaffer 1987) or only logarithmically (Wissel, et al. 1995), resulting in increased risk of extinction at even larger population sizes (Poethke, et al. 1996, p. 83-84). Thus, if the Service finds that contemporary viability models do not include all factors affecting demographic variables, or more likely, that not all factors affecting demographic variables are known with precision, it must err on the side of caution to fulfill the legislative mandate in the ESA.

Shaffer (1981, p. 133) reviewed the history and limitations of arbitrary rules of thumb, such as the "50/500 rule." Briefly, the 50/500 rule considered only genetic effects and did not account for the need to preserve long term evolutionary potential. When it first arose over two decades ago (Franklin 1980, Soule 1980), the lower limit of $N_e = 50$ was thought to prevent unacceptable short-term rates of inbreeding, and the N_e of 500 was thought to maintain genetic variability. Neither figure is, or was, intended to incorporate demographic or environmental stochastic factors. Such "magic numbers" as the basic 50/500 rule are suitable for informing lay audiences about the general dangers of small population sizes, even though subject to misunderstanding and misuse (Soule 1987). NMFS recognizes this and has noted criticisms of the 50/500 rule, including the arbitrary choice of 1% inbreeding, the assumption that selection is zero in wild populations, and others (Thompson 1991, p. 6, 25). As Culotta (1995) notes, more recent studies show that substantially higher population sizes are required to prevent extinction.

The best available science requires a minimum N_e of 5,000 for population viability (Lande 1995). This viability requirement for N_e translates to a census population of 10,000 to 20,000 individuals or more (Culotta 1995, Noss 2000). This is particularly true for populations that have been gradually reduced in size over time, such as sage grouse (Lande 1995, p. 786). Another factor which interacts with genetic phenomena is environmental fluctuation – such changes in the environment are likely to have fitness consequences, resulting in a high degree of variance in selection coefficients, which in turn "drastically decreases the mean time to extinction" (Lande 1995, p. 787). Such extinction risks are comparable to those from environmental stochasticity even for merely reasonable levels of variance of selection

coefficients (Lande 1995, p. 788). Mutation load of even slightly deleterious mutations "considerably enhances extinction risk for small sexual populations if it acts together with demographic stochasticity" (Gabriel and Burger 1994, p. 69; Gabriel, et al. 1991). Classical models of demographic stochasticity typically underpredict extinction risk (Gabriel and Burger 1992). Moreover, smaller populations face much greater synergistic interactions among risk factors, greatly amplifying overall extinction risk (Gabriel and Burger 1994, p. 70). Population sizes of 10,000 or more may be needed to maintain single-locus traits, such as disease resistance, which has been suggested as an important mating system effect in sage grouse (Lande 1995, p. 789; Boyce 1990). Moreover, synergistic interactions among risk factors must be considered in determining population viability, and such interactions likely require minimum population sizes greater than 10,000 individuals.

The Service has agreed that these population sizes are needed for viability. Mr. Terry Ireland (a FWS employee in Grand Junction, Colo. who is familiar with sage grouse) stated that "10,000 individual birds are necessary to maintain a population for 100 years" (Summary of North Park Working Group Meeting 1999, p. 6). Because 100 years is an easily foreseeable time frame, this determination alone requires listing. Besides the Service, federal land management agencies also recognize the extinction risk of small population size: "Smaller and more isolated disjunct populations are likely more susceptible to local declines or extinctions" (Marcot, et al. 1997; Quigley and Arbelbide 1997a, p. 77).

A population below the minimum size for viability must, *ipso facto*, be legally endangered. All populations smaller than about 10,000 individuals should be considered endangered, unless the best available scientific information can show that such populations are, for some reason or other, not in danger of extinction. For all known populations of sage grouse, the factors discussed here indicate that even much larger census sizes will be endangered.

A number of other factors show that sage grouse are likely to be even more at risk than other vertebrates with similar population sizes. Marginal populations are likely to be less variable than central populations, thus increasing the likelihood of extinction in such peripheral isolates. Peripheral populations may also occupy less favorable habitat, further increasing their risk of extinction (Wilson 1975, p. 113).

Sage grouse populations fluctuate with environmental conditions, and the lower the population level, the greater the risk of extinction (Hays, et al. 1998). Lande (1988a, 1988b) and later Caro and Laurenson (1994) noted that while genetic variation issues are serious and perhaps irreversible problems, environmental and demographic fluctuations are likely to cause the greatest risk of extinction in the near term. Vrijenhoek (1994) showed that genetic correlations can arise in small isolated populations, and that remnant variation is likely to be correlated with fitness, thus affecting population viability. Vrijenhoek's analysis is important both for understanding extinction vortices (*sensu* Gilpin and Soule 1986) and for appreciating the importance of peripheral populations. To ignore such correlations is to fall into the trap of "beanbag genetics" criticized decades ago by Lewontin (1974).

Population trends themselves can constitute risk factors for extinction (Mertz 1971a, 1971b). Populations that have been in declining trends for several generations, as have sage grouse, experience selective environments favoring delayed reproduction, reduced reproductive effort and increased longevity. These are precisely the demographic characteristics that make it more difficult to recover from sharp population declines, and thereby increase extinction risk (Wilson 1975, p. 100; Mertz 1971a, 1971b). The Service recognizes that extinction risk requires a time interval for any meaningful definition, and a minimum viable population size must be

sufficiently large to "endure the calamities of various perturbations and do so within its particular biogeographic context" (Shaffer 1981, p. 132). The National Marine Fisheries Service (NMFS) has also noted that the definition of "danger" does not imply a sense of immediacy – the term peril connotes immediacy of hazard (Thompson 1991, p. 2). Thus, the Fish and Wildlife Service must define risk of extinction over some fairly lengthy quantitative time period to avoid an arbitrary or capricious listing action. A definition which requires immediacy, as has been used by FWS in the past, appears to conflict with the Congressional mandate in the statute. Moreover, the Fish and Wildlife Service should defer and coordinate its listing policies with those of its sister agency responsible for listings, NMFS. The above threat factors, and others, are discussed further under each topical heading below.

Loss of Genetic Variation

Small populations face increased susceptibility to chance environmental and demographic effects, and also typically lose genetic variation due to drift, inbreeding or other population phenomena (Lande 1988a, 1988b; Caro and Laurenson 1994). Loss of genetic variation reduces mean population fitness and decreases the ability of the population to respond to environmental stressors (Westemeier, et al. 1998). Drift, founder effect, inbreeding and other factors causing reduced genetic variation increase as population size decreases and ultimately reduce fitness and survivorship (Allendorf and Leary 1986; Roelke, et al. 1993; Lacy 1987). Rare alleles are lost more rapidly in small populations, as is the proportion of heterozygous genes per individual and in the entire population (Avise 1994, Gyllensten 1985). This effect is known from populations of wild vertebrates (Soule and Mills 1998).

Sage grouse are even more susceptible to inbreeding depression because the lekking system greatly reduces the number of males which breed, radically reducing [*effective*] population size (Young and Minchella 1997, Bradley and Donnelly 1999, p. 25). Westemeier, et al. (1998) report a study on a species related to sage grouse, the greater prairie-chicken (*Tympanuchus cupido*), which also leks. Populations of greater prairie chickens may have become trapped in an "extinction vortex" (*sensu* Gilpin and Soule 1986) where loss of genetic variation interacts synergistically with demographic and environmental stochastic effects to drive populations to extinction. Populations of the greater prairie chicken, like those of sage grouse, exist in a series of isolated relicts with little habitat connections and only sporadic gene flow to restore genetic variation. The breeding population remained smaller than 500 individuals for 35 years. Prairie chicken population size, productivity, genetic heterogeneity, and fitness decreased even though both habitat quality and quantity increased, and predation and nest parasites were controlled (Westemeier, et al. 1998, p. 1697). Thus, both current and planned methodology to enhance sage grouse populations may prove ineffective.

Demographic Stochasticity

In small populations, *r* fluctuates due to demographic effects, even in a constant environment. Small populations thus suffer erratic swings in size due to demographic stochasticity, and at the same time, such small numbers provide no buffer against declines in numbers resulting in extinction. Because sage grouse exist in small demes (sub-populations) they are particularly susceptible to such effects. Moreover, sage grouse are subject to strong demographic effects of environmental variation on vital rates. This has strong effects on extinction risk. Populations "numbering many thousands may be at risk" in species "subjected to intense environmentally driven variation in life history parameters" (Quinn and Karr 1993, p.

452; Leigh 1981). Sage grouse is just such a species. Extreme variability in population size suggests "considerable risks of extinction in even locally abundant populations" (Quinn and Karr 1993, p. 452). This environmentally driven variation in vital rates "can lead to a substantial short term risk of extinction" even when a population is growing in size (Quinn and Karr 1993, p. 460).

The recovery time of populations subject to demographic stochasticity strongly affects extinction risk. Extinction risk also increases sharply as carrying capacity (K) decreases (MacArthur and Wilson 1967), and is strongly affected by r_m (Lande 1993). This factor is low in sage grouse, further increasing the likelihood of extinction. When the long-run growth rate is negative, extinction risk scales logarithmically with initial population size (Lande 1993, p. 912, 923). This result indicates that sage grouse are faced with extinction throughout their range, as no populations show long-term positive growth rates, even the largest ones.

Effective population size is also affected by the variance in production of progeny among individuals (Lande and Barrowclough 1987). Because of their breeding system, it would be difficult to find a species with greater skewness of reproductive contribution than sage grouse. Thus, all census estimates of population size must be reduced by the operation of demographic effects to adequately assess extinction risk. Demographic stochasticity can be an even greater threat to small populations than is genetic stochasticity (Westemeier, et al. 1998).

Environmental Stochasticity

May (1973b) may have been the first to distinguish between the effects of demographic and environmental stochasticity. Contemporary models of metapopulation dynamics often assume that persistence depends on the balance of extinction and colonization in a static environment (Hanski 1996). Environments are not static, however, particularly the grass and shrub lands that constitute the habitat of sage grouse. Besides extreme climatic variation, these habitats are being reduced in size, degraded in quality and fragmented at rapid rates. Large and unpredictable fluctuations in climatic and other environmental factors are known to occur frequently across the entire range of the species. These are thus anticipated risk factors that must be considered by the Service – no one can claim that these fluctuations are unanticipated natural events. Moreover, biotic ecosystem components exhibit more variability than do abiotic components, and animals exhibit more variability than do plants (Kratz, et al. 1995). Finally, environmental stochasticity can be more important than genetic or demographic stochasticity, especially in populations of moderate or greater size (Lande 1988a). This fact has been recognized by both NMFS (Thompson 1991, p. 4) and FWS (Shaffer 1987).

Environmental stochasticity can be fully examined only if the factors of predictability and amplitude of effect, as well as the periodicity and contingency of environmental variation are considered (Colwell 1974, Stearns 1981). Duration of effect, recovery time, spatial distribution, and frequency are other important metrics for evaluating disturbance effects (Sousa 1984; White and Pickett 1985; Wiens 1989b, II, p. 113). One of the major errors in the conservation planning for spotted owls was that environmental stochasticity not considered (Noon and McKelvey 1996, p. 148); consequently, the population models were overly optimistic and owls remain at risk.

Climatic and weather effects have long been recognized as primary factors affecting terrestrial populations (Allee, et al. 1949, chap. 22; Andrewartha and Birch 1954, part III; Watt 1968, chap. 11.3; Gessaman and Worthen 1982). Climate and its short-term analog, weather, are particularly variable and unpredictable in sagebrush ecosystems (Miller and Eddleman 2000, p. 15). Because it is located in a continental interior, the range of sage grouse is often completely

affected by climatic effects such as drought – no spatial refugia exist for the species. Moreover, sage grouse are "particularly susceptible" to the effects of drought (Storch 2000b, p. 63).

The ecosystem type inhabited by sage grouse is subject to more extreme fluctuations than most ecosystem types in North America, and is less temporally predictable (Noy-Meir 1973; Wiens 1974a). Shrub-steppe areas have "considerable climatic variability" on both short-term and long-term bases (Rotenberry and Wiens 1980b, p. 2), and have a "highly unpredictable climate" (Wiens 1976, p. 89). Miller and Eddleman (2000) note that the range of sage grouse is characterized by a "high degree of landscape variability and yearly weather fluctuations." It is thus highly likely that sage grouse populations will be subjected to periodic reductions and consequent genetic bottlenecks, further increasing the risk of extinction to the birds.

Moreover, environmental variation affects the ability of humans to manage ecosystem effects. Short-term variations in local or regional precipitation – upon which management planning often is based – are greater than the predicted change in the mean value of precipitation for North America (Shuttleworth, 1996).

Drought is perhaps the major climatic variable affecting sage grouse productivity and viability (Klebenow and Gray 1968; Peterson 1970b; Drut, et al. 1994a, 1994b; Gregg, et al. 1994). Drought is common within the range of the sage grouse, and precipitation deficits of 85% or less of the mean occur 20% to 30% of the time (Miller and Eddleman 2000, p. 15). These climatic regimes may last from 2 to 21 years and can affect plant distribution as well as their more immediate direct effects on sage grouse (Miller, et al. 1993). Drought events appear to be associated with extra-tropical oceanic circulation patterns (Miller, et al. 1993) and are exacerbated by global warming. Declines in sage grouse populations during the 1930's are strongly related to the drought in the continental interior at that time (Patterson 1952c). Populations recovered in most states in the 1950's (see Population Assessments sections) immediately after the period of abundant rainfall in the west during the World War II years (Malone and Etulain 1989, p. 111-112). Drought from the mid-1980's to the mid-1990's has also been suggested as a cause of sage grouse declines in Oregon and Idaho (Fischer 1994; Hanf, et al. 1994; Connelly and Braun 1997). In Oregon's Blue Mountains province, drought cycles peaked in the late 1980's and troughs (wet years) occurred in 1977 and the early to mid 1990's (Brooks 1996). In NE Washington state, the mid to late 1980's were also drought years, with wet years occurring in the late 1970's and early to mid 1990's (Brooks 1996, p. 52).

Drought strongly affects the food supply of both gravid females and maturing young sage grouse, and affects cover providing concealment and radiative and wind buffering (Autenrieth 1981; Hanf, et al. 1994; Fischer, et al. 1996b). Drought effects are particularly severe in areas that are overgrazed, and will "exacerbate the adverse effects of heavy, excessive livestock grazing on vegetation and soils" (Nevada State Office, BLM 2000a, p. 6). BLM acknowledges that excessive grazing has been the case in "many areas" (Nevada State Office, BLM 2000a, p. 6). Periods of low temperature and rain, snow or sleet can also cause nest failures (Patterson 1952c). Population viability models have been previously constructed for species affected by episodic droughts (Armbruster and Lande 1993). Environmental stochasticity can be an even greater threat to small populations than is genetic stochasticity (Westemeier, et al. 1998).

Sage grouse are highly susceptible to variation in precipitation. Rich (1985a) found that about 65% of the variation in juvenile/adult ratios was explained by the amount of precipitation in July and August. Moreover, 8 of 9 monthly weather variables that were significantly correlated with lek counts in Idaho were precipitation measures (Rich 1985a). At higher elevations, temperature may be more important (Rich 1985a, p. 12). Drought and grazing

pressure interact to exacerbate negative effects on sage grouse productivity (Blake 1970). During low precipitation years (less than 15 cm), meadows are critical habitats for sage grouse; unfortunately, they are heavily used by grazing cattle (Oakleaf 1971; Klebenow 1982, 1985; Evans 1986).

"[E]nvironmental stochasticity is a significant threat to Washington's sage grouse" populations (Bradley and Donnelly 1999, p. 28). Because the same effects are equally large or larger in other small populations of sage grouse, environmental stochasticity threatens them also. Many sage grouse populations are at high risk from environmental stochasticity, including weather related factors such as a drought year, a hard and snowy winter, or insufficient spring precipitation. Such events may occur in the next few months, i.e. this winter, spring, or summer, and could affect the entire range of the sage grouse. If these weather events were sufficiently severe, they might cause complete extinction of sage grouse. Even if a lesser severity or magnitude were to occur, a significant proportion of the sub-species would be extirpated. These threats are ongoing in nature and interact with other threats.

Effective Population Sizes

Effective population size (N_e) is a term used to incorporate various environmental, demographic, and genetic effects on population dynamics. N_e has been calculated in various ways, and can incorporate the effects of drift, inbreeding, and loss of alleles at segregating loci (Burgman, et al. 1993, p. 238). The population dynamics of small populations cannot be accurately estimated without consideration of effective population size. This is not a new result; instead, it dates from at least the time of Sewell Wright in the 1940's.

Various estimates of the ratio of N_e to N indicate that effective population sizes will be only 25% to 33% the size of the census population (Soule 1980, Wilcox 1986). Salwasser and Marcot (1986) suggested 50%, but they used unrealistically low minimum viable population sizes of 100 and 1,000. For vertebrates, minimum viable populations should be approximately 5,500 or more (Thomas 1990). NMFS independently derived similar a size of 5,000 (Thompson 1991; p. 8, Appendix B). The Service has used unrealistically low recovery goals for other species, for example the Southern Sea Otter, for which it used a "genetically effective population size of 500" (FWS Southern Sea Otter Recovery Team 2000, p. 25), which led to census population sizes of more than 2,650 for recovery, of 1,850 to 2,650 for the threatened category, and of 1,850 or less for the endangered category (id., p. ix). The Service did not adequately include environmental stochasticity and other effects in its draft determination, however. Schroeder (1998b) applied the N_e concept to sage grouse but only incorporated a subset of the effects. Thus, N_e will be lower than those calculated using the formula given by Schroeder (1998b). However, if used cautiously and conservatively, Schroeder's formulation is a useful metric until population viability models are established for the species. The Service must make its listing determination on the basis of the best available science regarding minimum viable population sizes, however. That science indicates that relatively large census populations are required.

One important effect on N_e in sage grouse is the fact that very few males mate with a large number of females, thus reducing genetic variation. A lager number of studies illustrate this phenomenon: in Wyoming, 2 males obtained 74% of 174 observed copulations (Scott 1942) and 86% of 42 copulations (Wiley 1973b); in Saskatchewan and Montana, 54% of 103 copulations (Lumsden 1968); and 66% of 533 copulations in Montana (Hartzler and Jenni 1988). Gibson, et

al. (1991) noted that females are nearly unanimous in mate choice, and Hartzler and Jenni (1988) found a single male that mated 169 times in a single season. Moreover, yearling males are unlikely to mate and occupy disfavored areas on the periphery of the lek (Dunn and Braun 1986b).

* * *

Allee Effects and Social Disruption

The term Allee effect refers to the negative effects on population processes of low population size or density (Allee 1938, 1951; Drickamer and Vessey 1992), sometimes also termed "undercrowding." Sage grouse are likely to show significant Allee effects because of the lekking habit – if the number of males declines sufficiently, the joint signaling function of having many males undergoing simultaneous sexual display and the advantage to females of gathering information regarding multiple males will both decline. Thus, as lek size decreases, the advantage of lekking collapses, at some threshold value. This is borne out by the numerous reports of lek abandonment below a threshold size. Other types of Allee effects are also likely to occur in sage grouse, including the difficulties of finding a mate (Dennis 1989), the ability to evaluate numerous potential mates for suitability, difficulty in detecting, evading or fending off predators or competitors (Boyce 1992, p. 493). Allee effects appear ubiquitous and occur across a wide range of taxa: for example, Allee noted that groups of fish survived toxic conditions better than single fish, as did groups of flatworms. Moreover, all the benefits of group size for predator protection and other ecological interactions (summarized in Wilson 1975) are lost when group sizes decrease. All available evidence points to substantial decreases in sage grouse group sizes. Soule (1983) notes that social disruption is likely to cause extinction long before genetic effects such as drift or inbreeding and long before demographic stochasticity. Even species with "high reproductive potential are vulnerable" and that a minimum viable population size may be two orders of magnitude larger when social disruption is involved (Soule 1983, p. 118). Soule specifically mentions two other species of grouse – the Heath hen and Attwater's Prairie Chicken – as examples of extinction thresholds being crossed despite high reproductive potential (Soule 1983, p. 118).

Because of Allee effects, decreases in population size are unlikely to be linear; instead, as population size decreases to some threshold value, rapid declines and extirpation are likely. Such declines may be so rapid as to be undetectable before they actually occur, or if detected, extirpation may not be preventable by that point. Certain aspects of the environment combine with Allee effects to greatly increase the likelihood of extinction for sage grouse. First, Dennis (1989) has shown that environmental stochasticity amplifies Allee effects. As explained elsewhere in this review, sage grouse populations fluctuate greatly and sage grouse habitat are subject to great amplitudes of environmental stochasticity as well as unpredictability of these fluctuations. Second, "harvesting also amplifies those [Allee] effects" (Dennis 1989, p. 481). Thus, hunting of sage grouse can greatly increase extinction risk, and this risk will not be accounted for in conventional models of population harvest. Petitioners request that the Service consider this and all non-linear effects of population declines in evaluating the status of sage grouse species. This is particularly important because non-linear, or threshold effects may cause populations that "appear safe for many years" to "decline suddenly" (Meffe and Carroll 1997, p. 218). Pulliam (1992) already modeled a situation similar to that for sage grouse –an example in which the population abruptly declines as the proportion of agricultural areas in the landscape

increases. Such declines are difficult to predict “because the problem may well go undetected until a critical threshold is reached” and causes “catastrophic population collapse” which has been documented repeatedly (Meffe and Carroll 1997, p. 219). One of the major errors in the conservation planning for spotted owls was that Allee effects were not considered (Noon and McKelvey 1996, p. 148); consequently, the population models were overly optimistic and owls remain at risk.

Cultural Inheritance

Modern behavioral ecology has documented numerous instances of cultural inheritance in non-human species (sometimes termed "memes"). Young sage grouse learn from older sage grouse (SMBCP 1998, p. 22), and thus important survival behaviors can be lost from the population if cultural transmission is interrupted. This effect operates most strongly in small populations, just as alleles are lost most frequently in small populations. Social disruption, and the removal of older more experienced individuals from a population, as in trophy hunting, can also be expected to remove learned behaviors from the population (Wilson 1975, p. 152, 168-172). Connelly, et al. (1988) suggested that seasonal movements may be traditional, hence culturally inherited. For example, roads often eliminate traditional movements from sage grouse populations because older, more experienced sage grouse are eliminated from the population by road deaths (SMBCP 1998, p. 22).

Thus, deaths of relatively old, post-reproductive grouse may have important population effects (contra Braun 1995e, p. 1). However, sage grouse only rarely live to be post-reproductive, so this potential cultural effect may be of merely theoretical importance.

Population Cycling

Sage grouse populations have been suspected to cycle for some time (Patterson 1952c). Rich (1985a) used power spectrum analysis to analyze 39 leks in Idaho, Utah, and Nevada, and found significant periodicity ranging from 8 to 10 years. Cycling populations have greater extinction risk for two reasons. First, they periodically experience low population sizes, with all the concomitant risk factors of small populations. Thus, it is not the periodic population maxima that are of greatest importance for population viability, it is the periodic population minima. Second, cycling populations may be composed of behavioral and genetic types of individuals who are adapted to high population numbers, but are then exposed to low population sizes that they are ill equipped to deal with. Similar arguments apply to species with longer lived individuals whose lifespan is greater than the periodicity of the cycles, except that such individuals are not adapted to large population sizes. Instead, they would be either developmentally canalized or physiologically acclimatized to high population size, and then exposed to very low population sizes during their lifetimes.

Climatic cycles are common in the sagebrush region inhabited by sage grouse and typically last from 2 to 21 years (Miller, et al. 1993, p. 108). It is tempting to hypothesize that sage grouse population cycles are driven by climatic cycles. Apparently, no studies have analyzed this linkage, and the entire realm of population cycling has generated a ponderous literature across many different species, ecosystems, and continents without resolving the issue. In the Great Basin, periods of increased precipitation are better known and “are probably associated with El Nino” events and other extra-tropical alterations in oceanic circulation (Miller, et al. 1993). Cycles in various species of grouse are not synchronized with those of lagomorphs or rodents, and tend to lead the mammalian population declines, suggesting that

predators do not drive grouse cycles (Hoffmann 1958).

Hamerstrom and Hamerstrom (1961) noted that sage grouse were subject to dramatic changes in abundance. Importantly, it is not known if sage grouse are even adapted to fluctuations in population size. No studies were undertaken of the birds before cattle and sheep grazing degraded the shrub-steppe. It is known that population fluctuations are greater in marginal habitat (Rich 1985a, Linden and Rajala 1981, Jenkins, et al. 1967; Hilden 1965; Rowan 1948). Furthermore, even if the birds are adapted to cyclicity, it is not clear that they are adapted to the degree of cyclicity that they now face, because a given variation in a climatic factor, such as precipitation, may have profoundly greater effects in degraded and fragmented habitat than it would in intact habitat. The likelihood that sage grouse are cyclic should not be used to excuse or hide mismanagement. As Connelly noted, there are "not any stable habitats" remaining that can be used to determine if sage grouse are truly cyclic or not, and "labeling a population as cyclic is dangerous because it is often used to excuse mismanagement" (Heath, et al. 1996a, p. 3, citing Connelly during discussion). Nonetheless, population numbers are subject to "dramatic fluctuations" (Schroeder 2001a), complicating management and recovery (Rich 1985a), and making extinction more likely than in more stable populations.

Reintroductions

Reintroductions of species are difficult and expensive. Once community structure is altered, introduction of a species – even one previously present in the community – can be difficult (Diamond 1975b).

Johnsgard (1983, p. 99) noted that there were few instances of successful propagation of grouse, thus complicating the recovery of populations that fall to very low levels and the introduction of sage grouse to their historic range (Batterson and Morse 1948; Pyrah 1963). Patterson (1952c, p. 300) noted that reintroductions and transplanting of sage grouse in Wyoming apparently had only token results, even when "extensive releases' were conducted. A more recent review also concluded that reintroductions of sage grouse were rarely successful (Reese and Connelly 1997). Reintroduction was tried in Montana with 242 sage grouse at 8 sites, but was unsuccessful (Martin and Pyrah 1971, p. 135). Reintroductions from captive breeding programs may have lower fitness than natural populations, and such programs may allow deleterious genes or gene combinations to increase as captives are provided with ad lib food, medical care, and a predator free environment (Caughley 1994). Captives are also likely to lose essential behaviors if there is any component that is transmitted culturally. Moreover, it has never been demonstrated that an extinction can be prevented by any reintroduction (Fyfe 1978, Berger 1978). Reintroductions also run the risk of introducing disease if a small natural population already exists.

Because reintroductions are so difficult, it is imperative that existing populations of sage grouse be conserved wherever found. It may not be possible to reintroduce sage grouse where they have been extirpated; thus, peripheral isolates are of great importance to recovery of the species.

Importance of Peripheral Populations

Contemporary understanding of evolution and population biology emphasizes the importance of populations at the extremities of a species range. It is in these peripheral populations that the evolutionary potential of a species is greatest (Gadgil and Bossert 1970, Levin 1970, Gadgil 1971). Peripheral populations often differ genetically from more centrally

located populations, thus adding genetic diversity to the species and providing genetic backgrounds where natural selection can more easily increase the gene frequency of novel alleles or combinations. "Such populations are often of evolutionary significance" (Scott, et al. 1993, p. 35), and "preserv[e] unique genetic material" which is "restricted to peripheral populations of native species" (Scott, et al. 1993, p. 36; Quinn and Karr 1993). Peripheral populations may be disproportionately important for conserving genetic diversity (Squires, et al. 1998).

Peripheral populations are also often located at the ecological limits of the species, thus exposing these novel genetic combinations to environmental circumstances that may later become prevalent in central populations, such as global warming effects. Such testing of the periphery can act to stabilize the entire species in the face of environmental change.

Rapid evolution is likely when a peripheral population is isolated from gene flow, allowing a local deme to evolve to a local ecological optimum (Garcia-Ramos and Kirkpatrick 1997). Such evolution can be the first step to speciation, independent of genetic drift ("genetic revolutions," *sensu* Mayr 1963, 1982) or founder event mechanisms (Carson and Templeton 1984). Quantitative traits have very high mutation rates (1 per 1,000) as opposed to the mutation rates typical of other loci, and are thought to be more closely related to fitness than are other traits (Lande and Barrowclough 1987; Nei 1987).

The importance of peripheral populations is likely to increase with climatic change (Hunter 1991; Quinn and Karr 1992; Scott, et al. 1993). Peripheral isolates are also of great importance to recovery of species where reintroduction is difficult, such as sage grouse.

Geographical Distribution

Historic Range

The historic range is based primarily upon accounts from the early 1900's and late 1800's. The range of sage grouse before Euro-American settlement of the west is unknown but likely exceeded that reported in the 1930's through the 1950's, because of the severe destruction of grass and shrublands caused by the overgrazing of livestock from the late 1800's to the early 1900's. Attempts to reconstruct the extent of the range prior to Euro-American settlement are difficult because this widespread habitat destruction occurred before scientific study took place, except for a few surveys. Thus, the pre-settlement range was likely larger than any estimates that have been presented in the literature. The historic range extended at least across all states of the Intermountain West in sagebrush shrub-steppe habitat, including eastern Oregon, eastern Washington, Saskatchewan, Alberta, southern British Columbia, and the panhandle of Oklahoma and the area of Kansas immediately north of Oklahoma (Schroeder 2000a). Their historic status in Kansas and Arizona is unclear (GBCP 1997, p. 5). In Arizona, sage grouse were last sighted in the vicinity of the Grand Canyon in 1937 (Smith 1999). The range of sage grouse thus extended across at least 15 (probably 16) states and 3 Canadian provinces (AOU 1983, Aldrich 1963, Johnsgard 1973, Braun 1995, Reese and Connelly 1997). The Service stated that Greater sage grouse formerly inhabited 12 states and 3 Canadian provinces (FWS 2001d, 66 Fed. Reg. 22984, 22985). Of the 15 or 16 states occupied by any sage grouse species, it is likely that the small portions of Oklahoma, Kansas, and possibly Texas occupied by sage grouse in historic times were occupied by Gunnison sage grouse.

Habitat conversion, invasion of various tree species, and other effects have reduced the range in historic times. For example, "sage grouse remains were unearthed" in the wooded Carson Desert Wetlands on the Stillwater National Wildlife Refuge "suggesting that the

vegetation composition in the surrounding lower slopes of the mountain ranges was different historically" (US FWS, Stillwater NWR 2000, p. 2-34).

Researchers have compiled a number of maps presented giving the historic range of sage grouse, including Aldrich (1946); Patterson (1952c); Edminster (1954); Johnsgard (1973, 1983); Drut (1994); and more recently, Schroeder (2000a). Johnsgard largely followed Patterson (1952c) in preparing his range map (Johnsgard 1973, p. 159, Fig. 22) along with the historic range of the bird Aldrich and Duvall 1955, p. 2, and map, p. 12). Both Clait Braun (Braun 2001d) and Mike Schroeder (Schroeder, personal communication, Sept. 2000) have made inquiries at the Smithsonian and at most other major museums, as well as placing advertisements in ornithological journals. These data were included in the historic range map compiled by Schroeder (2000a), which is largely based on Aldrich (1946, 1963) and Aldrich and Duvall (1955), according to Schroeder (personal communication). The data and field notes from the US Army Railroad and other surveys were not investigated for the Schroeder (2000a) map according to Schroeder (personal communication). Mapping staff at the Washington DFW used the above data, Kuchler's vegetation map (1964a) and standard USGS topographic maps to produce a "best estimate" of the historic range before Euro-American settlement (Schroeder, personal communication). The California portions of the map were digitized by California DFW (Schroeder, personal communication).

[*Schroeder's map of the current range*] was prepared as an initial draft, which was then reviewed by sage grouse experts in each state. Although the map compiled by Schroeder (2000a) is still considered a draft, it * * * and represents the best estimate of the historic range and of the range in 2000. Schroeder (personal communication) considers the map of the current range to be most accurate in the states of Washington, Utah, Colorado, and California; and least accurate in the states of Nevada, Wyoming, and Montana; with intermediate levels of accuracy in Idaho and Oregon. In Nevada, many areas within the range have very sparse populations and the same is true in Wyoming (Schroeder, personal communication). In Montana, some areas show as within the sage grouse range, but surveys across the border in Alberta have no birds (Schroeder, personal communication). This suggests that the range shown in Montana is overly optimistic.

[T]he data on which the map was based were a few years old, and because threats are ongoing, somewhat less of the range is occupied currently than is shown in Schroeder (2000a). Most of the historic range has been eliminated in the intervening decades. Scott, et al. (1993, p. 20) gives a general discussion of such issues, and Connelly and Braun (1997) do so for sage grouse.As range maps are typically presented, they include large areas that are not sage grouse habitat. Such gaps are common in small scale range mapping or where habitat types are not validated with a dense spatial pattern of on the ground surveys (Scott, et al. 1993, p. 20). The presence of such gaps is easily seen by comparing such range maps with maps of the extent of sagebrush habitat – for example, the map given by Franklin and Dryness (1973, p. 45, Fig. 27) or Paige and Ritter (1999, p. 3). It is unclear whether Patterson, and those who have followed him, included such considerations in their calculations of the extent of sage grouse habitats. The true pre-settlement range of the sage grouse may be even greater than has ever been estimated because the bird is known to have declined before any mapping of the range was undertaken. However, Schroeder disagrees (Schroeder 2001d), noting that there may have been local range extensions if human crops made food available in areas that were previously food limited, and Spanish settlement may have reduced the range in the southwest prior to 1800 (Schroeder 2001d).

Early Accounts

Before Euro-American occupation of the west, sage grouse were extremely abundant, and huge flocks of the birds were often described (Drut 1994). Flocks consisting of thousands of birds were "common" (Edminster 1954, p. 115). Historic reports describe sage grouse as abundant throughout their range (Coues 1893, Huntington 1897, Burnett 1905; Grinnell, et al. 1918; Rasmussen and Griner 1938; Patterson 1952c). Accounts variously describe gigantic clouds of the birds so large they blocked out the sun, birds so thick that one could get dinner by hitting them with a stick, and birds so abundant that they acted as a control agent for grasshopper outbreaks. Sage grouse were so abundant that they appeared in "flocks that blackened the sky" (Patterson 1952c, p. 19), and were comparable to "the original passenger pigeon flocks" (Patterson 1950a, p. 384). Travelers along the Oregon Trail often feasted on sage grouse, and the birds often "rose up before the wagon trains in clouds of hundreds and thousands" (Cade 1999). Long-time Montana residents also reported that "sage grouse were so plentiful that when they got up they darkened the sky" (Eustace 1995, p. 24). In Wyoming, sage grouse were once so numerous that people were able to gather eggs for table use (McDowell 1956 p. 6). Bendire (1892) quoted field notes from George Bird Grinnell that the sheer numbers of sage grouse reminded him of the "oldtime flights of passenger pigeons" he had seen as a boy. After this reminisce, Grinnell continued, describing the sage grouse as so numerous that they transformed the entire valley into a "moving mass of gray" (Bent 1932, p. 309; Patterson 1952c). In many Western towns, butcher shops offered "prairie chicken" for sale along with other game, and Audubon often frequented these shops for specimens to draw (Brown 1994, p. 170).

Today, these accounts seem almost mythological – the result of over a century of habitat degradation and destruction. The oldtime flights of sage grouse have joined the oldtime flights of passenger pigeons as historical relicts of the once great North American wildlife fauna, and the sage grouse is following the passenger pigeon towards extinction. No one today has a living memory of the biomass and ecological dominance of sage grouse in the West, just as no one has a living memory of the tremendous numbers of buffalo on the plains or the rivers crowded with salmon. What is more, no one today has a living memory of how pristine sage grouse habitat appeared. Sage grouse were an important food source for Native Americans and were commonly eaten by early settlers, until near the end of the 1800's when "encroachment of the white man on the range" created "serious decline" which "became critical soon after 1900" (Edminster 1954, p. 115).

Lewis and Clark reported sage grouse at the head of the Missouri River, on the plains of the Columbia, and at the mouth of the Snake River (Coues 1893, p. 868-869). They repeatedly describe the birds as present in great abundance. Their first report on Sept. 17, 1804, noted that "grouse, larks, and the prairie bird are common in those plains." On Sept. 30, 1804 Captain Clark related descriptions of the "white-booted turkey [prairie cock]" along the Cheyenne River. On Oct. 4, 1804, they "saw great numbers of prairie hens" along braided river channels. On April 14, 1805 Captain Lewis "met with great numbers of grouse or prairie hens" which were mating. Coues notes that Lewis and Clark had "repeatedly" sighted sage grouse by the time they reached the intersection of the Yakima River with the Columbia River on Oct. 17, 1805 (Coues 1893, vol. 2, p. 642, n. 17). Along the plains of the Columbia River, they found sage grouse "in great abundance" all the way from the "entrance of the southeast fork to Clark's River" (Coues 1893, p. 868). It is interesting that Lewis and Clark often saw the birds along major river courses: this suggests either modern-day ecosystem alteration, such as channelization by dams, or changes in the habitat affinities of the birds post-settlement, as has been noted for big horn sheep. In the

winter of 1827, naturalist David Douglas reported large flocks of sage grouse along the Columbia River between its confluences with the Spokane and Walla Walla rivers (Yocom 1956). There was probably little overlap of sage grouse with grazers such as bison (*Bison bison*), popularly called buffalo, as most sagebrush ecosystems were not grazed in prehistoric times (Mack and Thompson 1982, Daubenmire 1988).

Settlement and Degradation

The sagebrush shrub-steppe was one of the last areas of the conterminous United States to be explored or settled (Cline 1963). It was not until 1844 that Fremont concluded that the Great Basin did not drain into the Pacific or the Gulf of Mexico (Jackson and Spence 1970). The huge numbers of sage grouse were a result of the vast expanses of habitat. In Idaho, early settlers described vast "seas of wormwood" stretching as far as the eye could see (Quinney 2000, p. 91). Pioneers described a diverse sagebrush, forb and grass ecosystem – the expanses of sagebrush appeared like "a field of wheat" because of the tall rye grass stems protruding above the sagebrush (Quinney 2000, p. 91). Balsamroot (*Balsamorhiza* spp.) was the most commonly noted forb, and was so abundant that "mile after mile" of the sagebrush lands were colored yellow every spring (Quinney 2000, p. 91).

Despite the efforts of naturalists and the Army Topographical Corps, Historian Daniel Boorstin's aphorism that the West was "settled before it was explored" (Goetzmann 1986, p. 178) is particularly apt for sage grouse distribution and numbers. Rapid habitat degradation led to severe declines in * * * sage grouse, and these declines continue. Initially, degradation was highly localized and limited to the corridor of the Oregon Trail and other major trails, and in the vicinity of established forts. Oregon Trail users so heavily depleted the vegetation that they had to drive their livestock several miles away from the trail corridor to get enough forage (Quinney 2000, p. 92). In the early 1900's, sagebrush ecosystems rapidly became subject to settlement and grazing, and, after WWII, to industrialized agriculture. But, in the late 1800's and even into the 1920's, sage grouse were locally abundant. In parts of northern Nevada, sage grouse "clouded the sky" and boys were able to kill sage grouse by reaching out and hitting them with a stick (Wuerthner 1999). Huge bands of sheep destroyed nesting habitat, and hunters shot so many sage grouse that "a dead-axle wagon wouldn't hold the birds they killed," so the hunters "would just leave [them] on the ground in big piles to rot (Wuerthner 1999). In parts of Idaho, whole wagonloads of sage grouse were shot by hunters (Scutro 1999). In Colorado, sage grouse were found in the eastern plains, at least as far as 25 miles NE of Ft. Collins as late as 1949 (Bailey and Niedrach 1965, p. 279).

As late as 1858, white occupation of Montana was limited to a few forts clustered around the confluence of the Marias and Teton rivers with the Missouri river (Utley 1984, p. 25). Nor had any settlements penetrated deeper into the Intermountain West than Ft. Laramie in present day Wyoming and two forts east of the Rio Grande in present day New Mexico (Utley 1984, p. 62). Shortly thereafter, forts and towns were established at several places within the range of the sage grouse (Utley 1984, p. 121, 194-95).

After a series of wars, skirmishes, massacres, expatriations, ethnic cleansings and genocide, many native nations collapsed and remaining Indian tribes and bands were largely limited to small reservations (Utley 1984, p. 233). Native Americans had become ineffective as an ecological force, and the West, including the range of the sage grouse, was opened to white settlement and agricultural uses. In 1874, J. F. Glidden invented barbed wire, providing a cheap and effective means for containing livestock, which also led to the elimination of the long drives

of cattle to railheads and the death of the cowboy as anything more than a mythic figure. The extension of railway lines and invention of the refrigerated railway car opened western cattle operations to markets in the east, notably Chicago (Cronon 1991) and began the agro-industrialization of the West. By 1890, the Superintendent of the Census had declared the frontier dead, as Frederick Jackson Turner noted in his 1893 lecture explaining wilderness and frontier as effects shaping the American social and psychological character (Turner 1921). Farming and settlement accelerated during and just after World War I, when many homesteaders filed Desert Land Entry claims because of the demand for grain (Quinney 2000, p. 93). Many of the farms and ranches in the semi-arid and arid lands of the plains and cold deserts failed during the dust bowl years, and cheatgrass (*Bromus tectorum*) rapidly invaded the disturbed lands (Quinney 2000, p. 93). Later, especially during the 1940's and 1950's, increasing industrialization of the West began. As late as the 1960's, large tracts of sagebrush (although degraded by grazing and cheatgrass infestation) still existed south of present day Interstate 84 (Quinney 2000, p. 91). Habitat conversion – fostered by cheap irrigation water – increased rapidly in the 1970's following completion of the upper Snake River dams. In the 1980's, the next wave of habitat destruction became prominent – the increasing proliferation of suburbs, exurbs (Davis, et al. 1994), and ranchettes. Thus, in the space of a few decades, the vast prairies and shrublands of the west were rapidly converted from natural areas dominated by buffalo, prairie dogs and sage grouse into agro-ecosystems dominated by sheep and cattle [*and*] industrial landscapes dominated by mines, pipelines, powerlines, and roads, and into suburban sprawl.

Patterson (1952c) estimated that the pre-settlement area of habitat for sage grouse was about 90 million acres (36.4 million ha, or 140,625 mi^2) in 1952, with another 40 million acres (16.2 million ha) of less suitable habitat also available. Braun used earlier accounts of sage grouse and habitat estimates to approximate the historic numbers of sage grouse as about 2 million (Braun 2001c). However, applying contemporary density estimates to the known pre-settlement range suggests total numbers that are much larger. For example, if the 12.5 males/$mile^2$ estimate of Patterson (1952c) is multiplied times 2 to account for adult females, and then by the 140,625 mi^2 of the best habitat, a total of 3.5 million adult birds is obtained. If the estimate of Edminster (1954) is used, if Patterson's value of 40 million acres of less suitable habitat is added, if spring populations are used, if more than 1 female is assumed for every male, if density estimates higher than the contemporary ones are used (recognizing that all habitat has been degraded), or if it is recognized that sage grouse were already in decline at the time Patterson and Edminster estimated densities, then * * * a pre-settlement estimate of several million birds [*may be*] conservative. * * *

Present Range

Today, sage grouse have been extirpated from 5 states and the Canadian province of British Columbia (Schroeder, et al. 1999a; IUCN Red Book 1999), and are sparsely and locally distributed from [*eastern Washington*,] southeastern Oregon, southern Idaho, and southern Alberta and Saskatchewan south to eastern California, and eastward through Montana, Wyoming, Utah and Idaho to western Colorado, and extreme western North and South Dakota. Extinction is "imminent" in Alberta, and "only 6 leks" remain (Boyce; personal communication, June 26, 2000). The range of the species has been reduced in every state (Schroeder, et al. 1999a). Using the GIS data on which Schroeder (2000a) based his map, sage grouse of all species, sub-species, and distinct population segments currently occur in only 170 counties in the U.S., a reduction of about 40% from the 271 counties in which the bird occurred historically. A

large number of isolates have appeared where once there were continuous populations – e.g. 2 in Washington state, and numerous isolates in Colorado, Nevada, and California (Schroeder 2000a). Fragmentation has produced isolation within this range, and sage grouse within the above delineated area cannot be assumed to form a single population. Nor can all the sage grouse within any state be assumed to form a single population. Severely isolated populations of the sage grouse occur in California and in eastern Washington (Johnsgard 1983, National Geographic Society 1987, Wallestad 1975a).

Sage grouse have been extirpated in British Columbia, most of North and South Dakota, Nebraska, Kansas, Oklahoma, Arizona, New Mexico, much of Oregon, most of Washington, and central eastern California (Hamerstrom and Hamerstrom 1961; Ihli, et al. 1973; Schroeder 2000a). Thus, great contractions in the range have occurred, and other than a few remnant isolates, birds remain only in parts of Wyoming, Idaho, Montana, Oregon, Nevada and Colorado. However, populations are fragmented in these states as well, and "the species is depleted throughout most of its range" (Oregon Dept. Fish and Wildlife 1991).

In 1992, BLM estimated that 30 million acres of habitat on BLM lands were occupied by sage grouse but that another 10 million acres of habitat were unoccupied (BLM 1992, p. 5-6). This is far below the estimate of 130 million acres of total occupied habitat pre-settlement (Patterson 1952c). Most habitat is on BLM lands today, so if both estimates are correct, then about 90 million acres of habitat have been lost on private lands. BLM stated that these "declining populations trends are likely to continue" without changes in management (BLM 1992, p. 6). Yet BLM has not changed its management.

Sage grouse are undergoing a "range collapse" – a "rapid contraction[] of [a] once widespread species to one or a small number of isolated sites (Brown, et al. 1996, p. 612). This process is highly advanced in the Gunnison species. * * * Range collapse present in all sage grouse taxa is "distinct from the incremental expansions and contractions" that normally occur at the edges of the range for most vertebrates (Brown, et al. 1996, p. 612). Additionally, the perimeter to area ratio of the range is increasing in sage grouse (see Schroeder 2000a). In most species, the perimeter to area ratio of the range is nearly constant (Rapoport 1982; Brown, et al. 1996, p. 608). This change in perimeter to area ratios is driven by fragmentation and greatly decreases population viability. Many inhabited areas of the range have been split from the intact range and populations in those areas have gone extinct. Other inhabited areas have been separated from the intact range more recently, but sage grouse are likely to be extirpated in these areas soon. Holes and long "fingers" or invaginations have opened up in the range causing disjunct populations that are ripe for extinction. The process in which these finger-like areas are created from formerly intact habitat has been termed "habitat shredding" (Feinsinger 1997). In such long, linear areas, edge effects and interactions with the components of adjacent areas are of paramount concern (Forman and Godron 1986). Both the finger formation process and gap formation from perforation of the landscape matrix by holes are well-known stages in fragmentation processes (Meffe and Carroll 1997, p. 278). Importantly, there are "no source populations of sage grouse" anywhere within the range, and "all studied populations of sage grouse have been in decline for at least 40-50 years" (Braun 2000e). Worse, experts "know of no sage grouse range expansion anywhere, ever" (Braun 2001b). An Idaho Fish and Game biologist echoes this assessment: "There are no areas over the range of sage grouse that have shown a population increase or even stable populations over the last 30 years" (Reese 1998). Thus, the range consists solely of population sinks, which will perish as dispersal is reduced.

Even within their existing range, numbers have declined dramatically and these declines

are ongoing (Braun 1998a; Connelly and Braun 1997; Wisdom, et al. 1998). Populations are now disjunct, sporadic in occurrence, and thinly distributed across the landscape. Braun (1993) considered birds remaining in North Dakota, South Dakota, California, Colorado, Utah, Washington, Alberta and Saskatchewan to be "marginal" or "greatly reduced." For continuity, some present day extirpations and population declines are noted above, under relevant sub-sections of the Historic Range and Early Accounts sections.

Population Isolation

Of particular import for the assessment of population size, and hence viability, is the degree to which panmixis occurs across the landscape. If birds interbreed only between leks or small clustered groups of leks, then actual population sizes will be quite small. Various authors, particularly state and federal agency employees, have referred to the aggregate estimate of birds in an entire state as a "population." Although a tempting shorthand, there are no data to show that sage grouse do in fact form biological populations across an entire state. The use of the term population should be restricted to its biological meaning, otherwise, an overly optimistic misunderstanding of population viability is promoted, increasing the risk of extinction.

Many authors have found that hens are more likely to move between leks, while males are very site specific. Wallestad and Schladweiler (1974) observed complexes of leks and found that daytime movements were restricted to 0.8 to 1.1 miles from the strutting grounds. Of these movements, 82% exceeded 0.2 miles. Carr (1967b) found a similar pattern, observing that birds did not venture beyond 0.9 miles from the lek. Dominant males rarely move between leks (Johnsgard 1973, p. 164), and Dalke, et al. (1963) reported that in a two year study of 78 banded males and 107 banded females, only 6% of females and 18% of males were even observed present on lekking grounds other than where they were first banded. In the 2 year study, Dalke, et al. (1963) found that sage grouse showed great fidelity from the first year to the second year to the lek complex, but not to the lek itself. This suggests that unless lek complexes are adjacent to each other, the maximum size of sage grouse populations will be determined by the extent of the lek complex. Even this may overstate population sizes: in a previous study, Dalke, et al. (1960) found that 70% of banded birds did not change from one strutting ground to another, even over a several year period.

Sage grouse are unlikely to cross more than 6 to 8 miles of unsuitable habitat (NWEA 1999, p. 26; citing Braun, personal communication, and Connelly, personal communication). Even though they are capable of long distance movements, sage grouse "avoid[] areas without sagebrush cover" (Dunn and Braun 1986a). Since many landscape features such as roads, powerlines, reservoirs, and agricultural fields now subdivide sage grouse habitat, it is highly likely that the range now consists of a large number of isolated populations, rather than a large panmictic population or even a well-connected meta-population. The implications for extinction risk are enormous.

The best available scientific data indicate that sage grouse will tend to be isolated into separate populations unless continuous lek complexes occur across the landscape with no gaps exceeding about 2 miles. The type of gap will likely be important: degraded sagebrush habitat will no doubt be less of a barrier to movement, and hence gene flow, than expanses of agricultural fields, grasslands without shrubs, or powerlines. Johnsgard (1973) thought movements between leks to be rare.

Matings, and production of viable offspring would likely be much lower than these movement rates. Such movements, even if accompanied by matings, would not constitute

effective levels of gene flow unless impregnated females were able to raise viable offspring who could prevail during all life history stages and raise viable young themselves.

The fact that it is the young, inexperienced birds that are most likely to appear at multiple leks indicates that gene flow is probably small among different leks. These are precisely the males who are least likely to obtain matings, and the females who are least likely to successfully raise broods if they are mated. Moreover, if the sexual selection in this species is related to functional life history characteristics such as overwinter survival ability, ability to evade predators, and the like, then younger females or females mated by younger males that raise broods to maturity will still have lower fitness than more experienced females or those mated by more experienced males. Moreover, neither experienced males or experienced females show much movement among leks.

As with the movements among leks, yearlings are also the life history category that disperses the greatest distance (Dunn and Braun 1985). Females are more likely to disperse longer distances than are males, with yearling females being the life history category that disperses the longest distances (Dunn and Braun 1985). The fact that long movements are typically undertaken by reproductively naïve individuals increases the isolation of populations and creates much greater risk of extirpation. Sage grouse less than 2 years of age are less successful at hatching clutches and raising young than are older females (Braun 1995d, p. 2). Moreover, if sub-dominant birds are the major source of gene flow among demes, then the alleles that are introduced into these small sub-populations may well be deleterious ones, thus depressing mean population fitness and increasing the risk of extinction.

Habitat

Sage grouse are completely dependent on sagebrush-dominated habitats (Benson, et al. 1991). Sagebrush ecosystems are a little-loved landscape and have not received conservation interest in the past. Consequently, livestock grazing interests and other "special interest groups have successfully pressured government agencies" to alter and degrade these ecosytems to the detriment of wildlife (Braun, et al. 1976). Many managers of the public lands have perceived these ecosystems to have "little value" (Braun, et al. 1976), making such co-optation even easier. Habitats at low elevations, in more southerly latitudes, and more arid environments have been most damaged over the last century, and many are now uninhabitable (Schroeder 2001a).

Sage grouse habitat needs vary somewhat with life history stage and, consequently, with seasonality. Braun (2001f) recently summarized these requirements. Sagebrush is a crucial component of the diet year-round (Johnsgard 1983). The range of the sage grouse contains about 12 species of sagebrush, many of which have numerous sub-species. When selecting cover, sage grouse rely almost exclusively on sagebrush (Johnsgard 1983, Howard 1996). Both federal and state agencies agree that declines in the abundance and range of sage grouse "relate to habitat loss, habitat degradation, and habitat fragmentation" (MOU 1995). Sage grouse habitat and cover requirements are inseparably tied to sagebrush, but sage grouse also require abundant forb cover. Before Euro-American colonization of the West, natural shrub-steppe "was probably composed of open stands of shrubs with a strong component of grasses and forbs in the understory" (Miller, et al. 1993, p. 115). Over 50% of sage grouse habitat has been eliminated (Patterson 1952c, p. 12). Moreover, there are no known areas of habitat that have not been degraded or destroyed by conversion to other uses, livestock operations, or "rangeland treatments" (Braun 1998a). Reduction or elimination of grasses, cryptogamic crusts, and forb cover by livestock has deprived sage grouse of food and cover, and led to increased densities of sagebrush and juniper

invasion (Tisdale and Hironaka 1981).

Although habitats shift with seasonal resources and aridity, generally speaking the best soils, best vegetation, and most critical habitat were in fertile valley bottoms with slopes of less than 10% (Cadwell, et al. 1997; Livingston 1998). These were the areas that were most rapidly converted to agricultural uses and are now often in private hands. In the Columbia Plateau of Oregon and Washington "agricultural conversion has been concentrated" in these "areas of deep, arable soils" (Altman and Holmes 2000, p. 11), and the remaining valley bottom lands are the second most impacted ecosystem type in the region (Altman and Holmes 2000, p. 4-5, 8).

Sagebrush with more than about 30% canopy cover may cause reduction in forb cover due to competition (GBCP 1997, p. 40). This may be of particular concern in the Gunnison Basin because grasses and forbs are under-represented in a large proportion of the sagebrush areas of the Gunnison Basin (GBCP 1997, p. 39). Management recommendations for sage grouse habitat are presented in several sources (Call 1979, Gunnison Basin Sage Grouse Conservation Plan, GBCP 1997, Appendix E), and by the Western States Sage Grouse Technical Committee (WSSGTC 1999). However, the conventional measures and derived indices of habitat suitability in those sources do not include many threats associated with landscape features, such as fragmentation, edge effects, or movement corridors (Schroeder 1998a). Worse, the guidelines are not based on purely scientific criteria; instead, they result from a politicized process in which a "series of compromises" were made to reduce specificity and get various state governments to sign on (Braun 2001a).

Sage grouse occur at elevations from 1,200 m to 2,400 m in Oregon, and above 600 m in Washington. In Colorado, the birds occur up to 2,900 m (9,500 ft.). Elevation, per se, is unlikely to be a limiting factor in sage grouse distribution; instead, the presence of suitable habitat is likely set by such factors as elevation, soil moisture, and temperature, with grouse distribution a concomitant of sagebrush distribution.

Historically, shrubs dominated the Intermountain West below tree line, and true grasslands were limited to moist valley bottoms, riverine areas, and some hillsides (Vale 1975). Sagebrush extended from somewhere between Casper and Ft. Laramie, Wyoming in a nearly unbroken sea to the slopes of the Cascades in central Oregon (Vale 1975). Sagebrush shrub-steppe is a structurally simple habitat (Bendell 1972a, Dasmann 1981). And, at least before the era of Euro-American settlement, that habitat occurred in large blocks (Rich 1985a, Fig. 1; Leopold 1933). Sagebrush shrub-steppe habitat has now been severely fragmented. Loss of habitat by conversion to agriculture and habitat degradation has been "severe" and "the future for remaining sagebrush steppe in particular is bleak" (Paige and Ritter 1999). Welch (draft manuscript, Ch. II, p. 12-14) reviews the degradation and destruction of habitat by land managers under the aegis of "vegetation control," comments on the problems, and summarizes recommendations. Grazing of livestock has severely degraded most of the remaining sagebrush habitat: 30% is "moderately" grazed ("moderate" means that only "remnants of native herbs" remain), and another 30% has been so heavily grazed that "the native understory [is] replaced by introduced annuals (Paige and Ritter 1999, p. 7; West 1988, 1996).

Ricketts, et al. (1999b) note that 14 of 16 temperate grassland-savanna-shrub habitat types in North America are either in critical danger or are endangered (p. 63, Table 4.2). This includes virtually the entire range of sage grouse, and all of the range is listed as endangered, threatened, or vulnerable (Ricketts, et al. 1999b, Fig. 4.3). Of particular concern for the Wyoming Basin is the impending increase in energy and mineral development (Ricketts, et al. 1999a, 1999b; Sands, et al. 2000). The range of sage grouse contains little intact habitat

(Ricketts, et al. 1999b, Fig. 4.2). Over 80% of this ecosystem type has been "substantially altered" by human activities (Hemstrom, et al. undated, p. 3; West 1999b). Other scientists – including the National Biological Service (now the Biological Resources Div. in the US Geological Survey) – have classified ungrazed sagebrush ecosystems as "critically endangered (> 98% decline)," their most endangered category (Noss, et al. 1995; Noss 1999b). Moreover, little of this region is now ecologically intact (Ricketts, et al. 1999a, Fig. 4.2), and virtually the entire range is threatened by invasive alien plant species (Ricketts, et al. 1999a, Fig. 4.4a, b).

Some habitat types appear to be used at all seasons of the year, and for all life history stages. For example, relatively dense, tall stands of sagebrush are used by all age classes for roosting (Drut 1994). Also, substantial forb and grass cover is required at all life history stages for both food and concealment. This point was recently emphasized by Crawford (1997). Topographically, anecdotal observations suggest that sage grouse prefer areas with good visibility, probably for predator detection. Schmidt (1998) suggested that a topographic break with a depressed swale was preferred.

* * *

O'Connor (1986) has cautioned that it is unsafe to predict bird densities on simple linear, or even monotonic, habitat functions. Moreover, the mere observation that populations are abundant in an area cannot be used to justify an argument that habitat is adequate in that area (Van Horne 1983, O'Connor 1986). It is well known that crowding of individuals into remaining habitat patches occurs as habitat destruction or degradation takes place (Meffe and Carroll 1997, p. 290). Areas with relatively large or dense populations may not be productive habitats; indeed, such areas may be population sinks and may disappear if immigration is interrupted by fragmentation effects (Pulliam 1988). Such areas may also be attractive to individuals, yet not able to survive there because of predation or other effects, thus serving as an "ecological trap" (Gates and Gysel 1978, Ratti and Reese 1988). Thus, investigators may "easily be misled about the habitat requirements of a species" (Pulliam 1988, p. 659). Habitat analyses must include measurements of productivity, not merely density counts. Moreover, temporal fluctuations in environmental factors can change former source habitats into sinks – this is an important concern in areas subject to climatic variation and global warming.

Although nearly all analyses reviewed below assume that habitat selection is an optimizing process, many environmental factors and behavioral cues have changed as a result of anthropogenic effects. In a similar "flat" or 2-dimensional habitat (tall grass prairie), Johnson and Temple (1986) demonstrated that birds failed to select high quality nest habitats. Instead, birds chose habitats yielding lower nest productivity. Because sage grouse occupy similarly flat habitats, it cannot be assumed that they select the best quality habitats, and management actions must not focus only on areas near nests nor on areas that already contain the greatest numbers of birds.

Roosting often takes place on rocky outcrops (Crawford 1960, Dalke, et al. 1963) as well as ravines, stream bottoms, and tall sagebrush (Johnsgard 1983). In winter, sage grouse will burrow into snow (Patterson 1952c; Beck 1977; Hupp 1987d; Back, et al. 1987). Similar behavior is common in other grouse, birds and mammals because the sub-nivean environment is often less harsh than above-snow conditions.

Degradation of habitat is a significant risk factor throughout the range of the species (Braun 1999a, p. 1). The quantity of habitat, which is related to the geographic range, has been reduced so significantly that it too is a significant risk factor throughout the range of the species. Habitat requirements have been synthesized in a number of works (summary in Connelly, et al.

2000e) and simple habitat usage models have also been constructed (Ramsey, et al. 1994).

Beyond the amount and composition of habitat, it is now well known that the pattern in which habitat is arranged across the landscape, the spatial distribution of habitat, is an important factor in extinction rates and dynamics (Shaffer 1997). This issue is discussed more thoroughly in other sections of this review, with a synopsis in the Habitat Fragmentation section and its subsections.

Plant Associations

Sage grouse are obligate residents of the sagebrush (*Artemisia spp*.) ecosystem, usually inhabiting sagebrush-grassland communities. Sage grouse are rarely found far from sagebrush (Drut 1993). Much of what is termed sagebrush-steppe consists of areas where bunch grasses are co-dominant with sagebrush (West 1996). These areas occur mainly in Oregon, Washington, Idaho, Montana, and Wyoming (Paige and Ritter 1999, p. 3, map). Further south, in Nevada, Utah, southern Colorado, and northern New Mexico and Arizona (Paige and Ritter 1999, p. 3, map), sagebrush becomes the sole dominant (West 1996). Rhizomatous grasses occur further east in sage grouse habitat in the Great Plains. This dominance refers to potential natural vegetation – livestock grazing and "vegetation control" have removed most grasses and forbs from huge expanses of landscape. Meadows surrounded by sagebrush may be used as feeding grounds (Johnsgard 1973). All sage grouse are habitat specialists on sagebrush.

A substantial scientific literature exists on sagebrush. A bibliography with over 1,250 citations has been published by Harniss, et al. (1981), and Tisdale and Hironaka (1981) have reviewed much of the sagebrush literature. Numerous more recent references are found in Webb and Salvo (2001). Distribution of sagebrush, juniper, and other shrub and tree species across edaphic gradients is presented in Thompson, et al. (1999). In preparation is a large monograph on sagebrush (Welch, manuscript chapters).

Sage grouse occur across several different climatic zones, two sagebrush ecosystem types (sagebrush steppe and Great Basin sagebrush types), several geographic subdivisions of sagebrush types, and ecosystems with multiple plant associations (Miller and Eddleman 2000, p. 1). For convenience, this review will use the term sagebrush or sagebrush shrub-steppe to refer to the range of sage grouse sagebrush habitat in its entirety, and the more specific terms for the two different sagebrush ecosystem types, or the various plant associations, physiographic regions, cover types or climatic zones as defined in this section. Maps showing the extent of climatic regions, both sagebrush ecosystem types, and the geographic subdivisions of the sagebrush biome are presented in Miller and Eddleman (2000, p. 4-5, figs. 1-2). Wyoming big sagebrush communities are the most extensive and most arid of the sagebrush community types (Miller and Eddleman 2000, p. 21). This community type is "probably in poorer condition across its range than more mesic sagebrush types" (Miller and Eddleman 2000, p. 21). Thus, the most widespread sagebrush type is in the worst condition. Most non-eroded sagebrush steppe soils are Xerolls (drought affected Mollisols) and most sagebrush semi-desert soils are Aridisols (West 2000).

Sagebrush ecosystems may be analogized to forests in their vegetative structure. Sagebrush and other brush species form the canopy and various grasses and forbs from the understory. Two differences exist: grasses often reach into or above the sagebrush canopy, and human caused damage to this ecosystem has mainly been to the understory, rather than to canopy species (as with logging of old growth forests). The most common grasses are wheatgrass (*Agropyron* spp.), an introduced species, various fescues (*Festuca* spp.), bluegrasses (*Poa* spp.),

introduced bromes (*Bromus* spp.), junegrass (*Koeleria* spp.), needlegrasses (*Stipa* spp.), ricegrassses (*Oryzopsis* spp.), and wildrye (*Elymus* spp.). A great variety of forbs (wildflowers) are present, but one species, arrowleaf balsamroot (*Balsamorhiza sagittata*), is widespread and abundant relative to other forbs. Other common forbs include Yarrow (*Achillea* spp.), pussytoes (Antennaria spp.), locoweed (*Astragalus* spp.), larkspur (*Delphinium* spp.), and daisy (*Erigeron* spp.).

The sagebrush steppe ecosystem type harbors about 250 species of terrestrial vertebrates (Sands, et al. 2000). Most of the vertebrate species are birds (100 species) or mammals (70 species) (Braun, et al. 1976). A "vast landscape of agricultural developments and nonnative grasslands" fragments the ranges of most vertebrates that were formerly common and abundant (Sands, et al. 2000, p. 27).

Most of the range of sage grouse was assigned to the Great Basin (11) and Rocky Mountain (19) biogeographic provinces by Udvardy (1975), whose classification scheme subdivided North America into 24 provinces. Sage grouse are associated with the following physiographic regions and plant cover types (Howard 1996):

BLM Physiographic Regions:

4 Sierra Mountains
5 Columbia Plateau
6 Upper Basin and Range
7 Lower Basin and Range
10 Wyoming Basin
11 Southern Rocky Mountains
12 Colorado Plateau
13 Rocky Mountain Piedmont
16 Upper Missouri Basin and Broken Lands

Kuchler Plant Associations:

K024 Juniper steppe woodland
K038 Great Basin sagebrush
K055 Sagebrush steppe
K056 Wheatgrass-needlegrass shrub-steppe

SRM (Rangeland) Cover Types:

107 Western juniper/big sagebrush/bluebunch wheatgrass
314 Big sagebrush-bluebunch wheatgrass
315 Big sagebrush-Idaho fescue
316 Big sagebrush-rough fescue
320 Black sagebrush-bluebunch wheatgrass
321 Black sagebrush-Idaho fescue
324 Three-tip sagebrush-Idaho fescue
405 Black sagebrush
406 Low sagebrush
407 Stiff sagebrush
408 Other sagebrush types
612 Sagebrush-grass

SRM 107 and Kuchler type K024 will not be suitable sage grouse habitat because juniper trees serve as raptor perches. These ecosystem types have expanded into the range of sage grouse. Orians (1993) criticized the lack of a single ecosystem classification scheme for vegetation type mapping; however, that should not be a problem for sage grouse habitat mapping, as sage grouse habitat will include all areas of sufficient size with a sagebrush overstory and with adequate forb and grass understory that do not have threats located in them.

Sage grouse formerly occurred throughout the range of big sagebrush (*A. tridentata*), except on the periphery of big sagebrush distribution or in areas where it had been eliminated (Call and Maser 1985). Three sub-species of big sagebrush dominate the sagebrush zone. These are basin big sagebrush (A. *t. spp. tridentata*), Wyoming big sagebrush (*A. t. ssp. wyomingensis*), and mountain big sagebrush (*A. t. ssp. vaseyana*) (Wright, et al. 1979, p. 2). Sage grouse prefer mountain big sagebrush and Wyoming big sagebrush communities, to basin big sagebrush communities (Cronquist, et al. 1984; Cronquist 1994). In most areas, big sagebrush communities lie at lower elevations than juniper woodlands or pinyon-juniper zones (Wright, et al. 1979, p. 1). Where these tree types are absent, other forests, such as ponderosa pine, curleaf mahogany, Douglas fir, Gambel oak, or lodgepole pine border sagebrush communities at their upper elevational limit (Wright, et al. 1979, p. 1). Pinyon-juniper woodlands often lie below sagebrush communities in the Great Basin (Wright, et al. 1979, p. 1). Sagebrush communities are heavily invaded by juniper and cheatgrass.

Sagebrush cover types other than big sagebrush can fulfill sage grouse habitat requirements. Sage grouse in Antelope Valley, California, for example, use black sagebrush (*A. nova*) cover types more often than the more common big sagebrush cover types (Schneegas 1967). However, it is unclear whether this use of black sagebrush was because nearby big sagebrush areas were degraded or represents a true preference for black sagebrush. Sagebrush communities not included in SRM cover types (Howard 1996) but supporting sage grouse include silver sagebrush (*A. cana*) and fringed sagebrush (*A. frigida*) (Rasmussen, et al. 1938; Wallestad, et al. 1975). Sage grouse use of less common sagebrush communities (i.e., Bigelow sagebrush [*A. bigelovii*]) may occur but is not documented in current literature. Franklin and Dyrness (1973, p. 216-222, 234-242) describe northwestern sagebrush communities.

Estimates of the historical range of sagebrush vary. Beetle (1960) mapped big sagebrush, and estimated its original extent as 79.3 million hectares (ha), which equals 196 million acres, and the range of all sagebrush species as 109 million ha (269 million acres). Campbell and Harris (1977) estimated that big sagebrush (*Artemisia tridentata*) originally dominated over 36.4 million hectares, and Miller, et al. (1986) estimated that in the 1980's it dominated 36.5 million hectares. Some authors have suggested that sagebrush has expanded, but those who have examined this assertion closely disagree, believing instead that sagebrush range has contracted (Welch 1999). Rephotography projects, which compare photographs from the 1800's with those taken from approximately the same vantage points in the late 20th Century, do not show any significant expansion of sagebrush (Klett 1984). Instead, rephotograhic analyses show increased mining development (Klett 1984, p. 16), juniper incursion (Klett 1984, p. 16, 138), reservoirs (Klett 1984, p. 54-55, 106, 107), ORV tracks and roads (Klett 1984, p. 94, 102, 121, 154-155), suburban developments (Klett 1984, p. 98-99), fencing (Klett 1984, p. 103, 136, 137), utility poles (Klett 1984, p. 104), and habitat conversion (Klett 1984, p. 128, 129). These analyses thus graphically depict many of the threats to sage grouse that have been erected during Euro-American settlement (Klett 1984).

Livestock grazing has been suggested as an agent in increasing sagebrush range, but more recent studies show that this is not supported (Peterson 1995). Similarly, Vale (1975) found no increase in sagebrush range. "If anything, the rate at which sagebrush lands are lost is increasing in recent years" (Knick 1998). Moreover, declines in sagebrush may be masked by expansion of juniper/sagebrush associations (Altman and Holmes 2000, p. 39). Miller, et al. (1993, p. 102, Fig. 1) present a map of sagebrush steppe and Great Basin sagebrush semi-desert, and cite Kuchler (1970a) for areas of 44.8 million ha and 17.6 million ha respectively (totaling 62.4 million ha). Miller and Eddleman (2000, p. 2) cite West (1983a, 1983b) for a similar figure, 62.7 million ha. Another range map of sagebrush is presented in Nelson and Tiernan (1983, Fig. 1), but does not show the topographically induced fragmentation of sagebrush range in Nevada. Comparison of the range map of Nelson and Tiernan (1983) with that of Miller, et al. (1993) shows that sagebrush has been extirpated from nearly all of eastern and central Montana, from most of eastern and northeastern Wyoming, Nebraska and the Dakotas, from northern Washington and from central and northeastern Oregon, and has retracted eastward from parts of California.

A number of vegetation classifications have been offered for sagebrush ecosystems. McArthur and Ott (1996) favored the Kuchler (1964a, 1964b, 1970a, 1970b) classification over Bailey's because the Kuchler approach defines vegetation types on a finer scale. Kuchler's classification scheme remains the only assessment of major above-ground ecosystem diversity describing the entire United States in reasonable detail (Crumpacker, et al. 1988), although that may change in a few years. The amount of land in the two sagebrush dominated Kuchler associations was quantified by McArthur and Ott (1996) and West (1983a, 1983b) for each state. Crumpacker, et al. (1988, p. 111) present a breakdown for various federal land management agencies – not surprisingly, BLM manages 75% to 83% of sage grouse potential habitat and USFS manages about 9%. USGS employees believe that Kuchler's (1964a) map "probably represents the best approximation available today of the continent's vegetation before European settlement" (Loveland and Hutcheson 1995).

Importantly, Kuchler's classification and others are based on potential natural vegetation, not on the actual vegetation present currently. Kuchler's map thus does not delineate original from natural vegetation or include disclimax communities formed by disturbance effects (Loveland and Hutcheson 1995). Kuchler's map and other similar ones are thus "little more than informed guess as to what might be" present as vegetative communities on the ground (Scott, et al. 1987; Botkin, et al. 1984). Potential vegetation is "far removed from what actually occurs on an area" currently and "provides little guidance" as to habitat quality and biodiversity protection (Scott, et al. 1989, p. 85). Perhaps the first comparison between Kuchler's potential natural vegetation and extant plant communities was that of Klopatek, et al. (1979), which used data valid to 1967.

Remote sensing has also been used to estimate extant vegetation types and land uses. The most recent coarse level vegetation maps are from a 1990 USGS dataset, interpreted from the Advanced Very High Resolution Radiometer; however, radiometry data are nonetheless quite coarse (Loveland and Hutcheson 1995). That study did not include urban areas, but urbanization data are available from the Defense Mapping Agency (Loveland and Hutcheson 1995). Other classification schemes have been developed, for example the USFS's ecoregions (Bailey 1976), and the Nature Conservancy's National Vegetation Classification System (M. Anderson, et al. 1998; Grossman, et al. 1998), which uses a hierarchical classification system with over 4,100 plant associations, recognized at the lowest level of hierarchy. However, remote sensing is

unlikely to be able to resolve the degree of degradation of sage grouse habitat, particularly in the understory grasses and forbs that are so critical for reproduction and predator evasion.

For sage grouse habitat analysis, the area dominated by sagebrush is less important than fragmentation effects, and amount of area containing sufficient sagebrush, forbs, and grasses for good habitat. Proximity analysis (termed adjacency analysis by Mladenoff 1997) is also important – areas without sagebrush are used for feeding so long as they are near enough to sagebrush (or perhaps other bush types), which can function as cover for escape from predators. Such analyses are easily done using GIS (ASPRS/ACSM/RT 1992). Conversely, sagebrush dominated areas will not be adequate habitat if they contain juniper, pinyon, or other trees serving as raptor perches. In parts of Colorado, habitat has been invaded by Gambel oak (*Quercus gambelli*) (Commons 1997). Virtually all scientists working on sage grouse agree that habitat has greatly contracted, and has become increasingly fragmented (discussed further below).

Winter Habitat

Winter habitat is often the most limited seasonal habitat needed by sage grouse (Patterson 1952c, Eng and Schladweiler 1972, Beck 1977). The best winter habitat is below snowline, on flat or gently sloping south or west facing areas, where sagebrush is available all winter (Edminster 1954, Rogers 1964, Schneegas 1967, Jarvis 1974, Beck 1977, Autenrieth 1981, Martin 1976, Hupp and Braun 1989b). However, these are precisely the areas threatened by habitat conversion or already converted to agricultural fields (Miller and Eddleman 2000, p. 20). Moreover, in some areas only half the land surface is usable by sage grouse because of snow depth, slope, or disturbance to sagebrush (Beck 1977). Snows can drastically reduce available habitat. Wallestad noted that 12" of snow restricted sage grouse to only 7% of their winter habitat (Eustace 1995), and Beck (1977) found that the birds were restricted to less than 10% of available habitat.

Birds exist exclusively on sagebrush during the winter, and it is relatively nutritious (Edminster 1954; Welch, draft manuscript, ch. II). Tetraonids may select for winter foods on the basis of secondary plant defensive compounds rather than proximal nutritional content (Bryant and Kuropat 1980). Birds typically forage in the tallest sagebrush (over 25 cm high) with the greatest canopy cover (more than 15%) (Wallestad and Schladweiler 1974, Beck 1977, Autenrieth 1981, Schoenberg 1982). Herein are reported the findings of primary research as given by the original authors, usually wildlife biologists. Some cover measures appear unusually large and may have been obtained using different methodologies than are typically used by plant ecologists. Dalke, et al. (1963) reported that wintering grounds of sage grouse in Idaho were usually located where snow accumulation was less than 6 inches (15 cm). Deep snow restricts the use of various areas and sage grouse winter where sagebrush has grown above the snow level (Dalke, et al. 1963; Autenrieth, et al. 1982; Hupp and Braun 1989b). As snow begins to accumulate, sage grouse are restricted to areas that support taller, denser sagebrush stands, such as south facing slopes. Damage or removal of sagebrush in such areas could severely impact all sage grouse populations because other areas may be buried by snow. These concerns apply to all sage grouse and have been raised in particular for Gunnison sage grouse in the Gunnison Basin (GBCP 1997, p. 40). Adequate winter habitat is also unavailable for Gunnison sage grouse in parts of the San Miguel Basin (SMBCP 1998, p. 4).

Snow cover that exceeds one foot in depth tends to force sage grouse into areas with taller sagebrush (> 16 inches) in valleys and lower elevation flat areas, and roost in shorter

sagebrush along ridge tops (GBCP 1997, p. 4). In periods of extreme cold and deep snow, sage grouse often spend the night and portions of the day burrowed into snow drifts (GBCP 1997, p. 4-5).

Flock sizes in winter vary widely from 15 to over 100 birds, and flocks are often unisexual (GBCP 1997, p. 5). Flocks of males tend to be smaller than those of females. By early March, flocks are usually found within 2 to 3 miles of breeding areas (GBCP 1997, p. 5).

In winter and throughout the year, sage grouse select areas of little or no slope. Autenrieth (1986) found that birds selected areas of less than 15% slope. In a Colorado study of an area of 500 square miles (1,252 km^2) of sagebrush, nearly 80 percent of sage grouse winter use was on less than 35 square miles (87 km^2): on flat areas where sagebrush projected above the snow, or on south- or west-facing sites of less than 5 percent slope, where sagebrush was sometimes quite short but still accessible (Johnsgard 1983, Howard 1996). In Montana, during a winter with light snow cover, wintering areas were large flat expanses of dense sagebrush (Eng, et al. 1973). One study found that sage grouse selected wintering areas with slopes greater than 5 degrees, probably because of the severe winter with greater than average snow depths occurring in that study (Hupp 1987b).

Winter home ranges of 5 females in Montana varied from 2,615 to 7,760 acres (1,058-3,140 ha) during two different years (Eng, et al. 1973). Robertson (1991) found winter home ranges exceeding 140 km^2 (53 $mile^2$).

Beck (1977) and Schoenberg (1982) found that birds used only 10% of winter areas selectively. Such high concentrations of birds exposes them to both predators and disease transmission, and points up the greatly reduced amount of habitat available (Drut 1994). Birds select wintering areas with about 20% sagebrush canopy cover (Eng and Schladweiler 1972; Wallestad 1975a; Braun, et al. 1977; Autenrieth 1986). Aspect has also been found important for wintering areas, with birds selecting south or west facing slopes (Autenrieth 1986, Hupp and Braun 1989b). In years with heavier snow cover, most feeding activity occurs in drainages, or on south or west facing slopes (Hupp and Braun 1989b).

Availability of preferred food plants is also a factor determining winter habitat requirements (Hupp and Braun 1989b). Edelmann, et al. (1998) reviewed the literature and summarized plant characteristics for optimal wintering habitat as: 20-50% sagebrush canopy cover, 40-60 cm sagebrush height, and 0-4.5% slope. The probability of juvenile survival drops sharply outside these optima (Edelmann, et al. 1998, Fig. 5).

Inadequate winter habitat cover or winter food will reduce lipid reserves in male sage grouse (Hupp and Braun 1989a). Mating displays by males (Vehrencamp, et al. 1989), as well as egg formation and nesting activities by females are energetically demanding activities. The instantaneous energetic costs of male display (13.9 to 17.4 times basal metabolic rate) are as expensive as is flight (Rayner 1982), and thus lie at the upper extreme of the energy output that birds are capable of (sometimes termed metabolic scope) (Webb 1990). In fact, display costs are so high that they sometimes conflict with thermoregulatory expenditures (Bradbury, et al. 1989b).

Thus, breeding activities could be affected by winter habitat degradation, even if the reduction in lipid reserves was too small to affect individual survival. Because of the lekking habit and extreme degree of mate selection, this could have potent consequences for extinction risk of affected populations. Because the timing of lipid reserves, and not merely their size, is believed to be under strong selection, temporary disruption to winter foraging could affect populations, even if those lipid reserves were normal at other times (Hupp and Braun 1989a;

King 1972).

Loss or reduced availability of winter habitat can have disproportionately large impacts on sage grouse over large areas because it can directly reduce population size in the next breeding season (Sands, et al. 2000, p. 27). Area effects can be especially important in winter, where episodic temporal events, seasonal events and spatial limitations combine. Hupp and Braun (1989b) reported that during the severe winter of 1984, only 7% of the 1,600 km^2 of sagebrush vegetation was available to sage grouse, primarily located in drainages. This reduction in foraging area significantly affected reproductive condition (Hupp and Braun 1989b). Unfortunately, much sagebrush removal effort is concentrated in these same drainages (Hupp and Braun 1989b). Such sagebrush removal can easily endanger the bird, even though no effects would be seen in normal winters. Beside the total amount of area available to wintering birds, fragmentation of winter habitat can cause wind penetration into those fragments (Geiger 1965), and would be an especially severe problem for wintering birds by causing hypothermia or forcing them to raise their metabolic rate for thermogenesis (Sherfy and Pekins 1995). Sage grouse are not often seen in degraded areas of winter habitat, indicating that the birds avoid such areas (Beck 1977).

The combination of such episodic temporal events, together with seasonal events and spatial limitations must be considered in determining the degree of extinction risk for sage grouse populations – a severe winter, combined with restricted or degraded foraging areas could cause sage grouse populations to go extinct so rapidly that they would appear to evaporate from the landscape.

Lek Habitat

Open areas such as swales, irrigated fields, meadows, burns, and roadsides and barren areas or areas with low, sparse sagebrush cover are used as leks (Klebenow 1972; Ellis, et al. 1989; Klott and Lindzey 1989). Visibility on the lek itself is important for observation of male display, and visibility surrounding the lek is important for predator evasion (Gill 1965a, 1965b; Wiley 1973a). Sage grouse have tremendous site fidelity to lekking grounds and have been reported to use gravel pits, bare openings in sagebrush, wheat stubble, salt licks, remote air strips, bare exposed ridges, paved roads, knolls, dry lake beds, and the airport runways at Riverton and Jackson, Wyoming as leks (Connelly, et al. 1981; Welch, et al. 1990; Patterson 1952c, p. 280). Connelly aphorized the extreme lek fidelity of sage grouse by noting that some leks "have been used since God was a child" and J. R. Young noted that males continued to use a lek site even after a reservoir flooded the area – strutting on the bare ice, even though they were dangerously exposed to predators (Weidensaul 2001).

Of 45 leks, Patterson (1952c) reported that 11 were on windswept ridges or exposed knolls, 10 were in flat sagebrush, 7 were in bare openings, and the remaining 17 were on various other site types. In the Gunnison Basin, leks were located near river valleys Hupp (1987b, p. 56). Leks are often located near water, although water is not necessary on the lek (Call 1979). Leks are usually located on flat or gently sloping sites (Eberhardt and Hoffmann 1991, Cadwell, et al. 1994).

Leks are usually surrounded by areas with 20 to 50 percent sagebrush cover, with sagebrush no more than 1 foot (30 cm) tall (Klebenow 1972; Ellis, et al. 1989; Klott and Lindzey 1989). Nearby sagebrush for escape cover is of particular importance for leks (Welch, draft manuscript, Ch. II, p. 12). If forced to do so, sage grouse will use lek areas that lack surrounding cover – in Washington, numerous active leks exist that do not have surrounding escape cover

(Tirhi 1995 citing Schroeder, personal communication). Apparently, no comparisons of losses to predators on such leks have been made to leks with predator escape cover. Some known leks have become inactive, apparently because of the lack of nearby sagebrush habitat (SMBCP 1998, p. 4). Sage grouse need relatively tall (> 12") sagebrush near the leks (within 200 m) for cover. Such nearby shrub areas are used by males for foraging, shelter, and loafing and are usually within 1 km of the lek (Rothenmaier 1979, Emmons and Braun 1984, Autenrieth 1981). Areas near the lek with good forb and grass cover, shrub heights from 18 to 38 cm tall, and canopy cover of 20% to 50% are selected by males (Call and Maser 1985, Rothenmaier 1979).

When not on the lek, sage grouse disperse to the surrounding areas (Wallestad 1975a). Some females may travel between leks. In Mono County, California, the home range of marked females during 1 month of the breeding season was 750 to 875 acres (303 to 354 ha), enough area to include several active leks (Bradbury, et al. 1989a). Gibson and Bradbury (1986) noted that prior to nesting, females may range over areas 1,000 hectares per month. Schroeder, et al. (1999a, p. 4) note that there is "no evidence that lek habitat is limiting." Such conclusions are not new. Roberson (1986) reviewed habitat relations and found that nesting, brooding, and male-feeding and loafing habitats, as well as their spatial arrangement, were more important than lek habitat. Yet, BLM and other land management agencies put great emphasis on lek area management, "improvement," and creation (see "Management on Bureau of Land Management (BLM) Lands" section, below). If these analyses are true, then these management actions are unwarranted and a waste of agency resources. Instead, both males and females may require vast areas for foraging during the lekking time period in order to forage and store energy and nutrients.

Nesting Habitat

Sage grouse prefer relatively tall sagebrush with an open canopy for nesting. In Utah, 33 percent of 161 nests were under silver sagebrush (*Artemisia cana*) that was 14 to 25 inches (36-63.5 cm) tall, while big sagebrush of the same height accounted for 24 percent of nests (Rasmussen, et al. 1938). Sagebrush plants are preferred for nesting, and nests placed under sagebrush plants are more successful than nest placed under other bushes (Connelly, et al. 1991a, 1991b). In a three-tip sagebrush (*A. tripartata*) habitat averaging 8 inches (20 cm) in height, hens selected the tallest plants for nesting cover. No nests occurred where three-tip sagebrush cover exceeded 35 percent. Similarly, Patterson (1952c) reported that in Wyoming, 92% of sage grouse nests in Wyoming big sagebrush were in areas where vegetation was 10 to 20 inches (25-51 cm) tall and cover did not exceed 50 percent. In Idaho no hens nested in areas with less than 10 percent sagebrush cover or where sagebrush cover was greater than 25 percent (Klebenow 1972). Nest success at nest sites without sagebrush was less than half that of nests located under sagebrush (Connelly, et al. 1993). Hens also select nest sites with taller grass cover – over 18 cm in height (Connelly, et al. 1991a, 1991b; Gregg, et al. 1994). Nest predation is much greater at nests that lack grass cover, and this difference is highly significant statistically (Crawford and Delong 1993).

Klebenow (1982) found that sage grouse inhabited meadow sites with effective cover heights ranging from 7-16 cm, dependant on what was available. Dense grassy meadows that were grazed lightly or moderately were attractive to sage grouse. They avoided heavily grazed meadows in poor condition, with few grasses or forbs and dense, shrubby vegetation (Klebenow 1982). In areas where both three-tip sagebrush and big sagebrush were available, nests were typically associated with three-tip sagebrush (Klebenow 1969).

The quality of nesting habitat surrounding the lek is the single most important factor in population success (Autenrieth 1986). Where a 35% sagebrush canopy and 60 cm height are combined with residual herbaceous cover, the probability of predation is significantly reduced. As Crawford noted, herbaceous cover should be residual (i.e. left over from the previous growing season) because sage grouse initiate nests before the growing season for most grasses and forbs (Heath, et al. 1996a, p. 3, citing Crawford during discussion). The percentage of successfully nesting hens and the juvenile to adult females ratios are significantly higher in areas with robust shrub-grass production and where forbs are a common component of the spring range (Autenrieth 1986). Wallestad and Pyrah (1974, p. 632) found that successful nest had significantly greater sagebrush cover within 24 inches (60 cm) of the nest than did unsuccessful nests.

Both dense sagebrush and a healthy understory of grass cover are important components of nest habitat: shrub cover provides shading from the hot rays of the sun at midday and obscures the view of aerial, visually hunting predators such as corvids and raptors (Webb 1993b), while grass cover prevents wind penetration into the nest environment (Webb 1993b) during cold periods and obscures the view of visually hunting ground predators such as fox and coyotes (Webb 1993b; Tirhi 1995 citing Schroeder, personal communication). The sensory ecology of olfaction is poorly understood, but grass cover probably reduces the amount of odors from the nest that waft downwind, retaining them in the boundary layer.

The amount of grass cover surrounding a nest and the height of that cover (more than 18 cm) are crucial in determining predation rates (Crawford, et al. 1992). On Hart Mountain National Antelope Refuge, Crawford and Delong (1993) found nest depredation rates of 73%, and nesting success rates of only 20%. Several studies show that shrub height and grass cover surrounding the nest significantly reduce predation. Crawford and Delong (1993) found that nests placed in grass taller than 15 cm and shrubs ranging in height from 40 to 80 cm had the lowest predation rates, and Gregg, et al. (1994) confirmed these results in an independent study, finding that greater grass canopy cover (18% vs. 5%) and greater shrub cover (41% vs. 29%) were correlated with lower nest depredation rates. DeLong, et al. (1995) obtained the same result using artificial nests. For sage grouse in Washington, Cadwell, et al. (1997); Sveum, et al. (1998a) and Sveum, et al. (1998b) found greater nest success on the YTC where grass and shrub cover was higher. Lower nest success was directly linked to nest predation (Sveum, et al. 1998b). [F]emale [*grouse*] in Washington nested in areas with medium to very high sagebrush canopy cover (20%) and grass canopy cover (51%) (Schroeder 1994b, Sveum, et al. 1998b). It is clear that reductions in shrub cover by plowing, fire, grazing, or spraying cause reduced nest success (summarized by Schroeder, et al. 1999a). Grazing by domestic livestock is the primary land management practice affecting grass cover and height (Rickard, et al. 1975).

Even after complete cessation of grazing, grass and forb cover may not increase for years. Crawford and Delong (1993) attributed the lack of response of grass cover following cessation of grazing to the lag time in the response of vegetation to removal of grazing livestock, drought conditions, and possible competition from shrubs in limiting the establishment of new herbaceous seedlings.

Edelmann, et al. (1998) reviewed the literature and summarized plant characteristics for optimal nesting habitat as: 25-35% sagebrush canopy cover, 40-50 cm sagebrush height, 25-35% residual herbaceous cover, and 0-5% slope. The probability of a successful nest drops sharply outside these optima (Edelmann, et al. 1998, Fig. 3).

The amount and distribution of nesting habitat appears to be a limiting factor for sage grouse

in the Gunnison Basin (GBCP 1997, p. 39). Nest sites in the Gunnison Basin are in taller (> 20 inches), more dense (> 25% canopy cover) areas of sagebrush than average, and have an abundance of forbs and grasses (GBCP 1997, p. 3). Residual forbs and grasses remaining from the previous season are important because females nest in mid to late April, before most herbaceous plants in the Gunnison Basin begin growing (GBCP 1997, p. 3). Sage grouse are particularly susceptible to loss of nesting habitat because they show very strong nest site fidelity (Fischer, et al. 1993a, 1993b). In recapture studies, the mean distance between nests in different years was only 550m to 680m (Berry and Eng 1985, Lyon 2000, p. 21). This is remarkable, when one considers that hundreds or thousands of square miles are available as nesting habitat.

Unfortunately, land managers often desire conditions that are directly at odds with successful sage grouse nesting. Phillips (1972) expressed a desire for sagebrush cover of 12% to 15%, but sage grouse require sagebrush cover of 20% to 50% for nesting (see below; also Welch, draft manuscript, ch. II, and Braun, et al. 1977).

Aspect and Slope

Musil (1989) found that sage grouse chose sites for nesting that had flatter slopes rather than nearby sites.

Nesting Distance from Lek

Hens often nest near the lekking grounds (Schlatterer 1960), but some hens have been noted to fly as far as 12 to 20 miles (19-32 km) to favorable nesting sites (Gill 1966a, 1966b; Rogers 1964). Wallestad and Pyrah (1974) reported that the hens traveled on average, 1.5 to 1.7 miles from the strutting grounds to their chosen nesting site. Wallestad and Pyrah (1974) found that 68% of all nests occurred within 1.5 mile of the lek (mean = 1.5 mi for adults, 1.7 mi for yearlings). Only one nest was within 1 km of the lek. Most hens moved into a relatively small area and stayed fairly sedentary until nesting. In Colorado, females regularly moved 3 to 4 miles from a lek to nest, and were observed to move as much as 7 miles away (Johnsgard 1973, p. 165, citing T. May, 1970). In some cases, nests are placed over 20 km from a lek (Schroeder 2000b). The percentage of nests that are within 3 km of a nest varies dramatically, and is often low: estimates range from 91% (Wakkinen 1990) to 55% (Autenrieth 1981), down to 20% (Hanf, et al. 1994) and as low as 15% (Schroeder, et al. 1999a, p. 17). Estimates of nests within an annulus of any given size may be methodically inflated, as the closest areas to a lek are smaller and easier to search thoroughly than are the larger areas at increasing radii from a lek. Habitat guidelines that protect only a few km within a lek site are inadequate, and this has been known for years (Wakkinen, et al. 1992b).

In general, it will not be possible to adequately protect sage grouse nesting habitat by simply restoring habitat within a 2-3 mile radius of a lek site; instead, habitat within 20-30 miles of a lek site must be restored – and perhaps more, as radio telemetry studies cannot yet locate birds at great distances from the receiver. Oddly, a number of Environmental Impact Statements (EISs) and Environmental Assessments (EAs) have analyzed impacts on sage grouse solely in terms of nesting and lekking habitat. This is completely inappropriate. Sage grouse need habitat to carry out all of their life-history stages.

Nesting Distance to Other Habitat Components

Autenrieth (1986) found no relationship to proximity of water, meadows, or a brood food source such as anthills.

Feeding and Roosting Habitat in the Nesting Season

During the nesting season, cocks and hens without nests use relatively open areas for

feeding, and roost in dense patches of sagebrush (Klebenow 1969, 1972).

Edge Effects

Musil (1989) found that sage grouse selected nest sites farther from habitat edges, with more litter cover, less bare ground, and a greater density of mountain big sagebrush than in nearby areas. The probability that a site would be used as a nest site increased as the distance from habitat edge and the density of mountain big sagebrush increased.

Creation of edge greatly increases predation. Construction of linear facilities (such as pipelines, fences, roads, and powerlines) and the concomitant clearing of long swaths of land, is a major generator of edge habitats, which are favored by many predators on sage grouse.

Brooding Habitat

Brooding habitat requires relatively open canopy cover and abundant insect prey and forbs in close proximity to denser sagebrush stands for predator escape (Schroeder, et al. 1999a; Braun, undated, b). Brooding sites contain twice the forb cover as surrounding areas (APA 1998, p. 129). Juvenile sage grouse stay mostly in open sagebrush with a forb component through June (Gill 1965a, 1965b; Savage 1969a). As the season progresses, they move to riparian areas and other areas still containing green vegetation, such as meadows and areas associated with permanent and intermittent streams, springs, and seeps. By August, they are often clustered near permanently wet meadows and other such sites (Gill 1965a, 1965b; Savage 1969a, Klebenow 1969). Such riparian areas are of particular importance in dry years, as they may be the only food source for chicks (Miller and Eddleman 2000). Many such riparian areas have been destroyed by water developments for livestock or by conversion to agriculture. Indeed, 95% of the riparian habitats in the West have been altered, degraded, or destroyed (Ohmart 1994). Livestock grazing is the "most insidious threat to riparian habitats (Carothers 1977, p. 3, Ohmart 1994). "Riparian areas have been extensively impacted within the Columbia Plateau such that undisturbed riparian systems are rare" (Altman and Holmes 2000, p. 8; citing Knutson and Naef 1997). Other significant threats include dams, reservoirs, ground water depletion, instream flow reduction, flood control, and river flow and hydrology alteration (Ohmart 1994). BLM found that only 7% of riparian-wetland habitats were meeting management objectives (GAO 1992a). Young sage grouse are highly dependent on riparian and meadow vegetation until after 11 weeks of age (Oakleaf 1970).

High levels of food and shelter provided by forbs, grasses and low sagebrush are key requirements for chick survival (Klebenow 1972, 1985). Broods often make use of open meadows (Bean 1941, Carhart 1942, Eng 1952a, Rogers 1964, Klebenow 1969). For this reason, any effect that causes stream channelization, and reduces the belt of wet forbs and other vegetation that occur at considerable distances from streams, will harm populations at this critical stage. Livestock grazing is a notable cause of stream channelization.

In 158 Montana locations, young broods used areas of low plant height (9 to 15 inches [23-38 cm]) and density, while older broods and adults used areas where plants were taller (7 to 25 inches [18-63.5 cm]) (Martin 1970a). In areas where both three-tip sagebrush and big sagebrush were available, broods were typically associated with big sagebrush (Klebenow 1969). Moreover, birds avoided extremely dense sagebrush stands, where forbs were lacking (Klebenow 1969). Broods moved higher in elevation as the summer progressed, following a gradient of green food plants such as forbs (Klebenow 1969).

Early brood rearing habitat has a relatively open canopy of sagebrush and a fairly low height of sagebrush. Canopy cover was less than 25% in Montana (Wallestad 1975a, Martin

1976), and less than 31% in Idaho (Klebenow 1982), and these sites were primarily associated with feeding. Also in Montana, Peterson (1970b) found canopy cover to be 6% and shrub heights to range from 15 to 30 cm in June, and by August canopy cover was 12% and shrub heights ranged from 30 to 45 cm. Pyrah (1971) found canopy cover was 14% in June and increased to 21% by September. Birds in Oregon used low sagebrush for the first 6 weeks post-hatch, and moved into taller sagebrush (big sagebrush) stands as they matured (Drut 1993; Drut, et al. 1994a).

It is thus reasonable to divide the brooding season and life history stage into the early brooding season and the late brooding season. The key event marking the difference between the two is the diminished availability of forbs for the juveniles. Hens with broods generally remain in upland habitats as long as forbs remain available, then move to more mesic sites (Drut 1994). These movements emphasize the crucial importance of forbs to juvenile sage grouse. In years with greater precipitation, hens delay their movements to mesic areas because forbs remain available longer in the upland sites (Klebenow 1969, 1985; Wallestad 1975a; Autenrieth 1981; Drut 1994). Grazing or other effects that remove or damage forb cover or grass cover damage sage grouse habitat and productivity. This has already occurred over the entire range of the bird (Connelly and Braun 1997; Braun 1998a, 1999a; Paige and Ritter 1999).

Broods require forbs, insects and cover for growth, concealment and shade (Autenrieth 1986; Patterson 1952c). Where these requirements are met at or near the nest site, the brood moves less, reducing exposure to predation and conserving energy (Autenrieth 1986). Birds also use denser areas of sagebrush in late summer when the forbs on preferred habitat are desiccated (Wallestad 1970, p. 25). On dry ranges, however, broods are forced to move to the nearest meadow for attaining their needs. Broods follow moisture gradients to higher elevations (Oakleaf 1971) or move to bottom lands and fields where forbs are more available (Klebenow 1969; Peterson 1970b; Wallestad 1975a; Call and Maser 1985; Connelly, et al. 1988; Sveum, et al. 1998b). Such movements expose the young birds to predators and desiccation, and can deplete their energy reserves. When the birds move to farmed fields, they may become exposed to high levels of pesticides and herbicides, as well as enhanced predation or attacks by domestic dogs and cats. Hens remain near the nest site with their broods until forced to move by desiccation of the vegetation (Gregg, et al. 1993; Connelly, et al. 1988). In wetter years, movements away from the nesting area is delayed (Klebenow 1969, 1985; Wallestad 1975a; Autenrieth 1981). Thus, any activities that cause drying of nesting area vegetation, such as stream channelization by cattle or ground water pumping for livestock "guzzlers," will increase the threats to the birds by forcing the hen to prematurely move her young brood into or through areas with high predation risk.

Upland meadows receive concentrated use in late summer because forbs and water can only be obtained in those areas (May and Poley 1969b, Oakleaf 1971, Schoenberg 1982, Klebenow 1985, Evans 1986). Because water projects and livestock operations have concentrated the areas where forbs and water can be obtained, the birds concentrate in those areas. Unfortunately, this aggregation exposes the birds to predation and disease spread. Birds appear to select for smaller meadows over larger ones (Oakleaf 1971, Drut 1993), again illustrating that predation pressure is a significant effect away from shrub cover.

Edelmann, et al. (1998) reviewed the literature and summarized plant characteristics for optimal brooding habitat as: 15-20% sagebrush canopy cover, 30-40 cm sagebrush height, 30-40% residual herbaceous cover, and 0-5% slope. The probability of brood survival drops sharply outside these optima (Edelmann, et al. 1998, Fig. 4). The authors did not separate early and late

brooding habitat in their analysis.

The importance of wet meadows to sage grouse cannot be over emphasized, and "has been repeatedly demonstrated" throughout the range of both species (GBCP 1997, p. 4). The best and most recent scientific data show that a 200 m band of sagebrush around wet meadows is required by sage grouse (Dunn and Braun 1986b; GBCP 1997, p. 3) – the 100 m band of vegetation recommended in earlier studies is inadequate (GBCP 1997, p. 3).

Like the effects of environmental variation on winter habitat discussed above, combined effects could operate at other life history stages, in particular the highly susceptible brood-rearing stage. Episodic summer drought reduces insect populations needed by juveniles, and juvenile mortality over the summer period may be even more variable than mortality over the winter (Rich 1985a, p. 13).

Western riparian habitats are assemblages of plant communities occurring at interfaces of terrestrial and aquatic communities. They create well-defined, narrow zones of vegetation along ephemeral, intermittent, and perennial streams and rivers. “Riparian areas are among the most threatened habitats on the continent” because they are favored for many uses including livestock grazing, agriculture, water management, timber harvest, recreation, and urbanization (Saab, et al. 1995). The extent and type of riparian vegetation in the Columbia Basin has changed significantly. There has been a decline in shrublands in the riparian zones in more than half the Ecological Reporting Units (ERUs) in the Basin (Quigley and Arbelbide 1997c, p. 1086). These types of areas are the most modified in the West (Chaney, et al. 1990, 1993a). Grazing on riparian areas in arid lands is particularly damaging (Platts and Nelson 1985; Chaney, et al. 1990, 1993a; Platts 1981a-c, 1991). Livestock grazing effects riparian vegetation by altering, reducing, or removing vegetation, and by actually eliminating riparian areas through channel widening, channel aggrading, or lowering the water table (Platts 1991). The quality, amount, and distribution of early brooding habitat appears to be a limiting factor for sage grouse.

Non-brooding Birds During Summer

During summer, females without broods and males select big sagebrush stands with canopy cover ranging from 20% to 35% (Patterson 1952c, Martin 1970a, Wallestad and Schladweiler 1974, Wallestad 1975a; Braun, et al. 1977; Ellis, et al. 1989). During summer and early fall, male sage grouse remain segregated from brood and hen flocks, typically remaining within 2 to 3 miles (3.2 - 4.8 km) of the lek (Wallestad 1975a). Hens without broods and male flocks are less dependent on wet meadows and riparian areas than are hens with broods; however, some dependence is still present, and these birds follow the same habitat use patterns as do hens with broods (GBCP 1997, p. 4).

Fall Habitat

Dalke, et al. (1963) reported that birds collected near water holes as temperatures approached freezing. Birds usually remained in a single place for several days, and then moved out in groups. Pyrah (1954) reported that immature females were the first to leave for wintering areas, followed by mature females, then adult males.

Habitat Degradation

Degraded habitats typically do not support as many individuals as higher quality habitats, but may support an equal number of breeding males (Gibbs and Faaborg 1990). Thus, surveys of breeding males may overestimate population viability (Gibbs and Faaborg 1990).

Mechanistically, this effect can arise when degraded or marginal habitat is adequate for males but not for breeding females, a condition that is likely common throughout sage grouse range. Habitat loss and degradation are the "most frequent causes of species endangerment" (Schwartz 1999, p. 86; Wilcove, et al. 1993; Foin, et al. 1998).

Sagebrush habitats have been degraded by a wide variety of effects, ranging from depletion of the understory plants needed for juvenile and female nutrition, to erection of structures that serve to enhance predator populations, to outright removal of sagebrush itself. In many cases, sagebrush removal has been touted as a way to enhance wildlife populations, even including sage grouse. Sagebrush removal will not benefit sage grouse unless increased forb production occurs, and only if sagebrush density does not become too low (Autenrieth 1986). Sagebrush has been removed with herbicides, intense fire, and by chaining or bulldozing in most of the range of the sage grouse. Livestock grazing has spread exotics such as cheatgrass, removed valuable cover, and reduced forbs to such an extent that birds are apparently unable to maintain adequate nutritional levels for periods of high nutritive demand, including egg formation and development. Consequently, populations have plummeted.

Moving livestock away from riparian areas (for example, to improve fish and riparian habitat, or to improve late season brooding habitat for sage grouse) could pose a significant detriment to upland habitat that sage grouse rely on for most of their life history.

In one study, Webb (1993b) was unable to find even small portions of non-degraded habitat in Wyoming outside of a National Park. This accords with the findings of Connelly and Braun (1997), Braun (1998a, 1999a), and Paige and Ritter (1999) as well as with the findings of plant ecologists. For example, with respect to sagebrush ecosystems, West (2000, p. 16) stated "pristine ecosystems … no longer exist, nor are they likely to be recoverable;" moreover, any areas of sagebrush that have escaped "direct human influences" exist only as "remnants" and as "relicts" that are not complete ecosystems. Only about 1% of sagebrush lands are in such relicts and about 5% has an understory dominated by native herbaceous vegetation (West 2000, Fig. 4, p. 23; Sands, et al. 2000, p. 29). About 25% of sagebrush lands have severely depleted herbaceous understories, while about 25% has an understory composed of annuals (which provides marginal nesting cover and little forage value for sage grouse), and another 25% of the landscape has already converted to annual grasslands of no value at all to sage grouse (West 2000, Fig. 4, p. 23; Sands, et al. 2000, p. 29-30). The remainder consists of crested wheatgrass, knapweeds, yellow star thistle and mixtures of these invaders (West 2000, Fig. 4, p. 23; Sands, et al. 2000, p. 30-31). Thus, only about 6% of the sagebrush landscape is of much value as habitat. The scope of habitat degradation and the various threats causing degradation are discussed throughout this review, but salient point is particularly chilling: West (1999b) estimated that 50% or more of historical sagebrush areas had reached vegetative transition states, dominated by exotic plants, from which they could not be recovered at all, given current technology (see also Wisdom, Rowland, et al. undated). These habitats are gone forever.

Habitat degradation causes severe endangerment to species. Successful recovery of species under the ESA has primarily involved species threatened with predation and pollutants. "It is much more difficult to recover species where habitat degradation and loss are the primary causes of endangerment" (Schwartz 1999, p. 86). Because this is the case with sage grouse, the Service should act promptly and comprehensively to list sage grouse and to restore habitats.

Home Range

Home range size varies with season, being smallest in summer, but is generally larger

than those of other grouse (Bergerud 1988b). Summer home ranges may range from 3 to 7 km^2 (Connelly and Markhamer 1983, Gates 1983). Annual home ranges may be as large as 1,500 km^2 (577 $mile^2$) (Paige and Ritter 1999, p. 33, citing unpublished data of Connelly). On the YTC in Washington, home range sizes are 24 to 26.6 km^2 in summer and spring, and 44.2 km^2 in fall (YTC CA 1994). Home range sizes will be much larger for grouse that travel some distance among different habitat components than for those birds that have all the habitat types they need adjacent to each other. Home ranges will also be small in birds that simply cannot find their needed habitat except in a small remnant land area. Habitat degradation or fragmentation is likely to result in larger home ranges as birds must travel further and further to find needed resources.

Habitat Fragmentation and Landscape Effects

Habitat fragmentation is one mechanism that has been proposed to explain declines in a number of species, and has perhaps been most extensively studied in forest dwelling birds, particularly neotropical migrants (Wilcove, et al. 1986; Finch 1991; Faaborg, et al. 1993; Morrison, et al. 1992a; Sherry and Holmes 1993). Fragmentation effects are by no means restricted to forest landscapes, however, and have been frequently demonstrated in flat, or two-dimensional landscapes such as sagebrush shrub-steppe (Johnson and Temple 1986; Burger, et al. 1994; Herkert 1994; Knick and Rotenberry 1995b, 1999b, p. 105; Welch draft manuscript, ch. II) and specifically, in sage grouse populations (Kerley 1994; Commons, et al. 1996a; Schroeder 1994a, 1997b). Forest fragmentation effects are not qualitatively different from those in the sagebrush shrub-steppe (Wiens 1989b, II, p. 204). Moreover, sage grouse may be unusually sensitive to fragmentation effects because of their specialized food habits, generalized anti-predator strategies, and other life history factors (Braun, et al. 1994, p. 432). Both coarse-grained and fine-grained fragmentation can affect sage grouse (Braun, et al. 1994, p. 433), and sage grouse are considered to be "area-sensitive species" (Sands, et al. 2000, p. 31; Altman and Holmes 2000, p. 25). Because sage grouse have narrower habitat requirements than do sharp-tailed grouse and depend so strongly on sagebrush, their area requirements for even a small group of birds – much less a viable population – will greatly exceed the estimate of 3,000 hectares for sharp-tailed grouse (Sands, et al. 2000, p. 31).

Habitat fragmentation occurs when a large tract of habitat is dissected into smaller patches isolated by other habitats or vegetation types different from the original (Wilcove, et al. 1986; Morrison, et al. 1992a; Faaborg, et al. 1993). These patches (also referred to as fragments, islands, or isolates) are redistributed into variable sizes, shapes, and locations from the original area (Diamond 1975a; Wilcove, et al. 1986; Morrison, et al. 1992a; Faaborg, et al. 1993). Fragmentation causes increased extinction risk and population declines as compared to habitat loss alone (Andren 1994). When fragmentation effects exist, species abundance is less than that expected from the total amount of habit present; instead, abundance is more closely related to a smaller metric – the area of patch interior present, termed "core areas" (Temple 1986a). Forman and Godron (1981) offer a readable introduction to patch dynamics, and a variety of textbooks offer simple introductions to fragmentation concepts (Primack 1993, Meffe and Carroll 1997). Wilcove (1987) identified four ways that fragmentation can cause extinction: (1) a species can be excluded from protected patches by the loss of internal heterogeneity due to invasion of edge plant species; (2) it creates isolated populations that are susceptible to catastrophes and genetic drift; (3) it interferes with ecological relationships; and (4) fragmentation creates edge

environments which typically increase predation. Fragmentation and insularization (the creation of disconnected, "island" like habitat patches) are known to cause higher extinction rates than those from reductions in area size alone (Wilcove, et al. 1986). Spatial scale is important in fragmentation effects such as dispersal (Doak, et al. 1992); however, the spatial arrangement of habitat patches does not mitigate against habitat loss in fragmentation processes (Fahrig 1997). Fragmentation and insularization are well advanced across the range of sage grouse (see discussion of the species range and the map compiled by Schroeder elsewhere in this review).

Meffe and Carroll (1997, p. 75) recently summarized the theoretical and empirical studies on habitat fragmentation effects: fragmentation "sets the stage for rapid local extinctions" because "extinction probabilities increase greatly in small populations" and extinction often occurs quickly – "in a matter of years or decades." Many of the effects of fragmentation are explicable by the MacArthur-Wilson theory of island biogeography, which predicts a balance between immigration and extinction rates represented by the number of species on an island (MacArthur and Wilson 1967; Diamond 1975a; Whitcomb, et al. 1981; Morrison, et al. 1992a). This equilibrium number of species is dependent upon island size, distance from other colonizing populations, dispersal abilities, and population densities. Most importantly, equilibrium species number decreases with island size. Habitat fragments are similar to islands because there is an obstacle to dispersal, whether it is an agricultural area, a road, or a utility corridor that isolates them from other similar habitats (Diamond 1975a; Wilcove, et al. 1986). Fragments are also particularly susceptible to incursions by predators, invasive alien species, and competitors. Fragments are subject to higher invasion rates by parasites, parasitoids, and disease vectors. Populations in isolated fragments have lower growth rates than those in connected areas, and are thus more prone to extinction (Fahrig and Merriam 1985).

Fragmentation can affect species diversity, population persistence, and community structure, because it isolates individuals, breeding units, and sub-populations of patch-interior species into smaller sub-populations or demes. Smaller populations experience negative genetic effects, such as higher genetic drift and inbreeding depression (Lacy 1987, Wiens 1995), as well as being more susceptible to environmental and demographic fluctuations.

Smaller patch sizes may be unable to effectively contain the home ranges of individuals in a species (Wilcove, et al. 1986), and also increase the risk of extinction by altering microclimates, decreasing cover availability, increasing predation, competition, or parasitism, and increasing the chances of human encroachment. In addition, the quality and quantity of resources decrease while the susceptibility of fragments to disturbance, such as wind blown weed seeds and fires increase (Morrison, et al. 1992a). All of these pressures on habitat-interior species increase as the size of the habitat fragment decreases.

Fragmentation not only causes a decrease in effective area size, but also affects habitat heterogeneity (Wilcove, et al. 1986). In forested areas, forest-interior bird species are dependent upon large expanses of their preferred habitat (Wilcove, et al. 1986; Morrison, et al. 1992a). Several studies have shown that birds are habitat-specific (Lynch and Whigham 1984; Wilcove, et al. 1986; Morrison, et al. 1992a) and sage grouse are particularly habitat specific, being limited to sagebrush ecosystems. When an area is fragmented, individual fragments may not have all the habitat types that were initially found in the original block. Therefore, species that require specific habitats are vulnerable to local extinction (Wilcove, et al. 1986). If a fragment lacks a required habitat for a given species, then establishment of breeding populations in that fragment cannot occur (Wilcove, et al. 1986). Local abundances of individual bird species are influenced by the structural and floristic characteristics of the vegetation and these vegetation

characteristics vary with area size (Lynch and Whigham 1984; Wilcove, et al. 1986). Many species, including sage grouse, require more than one habitat type for survival and reproduction. For example, within the overall sagebrush ecosystem type, sage grouse require low elevation, sparsely vegetated lek sites with sagebrush cover adjacent to the lek sites, nesting areas with abundant forb and grass cover, upland meadows that are rich in forbs, and low elevation wintering grounds, usually on south facing slopes. Habitat fragmentation isolates the various habitats needed by sage grouse from each other, preventing or reducing transit among required habitat types.

Another important effect that fragmentation has on birds is the creation of edge (Wilcove 1985; Wilcove, et al. 1986; Morrison, et al. 1992a). Gates and Gysel (1978) observed higher densities of nests along forest edges which may have resulted in increased predator densities or predator search efforts in edge habitats. Such effects may operate in sagebrush ecosystems. Plant and animal species associated with patch interior conditions are sensitive to early serial stages and edge habitats. Habitat fragments are susceptible to drying, wind penetration, and invasions by early successional plant species along edges and large openings (Morrison, et al. 1992a). Wind penetration into fragments would be an especially severe problem for wintering birds. Edges increase predation on avian nests because a wide variety of avian, mammalian, and reptilian predators are abundant in such areas (Wilcove 1985; Wilcove, et al. 1986; Morrison, et al. 1992a). In flat habitats such as prairies, vertical elements that fragment such habitat can result in a tripling of nest predation rates (Burger, et al. 1994). Negative effects of fragmentation may also be indirect – fragmentation is known to affect community development, vegetation dynamics, and succession (Robinson, et al. 1993), all of which can reduce habitat quality for animal consumers.

Sage grouse nest on or near the ground, use open nests, and have few broods per year. In these respects they are similar to forest dwelling birds that have been found particularly susceptible to reduction in productivity by fragmentation (Whitcomb, et al. 1981). Such fragmentation may allow for high rates of nest predation (Askins, et al. 1990). Wilcove (1985) showed that open-cup ground nests were more susceptible to predation than low-canopy cavity nests. In one respect – susceptibility of nests to location from above by visually hunting predators – sage grouse are at significantly greater risk than forest dwelling species. The effects of edge on nest predators in forested areas can extend over 600 m into a fragment (Wilcove 1985), meaning that a fragment as large as 100 hectares would have only edge and no interior, reducing its value to essentially zero. The exact relation of nest predation with respect to distance from an edge, and of the type of edge formed, is not known for sage grouse, but prudence in conserving the species dictates that wide buffers be provided around any sage grouse habitat.

Both the range of sage grouse and the shrub-steppe ecosystem itself are severely fragmented. One scientist, familiar with shrub-steppe for decades, noted that “many regions are fragmented all to hell” (Rotenberry 2000). Sage grouse are "especially sensitive to fragmentation because of their fidelity to lek, nest, winter, and brood-rearing sites" (GBCP 1997, p. 41). Although this statement was made in the context of Gunnison sage grouse, it applies to all sage grouse. Fragmentation has caused the near extinction of the greater prairie-chicken, a close relative of the sage grouse (Westemeier, et al. 1998; Bouzat, et al. 1998). Sage grouse are adapted to large expanses of a continuously distributed habitat type, and such species may suffer especially from the effects of fragmentation (Temple and Cary 1988). Fragmentation has been a “major cause of the decline of sage grouse throughout its range” (Taylor, et al. 2000).

Metapopulation Effects

Fragmentation splits a single large, cohesive population into a system of small sub-populations (demes) that are linked by gene flow into a metapopulation. (Alternatively, the sub-populations are not linked and, if small, become extinct.) In either event, it is critical that demes be recognized as such and not aggregated into a single large population – such errors will cause the observer to underestimate extinction rates (Wilson 1975, p. 108).

Metapopulation concepts date at least to the early population genetics syntheses of Sewell Wright (1940), and the term was apparently first introduced by Levins (1969, 1970). Extinction risk is generally higher for metapopulations than for intact populations of equal size – often significantly higher (see below). One possible advantage of a metapopulation is the spatial "spreading of risk" from environmental fluctuations (den Boer 1968). This will be an advantage only if the spatial extent of the metapopulation is greater than that of the intact population. There is no evidence that this was ever the case for sage grouse – instead, the metapopulation structure for this species arises from the extirpation of birds from various areas and the creation of human caused barriers to dispersal. Also, spatial spreading of risk will be ineffective if environmental fluctuations are spatially correlated as is generally true for the mid-continental climate throughout the range of the sage grouse.

Various types of metapopulation concepts have been elaborated: Boorman and Levitt (1973) postulated a large source population with geographically static sub-population sinks which experience rapid and recurrent cycles of colonization, population turnover, and extinction. Levins (1970) postulated a system of interacting sub-populations where most of a fixed number of habitat patches were empty at any given time due to dispersal difficulty. In both models, the balance of immigration and extinction rates determines deme dynamism – the occupancy of patches and the size of colonies in each patch. Wilson (1975, p. 112) provides a simple comparison of these two models, and a tripartite spectrum of situations ranging from a mainland with satellites to equally distributed and sized isolates is illustrated in Poethke, et al. (1996, p. 86). Gill (1978) suggested a model in which patches were ephemeral to the point of altering reproductive success – a given patch would change from a source of emigration to a sink (no emigration) with a minority of patches serving as sources. Harrison (1991) noted that a decline of a species across a large region often accompanied habitat fragmentation, a process strikingly similar to that confronting sage grouse today.

As with most species in severe decline, sage grouse probably occupy all available patches of adequate habitat, thus the empty patch model of Levins (1970) seems inappropriate here – and is more likely applicable to colonizing species (Harrison 1991, 1994; Thomas 1994). As Thomas (1994) puts it: local extinctions "rarely generate empty patches of suitable habitat." Moreover, no suitable, but empty patches of sage grouse habitat are known. Instead, some of the features of Gill's model seem to fit sage grouse. Because of severe habitat degradation and various threats, there are no source populations left (Braun 2000e). As with various other species declining in abundance because of habitat loss and fragmentation, it is not likely that sink patches will become source patches – thus extinction processes will predominate over immigration processes.

Model outcomes differ significantly between mainland-satellite metapopulation models (Fig. 3C in Poethke, et al. 1996, p. 86) and those with nearly equally distributed and sized isolates (Fig. 3A in Poethke, et al. 1996, p. 86). It is both intuitively obvious and easily shown mathematically that the latter situation carries higher risk of metapopulation extinction – local extinction rates must be smaller than colonization probabilities, else the entire metapopulation will become extinct (Hanski and Gilpin 1991; Poethke, et al. 1996, p. 87). This occurs because

there is no large mainland source population which is so well buffered that it always serves as a source of immigration into patches. Instead, colonization probability is a function of the number of occupied patches. The number of linked patches is an important determinant of metapopulation extinction. For a finite number of linked isolates, metapopulation persistence depends on the number of interconnected local populations and the ratio of colonization probability to extinction rate must be 50% greater than with a very large number (near infinite) of isolates (Poethke, et al. 1996, p. 87).

Unfortunately, there appear to be no documented sage grouse populations which resemble the mainland situation. Instead, habitat fragmentation and degradation has produced a matrix of isolates where once there was a veritable sea of sage grouse. Worse, there are no documented sage grouse populations that serve as source populations (Braun 2000e).

Storch (1997) studied several grouse species closely related to sage grouse and concluded that metapopulation concepts were important for those species and that "attempts to stabilize a population below minimum viable population size will fail unless dispersal from neighboring populations occurs." Grouse are "poor colonizers with relatively short dispersal distances" (Braun, et al. 1994), and this appears to be the case for sage grouse, despite their high mobility among different seasonal use areas. Hansen, et al. (1993) discuss dispersal ability in conjunction with variable patch size in a landscape context.

Even when subpopulations are protected and appear viable, extinction risk may remain high. Metapopulation persistence is not possible below a threshold minimum metapopulation size – the number of subpopulations required to support metapopulation survival (Hanski, et al. 1996a). Extinction thresholds also result from the minimum amount of suitable habitat present in a region (Lande 1987). Metapopulation concepts are of particular importance for sage grouse because extinction can occur even when a great deal of suitable habitat exists if barriers prevent movement so that extinction rates of local patches exceed colonization rates (Levins 1969, 1970; Lande 1987). This is precisely the situation that sage grouse appear to face as supported by the data below.

Area Size

One of the most important insights of contemporary landscape ecology is that small areas of habitat are of limited value in conservation. Moreover, that value decreases as area size decreases and reaches zero before the size of the area reaches zero, thus creating a minimum threshold for the size of an area which will support a viable sage grouse population. There is little value to a small conservation reserve. Such "living museums" are necessarily subject to species-area and edge effects because of their isolation and small areal extent (Diamond 1975a; Wilcove, et al. 1986; Wilcove 1987; Wilcox and Murphy 1985; Harris 1984).

The same concept also applies to any given type of sage grouse habitat, for example, there appears to be a minimum size for leks at which they are abandoned. There may also be a minimum size for an area for a lek, set by the minimum usable display area. Similarly, a minimum size for nesting areas will be determined by distance to the edge (as discussed elsewhere in this review). Individual sage grouse are known to use a yearly range of 30 to 60 $mile^2$ (Anonymous undated document 4). Determination of minimum area sizes for various life history stages and behaviors is complicated by the non-linearity of species responses to different sized areas. These incidence functions are "usually not linear" and instead show "sharp breaks" as area size varies (Wiens 1994, p. S99).

In determining the minimum area sizes needed for sage grouse, it is important to also consider trophic linkages and other community and ecosystem processes. For example, areas

might appear large enough for sage grouse based on present vegetative conditions, but be too small for fire and other processes to create suitable vegetative mosaics. Moreover, predators and predation are known to be an important effects determining minimum area size (Wilcove, et al. 1986). What is clear is that sage grouse require large areas of intact sagebrush habitat "as large as 2,500 square miles per population" (Rich and Altman 2001) for viability.

Minimum Dynamic Area

Pickett and Thompson (1978) noted that reserve design should focus on the disturbance dynamics inside the reserve because extinction processes will predominate over immigration processes. This is intuitively obvious – by the time a reserve is established, the surrounding habitat will be degraded, and recolonization rates will be low or nonexistent. This is particularly true for sage grouse because vast expanses of habitat have been degraded, and because reintroductions have generally failed.

Pickett and Thompson (1978) proposed the term "minimum dynamic area" to denote the smallest area in which metapopulations could be viable given natural disturbance processes generating patches of suitable habitat, and the frequency and longevity of those patches. Meffe and Carroll (1997, p. 215) referred to the size a landscape must become before population dynamics within that landscape are essentially independent from events external to that landscape, and referred to the term "spatial autonomy" used by Pulliam, et al. (1995). Other authors have noted that "disturbance regimes … must be protected to preserve associated genetic, population, and assemblage dynamics" (Karr and Freemark 1985, p. 167; internal citations omitted). US Forest Service scientists have noted that such protection is a "key premise of ecosystem management" (Swanson, et al. 1994, p. 80). Pickett and Thompson's phrase connotes more readily the concept involved, at least as a noun, and that term is used in this review. The minimum dynamic area size must be substantially larger than the largest disturbance patch size (Pickett and Thompson 1978, p. 34). For sage grouse, this means that areas to be preserved as suitable habitat must be substantially larger than the typical fire burn area in sagebrush – including the effects of cheatgrass on fire regimes. Moreover, natural catastrophes will occur even if climatic regimes are stable (Noss 1992), so that sufficient geographic area must be included in reserves for these natural fluctuations in weather, as well as more broad scale climatic change. Both factors are substantial in the interior continental range of the sage grouse. Additionally, sage grouse ranges are unprotected by forest cover and hence undergo greater climate and weather related changes.

The minimum dynamic area must also include internal recolonization sources (or "hot spots" *sensu* Diamond 1975a), different ages of patch types, and separate minimum dynamic areas of each included habitat patch type. The latter two criteria have been discussed above in the various Habitat sections of this review. The former criterion is essentially a joint requirement for large and growing demes, with concomitant successful dispersal, and hence gene flow, from those demes – this requires that the macro-habitat (*sensu* D. R. Webb 1981) be permeable to dispersing sage grouse. The actual amount of habitat required for a viable sage grouse population is probably a minimum of several thousand acres (Paige and Ritter 1999, p. 11). Thus, the minimum dynamic area for most sage grouse refugia will be considerably larger – probably on the order of a few hundred thousand square miles for each refuge. For comparison, the state of Wyoming is approximately 96,988 mile^2 in area. Expansive reserves are needed because species are extirpated from even relatively large and protected reserves (Newmark 1987, Belovsky 1987). For some species, habitat protection plans have been based on 95% likelihood of persistence for 100 years (Noon and Murphy 1997, p. 437). For persistence over evolutionary

time scales, even larger reserves will be needed, on the order of a few million mile^2 (Belovsky 1987, Soule and Terborgh 1999).

Habitat Connectivity and Permeability

The ability of individuals to cross intervening areas between habitat patches and to venture across various types of boundaries has been termed permeability. The likelihood of an individual crossing a boundary between two vegetation types has been termed "boundary permeability" (Wiens 1989b, II, p. 220), and this likelihood is a function of the sharpness of the boundary discontinuity or contrast between patches (Wiens, et al. 1985a). Such boundary discontinuities have also been termed hard edges or soft edges, depending upon the degree of discontinuity (e.g. Rolstadt 1991). These boundary effects determine the degree of gene flow among demes in metapopulations, and hence influence extinction probabilities. When discussion focuses on habitats or landscapes rather than species, the term connectivity is often used. Spatial areas are considered connected when at least certain life history stages of various species can move from one to another. Connectivity thus summarizes movement probability among habitat patches in a landscape (Merriam 1991; Taylor, et al. 1993).

A special case of habitat connectivity is the movement corridor, which is a discrete area that often serves as a valuable linkage among core habitat areas (Beier and Noss 1998). However, corridors must be sufficiently wide, contain adequate dispersal habitat, and not have such hard or abrupt edges as to form barriers to dispersal. The effect of corridors on gene flow and population linkage is probably species specific (e.g. Mech and Hallett 2001). In particular, powerlines will isolate sage grouse core areas, shutting off gene flow. Soule (1991b) identified three types of movement needs: corridors for periodic migrations, corridors for access to seasonally moving resources and for movement among different patches, and for immigration into smaller, less viable populations. All are applicable to at least some sage grouse populations. Corridors must not be too narrow, and broad swaths of intact habitat will best serve sage grouse movement needs.

For sage grouse, many types of objects, facilities, landforms, and land uses intervene between different areas of habitat. Moreover, these potential barriers to movement are of variable widths. At one extreme, large expanses of agricultural lands have limited movements in Washington. Burned areas significantly alter migration (Fischer, et al. 1997, p. 89). Very narrow facilities such as powerlines and high speed highways (such as Interstate freeways) may also serve as dispersal barriers. Large expanses of degraded sagebrush habitat could also restrict movements if birds are unable to find usable habitat (e.g. with adequate forbs) and give up on searching vast areas. Reservoirs and lakes may constitute barriers, and birds have been found dead from apparent attempts to fly across reservoirs. In conducting further research into barrier effects, it may prove useful to ordinate studies along the factors such as the width of the hypothesized barrier, the shape ratio or length of the barrier in relation to its width ("peninsula effect," *sensu* Emlen 1978), the visual appearance from the air and to a bird walking, and the degree of risk in crossing the barrier. The degree of risk may need to be evaluated as apparent risk – sage grouse avoid powerlines even when no raptors are present. Even if birds are able to cross certain barriers, they may be reluctant to do so because of predation risk. Also, flying over a barrier entails increased energetic loss, as the birds prefer to walk and are poor flyers.

Disjunct patches of sagebrush that were previously connected to other patches are likely to now be unsuitable source habitat for sage grouse because the birds require large home ranges. This need is especially strong for wintering flocks. Grouse select winter use sites based on snow depth and topography (Connelly 1982, Hupp 1987a, Robertson 1991) where sagebrush is

accessible. Sagebrush heights of 25 to 30 cm (10 to 12 in) and canopy cover of 10 to 25 percent, regardless of snow cover, are important for winter use by sage grouse.

Habitat Vegetation Analysis

Traditional Clementsian succession theory (Clements 1916, also known as monoclimax theory) was applied to arid ecosystems early on (Sampson 1919) and even forms the basis for government manuals and early range management textbooks (Fleischner 1994). At its simplest, community development theory encompasses essentially monotonic successional changes from priseres to cliseres (cliseres are often dubbed "old growth" or "ancient forests" for various forest ecosystems). Typically, only a single pathway to climax seral stages was recognized, and the process envisioned was one of "progress" towards that "vegetative goal." Clementsian succession concepts no doubt were influenced by then current notions of evolutionary and social "progress" and goal directedness. Ellison (1960a, 1950b) summarized this development. In sagebrush and similar ecosystems, annual grasslands may represent stable ecosystem states that cannot be altered by natural processes (Westoby 1980). Computer simulation models predict that invaded and degraded areas in the Snake River region cannot recover in less than a century and then only if optimal moisture, fire control, and seed dispersal conditions are present (Knick 1998, USDI 1996). More recent understandings of community development in sagebrush ecosystems, incorporating multiple cliseres and disturbance mediated shifts among these multiple stable states as well as to early stages, have been proposed by Westoby, et al. (1989). Laycock (1991) and Friedel (1991) noted the applicability of these concepts to sagebrush ecosystems. A large body of theory on community development, together with numerous experimental tests and extended field data, exist for forest ecosystems, particularly North American forests. This body of work has led to numerous predictions on the effects of forest management practices on birds (such as spotted owls), various forest carnivores (wolverine, fisher, lynx), and on fungi, amphibians and many other species. In contradistinction, little such work has been done on sagebrush or other shrub and grassland ecosystems. Donahue (1999) summarizes successional theory development, and discusses its applicability to sagebrush ecosystems.

What is key to such state and transition models of community development is that if correct, then grazing or alterations to the fire regimes in areas of present or former sage grouse habitat may produce situations from which the community cannot recover naturally (West 2000). Recent government studies suggest that this is indeed the case (USGS 1999). At worst, cessation of livestock grazing would not allow, for example, recovery of adequate forb density, and sage grouse would be doomed. Alternatively, habitat is likely to recover so slowly that sage grouse would be locally extirpated even after livestock were removed from an area, necessitating natural migration or expensive and ineffective reintroduction efforts in an attempt to repopulate the area.

Population Assessments

Sage grouse populations have seriously declined throughout their entire range (Connelly and Braun 1997). Sage grouse are declining over both the long-term (last 100 years) and currently (last 20 years) (Hoffman and Stiver 2000). As Connelly (1997) put it, sage grouse are "currently undergoing range-wide population declines." The Service recognizes this and described these rapid and widespread declines as a "consistent decline in sage grouse in all states" like "an F-16 fighter going down" (Deibert 1999d). Sage grouse have been extirpated in 5 states and 1 Canadian province. In 3 other states and 2 provinces, breeding populations now number less than 2,000 birds, and effective population sizes are much lower. The "long-term

existence" of sage grouse in at least 6 states and 1 province is uncertain (Gunnison Basin Sage Grouse Conservation Plan 1997, Preamble). Sage grouse have been uniformly extirpated from the entire periphery of the range, and "greatly reduced in distribution and abundance within their former core range" (Braun, et al. 1994). Sage grouse specialists have used various narrative terms to describe the degree of endangerment of sage grouse (Braun 2001l). Dr. Braun is concerned about the use of these terms, including the term "secure" and intends to publish a critique of the terms "secure," "persistent," "marginal," and "at risk" in the near future (Braun 2001l). The Service should exercise caution in evaluating population status based on information using these terms.

Even in states with the largest numbers of birds, those numbers are in decline. Overall, populations have declined by 80% to 90% during just the last 25 years. Oddly, most state wildlife agencies have not gathered detailed demographic data on populations and have not undertaken assessments of habitat degradation, despite the long historical slide in both populations and ranges. The wildlife trust doctrine devolves onto the states, and it is difficult to reconcile the lack of interest in sage grouse with the fiduciary duties of the states in this regard. Numbers in Alberta are reduced by 80% (Aldridge 1998a). Aldridge (1998b) presents a synthesis of the Canadian literature. Braun (2001h) believes that there "is no hope" for sage grouse in Alberta or Saskatchewan.

The Western States Sage Grouse Technical Committee (WSSGTC) estimates that sage grouse numbers have fallen from 1.1 million birds to about 150,000 (WSSGTC 1999). The 150,000 number appears optimistic and is higher than the estimate of Braun (1998a). Adding the numbers given by Braun (1998a) reduces the range-wide numbers of the WSSGTC by about 1/3. What is most alarming however, is not the absolute number of birds but the very sparse distribution of birds in population isolates over a vast landscape, and the extremely rapid population declines from 1980 to 1990 and the present. The graph on the second page of WSSGTC (1999) shows a sharp decline from over 600,000 birds in 1980 to only about 20% of that number by 1990. Apparent increases in the 1999 report are "probably the result of more intensive surveys and [increased] precipitation" (WSSGTC 1999). The BLM estimates that sage grouse in the Great Basin have declined over 33% in just the last 15 years, and notes that sage grouse may not recover (R. Johnson, et al. 1999, p. 10-11).

Species can become endangered even if populations are not declining. Of the 581 species listed under the Endangered Species Act as of October 1, 1990, only 38% were considered to have declining populations, while 31% had stable populations, and 10% had increasing populations (Flather, et al. 1994). Nonetheless, the declines in sage grouse numbers are troubling, and increase the likelihood of extinction. Sage grouse declines may be linked to the widespread decline of other species in flat, or two-dimensional habitats. For example, declines in grasslands bird species are occurring on a continental scale unlike the declines in neotropical migratory birds, which are primarily limited to the northeastern US (Knopf 1995, p. 298).

In early historical times, sage grouse were abundant (Bent 1932, Patterson 1952c). The WSSGTC estimate of 1.1 million birds noted above is likely an underestimate of populations before settlement, which probably numbered 2 million (Braun 2001c), or in the tens of millions. Their range included 16 states and 3 Canadian provinces, closely following the distribution of sagebrush, predominantly big sagebrush (*Artemisia tridentata*), and including other sagebrush species at the periphery of the range, such as *A. cana*, *A. filifolia*, *A. nova*, and *A. tripartita* (Braun 1998a). The range extended from southern Canada to northern New Mexico and Arizona (Bent 1932, Girard 1937, Huey 1939), and from the western edge of the sagebrush region along

the Cascades and Sierra Nevada eastward up to the shortgrass prairie in the Dakotas. A disjunct population is known from the Oklahoma panhandle (Wood and Schnell 1984), but it may have been more extensive before it was first studied.

Sagebrush species were widely distributed prior to Euro-American settlement of the west (Vale 1975), affording a large habitat for sage grouse. This habitat may have been fragmented on a large landscape scale by mountain ranges, deserts, and forests (Patterson 1952c, Rogers 1964). This large scale habitat interdigitation is not comparable to the highly dissected and insular habitats found on small and mid-landscape scales today. Likewise, the fragmentation of today is not comparable to the historical mosaic of sagebrush on a pattern of a few meters or tens of meters caused by natural fire regimes.

Few data exist on the status of sage grouse or of sagebrush ecosystems before the arrival of paleo-Indians approximately 15,000 years ago. It is likely that the demise of most large North American mammals at about the same time affected sage grouse and sagebrush ecosystems in some way, but information is unavailable. Sage grouse might have expanded their range or abundance with the demise of large mammals (Martin and Szuter 1999). Many Indian tribes in and near the Great Basin acquired horses by about 1690 (Haines 1970, 1971), following the re-introduction of that species to North America by the Spanish. The impact of horses on sagebrush ecosystems and sage grouse is unknown. In all, impacts of native Americans from fire management, from their horse culture, or from other effects, could not have been great because early European explorers and settlers were impressed by the vast numbers of sage grouse in the West.

Cattle and other domestic livestock were introduced to what is now the western United States by the Spanish. In 1789, the Spanish introduced a small number of cattle to Vancouver Island, BC and cattle reached the Okanogan Valley by 1826 (Galbraith and Anderson 1991). However, large numbers of cattle and sheep did not reach the range of the sage grouse until the mid 1800's. Domestic cattle and sheep were completely unregulated in the 1800's and until the early 1930's (Edminster 1954; Drut 1994, p. 20; Foss 1969). Degradation of sage grouse habitat from grazing caused severe declines in populations (Edminster 1954, Autenrieth, et al. 1982; Klebenow 1982, 1985) and rendered much sage grouse habitat unsuitable, perhaps permanently (Autenrieth 1981).

Livestock accompanied settlers traveling along the Oregon and California trails; however, traffic along these trails did not exceed 5,000 humans until the late 1840's. Cattle were reported in eastern Oregon and northern Nevada as early as 1861 (Oliphant 1968). And 200,000 cattle were present in Oregon and Washington by 1860 (Galbraith and Anderson 1991). Large numbers of domestic livestock were introduced to the west in the late 1800's. Cattle, sheep, and horse numbers rapidly increased thereafter, peaking in the early 1900's (Oliphant 1968), with an estimated 26 million cattle and 20 million sheep in the western United States (Wilkinson 1992). By the late 1880's, overgrazing and overstocking of livestock led to the disaster of 1886-1887, the "great die-off" or "big die-up" (Schlebecker 1963, Limerick 1987). A conjunction of factors coalesced to cause massive mortality of cattle: cattle were weakened by drought and overgrazing followed by a severe winter. Millions of cattle died in this event. Only a few years later, in 1907, another massive "die-up" again caused by over-grazing combined with a harsh winter, killed nearly as many cattle.

Within 15 years of the large scale introduction of livestock, vast areas were literally denuded of grass and forb vegetation by cattle grazing (Yensen 1981; Dobkin 1994; Paige and Ritter 1999, p. 7). Shortly thereafter, sage grouse began to decline, and by the early 1900's, sage

grouse were found in 14 to 15 states and was the principal upland game bird in 9 states (Rasmussen and Griner 1938). By the 1930's, however, it was a major upland game species in only 4 states (Montana, Wyoming, Idaho, and Nevada), and only Montana maintained a regular open season (Johnsgard 1973). In the 1920's and 1930's sage grouse were believed to be declining throughout their range by all extant authorities (Bent 1932, Gabrielson and Jewett 1940, Rush 1942, Patterson 1952c, Rogers 1964). So steep were the early declines that some predicted extinction (Visher 1913, Hornaday 1916). Concomitant with the declines in sage grouse, and an apparent cause, was the destruction of habitat. The destruction of sage grouse habitat also decreased the capacity of the ecosystem to support livestock, and grazing capacity was estimated to have declined by 60% to 90% by the 1930's (Miller, et al. 1993, p. 119). Some of the most palatable species, such as giant wild ryegrass, as well as dense stands of bunchgrasses were devastated by 1880 (Miller, et al. 1993, p. 119).

Most states limited the number of birds any hunter could take (bag limits) and reduced the length of the hunting season (Patterson 1952c). The Taylor Grazing Act of 1934 limited the worst of the livestock grazing abuses; however, livestock operations continue to represent a significant risk of extinction to the bird. By the close of the New Deal, more than 11 million livestock grazed over 140 million acres (57 million ha) of public land (Malone and Etulain 1989, p. 97).

Populations have never truly stabilized (see below) but the rate of decline did decrease. Populations increased somewhat in the late 1930's, either as a result of the Taylor Grazing Act or because large numbers of livestock had died from a combination of drought and overgrazing. After 1943, Montana also closed its hunting season, which lasted for 9 years (Johnsgard 1973). Sage grouse experienced another, and deeper decline in the 1940's, and increased somewhat in the 1950's. Although harvest was heavily regulated, sage grouse continued to decline (Aldrich 1963).

The bird recovered somewhat in the 1960's, though it never reached anything near its former range and numbers, and several states re-opened their hunting seasons (Johnsgard 1973). Conversion of habitat to agricultural uses and the spraying of herbicides continued, however, and Johnsgard (1973, p. 159) noted that "it is difficult to be optimistic about the long-term future of the sage grouse" despite the increased abundances in the 1960's and 1970's. Drut (1994, p. 10, Table 1) reviewed harvest data for every state, and found that harvests had declined in every state. From 1979 to 1990, harvests typically declined by about 50%.

Today, population declines continue (Braun 1998a), and only 3 of the 16 states that originally harbored [*perhaps*] millions of birds have populations with more than 20,000 birds (Braun 1998a, Table 1). However, hunting continues today in many states. Braun (1998a) estimated that the remaining range of the bird is declining by an average of 33%, and that in 1998 a total of about 142,000 birds remained throughout its range. There is no good news regarding population status for this species: Braun (1998a) relied on the data collected by the Western States Sage Grouse Technical Committee (1995) and stated that there were "no sustained increases in sage grouse population levels within any portion of the range of this species." In 1999, The Technical Committee found that populations had failed to rebound in every state and province that submitted a report (WSSGTC 1999). Apparent increases in the 1999 report are "probably the result of more intensive surveys and [increased] precipitation" (WSSGTC 1999).

Rich (1985a) found that sage grouse population numbers are cyclic. However, Braun (1998a) noted that these cycles take place within a pattern of overall decline, and as noted above,

it is the lows in population size that are most important for extinction risk. “Cycles are not an adequate explanation of long-term sage grouse population declines” (Braun 1987b). If cycles exist, the cycles trend lower approximately every decade – the bird is thus cycling ever downward – stair-stepping towards extinction.

As Braun (1998a) put it in his conclusion:

> Overall distribution has decreased by an estimated 50% since settlement while apparent breeding population size has decreased from 45 to 80% since the early 1950's.

This writer knows of no other game animal that is in such perilous risk of extinction. Braun (2001h) predicts “that there will be great loss in overall distribution for sage grouse in 20 years” (Braun 2001h). This is in addition to the vast decreases in distribution and population that have already taken place. The best available scientific data clearly shows that sage grouse are threatened throughout their range.

Methodology

Numbers of individuals are assessed here on a state by state basis, following Braun (1998a), because that is the manner in which the data have been gathered. Connelly and Braun (1997) compared long-term (30 to 40 years) breeding numbers in each state with breeding numbers over a 10-year period after 1984. In the state-by-state discussion that follows, this compilation will be referred to as recent breeding numbers.

Considering bird numbers on a state-by-state basis almost certainly underestimates extinction risk for each population because populations are not necessarily linked into a state-wide metapopulation. A more thorough analysis would consider each population and delineate sub-populations, analyzing the connectivity of habitat among those sub-populations, with an analysis of gene flow among each sub-population. Thus, the assessment presented herein is almost certain to be overly optimistic in terms of the viability of the populations discussed in each state. Other factors also lack data. These include: loss of genetic variation in the populations, effects of disease and parasitism on a population-by-population basis, and breakdown of the social structure in small populations. Each of these factors would also act to reduce population viability estimates.

Historic estimates of sage grouse abundance are narrative or anecdotal as few systematic surveys were undertaken until the 1950’s (Braun 1998a). Even today, census techniques are not standardized, and use different assumptions – some highly liberal – in arriving at population estimates (Dobkin 1995). Younger birds are more susceptible to hunting harvest, thus population estimates derived from harvest data are likely to overestimate the actual number of reproductive adult sage grouse in populations (Drut 1994, p. 13).

Large populations alone cannot ensure viability. As long ago as 1973, Johnsgard warned that despite “the seemingly comfortable number of birds” widespread habitat conversion and degradation, together with the large amount of herbicide spraying over the range “are likely to further reduce sage grouse habitat and populations in future years (Johnsgard 1973, p. 159). This cautionary augury has now come to pass, and sage grouse are in danger of extinction over vast areas. Like the black-tailed prairie dog, sage grouse are sparsely distributed over a vast landscape, making both management and recovery difficult.

The methodology used to estimate population numbers can also produce overly optimistic population projections. Jenni and Hartzler (1978) cautioned that hen copulation numbers may be a more accurate estimate of the number of hens than are simple counts of hens at leks, since hens may visit leks multiple times.

Counts of males at a lek provides counts of only one small area. Such monitoring, at best, reflects local conditions for one sex only. If other areas of habitat are degraded, the count at a particular lek could even increase while overall population trends decline. Brood surveys are "questionable as a management tool" because the young of the year "are highly susceptible to many forms of mortality before they even near breeding age" (Denson 1997, p. 19). Jenni and Hartzler (1978) also found that evening lek counts are unreliable predictors of numbers using morning leks. Moreover, counts of males at leks within 2 miles of each other on different days are inherently biased, as males as known to visit different leks at different times – such counts of unmarked birds thus count some males multiple times (Beck and Braun 1980, Emmons and Braun 1984, Braun 2000d). Harvest counts (birds killed by hunters) can easily inflate population size by 100% (Schroeder, personal communication). There are two reasons for this: the number of birds taken that are reported on questionnaires are often inflated by hunters, and the proportion of birds taken relative to the true population is often inaccurate. Very few state wildlife agencies have described their methodology for lek counts. The Service should take into account the likelihood that lek counts inaccurately estimate the number of birds in a population – in particular, these counts likely overestimate the number of breeding males extant. Moreover, the Service has cautioned against the use of short-term data, and recognized the importance of long-term data (La Roe 1993).

Another concern regarding population estimates is that state wildlife agencies and cooperating scientists have typically estimated population size in the spring. Estimates made after hatching will over-estimate the reproductive population size, because of mortality during summer, fall, and winter. Reproductive population size is the metric of interest for determining extinction risk.

Population Densities

Patterson (1952c) estimated the density of strutting grounds to be 1 per 5.7 square miles (0.18 leks/mile^2), and the density of males to be 12.5/mile^2. He did not estimate densities of females, or non-adult life history stages. Edminster (1954) estimated the total spring population density (including young of the year) to range from 30 to 50 birds/mile^2, or from 13 to 21 acres (5.2 to 8.5 ha) per bird. Rogers (1964) found that only certain counties in Colorado supported densities of 10 to 30 birds/mile^2 and only in some sections within those counties, with the remaining habitat supporting birds at the much lower densities of 1 to 10 birds/mile^2. In Oregon, Gregg (1992) reported very low densities of 3 birds/km^2 even in the better habitat, and densities as low as 1 bird/km^2 in other habitat (from 1.16 to 0.39 birds/mile^2). In Nevada, densities in recent springs have been as low as 0.1 to 3 males/km^2, and in recent autumns as low as 0.4 to 5 males/km^2 (Zunino 1987). These data show that densities have fallen precipitously since the 1950's, much less since earlier periods when sage grouse were "too thick to drive a wagon through." Taken together, the density estimates follow the range data and population size data, in indicating progressive declines in sage grouse populations throughout the west. Both high and low densities can have seriously detrimental effects on sage grouse populations (see sections on Allee Effects, Disease, and Parasitism).

Extirpated State Populations

Sage grouse have been completely extirpated from the states of Arizona, New Mexico,

Kansas, Nebraska, Oklahoma, and the province of British Columbia (Braun 1998a; Cordova 1999). At one time New Mexico had "fairly large numbers of sage grouse" and they were found in 4 different counties (Taos, Rio Arribal, Sandoval, and San Juan). But sage grouse were extirpated from New Mexico by 1905 (Patterson 1952c, p. 14). * * * Sage grouse apparently were extirpated from British Columbia early in the 1900s. British Columbia has attempted to reestablish the bird after it was extirpated (Hamerstrom and Hamerstrom 1961). There are no Oklahoma records since 1920 (Sutton 1967). Likewise, there are no recent specimen records from Nebraska (Johnsgard 1973).

In the late 1800's, sage grouse were relatively common in north central New Mexico, but were extirpated from the state by 1912 (Ligon 1961, Merrill 1967). Patterson (1950a) notes that the bird was extirpated in 1905, but only placed on the protected list afterwards. The main cause of the declines has been blamed on over harvest, however, the massive numbers of livestock introduced in the late 1800's cannot be discounted as a major cause of the extirpation. Reintroduction of sage grouse was attempted in 1993 but was ultimately unsuccessful – by 1989 the birds were again extirpated from the state (Drut 1994, p. 19).

Sage grouse were restricted to the Okanagan Valley of British Columbia (Taverner 1928, Campbell, et al. 1990). Four records are known from the late 1800's, and the last reference to native populations was a male shot in 1918 near Oliver, BC. In 1958, 57 birds were transplanted from Malheur County, Oregon to a site near Richter Lake (Campbell, et al. 1990). Of course, any locally adapted gene complexes, or culturally transmitted behaviors were lost when the native British Columbia population went extinct. A few questionable sightings occurred in the 1960's, and the last record is from a dead sage grouse reported near Osoyoos Lake in 1966 (Campbell, et al. 1990). Some sage grouse habitat remains in the southern Okanagan Valley, but it is unlikely that any individuals remain, and no plans exist for future transplants (Drut 1994, p. 11). The transplants may have failed because they were small populations (Drut 1994), because the birds were either not well adapted genetically to the transplant area, because they lacked cultural and behavioral abilities needed in the local area, or because sage grouse are intrinsically not easily transplantable. Indeed, most transplants of sage grouse have failed (Schroeder, et al. 1999a, p. 18).

Additionally, only about 500 birds survive in the provinces of Alberta and Saskatchewan (Braun 1998a). In Alberta, the number of leks occupied has plummeted since 1995 (WSSGTC 1999, Alberta section). The range of the birds in Canada has declined by about 90% and critical habitat is highly fragmented into long "stringers" with high edge effect (WSSGTC 1999, Saskatchewan section). Populations have declined 66 to 92% in 30 years and the range has contracted by 90% (Aldridge 2000a, 2000b). As late as the mid-1990's, sage grouse populations in these provinces were thought to be stable at between 2,000 to 5,000 birds each (Drut 1994, p. 12). That populations are capable of such rapid declines is a sobering issue facing all states, even those which believe they have large numbers of birds. Even if the birds in each of these provinces were in one single, intact population that population would be likely to go extinct because it would be too small to survive demographic, environmental, and genetic stochastic effects. Birds in these two provinces face imminent extinction.

Effects Occurring throughout the Interior Columbia Basin

Habitat degradation has occurred over the entire range of the sage grouse. "By the mid-1800's, Euro-American settlers had begun to substantially alter the [Columbia] Basin's landscape and aquatic habitats". (Quigley and Arbelbide 1997a, p. 63). By 1860, over 200,000 cattle were

settled in Oregon (USDA – Forest Service 1996b). Toward the end of the century, sheep were so numerous in eastern Oregon that reports and photographs suggested summer ranges so laden with sheep that they appeared to be snow drifts. Overgrazing damaged stream and riparian vegetation in many basins in eastern Oregon and Washington. Overgrazing also facilitated the spread of annual cheatgrass and reduced vegetation that had provided fuel for fires. In the early 1900's, declines in native vegetation abundance and condition in the Great Basin portion of the Interior Columbia Basin and in eastern Oregon and Washington became obvious. Excessive livestock grazing pressure was vividly apparent on Steens Mountain in southeastern Oregon (Quigley and Arbelbide 1997b, p. 764). The greatest historic declines in ecological integrity in the Interior Columbia Basin have occurred in native upland types, including native grasslands and shrublands (Marcot, et al. 1998). "Still-diminishing vegetation conditions [occur] principally in: rare plant communities, native grasslands, native shrublands and late seral forests" (Marcot, et al. 1998, p. 114). Of all the vegetative cover types in the basin, shrub-steppe habitats "have suffered the most drastic declines" (Saab and Rich 1997, p. 19; USDA – Forest Service, USDI – BLM 2000d). Wet meadows and riparian vegetation – cover types crucially important for brood-rearing by sage grouse – have declined substantially since historical times (Lee, et al., 1997; Quigley, et al. 1996). Moreover, these are "special habitat features" (Wisdom, et al. 1998, p. 2-147). "Rangeland integrity" is low in many areas within the range of sage grouse (Quigley and Bigler Cole 1997, p. 11). The majority of the range of sage grouse is highly susceptible to cheatgrass invasion and is also susceptible to spotted knapweed invasion (Quigley and Bigler Cole 1997, p. 15). Nearly all the range of sage grouse is susceptible to some form of exotic weed invasion (USDA – Forest Service 1996b). Indeed, GAP analysis conducted by the Institute shows that many areas have already been invaded by cheatgrass. As the Forest Service and BLM note, "noxious weeds are spreading rapidly, and in some cases exponentially" throughout the range of sage grouse, and in the Eastside areas of the Interior Columbia River Basin cheatgrass has "taken over" many dry shrublands (USDA – Forest Service, USDI – BLM 1997a, p. 89). There is "increased fragmentation" and "loss of connectivity" in habitats, "expecially in shrub steppe and riparian areas" (USDA – Forest Service, USDI – BLM 1997a, p. 89-90). Disjunct "patches of sagebrush that were previously connected to other patches may now be unsuitable" because sage grouse require large areas, e.g. for wintering (Wisdom, et al. 1998, p. 2-147). The agencies also expressed "special concern" regarding sage grouse, noting the "significantly reduced plant and insect forage, nesting cover, and hiding cover" for the species, as well as the "60 percent decline" since 1940 in sage grouse populations (USDA – Forest Service, USDI – BLM 1997a, p. 89, 100). These concerns are echoed – often in identical language – for the Upper Columbia River Basin (USDA – Forest Service, USDI – BLM 1997b, p. 23, 76).

Road creation and use has contributed to increased human disturbance in areas most important for sage grouse, and can be "especially harmful to sage grouse" during lekking and wintering seasons (Wisdom, et al. 1998, p. 2-149). Road densities (0.4 to 1.0 km per km^2 [0.7 to 1.7 mi per mi^2]) are typical in the Northern Great Basin, the Owyhee Uplands, and the Upper Snake River area. Roads and associated human disturbance can be especially harmful to sage grouse during the lekking and wintering periods. Proximity to roads thus causes habitat loss causes. Consequently, source habitats for sage grouse are projected to fall from about 140,000 mile^2 currently to less than 100,000 mile^2 under all management alternatives (Raphael, et al. 2000, p. TER 157). (The use of the term "source habitats" in ICBEMP documents apparently does not accord with standard use by population biologists, meaning an area producing a surplus of individuals that can then emigrate; instead, ICBEMP's use of the term appears to merely

connote a habitat that is assumed to have only a stable population of the species in question (Wisdom, et al. 1998). Of course, there are no known stable populations of sage grouse, so the use of this term with respect to sage grouse is dubious at best.)

ICBEMP scientists were asked to identify actions that would improve sage grouse habitat (Mills 2000). They recommended a 50% reduction in livestock grazing (although additional benefits would accrue from a complete cessation), together with various restoration projects. They emphasized the high cost and difficulty of the envisioned restoration – worse, even with full implementation of these actions, sage grouse source habitats would only increase by 9% (Mills 2000). Some of the proposed restoration projects present grave risks to sage grouse – for example, burning is proposed to remove juniper seedlings (USDA – Forest Service, USDI – BLM 2000d). This will destroy sagebrush in the burn area, and since prescribed fires often escape their boundaries, huge swaths of sage grouse habitat could be destroyed.

Worse, all ICBEMP alternatives project virtually no areas with a high environmental index for summer sage grouse habitat in summer (Raphael, et al. 2000, p. TER 158) or for winter sage grouse habitat (Raphael, et al. 2000, p. TER 161). Instead, environmental indices will decline to zero or low throughout the range. Habitat for sage grouse and other shrubland dependent species will "decrease from current levels under all alternatives" (USDA – Forest Service, USDI – BLM 2000d). Notably, the ICBEMP analysis does not include the most recent analyses of juniper invasion (Shafer, et al. 2001) or many of the other threats discussed in this review. Thus, habitat will decline more rapidly and to lower levels than even the predictions of the ICBEMP analysis, making extinction of sage grouse [*possible*] within this century. The Service is aware of this, and has expressed concern to the agencies implementing the ICBEMP plan, noting that many species, "especially those of the sagebrush shrub-steppe habitats, will seriously decline under all the alternatives" considered for management of this region (Shake 2000, p. 11 of Attachment 1). * * *

Scientists on the ICBEMP team were asked to predict the effects of sagebrush restoration on both sage grouse habitat ("environmental outcomes") and on sage grouse ("population outcomes"). Again, these modeling efforts did not include the full effects of juniper invasion; moreover, there is "high uncertainty" as to the success of restoration projects (Wisdom, et al. undated, p. 11). The authors recognize that restoration is "fraught with uncertainties of knowledge and challenges to effective implementation" (Wisdom, et al. 2000, p. 33). The authors state that their approach was conservative, in an attempt to compensate for the uncertain likelihood of successful restoration. However, Wisdom, et al. (undated, 2000), Hemstrom, et al. (undated) did not present their models in any relevant detail, so it is impossible to say whether the modeling efforts used conservative assumptions or not. The modelers did make a "critical assumption," that conditions on non-federal lands will not be degraded over time. This is entirely unrealistic – these lands are threatened by cheatgrass and juniper invasion, development, and continued, unregulated livestock operations. Moreover, it is not clear if conservative modeling assumptions will be able to compensate for the uncertainty of successful restoration – nothing even approaching this scale has ever been attempted before. Further, arid ecosystems are notorious for the difficulty of restoration. Finally, the models do not account for effects of low population size, competition, predation ("other organisms"), or many other effects (Wisdom, et al. 2000, p. 15-16, fig. 1,2).

The results of the management changes envisioned by Wisdom, et al. (2000) [*were*] class C for environmental outcomes (meaning that suitable habitats are patchy or in "low abundance" causing population isolation) and only class D for population outcomes (near extinction

throughout the basin: “frequently isolated” or in “very low abundance” with only some populations self-sustaining). Historically, sage grouse were in class A status throughout the basin (“continuous, well-distributed”).

Importantly, the grazing restrictions and active habitat restoration envisioned by Wisdom, et al. (undated) are ***not*** planned actions by any land management agency. In fact, the restoration and grazing restrictions [*were*] not contemplated in any alternative in the voluminous ICBEMP documents. There are no plans to carry out these actions, and proposed or current management will only render sage grouse extinct in the basin. Nonetheless, the ICBEMP analysis by Wisdom, Rowland, et al. (undated, 2000) represents the best possible scenario for sage grouse in the region, with all federal land management agencies doing their best to actively restore sage grouse habitat. Further, these models represent relatively optimistic assumptions regarding population and environmental outcomes. Yet, the models predict near extinction of all sage grouse in the region. Not only are there no current actions that will prevent extirpation, there are no proposed or planned actions, and – worse – there are no ***known*** actions on federal lands that ***could*** prevent extirpation of sage grouse. Only a listing under the ESA – with its ability to affect actions by the states and private land management – can prevent extinction of this sub-species. As Wisdom, Rowland, et al. (undated) note, “Restoration of sagebrush-steppe over vast areas is fundamental to improving landscape conditions for … sage grouse.”

States with less than 2,000 Birds in 1998

Braun (1998a) estimated that the following states contained fewer than 2,000 sage grouse. Populations in these states are at risk because of long term declines and habitat fragmentation (Connelly and Braun 1997). Additionally, the other threats analyzed elsewhere in this review endanger the birds throughout their range. Braun (2001h) believes that there “is no hope” for sage grouse in North and South Dakota – that extirpation is inevitable in both states.

North Dakota Population Assessment

Theodore Roosevelt (1885) described hunting sage grouse in the Bad Lands and reported seeing great numbers of the birds. As of the mid 1990’s, sage grouse populations were small and declining (Drut 1994, p. 12, 20). Males per lek decreased from 35 in 1951 to only 10 in 1989, while the number of leks remained constant (Drut 1994, p. 20). This suggests that steady habitat degradation occurred, but that large amounts of habitat within the area censused was not completely destroyed. However, North Dakota Game and Fish personnel have expressed concern regarding habitat loss (Drut 1994, p. 20). Recent breeding numbers have declined by 27% (Connelly and Braun 1997, Table 1). * * * The most recent data show that fewer than 200 male birds are known to occur in the entire state, and worse, that numbers and males/lek both declined steeply in the last year (WSSGTC 1999, North Dakota section).

The BLM has collected census data revealing the extreme declines in North Dakota: from a high of 367 males, populations declined to only 124 males in 1998 (Anonymous BLM document 1999). Moreover, only 18 leks were known and graphs included in this document shows that the population declines have been particularly sharp since 1989 (Anonymous BLM document 1999). If time to extinction is projected linearly from these trend lines, the sage grouse [*may*] be extirpated from the entire state of North Dakota by 2004.

South Dakota Population Assessment

Sage grouse were originally found in “many sections” of western South Dakota (Visher 1913). By 1907, they were extirpated from areas outside the badlands and the northwestern

portion of the state, and by 1910 remained in only 2 counties, Harding and Butte (Visher 1913). Visher noted that homesteading was eliminating sage grouse habitat, and he predicted the ultimate demise of the species in the state (Patterson 1952c, p. 20).

By the mid-1990's, sage grouse were restricted to the northwest and southwest corners of South Dakota. Presently, sage grouse occur only in the extreme western part of the state – primarily in Harding, Butte and Fall River counties. Loss of habitat is the primary concern among Dept. of Game, Fish, and Parks personnel. Recent breeding numbers have declined by 45% (Connelly and Braun 1997, Table 1). Hunting seasons were closed in 1976.

As with North Dakota, males per lek have trended downward since 1972, although the number of leks counted has not changed (Drut 1994, p. 12, 20). As late as the 1950's, there were about 20,000 birds in the state (today, no state has over 20,000 birds). By the 1950's, however, only about 2,000 to 5,000 birds remained (Drut 1994, p. 20). Males/lek declined from nearly 30 in 1973 to about half that from1978 to the present (WSSGTC 1999, South Dakota section). Although males/lek fluctuates, the trend from the late 1970's to the present appears downward, although there appears to be a slight increase from about 5 males/lek in 1997 to about 12 in 1999 (WSSGTC 1999, South Dakota section). The total number of males counted has declined, and although the number of leks counted was not presented in the WSSGTC 1999, South Dakota section, this suggests that some leks no longer exist. If so, then the birds in South Dakota [*may be*] in the final phase of extinction, where insufficient birds exist to populate a lek. Today, even optimists believe that fewer than 1,200 sage grouse exist in all of South Dakota (A. Smith 2001). This number is not a census estimate, but is merely based on "guesses" by county conservation officers (A. Smith 2001).

On BLM lands, the best available data show that only 3 areas support 12 leks in the entire state of South Dakota. In Butte Co., only 69 males were found on 5 leks, yet this is the best population on BLM lands in South Dakota. Harding County has only 63 males on 6 leks, and Fall River Co. has only 11 males on a single lek (Sage Grouse Strutting Ground Count, document attached to South Dakota Resource Area (1985).

Washington Population Assessment

Before settlement, shrub-steppe covered vast areas of eastern Washington from the eastern slopes of the Cascades to the prairies of the Palouse region (Daubenmire 1942, p. 57). This habitat type once covered approximately 4.16 million hectares (Dobler, et al. 1996). Sage grouse habitat used to occur in large, contiguous patches that supported numerous interacting sage grouse populations (Johnsgard 1983; Dobler, et al. 1996; Hays, et al. 1998; Daubenmire 1942, p. 57). The range of the sage grouse was contiguous and extended from British Columbia in the north, through Washington, to Oregon and Idaho in the south and southeast (Yocom 1956, Johnsgard 1983, Drut 1994, Tirhi 1995, Schroeder 1998c). Sage grouse were known from the lower section of the Columbia River valley, north along the Columbia to the Big Bend area, and north along the length of the Okanogan River valley all the way into Canada. Sage grouse were found along the lower Palouse River and along the Snake River, as well as in Columbia County and bordering the Touchet and Walla Walla Rivers. Sage grouse were "common" in the Yakima Valley all the way across to the Columbia River, and were known from Miles, near the mouth of the Spokane River, and along the west side of Spokane County, and were "abundant" in some areas (Yocom 1956).

Today, sage grouse in Washington are divided into two tiny, remnant groups of birds. Recent breeding numbers have declined by 47% (Connelly and Braun 1997, Table 1). The range

of the sage grouse in Washington has decreased by 90 to 92% (Hays, et al. 1998). The species survives in only 4 of the 16 counties it formerly occupied. The loss of habitat in these counties ranges from 38 to 77% and these declines in habitat are ongoing (Tirhi 1995). Because of the small, disjunct populations, sage grouse in Washington can be expected to become extinct in the near future.

The entire range of sage grouse in Washington is now reproductively isolated from the remaining birds of the sub-species in Oregon (Tirhi 1995; Hays, et al. 1998; Livingston 1998). This connection is crucial because the sub-species will be lost unless it is connected with Oregon birds…. Intermediate forms might result from such introgression; however, the Washington birds are also cut off from [sage grouse] in Idaho (Tirhi 1995; Hays, et al. 1998; Livingston 1998). This increases the risk of complete extinction of birds in Washington.

Formerly, sage grouse were common and abundant in eastern Washington. In 1805, Lewis and Clark described large numbers of sage grouse near the mouth of the Snake River (Jewett, et al. 1953; Yocom 1956; Hoffmann 1991). Sage grouse were also known to be abundant in the 1800's in the Blue Mountains area, Columbia River and its associated plains, the Simcoe and Yakima river valleys, and near Alder Creek (Baird, et al. 1874, Yocom 1956). The largest populations were in Douglas, Grant, Lincoln, Adams, and Franklin counties (Yocom 1956).

Cattlemen were the first settlers in eastern Washington and introduced cattle in 1834, sheep in the 1880's, and expanded feral horse herds from 1830 to 1880 (Daubenmire 1988). Excessive grazing reduced the density and canopy cover of native plants, created microsites for seed germination, and transported seeds deep into the interior – all effects favoring the invasion of alien exotics (Daubenmire 1988, Mack 1981, Belsky and Gelbard 2000).

Conversion of habitat to agriculture began in 1863, and by the 1930's most lands that had wet meadows or were otherwise well-suited to agriculture had already been converted (Harris and Chaney 1984, Yocom 1956). Early dryland farming required large teams of horses, which were turned loose to graze, exacerbating habitat conversion with habitat degradation (Harris and Chaney 1984). Sage grouse vanished from the vicinity of Spokane after 1908 (Jewett, et al. 1953, p. 217).

Severe declines occurred in the 1930's, and the newly formed Washington Dept. of Game placed a moratorium on hunting in 1933. Populations slowly returned and despite the destruction of the best habitat, in the 1950's sage grouse were still sufficiently numerous that Kittitas County farmers complained about potential crop damage (Yocom 1956). The first open season was held in 1950 for 2 days in the Badger Pocket area of Kittitas County and about 2,700 birds were killed. The hunt was expanded over the next 3 years to include 3 additional counties, and the harvest increased to 4,000 birds. By 1956, Yocom had already warned against loss of habitat and its consequent negative effects on sage grouse. However, habitat destruction continued.

Large scale reclamation projects and conversion of shrub-steppe to agriculture during the 1950's and 1960's severely reduced sage grouse distribution (Hoffmann 1991, Todd and Elmore 1997). Between 1947 and 1982, over 301,500 acres (122,000 ha) of brush in Washington were documented as being destroyed, according to the federal Agricultural Conservation Program and the Columbia Basin Project (Pederson 1982). The 4 counties containing the most sage grouse accounted for 20% of the brush control. Over half of the sagebrush shrub-steppe in Washington has been destroyed (Welch 1999) and the remainder is highly fragmented. Dobler and Eby (1990) and Dobler, et al. (1996) estimated that only 40% of

sagebrush steppe remains. Most sage grouse habitat occurs in the form of small isolated patches surrounded by agricultural lands (Dobler, et al. 1996; Hays, et al. 1998, appendix A). The largest blocks of remaining habitat in Washington occur on the lands of the Yakama Indian Nation, the Hanford Nuclear Reservation, and the Yakima Training Center in Yakima and Kittitas counties; however, only the latter contains any birds (Dobler, et al. 1996). Moreover, the lands abutting sagebrush areas are typically agricultural fields, thus forming what is often termed a "hard edge" in landscape ecology. By 1980, the range of sage grouse had contracted into two small disjunct population isolates (Pederson 1981; Drut 1994, Fig. 3). However, hunting was not ended until 1988 (Drut 1994, p. 16) and hunting data show marked declines in the number of birds harvested from 1951 to 1987. The size and range of these populations have contracted even further since that time (Hoffmann 1991; Drut 1994, Fig. 3) and have been declining for at least the last 40 years (YTC CA 1994). The range has declined by 92% – only 8% to 10% of suitable habitat remains (Schroeder 1998c; Hays, et al. 1998). Even within the two isolates, the remaining habitat is fragmented.

Of these two remnants, the northern area is the largest, but occurs in Douglas and northern Grant counties on private land (Schroeder 1994b; Tirhi 1995; Hays, et al. 1998). Because this group of birds resides on private land, no legal mechanisms apply to protect it. Moreover, the habitat within the northern area consists of small, widely scattered and isolated patches of sagebrush. The southern area is on a military area, the Yakima Training Center (YTC), which is federally owned and administered by the US Dept. of the Army. Although reduced in size to a remnant, the YTC lands do represent the largest contiguous portion of shrub-steppe in Washington state (Hoffmann 1991, Dobler, et al. 1996). Only 5 lek sites are known on the entire YTC (YTC CA 1994). Sage grouse on the YTC are threatened by troop movements, and fires caused by military activities (Hoffmann 1991). Populations have decreased since 1981 on the YTC, with only 123 males observed at leks in 1990 (Drut 1994, p. 16), and the percentage of adults with broods also declined steadily since 1975 (Hoffmann 1991, Drut 1994, Fig. 6, p. 17). Protections on the YTC are limited – for example, 25% of the females on the YTC are not required to be directly protected by the Conservation Agreement (YTC CA 1994, p. 3, section VI.A.2), troops will be allowed to shoot into lek areas in the evenings (YTC CA 1994, p. 3, section VI.E), and leks are only protected by closures within 1 km (about 0.5 mile) (YTC CA 1994, p. 3, section VI.A.1). These protections are inadequate.

The sage grouse population in north-central Washington migrates between distinct spring-summer and fall-winter areas (Schroeder 1994a, 1994b). Home ranges of sage grouse on the Yakima Training Center (YTC) are 26.6 km^2 in spring, 24 km^2 in summer, and 44.2 km^2 in autumn (Eberhardt and Hoffmann 1991). These home ranges are unusually large, much more so than the nearest population outside of the YTC in Douglas Co., Washington (Pederson 1982). Eberhardt and Hoffmann (1991) attributed the unusually large size of the home ranges on the YTC to the disturbance caused by military operations. Thus, large home ranges, and consequent energetic stress and predator exposure, is likely when other disturbing activities are present, such as oil and gas operations, mining, off road vehicles, and high road densities. Sage grouse on the YTC are known to generally stay within the boundaries of the reservation (Cadwell, et al. 1994). The areas immediately surrounding the YTC are either severely degraded or converted to agriculture, thus constituting a "hard edge" in the parlance of landscape ecology – one that sage grouse will not cross. The YTC population thus yields important data on fragmentation because it offers an example of what width of intervening space will serve to fragment sage grouse populations and cut off gene flow.

Military operations significantly increase the likelihood of fire, particularly between May and October (Livingston 1998). Fire rates are positively correlated with military training operations (Stephan, et al. 1996). Training has caused the ignition of fires almost every year (CH2M-Hill 1996). Fires are large in extent: for example, in August 1996, a fire began in a military impact zone on the YTC and burned over 150,000 hectares on the YTC, and an additional 5,000 hectares on adjacent lands (Hays, et al. 1998 citing M. Pounds, personal communication). Luckily, this particular fire happened to miss areas of critical sage grouse habitat. However, even a single fire "of this magnitude in the primary sage grouse use areas would jeopardize the species persistence at YTC" (Livingston 1998). Despite the Army's intentions or attempts to control fire, it is an inevitable result of training activities and an imminent and substantial threat to sage grouse on the YTC.

Two types of data on population levels have been collected in Washington: lek counts and hunting harvest data. Sage grouse hunting harvest data cover the period from 1950 to 1988, when WDFW terminated hunting. In 1950, a 2-day hunt yielded approximately 2,700 sage grouse (Hays, et al. 1998). From 1951 to 1973, annual hunts yielded a stable number of birds (mean = 1,842), and fewer than 1,000 birds after 1974. In 1987, only 18 birds were harvested. Thus, in only 7 years, from 1974 to 1980, sage grouse hunter success was cut in half, from 0.43 birds/hunter to 0.23 birds/hunter, even though length of season and the areas open to hunting were constant over the period. These data solidify the observation that sage grouse can experience very rapid population declines.

Leks counts cover the period from the 1950's to the present (Schroeder 1998c). Lek surveys were used to establish hunting seasons and bag limits. After pronounced population declines, more comprehensive lek surveys were undertaken by WDFW, including searches for new or previously undiscovered leks, and multiple counts of males on known leks. Since 1992, virtually all sage grouse leks in the state have counted annually by WDFW or by US Army personnel on the YTC. Surveys for new leks are made each spring.

The lek count data show dramatic declines in both distribution and numbers of sage grouse in Washington (Schroeder 1998c, Hays, et al. 1998; Livingston 1998). Since 1954, 72 lek complexes have been documented (Schroeder 1998c). The average maximum number of males on these leks is 21.2 based on 480 annual counts, with 95% confidence intervals from 19.6 to 22.8. Numbers of males observed on leks declined at a rapid rate: the rate of decline was 3.5% per year from 1960 to 1998, and these declines were statistically significant at the $P = 0.05$ level, although annual fluctuations resulted in a low correlation coefficient of $r = 0.05$ (Schroeder 1998c). Biologists increased the number of leks visited after 1970, but the number of males found continued to decline. In Douglas County, the males observed on leks increased from 100 in 1986 to 308 in 1990. However, at such small sizes risk of extinction is imminent. DNA samples from 7 birds on the YTC were included in a study of genetic variation conducted by J. R. Young (1994b). The Washington birds had significantly lower genetic variation (within population similarity index) than birds from Colorado or Utah. This suggests reproductive isolation and a reduction in fitness and reduced ability to respond to selection pressure (adaptability) (J. R. Young 1994b).

Another important source of data on population levels and trends is the number of active leks. Trends in the numbers of active leks are strongly downward. Of the lek complexes that were active from 1954 to 1998, 52 are now vacant, and 26 of these are outside the current distribution of sage grouse (Schroeder 1998c). These data illuminate the rapid decrease in both population size and range – both of which are important for population viability. If one assumes

equal spatial lek density over time, the data on loss of active leks indicates a reduction in geographic range of 36% over the last 45 years. However, the current range is known to have a higher density of leks than did the previous range; therefore, the rate of decline is the range is much greater (Schroeder 1998c).

Schroeder (1998c) estimated the state-wide population by assuming a female/male sex ratio of 1.6 and that all males were counted on known leks, summing the numbers counted on leks for each consecutive year. As discussed elsewhere for Gunnison sage grouse, this may inflate absolute population estimates (though by less than do the various Gunnison sage grouse conservation plans). However, the rate of decline will not be affected by these assumptions, and was estimated as 83% (Schroeder 1998c). As large as this decline is, it is probably an underestimate, because the number of leks included in the count increased in later years as more intensive surveys were carried out. Schroeder (1998c) estimated that from a population of 5,900 birds in 1960, sage grouse declined to only 3,800 birds in 1970, and only 1,020 birds in 1998.

Both groups of birds in Washington have experienced population lows between 100 to 150 females during the 1990's (Hays, et al. 1998), and thus both groups are likely to be experiencing genetic bottleneck effects and loss of genetic heterogeneity and rare alleles. Early on, numerous authors found that population viability is significantly reduced when population size falls below about 500 interbreeding individuals (Lande and Barrowclough 1987, Dawson, et al. 1987; Grumbine 1990b). This estimate appears overly optimistic, as more recent studies indicate that 500 individuals will not conserve a species, and approximately 5,000 to 10,000 individuals are required for population viability (Lande 1995).

The rate of population decline differs in different parts of the state. The sage grouse population in Lincoln County had 388 birds in 1970. Its rate of decline (birds/year) was notably less than rates of decline in Yakima/Kittitas and Douglas/Grant counties, but the Lincoln County birds became extinct in 1985, only 15 years later. This points up the danger of small population sizes in sage grouse. The Yakima/Kittitas County group declined 70.5% from 1970 (1,235 birds) to 1998 (364 birds). The Douglas/Grant County group declined 66.4% from 1970 (1,858 birds) to 1998 (624 birds). Note that both these groups are now in the same extreme low population situation that the Lincoln County birds were in just before they went extinct. There has been a minor increase in these two groups in the last two years but this apparently results from abundant precipitation in those years (NWEA 1999, p. 24 citing Schroeder, personal communication). In 1998, there were also about 200-300 sage grouse on the YTC (Livingston 1998), and about 600-700 occur primarily in Douglas County (Schroeder 1998c).

Drut (1994) estimated that during spring breeding, the entire state of Washington only contained 1,500 birds. Sage grouse are highly vulnerable to fire, climatic effects, land conversion, predation, and grazing (Drut 1994). Birds are so sparsely distributed over the landscape that breeding and other social behaviors may be affected – Drut (1994) reports that densities are often 2 birds per km^2 or even less.

The steepest declines in Washington sage grouse populations occurred from the early 1960's to 1970's, but significant losses are occurring now. Males/lek on the YTC declined from 35.7 in 1989 to 11.3 in 1998, with 7 of 9 years exhibiting downward trends (Livingston 1998). After habitat alteration at the Canawai Creek and Creston Butte leks in Region 1, sage grouse visitation declined (Tirhi 1995 citing Hickman, personal communication). Both leks then became inactive as bird visitations fell below the critical threshold, and lek counts for Region 1 declined from 66 birds in 1981 to no birds at all in 1995 (Tirhi 1995).

The rate of decline in Washington appears to be similar to that in Idaho and Oregon,

thereby suggesting common, widespread factors affecting these populations. A complicating factor is that sage grouse may exhibit population cycles with a periodicity of around 10 years (Rich 1985a; Willis, et al. 1993). Thus, apparent trends over short periods should be regarded with caution.

Although all threats discussed above affect sage grouse in Washington, the most critical threats to the birds are the continual reduction and degradation of habitat from military training exercises, uncontrolled fires, agricultural development, invasion of habitat by non-native species, livestock operations, particularly grazing, and sagebrush control. Existing habitat problems are exacerbated by the spraying of chemicals, predation, human disturbance, disease, weather events, hunting and poaching, genetic drift, and demographic fluctuations.

Schroeder (1998b) calculated N_e for sage grouse and found N_e to be 415 in Douglas/Grant counties and 242 for Yakima/Kittitas counties. As described in the Population Mechanisms and Vulnerability section, this particular formulation will overestimate both N_e and viability. Neither is within an order of magnitude for a viable population, which is conservatively estimated at approximately 5,000 organisms (Lande 1995). As Schroeder (1998b) noted, both Washington population numbers are "substantially lower" than the suggested target for viability. As discussed elsewhere in this review, Schroeder's population viability analysis is an important first step, but is non-conservative and over-optimistic – it does not consider all threats to the species and uses a lower and inappropriate standard (500) for viability instead of the standards of 5,000 to 10,000 now recognized in more modern analyses. Moreover, the 10,000 standard is the one that the Service has recognized (Summary of North Park Working Group Meeting 1999, p. 6).

These low population levels are lower than even the most liberal viable population estimates of 500 (Lande 1995). The issue, then, is not whether sage grouse in Washington will become extinct, but how quickly they will become extinct. Schroeder (1998b) recognized this and concluded that no population in Washington is viable. The danger of extinction in Washington is imminent, and depending on weather and other events, could occur at any time. Braun (2001h) believes that there "is no hope for the two populations in Washington," and that they do not "have a ghost of a chance to be viable in 20 years."

States with 2,000 to 10,000 Birds in 1998

Braun (1998a) estimated that California contained between 2,000 and 5,000 sage grouse in 1998. Yet, sage grouse were once present in great numbers in the state. Belding (1890, p. 20) stated that although the birds were "numerous" in many portions of the Intermountain West, they were "even more abundant" in eastern California. Over the next 20 years, the birds declined because of sheep grazing (see below), but were still "fairly common" in California (Grinnell, et al. 1918), and occurred in 9 counties along the eastern side of the state. Today, the range is much reduced and fragmented into a series of isolates with large gaps between them. Examination of Schroeder (2000a) shows that sage grouse have been extirpated from 4 counties (Siskiyou, Shasta, Plumas, and Sierra counties). A tiny remnant population remains near the border of Alpine County and Mono County. Today, sage grouse survive in only two disjunct areas in California.

California Population Assessment

Populations in California are declining (Popham 2000) and are quite small – fewer than

5,000 birds survive over the entire state (Braun 1998a). These data may represent over-estimates. California Department of Fish and Game (CDFG) population assessments are inflated in numerous ways. For example, the agency first counts the number of males seen, then assumes that 33% more males exist, and then further assumes that two females exist for every male, even the ones that were not actually censused (F. A. Hall 1995, p. 13). There are no published studies supporting such non-conservative estimates in California. The number of sage grouse estimated in this fashion by CDFG is thus highly optimistic, and is nearly 3 times the number actually censused. It is unwise to inflate population estimates in this manner for any species that is declining and at risk, much less one with such mating bias. Another problem with the data collected by CDFG is the large amount of variation in sampling and census efforts – apparently no attempt has been made to correct the data for these biases (Gibson 2001a, p. 1).

In northern California, the broad band of sage grouse range has contracted and fragmented into 4 areas – one of about 2800 miles^2 in Lassen County, a smaller area in Modoc County, a very small area, also in Modoc County, and an area along the Nevada and Oregon borders (Stermer, undated). The California Dept. Game and Fish map (Stermer, undated) shows a few other extremely small areas of current range, but none contains any leks. Sagebrush habitat areas are presented in Kuchler (1988a, 1988b). The largest lies along the Nevada border and extends from near Honey Lake to the Oregon state line, but it is dissected by several large areas of non-habitat (Kuchler 1988b).

*Populations in California are at risk because of long term declines and habitat fragmentation (Connelly and Braun 1997). Few lek sites remain, and the current range has greatly contracted into a series of small isolates (WSSGTC 1999, California section). Many of these are currently "at risk," including Rocky Prairie in Modoc County, upper Long Valley in Lassen and Sierra counties, Bagley Pass in Alpine and Mono counties, and the Fales area of Mono County (F. A. Hall 1995, p. 39). * * * In the north, sagebrush habitat extended westward across the Modoc Plateau from the eastern border to Yreka, progressively narrowing at the western margin near Mount Shasta and Mount Lassen (J. A. Young, et al. 1977, p. 765). From Honey Lake, sagebrush habitat extends in a narrow strip along the eastern border with Nevada as far south as the town of Bishop (J. A. Young, et al. 1977, p. 765). The range of sage grouse in California has been reduced by 58% (F. A. Hall 1995, p. 17; fig. 1, p. 2). Sage grouse have been extirpated from 3 counties (Shasta, Siskiyou, and Plumas) and have nearly been extirpated from Sierra and Alpine counties (F. A. Hall 1995, p. 17). * * **

Cheatgrass has invaded and "changed succession" in the "entire vegetation type" (J. A. Young, et al. 1977, p. 780). Degradation of sagebrush habitat is pervasive, and agricultural conversion has destroyed nearly all riparian and wet meadow habitats of use to sage grouse, particularly in the Modoc Plateau. Most waterfowl refuges in sagebrush habitat have a developed aspect with steep banks forming hard edges along the margins, rather than gentler slopes which would create the moist riparian soils that promote plant growth favored by sage grouse, particularly late in the brooding season. Extensive forest and lava flows form inclusions in most habitat in the Modoc Plateau, fragmenting that habitat. Road densities are very high in nearly all California habitat, and industrial developments such as high speed highways, powerlines, and military installations are ubiquitous. Data from the Soil Conservation Service (NRCS) shows that 25% of non-federal forests and rangelands are experiencing excessive soil surface erosion (Noss, et al. 1995, p. 46), damaging the ability of plants to produce food for herbivores such as sage grouse.

Formerly, sage grouse were abundant, and Grinnell noted they had been "found in great

numbers" in Long Valley, Mono County (Hornaday 1916, p. 202). Newberry reported that sage grouse were "very abundant" on the shores of Wright and Rhett lakes (Newberry 1857a, p. 96), and also saw sage grouse "high up on the Pit River" near a warm spring (Newberry 1857a, p. 95). The latter location would be in present day Modoc County. In the Crowley Lake area, early settlers reported thousands of sage grouse (Schneegas 1967, p. 271). Dawson (1923) described sage grouse range as extending from eastern Siskiyou County to eastern Modoc County along the Oregon border, and extending south to northern Modoc County. In August 1870 Leconte passed through the eastern slope of the Sierras and noted that sage grouse were "very abundant" near Bridgeport (Leconte 1994, p. 88). Grinnell and Miller (1944) described the range as extending from the Nevada line west through Modoc Co. to the west side of Lower Klamath Lake in eastern Siskiyou Co., and south along the east side of the Sierra Nevada at least to Big Pine in the Owens Valley, Inyo Co. Water diversion by the City of Los Angeles probably impacted sage grouse as much as it did the farmers in Owens Valley. The altitudinal range extended from 3,500 feet near the Pit River in northeastern Shasta Co. to 12,000 in the White Mountains of Mono Co. (Leach and Hensley 1954). Cooper (1869f, p. 188) reported sage grouse from the Mojave River valley in San Bernadino County (also related in Grinnell, et al. 1918). Contemporary scientists have discounted this observation (Braun, personal communication). But Cooper relates that he saw a bird killed, and presumably had an opportunity to observe it carefully. Cooper was familiar with sage grouse (Cooper 1860, 1868a, 1869c). If accurate, this would represent a much larger historic range than previously thought.

Sage grouse were largely extirpated from north central California as riparian areas were dried out because of water developments in the Klamath Basin (Horsfall 1932). On what is now the Lava Beds National Monument, sage grouse were "fairly abundant until 1930" but have only been seen sporadically since that time (Bloch 1963), and were last sighted in 1960 (Forsell 1961). Birds were extirpated after massive water projects were constructed to benefit agriculture in the Klamath Basin, affecting water levels in Tule Lake. The last birds in the area were found in Clear Lake NWR (Summers 1993). The birds became concentrated and subject to heavy hunting pressure. By the early 1990's, sage grouse were declining in Region 5 of California (consisting of Inyo and Mono counties), and CDFG claimed sage grouse were much reduced but stable in Region 1, the counties of Lassen and Modoc (Letter from Calif. Dept. Fish and Game, in Drut 1994, p. 41). However, "the numbers of grouse counted are low in many years" in Lassen County (F. A. Hall 1995, p. 20). It is unclear how to reconcile these two apparently differing statements. Statewide, sage grouse populations had declined by more than 50% by the mid-1990's (DeSante and George 1994).

The present distribution is disjunct and sage grouse are now absent from 3 counties in east-central California, and are much reduced in Siskiyou County. This fragmentation means that the actual population sizes are much less than the total number of grouse in the state, and that the consequent effects of demographic and environmental stochasticity will be major factors reducing population viability.

In the eastern Sierra region, significant livestock grazing began in the mid 1800's and "was extremely high during the World War I years" (Menke, et al. 1996, p. 921). Beginning in the 1960's, the Forest Service sprayed sagebrush and seeded grasses to support livestock grazing (Menke, et al. 1996, p. 921). Consequently, big sagebrush cover declined and cheatgrass is now the most common non-native component throughout the 7 National Forests in eastern California (Menke, et al. 1996, p. 934).

In the 1990's most of the remaining birds were located in four counties: Modoc and

Lassen in the northeast, and Inyo and Mono in central California along the Nevada border (Drut 1994, p. 18). Harvest data indicate a downward trend from 1959 to 1990, although birds/hunter and birds/(hunter-day) measures were relatively stable. Seasons were closed in 1967, 1968, and 1983 to 1986 (Drut 1994, p. 18). In 1991, the Calif. Dept. of Fish and Game estimated that 346,000 to 559,000 birds existed in the state (Drut 1994, p. 18). Such estimates are startling, and if even close to the truth, would give California the largest numbers of sage grouse of any state, by more than an order of magnitude. These estimates were derived by using density estimates obtained by Hoffman in 1964. Yet, in the same document, the Calif. Dept. of Fish and Game classified the birds as a species of special concern (Drut 1991, p. 18). The agency's 1991 estimates are perhaps appropriate for pre-settlement levels, but seem wildly optimistic if applied to any of the last few decades. BLM estimates about 4,000 to 8,000 birds in the state (Drut 1994, p. 18), and this seems much more reasonable, though still perhaps an over-estimate.

*A number of large fires have burned areas of sage grouse range recently. The National Interagency Fire Center (NIFC) has recently collected information on maps showing the [areas burned] * * * (http://firemapper.fs.fed.us/cgt2001269.jpg).*

In 1994, only 601 males were counted at leks in all of Modoc County (F. A. Hall 1995, p. 66), and only 48 males were counted in 1990 (F. A. Hall 1995, p. 65). The Clear Lake area (in Modoc Co.) was hit by a lightning strike recently and much of the sagebrush burned. Biologists have found only 6 birds in the area. As one biologist put it, "if it makes it through the next year, it will be amazing." Sage grouse populations "are so low that they do not respond to improved [habitat] conditions (Bradley 1998). US Forest Service administrators have called for the cessation of hunting in the state (Bradley 1998).

States with 5,000 to 20,000 Birds in 1998

Braun (1998a) estimated that these states contained between 5,000 and 15,000 sage grouse in 1998. Populations in these states are at risk because of long term declines and habitat fragmentation (Connelly and Braun 1997). The other threats analyzed elsewhere in this review also endanger the birds throughout their range.

Utah Population Assessment

* * * Both the Greater and Gunnison sage grouse once ranged throughout most of Utah with the exception of the shadscale (*Atriplex confertifolia*) areas in the valleys and foothills of western Utah (Ryser 1985, p. 278; WSSGTC 1999, Utah section). Birds were found in all of Utah's 29 counties and were abundant (WSSGTC 1999, Utah section, p. 1). In 1897, Huntington noted that one of the most abundant areas was near Fort Bridger and south to the Uintah Mountains (Bent 1932, p. 300). Sagebrush was once found in large islands scattered across the entire state (Foster 1968). Early explorers described hillsides covered with abundant grasses (Miller, et al. 1993, p. 116), and pioneer journals indicate that sage grouse were abundant in Utah in the early 1800's (Utah Draft Conservation Agreement 1998). Grasses and forbs were so abundant that large areas in northern and central Utah resembled the Palouse area of Washington state (Miller, et al. 1993, p. 116).

Settlement began in Utah during the 1840's, but much of the region did not experience settlement until the 1860's (Miller, et al. 1993, p. 117). Since settlement, sage grouse in Utah have declined by 50% or more (Drut 1994, p. 20; WSSGTC 1999, Utah section, p. 1). Utah Div. of Wildlife Resources personnel have noted that males per lek, and hunting harvest levels have declined since 1959 (Drut 1994, p. 20); however, these personnel maintain that production has been stable since 1959, something that is difficult to reconcile with decreases in harvest levels

and males per lek. Males per lek have declined from about 50 in the 1960's to a low of about 10 in 1995, and then increased slightly to about 18 males/lek in 1998. Chicks per hen increased from the long term average of 2.07 to 4.2 in 1997. Recent breeding numbers have declined by 30% (Connelly and Braun 1997, Table 1). The largest remaining populations of sage grouse are found in Rich County, the Park Valley area of Box Elder County, on Diamond and Blue Mountains in Uintah County and on the Parker Mountains in Wayne County (Utah Draft Conservation Agreement 1998). Although Rich County contains some of the largest populations in the state, the county has been termed a "desperate situation" by state agency scientists working on the grouse there (Grandison and Welch 1987). Sage grouse harvest numbers fell from 3,000 birds in the early 1970's to only 320 birds by 1987 (Grandison and Welch 1987). This debacle was caused by "widespread sagebrush eradication" from BLM mis-management and by private parties (Grandison and Welch 1987). BLM again pursued sagebrush habitat destruction in the late 1980's and early 1990's (Grandison and Welch 1987).

Utah claims to have an estimated 12,744 sage grouse (WSSGTC 1999, Utah section, p. 1) although only 126 leks were found in recent surveys (Utah Draft Conservation Agreement 1998). Leks in Utah average only 10 males each (Beck and Mitchell 1997). It is thus unclear how this population estimate was derived, because only 2,124 males were counted at leks in 1998 (WSSGTC 1999, Utah section, p. 1).

The above estimate is based on the assumption that twice as many males exist as were counted, and that the sex ratio was 1:1. Besides the dubious practice of assuming that birds exist even when they are not found, using both these assumptions would only yield an estimate of 4 * 2,124, or 8,496 birds in the state (which would be fragmented into numerous small populations, not a single large population). The estimate of over 12,000 birds is not supported in the document where it is presented (WSSGTC 1999, Utah section, p. 1). Perhaps the estimate includes juveniles, but this is poor management practice, as juveniles are unlikely to survive to adulthood and breed – particularly in declining populations, such as occur throughout the range, and especially in Utah. Such assumptions form the rationale for the claim that hunting only replaces other mortality sources. If this is true, then juveniles cannot be counted as a part of stable populations. If it is false, then hunting of the bird must be ended across its range until populations rebuild.

Habitat has declined by 50% (WSSGTC 1999, Utah section, p. 1), and remaining habitat is highly fragmented (Drut 1994, p. 12). Large blocks of habitat have been lost, and the remaining habitat is degraded and eliminated by livestock grazing, agricultural development and urbanization (WSSGTC 1999, Utah section, p. 1; Beck, et al. 1999). Massive amounts of habitat have been converted to cheatgrass in Utah, and this conversion has been caused by cattle grazing and fire (Sparks, et al. 1990). Analysis of satellite imagery in Utah shows striking declines in sagebrush habitat with open canopies (Utah Draft Conservation Agreement 1998). Less than 4.6% of sagebrush and mixed sagebrush and perennial grasslands in Utah are well protected (Edwards 1995). Land protection has been "more of a random product than a systematic approach" in Utah (Edwards 1995). Some lands have been enrolled in the Conservation Reserve Program (CRP) but most of these contracts expired in 1995-96 (Utah Draft Conservation Agreement 1998). CRP offers minimal protection for sage grouse in any event.

Grazing has clearly had adverse impacts in Utah. Mitchell summarizes it as follows: "Excessive grazing has severely impacted the vegetative composition of sagebrush-steppe habitat on foothill and bench rangelands in Cache, Morgan, and Weber Counties. In many instances, annual grasses have replaced native bunch grasses and the canopy coverage of sagebrush is too

dense. Excessive livestock grazing of riparian habitats in eastern Box Elder County has eliminated or reduced many bud-producing shrub species." On the other hand, not all areas have been affected in these ways. "Most of the sagebrush-steppe within dry-farm lands is in good ecological condition. This includes approximately 65 percent of the current distribution of sharp-tailed grouse, most of which is in eastern Box Elder County" (Mitchell 1999). These areas, too, may be threatened in the future, however. Mitchell continues "Although many tracts of sagebrush-steppe are partially fenced, most are not grazed or grazed lightly because of the lack of livestock water. Future livestock water developments could change existing conditions."

In the Hickman Flat area, habitat has been "extremely negative[ly]" impacted by root plowing and overgrazing (Braun 1996c). These problems are compounded by drought and land ownership issues. The habitat in the Hickman Flat area is "degraded, highly fragmented, and occurs in small pieces" (Braun 1996c). "Brood habitat is exceedingly limited," and "it is probable that sage grouse will be extirpated in this area within 5 years" (Braun 1996c). This is not merely another population extirpation in a species near extinction. Worse, the Hickman Flat area is the "key genetic interchange site between Colorado and Utah Gunnison[] sage grouse populations" (Woyewodzik 1999). Thus, this extirpation will trigger extinction of the Gunnison sage grouse in Utah and hasten the extinction of the entire species. BLM is attempting to purchase private land in the area, but surprisingly, BLM does not contemplate any changes to grazing permits to benefit sage grouse until the permits "come up for renewal" " (Woyewodzik 1999). Perhaps, BLM is powerless to do so. Listing of this species would allow the needed adjustments to be made.

The Colorado BLM has proposed oil and gas leasing throughout sage grouse habitat with stipulations that are clearly inadequate to protect the species (District Manager, Montrose District 1994; Anonymous, undated document 5). BLM admits that "the intent is not to protect all nesting habitat from disturbances" (Anonymous, undated document 5, p. 1). As field personnel in the BLM asked, "why are we [BLM] allowing continued loss of habitat outside of the nesting season?" The state office replied that oil and gas operations would be allowed to disrupt sage grouse and would only be interfered with if disturbance of lekking activities "exceeds the 10% threshold" (Anonymous, undated document 5, p. 1). This threshold relates to 10% of the geographic area around the well site, not to damage per se to sage grouse. Significant damage to nesting habitat would occur before the threshold was reached (District Manager 1994, p. 2). The state office also did not explain how this threshold would be monitored. BLM realizes that oil and gas disturbance constitutes a "cumulative" threat to sage grouse in combination with other threats (Anonymous, undated document 5, p. 1) but does not provide any monitoring analysis or explain how enforcement would occur. The Montrose District of the BLM formally requested a stronger stipulation for its area (District Manager 1994).

Drut (1994, p. 20) also summarizes some data on males per lek: from 50 in 1959, males/lek fell precipitously to 15 in the mid-1980's, then increased slightly to 20 by 1990. Hunting harvest increased from 10,000 in 1959 to 23,000 in 1976, then fell to 12,000 in 1984, and was 14,000 in 1990, although some areas were closed to hunting in that year (Drut 1994, p. 20). Productivity fluctuated between 0.8 and 2.1 chicks/hen with no discernible trend, and threats to the bird include grazing and habitat fragmentation. The estimated annual harvest in Utah is nearly 25% and total annual mortality of sage grouse in Utah is about 60% (Utah Draft Conservation Agreement 1998). Thus, hunting is a significant proportion of total mortality. Because of the political interference with the Utah Div. of Wildlife Resources detailed in Wilkinson (1998), all data and conclusions of this agency should be carefully evaluated.

Today, sage grouse occur in only 19 of the former 29 counties (WSSGTC 1999, Utah section, p. 1). Only 4 counties have estimates of more than 500 birds: these populations are found in Rich County, the Park Valley area of Box Elder County, on Diamond and Blue Mountains in Uintah County, and on Parker Mountain in Wayne County (WSSGTC 1999, Utah section, p. 1). Garfield County has the next largest population (WSSGTC 1999, Utah section, p. 1); however, sage grouse ranges in Garfield County are particularly fragmented, occurring in 4 separate isolates (WSSGTC 1999, Utah section, map). Some populations are only 10% of the level in the late 1930's (Welch, et al. 1990). Braun (2001h) believes that all sage grouse in Utah will become extinct within 20 years, except those in Box Elder, Rich, Uintah, and Wayne counties. Continued advance of cheatgrass, juniper, and pinyon would accelerate extinction and render populations in those 4 counties extinct also.

In the Strawberry Valley (southeast of Salt lake City), sage grouse have declined drastically since 1939, with only 4-6% of the birds remaining by 1990 (Welch, et al. 1990). The cause of these declines, as elsewhere, was management for livestock production (Welch, et al. 1990, p. 1). In the early 1900's, the Bureau of Reclamation withdrew several thousand acres of public lands and constructed a large reservoir, which no doubt flooded the best wet meadow and riparian habitat. The familiar cycle of the agro-industrial livestock complex followed: cattle grazing degraded the uplands, while water from the reservoir was used to irrigate alfalfa and other low value cattle feeds in what had been prime lowland sage grouse habitat before conversion. Predictably, sage grouse populations plummeted (Welch, et al. 1990, p. 2). The reservoir is now stocked with fish, attracting red fox, and this will likely result in the extirpation of this sage grouse population (see discussion in Predation section).

Colorado Population Assessment

Sage grouse were abundant in the sagebrush of western Colorado before the 1930's (Bailey and Niedrach 1965) and occupied at least 26 counties (Braun 1991a; confirmed in 23 counties and probably 4 others, Malmsbury 1996). The Gunnison Basin Sage Grouse Conservation Plan refers to a historical occupation of 23, and probably 27 counties in Colorado (GBCP 1997). Fremont had noted sage grouse in the valley of the Grand River in 1845 (Patterson 1952c, p. 19). In 1925, Bailey found sage grouse "still numerous" in northwestern Colorado and thought their center of abundance to be near Craig and Sunbeam (Patterson 1952c, p. 20). Bailey noted that a key protection for the birds was the "inaccessibility of the regions" they inhabited (Patterson 1952c, p. 20). But by the 1930's, sage grouse were near extinction and hunting seasons were closed from 1937 to 1953 (Drut 1994, p. 18). Populations increased over this 16 year period, and hunting seasons were reopened in 1953. Hunting harvest averaged 11,000 birds by the 1960's, but habitat fragmentation continued (Drut 1994, p. 18). In 1965, Bailey and Niedrach (p. 282) expressed concern regarding the "destruction of the sage habitat" in Colorado, and noted that the birds were holding their own only in remote areas, and were "in need of close protection" elsewhere. Distribution of the birds has decreased by more than 50% since the early 1900's (Braun 1995). These declines continue and recent breeding numbers have declined by 31% (Connelly and Braun 1997, Table 1).

In the early 1990's, Braun (1991) noted that sage grouse were then found in only 18 counties, and regarded only 6 counties as having secure populations. Dr. Braun is concerned about the use of the term "secure" and intends to publish a critique of the terms "secure," "persistent," "marginal," and "at risk" in the near future (Braun 2001l). As late as the mid-1990's, sage grouse in Colorado were thought to be stable (Drut 1994, p. 12). A few years later, Braun (1998a) noted recent declines in the number of active leks, and found that declines in the

number of males ranged from 44% to 82% in two counties. These data indicate that no population studied was truly secure and that sage grouse can easily decline even when they are believed to be stable. Braun (2001h) expects that all sage grouse in Colorado will be extinct within 20 years, except for those in Jackson and Moffat counties and the small population of Gunnison sage grouse in the Gunnison Basin. However, Braun's predictions do not take into account the spread of juniper, pinyon, and cheatgrass – thus complete extirpation could occur within 20 years.

Range maps based on the latest data show sage grouse of any species present in what appears to be only 14 counties in Colorado; they "have been extirpated from at least 8 and more probably 16 counties in Colorado" (Braun 1995). This is a decrease in occupied counties of over 44%. Moreover, only 5 counties show either species present in any significant areas (WSSGTC 1999, Colorado section).

Moffat County has the largest amount of habitat and largest flock of sage grouse, but even this group has declined 80% since 1982 – including a 40% loss in North Park (Myers 1999 quoting Braun). Yet, according to Col. Div. of Wildlife personnel, North Park is the "best sage grouse area in the state" (Toolen 1999b). Moffett County has averaged only 943 males over the last 3 years (id., p. 6). In lower Moffat County, sage grouse leks are vanishing rapidly – from 1979 to 1996, known leks decreased from 62 to only 24 (Anonymous 1996, p. 7). The number of individuals is also rapidly declining: over the same time period the number of males counted has decreased from 3,166 to only 290 – more than an order of magnitude decrease (Anonymous 1996, p. 7).

In the entire area from Sapinero Mesa to Sim's Mesa between Montrose and Gunnison, only 6 lek sites have been located and only 33 grouse were counted (Potter 1995). Few sage grouse exist west of Cerro Summit and numbers are low in the Cimarron area (Braun 1995c). Middle Park is "currently in bad shape with a total of 1,000 birds" " (Summary of North Park Working Group Meeting 1999, p. 6). Note that this estimate is likely optimistic as the Colorado estimates grossly inflate the number of birds beyond those actually counted. In recent times, at least 40 to 50 leks were known in Routt and Eagle counties, but today only 6 leks remain in these two counties (Toolen 1999b) and only 300 to 400 birds remain with declines continuing since 1994 (Toolen 1999c, p. 15). Sage grouse densities in these two counties are extremely low – instead of 15 to 20 birds/mile^2 – densities are only 1 or 2 birds/mile^2 (Toolen 1999a). In the Colorado/Eagle River area south of the Yampa-Toponas area, "most leks" are "declining" or are "seeming to disappear" (Toolen 1999d). In the Middle Park area of Colorado (Grand and Summit counties), "long-term population data indicate a decline in numbers" (Middle Park Sage Grouse Meeting Notes 1999, p. 1 of Draft Plan). Slight increases from 1997 to 1999 are believed to be the result of population cycling (id., p. 11 of Draft Plan).

Extirpation of sage grouse in Colorado continues: since 1980, sage grouse have been completely eliminated from 4 counties (Delta, Montezuma, Ouray, and Pitkin); additionally, "populations within occupied counties have become smaller and more fragmented…" (Braun 1995).

Habitat has been heavily impacted throughout the range of the sage grouse. For example, the area north of US Highway 50 represents an unhealthy "vegetation complex" because of "soil loss, and reduction in the forb and grass component" caused by overgrazing (Braun 1999d). Defenders of the cattle industry had attempted to mischaracterize the unhealthy vegetation as resulting from "decadent," over-mature sagebrush. Instead, sagebrush is continually being renewed through seedling establishment, and regrowth of injured sagebrush (Braun 199d). Dr.

Braun also pointed out that large "intervention to remove the sagebrush overstory" as had been proposed by livestock lovers would be "devastating for persistence of a viable population of sage grouse" (Braun 1999d).

What is worse, habitat fragmentation was an important additional factor, thus compounding the effects on sage grouse beyond those of mere habitat conversion (Braun 1999a, p. 2; Oyler-McCance 1999). Finally, Dr. Braun notes that the above are merely minimum estimates because "ranchette development" since 1993 appears to have increased habitat loss in some areas (Braun 1999a, p. 2). Many riparian areas have been degraded or lost altogether, impacting some of the most important habitat for sage grouse.

Interstate and US Highways transect Colorado – these roads have high traffic flows which serve as dispersal barriers to sage grouse. Sage grouse in Colorado are threatened with significant habitat destruction from coal mining. The Kerr coal lease will impact 46% of the male sage grouse at the Raven lek in North Park (Schoenberg 1982, p. 73).

Meeting notes for the draft Moffat County plan in North Park reveal some of the deficiencies of these Conservation plans. One participant in the working group noted that the plans are not purely scientific but are political documents, limited by what locals will approve – including the "County Commissioners, the Soil Conservation District and the Water Conservancy District" (Summary of North Park Working Group Meeting 1999, p. 1). As one example, the number of birds needed to achieve a viable population in North Park was presented to the working group by Dr. Braun; however, this did not meet the groups political goals and "a majority of the group" did not feel these numbers "realistic" (id., p. 5). The same document reveals an apparent bias by the Service against the listing procedure: "Mr. Ireland [a FWS employee based in Grand Junction, Colo.] is trying to keep all the players in the loop so a petition is not started" and is "trying to slow things down." Id. Such actions are per se arbitrary and capricious and implicate violations of the Service's duties and trust responsibilities. Mr. Ireland then stated that conservation plans could provide some "relief or relaxation from [ESA] listing" (id., p. 2) and that after a listing "grazing will not be shut down at all" (id., p. 3).

* * *

Nevada Population Assessment

Sage grouse once ranged throughout most of Nevada except for the shadscale region extending from SW Nevada across the Walker Lake depression to the Lahontan Basin of western Nevada (Ryser 1985, p. 278). McQuivey (2000) relied on anecdotal reports to claim that Nevada habitats historically supported few sage grouse. Besides its highly anecdotal and speculative nature, this assertion does not match the analyses done by Kuchler (1964a, 1970a), the BLM (USDI 1994a, color vegetation maps in the Draft EIS), or other historical vegetation studies. Nor does it match the careful analyses done by sage grouse biologists such as Johnsgard (1983) or Schroeder (2000a). McQuivey (2000) also speculated that extensive early mining in Nevada removed forest cover, allowing growth of sagebrush and consequent expansion of sage grouse populations. The purported forest cover that was then removed does not appear to coincide with current areas of sagebrush habitat. Finally even if McQuivey (2000) were correct, his assertions are legally irrelevant – the ESA protects against all threats whether natural or anthropogenic.

Distribution in Nevada apparently changed little between that described by Gullion and Christensen (1957) and that described by Johnsgard (1983). However, both harvest levels and productivity declined over the past 25 years (Drut 1994, p. 19). During the mid-1990's populations were believed to be stable (Drut 1994, p. 12). The Nevada Dept. of Wildlife (NDW)

has expressed concerns about decline in the northwestern populations (Klebenow, et al. 1990; Drut 1994, p. 19). Chicks/hen (estimated from brood surveys) and harvest levels were both more depressed in northwestern Nevada than in the northeastern part of the state (Drut 1994, p. 19). Despite this low productivity, males/lek increased during the same period, again indicating that males/lek is not the best metric for population assessments. Stiver suggested that low adult mortality and long lifespan may compensate for impaired productivity in the short term (letter from S. Stiver, Nevada Dept. Wildlife, cited in Drut 1994, p. 19). Such factors cannot, of course, compensate for low reproductive output over periods of even several years (the lifespan of adult birds). If birds are not added to the population, then it does not matter how long adults live – the population is doomed.

Habitat conditions in Nevada are suboptimal. Sagebrush has been reduced by more than 55% in northwestern Nevada (Campbell 2000b). Reduction of forb understories, cheatgrass induced fires, and other poor habitat conditions have caused declines in the 1990's similar to those in Oregon, particularly in northwestern Nevada (Drut 1994, p. 19, citing personal communications from San Stiver, Nevada Dept. of Wildlife). Reduction of forb understories is typically caused by overgrazing. Nevada has extreme cheatgrass invasion problems, and a state agency biologist stated that "Nevada is the definition of cheatgrass" problems (San Stiver, Nevada Dept. of Wildlife, personal communication). Robert Abbey, Director of the BLM in Nevada, stated that conditions are "almost to the point of no return" (Christensen 2000). Range fires burned over 1.8 million acres in 1999 alone –most of it sage grouse habitat (Weidensaul 2001, p. 63).

Sage grouse have been extirpated from two counties in Nevada (WSSGTC 1999, Nevada section). Only one county, Elko, has stable harvest trends recently (from 1961 to 1998), and harvest trends are decreasing in every other county in the state (WSSGTC 1999, Nevada section). Statewide, harvests have declined from nearly 30,000 birds in 1980 to about 6,000 in the late 1990's (WSSGTC 1999, Nevada section). "Southern and central Nevada also have great problems" with extinction of sage grouse (Braun 2001h). Recently, sage grouse populations have declined by "approximately 40%" and declines have occurred in "all regions" of Nevada (D. Pulliam 1999).

By 1997, harvest rates (per unit effort) had fallen to the "lowest recorded since …1960" (Saake and Stiver 1998, p. SS-1). Populations are no longer resilient – even when "very favorable range and precipitation patterns" are present for several years in a row, sage grouse populations "failed to reach peaks experienced during previous population highs" (Saake and Stiver 1999, p. SS-2)

States with More than 20,000 Birds in 1998

Braun (1998a) estimated that only 4 states – Oregon, Montana, Idaho, and Wyoming – contained more than 20,000 birds in 1998. * * * Moreover, these estimates now appear to have been overly optimistic. If they were accurate, then the data show that population declines have been even more rapid than previously thought.

Oregon Population Assessment

* * * Sage grouse were first reported [*in*] Oregon by J. K. Townsend in 1839 (Gabrielson and Jewett 1940, p. 218; Crawford 1982b). In the mid 1800's, areas such as the flat valley formed by the Silvies River were "carpeted with bunch grass, wild pea vines and red clover, interspersed with fields of camas" (Clark 1932, quoting topographic engineer Lt. Joseph Dixon). Western Juniper was found only in scattered stands, rather than the dense woodlands of today

(Miller, et al. 1993, p. 116).

Consequently, sage grouse were common and abundant east of the Oregon Cascade Mountains (Suckley 1860, Bendire 1892, Gabrielson and Jewett 1940, p. 218), but populations declined substantially and the range decreased shortly after livestock became common. Until the early 1900's, sage grouse ranged throughout all of Oregon's sagebrush dominated areas except Wallowa County (Gabrielson and Jewett 1940; Drut 1994, Fig. 2a). Sage grouse occupied all of southeastern, and most of central Oregon (WSSGTC 1999, Oregon section). By 1920, sage grouse had decreased so much that they were considered scarce except for local populations in southeastern Oregon (Gabrielson and Jewett 1940, Meyers 1946). Observers noted only short term increases in populations, and these never came close to previous levels of abundance. By 1936, sage grouse distribution was approximately 2/3 of its original range (Sexton 1936; Meyers 1946; Drut 1994, Fig. 2b). By 1940, the bird occupied only half of its original range in the state (Crawford and Lutz 1985), and Gabrielson and Jewett (1940, p. 218) described scattered populations in Union, Baker, Crook, and Deschutes counties, and the Silvies Valley and on the Big Summit Prairie east of Prineville. Most birds were found in southeastern Oregon in Malheur, Harney and Lake counties (Gabrielson and Jewett 1940, p. 218). In the Klamath Basin, water developments dried up riparian habitat, causing extirpation (Horsfall 1932). By 1970, only 320 sage grouse were present in all of Klamath County (Heath 1987, p. 1 of attachment). Sage grouse have declined since then (Heath 1987, p. 1 of attachment). By 1996, sage grouse could no longer be found at leks (Opp 1996a, 1996b) and the Oregon Dept. of Fish and Wildlife has not been able to document any sage grouse "for the last 5-7 years" (Oregon Dept. Fish and Wildlife 1999b).

Population declines in Oregon and Washington are directly linked to loss of habitat, primarily because of fire, livestock grazing (Downs, et al. 1995) and wide scale habitat conversion to agriculture. By the 1980's, the least damaged populations were at elevations between 4,000 feet and 8,000 feet (Call and Maser 1985).

Contraction of the range continued through the 1950's – by 1955 the range had contracted by 50% from its 1900 size, and sizeable portions of Lake and Grant counties were depopulated (Masson and Mace 1962; Drut 1994, Fig. 2c). Between 1934 and 1983, an area of 388,144 acres were treated to kill sagebrush and increase livestock forage (Call and Maser 1985). Declines have continued, and by the 1980's, the decline in numbers totaled 60% from the already reduced populations of 1940 (Crawford and Lutz 1985). Between the 1950's and the 1970's, spring lek counts "were down by 56%" and in the early 1980's, the trend of sage grouse populations was "downward for the past 30 years" (Crawford 1982b). Trends have not improved – Crawford and Delong (1993) reiterated the 60% decline in sage grouse numbers and found that sagebrush habitat had declined by nearly 50%. BLM recognizes these large declines and acknowledges that the "great majority" of sage grouse exist on lands managed by BLM (Bradley 1999). Population declines in Oregon have been "significant" and "steep" (Wisdom, et al. 1998, p. 2-151).

By the 1980's, sage grouse had been extirpated from 6 counties (Jefferson, Wasco, Sherman, Gillman, Marrow, and Umatilla counties), and their range was reduced in only other counties in which they were found (Klamath, Lake, Deschutes, Crook, Wheeler, Grant, Baker, and Union Counties) (Crawford and Lutz 1985; Crawford and Carver 2000). The number of sage grouse in Oregon "declined approximately 60% from the late 1950's to the early 1980's" (Crawford and McDowell 1999, p. 4; Crawford and Lutz 1985). ODFW (Oregon Dept. Fish and Wildlife) acknowledges that their "counts show sage grouse populations down 50 percent"

(Denney 1980). Productivity also plummeted – both the ratio of chicks/adult and the proportion of adults with broods declined by nearly 80% over the same period (Crawford and McDowell 1999, p. 4; Crawford and Lutz 1985).

ODFW claimed that over 27,000 sage grouse inhabited Oregon in 1992 (Willis, et al. 1993). In 1999, however, ODFW has been able to find only a fraction of this number. Moreover, some of these birds may have been counted twice, and some of the leks may be merely satellite leks that are used only sporadically, thus inflating counts (Rickerson, ODFW cited in Salvo 2001b).

Today, the bulk of the remaining sage grouse are found in Malheur, Harney and Lake counties, in the extreme southeastern portion of the state. * * * Only 5 other counties are known to harbor sage grouse and they are considered rare in two of those counties (Drut 1994, p. 3). Moreover, the proportion of habitat loss is much higher than statewide figures (Drut 1994, p. 13). Even in the counties containing the most sage grouse, the situation is grim. For example, in 1997, ODFW biologists noted that populations in Harney County were "precariously low" even in the face of improvements in production, and lek counts had reached the "lowest point since 1979" (Lemos and Garner 1997).

Birds occur on a mixture of private, BLM, USFS and some FWS national wildlife refuge (NWR) lands. On Malheur NWR, sage grouse have declined since the 1940's and are now rare to uncommon on the refuge (Littlefield 1990). * * * Demographic classes are skewed, indicating rapidly declining numbers. In the autumn population, the average is now only 1 chick/hen, portending serious population reductions. As an ODFW biologist put it: this is "a tremendous loss of reproductive potential" (Associated Press 2001). As with Idaho (see elsewhere in this review) and Canada (Aldridge and Brigham 2001), chick survival appears to be a major factor in declines.

Range reductions and population decreases in Oregon are ongoing. Between 1985 and 1992, sage grouse were extirpated in Wheeler County and their range was reduced in Crook County (Crawford and Lutz 1985; Crawford 1992a). The range has been reduced by "approximately 50% from [its] original" extent (Anonymous, undated document 6). University scientists agree that approximately 50% of the former range in Oregon is gone (Crawford 2000c). All measures of population size have decreased: "males/lek has declined 58%," and birds/16 km has "declined 63%," chicks/adult has declined 82%, "% of adults with broods has declined 78%," and brood size has declined 27%" since the "late 1950's" (Anonymous, undated document 6). Consequently, the number of sage grouse has declined by 60% within the existing range (Anonymous, undated document 6). Many population parameters could reach zero at virtually any time, based on projections of temporal relationships (Anonymous, undated document 6). If these "trends continue, sage grouse could be virtually extinct from Oregon within a decade" (Anonymous, undated document 6).

Drut (1994) reviewed Oregon Dept. of Fish and Wildlife abundance estimates from 1941 to 1991. Both estimates (males/lek and grouse/16 km) declined from 1941 to 1983, and exhibited a slight upward trend from 1984 to 1991, then turned downward again (Drut 1994, p. 12). Drut (1994) thought the data also exhibited a cyclicity, but noted that subsequent peaks did not reach previous highs, and lows were lower for each cycle. This accords with the warnings of Braun (1987b). Harvest figures have also dropped precipitously from about 15,000 birds in the 1950's to less than 1,000 birds in the 1980's, necessitating the closing of hunting seasons four times (Drut 1994, p. 12, Table 3). By the 1990's, only a few hundred birds were harvested each year (Drut 1994, p. 12, Table 3). Males per lek have dropped substantially from about 90 in 1950 to

about 30 in 1960 (WSSGTC 1999, Oregon section). Since 1960, declines have continued at a slower pace, and males/lek was about 12 from 1995 to the present (WSSGTC 1999, Oregon section). Total males counted have increased, but this is purely the result of the number of leks counted (WSSGTC 1999, Oregon section: compare graphs 1 and 3). The apparent increases in the total number of males reported are "the result of more intensive surveys" and probably not due to increased precipitation or better habitat, as males/lek did not increase (WSSGTC 1999).

Crawford and Lutz (1985) identified impaired productivity as the primary factor in this serious decline, and Crawford and Delong (1993) identified inadequate nesting and brood rearing habitat as of primary importance in this decline. Drut (1994) reviewed these studies and plotted the three productivity factors (Chicks/Adult, %Adults with Broods, and Mean brood Size) as his Fig. 5. All productivity factors decreased from 1950 to 1993. Particularly worrisome is the sharp decrease in each productivity factor at the end of the data series, from about 1990 to 1993 (Drut 1994, Fig. 5, p. 14). Gregg (1992) examined habitat conditions and productivity at 2 sites in southeastern Oregon. He ascribed poor productivity to low nest success (averaging only 15%), which is caused by habitat degradation, particularly height of the grass cover at the nest site (Gregg 1992). This accords with the other studies reviewed herein in the sections on Grazing and Nesting Habitat: grazing reduces the concealing vegetation near the nest, allowing predators to find the nests and eat the eggs and/or the hen.

In his analysis, Drut (1994) ruled out survival as a significant factor in the declines. He plotted survival index on the same temporal axis as the other measures, and showed that although it fluctuated, the survival index did not decline with time as did the other measures. Thus, survival cannot be a significant factor responsible for the declines. Particularly troubling is that drought conditions coupled with low population productivity on degraded habitat create the potential for extraordinarily rapid and severe drops in sage grouse populations (Drut 1994, p. 12).

The Oregon Dept. of Fish and Wildlife (ODFW) contends that populations are stable in Oregon, based on solely on males/lek estimates (Willis, et al. 1993). Unfortunately, this is the weakest and least reliable population estimation metric available (Emmons and Braun 1984). Moreover, although Autenrieth, et al. (1982) established a standard protocol for lek counts, that protocol was not followed by the ODFW. As Drut (1994) pointed out, the ODFW study ignores the downward trends in summer measures of abundance (grouse/16 km), ignores all 3 measures of productivity, and ignores the severe reductions in harvest over the time period. The ODFW study fails to examine the best available scientific and commercial data. Additionally, the ODFW study excluded certain data from their analysis, claiming that the sampling was inadequate. Yet, most data collected on sage grouse are inadequately sampled. Moreover, Drut (1994) noted that the exclusion of the data was statistically unwarranted. Drut's analysis (1994) presents a convincing case for significant population declines in Oregon. However, even if populations were "stable" they would not be viable. Sage grouse in Oregon are in habitat that is too fragmented to ensure interconnection, the populations are too small for viability, and the habitat is too degraded for populations to persist through the frequent periods of environmental fluctuations that occur within the range.

In all of Deschutes County there are only 21 leks remaining, with only 225 male sage grouse counted (Prineville District, BLM; undated). BLM makes the same two females for every male assumption that was made in Colorado (see Webb 2000, which is incorporated here by reference), and lists the total number of birds as 675 (Prineville District, BLM; undated). However, BLM is aware that the actual sex ratio is only 60% females (which would yield a

population of 562 birds), yet it still reports and cites the higher number (Prineville District, BLM; 1991). Even if the 2 for 1 assumption is accurate, this is far from a viable population. In Crook County, ODFW has only been able to find an additional 24 leks (for a total in both counties of 45 leks), thus the population in that county is at best only slightly larger than in Deschutes County, and similarly endangered (Prineville District, BLM; undated).

Leks appear to be vanishing from the Beatys Butte area, formerly one of the denser areas of the range. In 1998, researchers employed fixed wing aircraft to search for leks near Lone Grave Butte, Beatys Butte, Shirk's Lookout and other areas south to Spaulding Reservoir, but war unable to find a single lek or any individual sage grouse during the entire flight (Crawford and Swanson 1999, p. 12). Moreover, 4 of 5 nearby leks showed declines (Crawford and Swanson 1999, p. 12). From 1958 to 1990, dozens of adult sage grouse were sighted in the Catlow Valley – Sagehen Springs area, but since then no more than 9 adults have been sighted and none were seen in the last 2 years (Crawford and Swanson 1999, p. 16, Table 7). Recent breeding numbers of all sage grouse in Oregon have declined by 30% (Connelly and Braun 1997, Table 1).

Sagebrush habitats in eastern Oregon once covered 10 million hectares (Winward 1980, Doescher, et al. 1986). Today, habitat is severely reduced, fragmented, and degraded. Habitat in Oregon often has excessive shrub canopy cover. Two studies found shrub cover typically ranged from 25% to 30% (Gregg 1992, Drut 1993); however, recommended shrub cover of 8% to 12% for Wyoming big sagebrush, and 15% to 20% for both mountain and basin big sagebrush (Winward 1991a). Drut (1994, p. 22) suggested that the excessive shrub cover was due to severe overgrazing during the 1930's, and moderate grazing since that time, which has prevented reestablishment of grass and forb cover required for predator concealment. Habitat conversion is a serious threat – in the Umatilla Basin, only about half the sagebrush habitat remains (Prineville District, BLM 1997, 1998, p. 58). The Conservation reserve program has been ineffective in recovering sage grouse habitat, even temporarily, because "these areas were reseeded with non-native grasses and forbs." (Prineville District, BLM 1997, 1998, p. 58). Birds in Oregon require low elevation wintering habitat for periods when snows force them to areas having cover and food (BLM 1999c).

Perhaps the greatest problem in Oregon is the lack of forbs which serve as food for juveniles, and for nesting hens. ODFW biologists have noted that "one of the concerns with much of the sage grouse habitat across the range of the bird is too few forbs" (Van Dyke, 2001). The lack of forbs results from grazing by livestock and is exacerbated by drought. Some preliminary blood chemistry data for sage grouse suggest that the birds are almost literally starving in their natural habitat.

Juniper invasion of sagebrush areas is a severe problem in Oregon. As of 1988, Juniper covered 5 million acres (2 million ha) in Oregon and another million acres contains numerous juniper seedlings and saplings which will soon grow large enough to serve as raptor perches (Gedney, et al. 1999). Indeed this may have already happened since the 1988 inventory because juniper is spreading so fast that each new year brings a noticeable range expansion. The area of juniper invasion in Oregon has increased 5 fold in the last 50 years. All sage grouse habitat below about 7,000 ft. elevation is at risk from juniper invasion (Miller and Rose 1995). The destruction of habitat from juniper invasion is worse than is portrayed in the maps presented in Gedney, et al. (1999) because the mapping effort did not include "a lot of juniper areas with spread out trees" (Bates 2000, personal communication). Besides rendering habitat unsuitable because they serve as raptor perches, juniper can also dry up wet meadows and riparian areas needed by sage grouse.

Cheatgrass invasion and fire are significant problems in Oregon. Fires have affected private, Forest Service, and BLM lands. In 1989, the Dooley Mountain fire burned over 10,000 acres on the Wallowa-Whitman National Forest on the edge of the sage grouse range (Johnson 1998, p. D-3). In 1994, the Jordan Springs fire burned nearly 5,000 acres on the Malheur National Forest, killing many sagebrush plants and reducing sagebrush cover from 45% to only 1% (Johnson 1998; p. 62, D-3).

The birds are currently trending towards extinction. If current trends in threats continue, "it will be unlikely that viable sage grouse populations will continue to be present in Oregon" (Crawford 2000c).

What is particularly troubling about the population declines in Oregon is that this state had formerly been regarded as one of the strongholds of the sage grouse. While there are more sage grouse in Oregon than in most states, the bird is rapidly declining in the state, habitat is highly degraded and fragmented, and the very low productivity makes it unlikely that these declines can be reversed or even stopped. Without serious recovery implementation, it will merely be a matter of time before the bird is extirpated from Oregon.

Wyoming Population Assessment

Populations continue to decrease in Wyoming and sage grouse have been completely extirpated from Goshen County. Males/lek has decreased by about 17% since 1985 (Connelly and Braun 1997), and "regional declines as high as 70% have been recorded" (Holloran 1999, p. 1 citing Bohne, personal communication). Decreases in sage grouse numbers have been widespread since the 1970's (Holloran 1999). Leks have also decreased – on the Bates Creek Grazing Allotment, the number of active leks "has declined 53% since 1985 (Holloran 1999, p. 2). This is the area where Grinnell saw such large clouds of sage grouse in 1886 that they darkened the sky. Sage grouse are now sparse and relatively hard to find in this area (personal observation). Additionally, sage grouse have been extirpated from almost all of Laramie county, all but a tiny area in northern Platte County, about half of Niobrara County, from southern Albany county, from western Sheridan county, and the eastern portions of Crook and Weston counties. A small isolated population remains in Teton County, but it will go extinct soon, because of its small size, if not for other reasons (Braun 2001h). Likewise, all populations east of Interstate-25 from Casper south to the Colorado state line will also become extinct within approximately 20 years (Braun 2001h). Some have attempted to blame drought for sage grouse declines in Wyoming (e.g. Heath, et al. 1997b). Although drought can be a factor, episodic droughts are common in sagebrush ecosystems. When sage grouse were not facing the current array of threats, natural fluctuations such as periodic droughts, caused only minimal impacts and populations rebounded quickly. This is not the case now.

As late as the early 1900's, vast areas of Wyoming shrub-steppe held huge numbers of sage grouse. Birds were found in every county as late as the 1950's (Patterson 1952c, p. 28). In Jackson Hole, flocks were so numerous that they were reported to form thick "clouds," but the birds were "nearly all gone" by 1916 (Hornaday 1916, p. 198). This extirpation coincided with increased cattle grazing in the area. Only about 100 cattle were known in Jackson Hole in 1883 (Daugherty 1999, p. 147), but numbers escalated rapidly to at least 1,339 cattle by 1899 (Daugherty 1999, p. 149). Conversion of native ecosystems to pastures also progressed rapidly, and pronghorn became extirpated from the valley by 1906 (Daugherty 1999, p. 161). With the reduction and then extermination of wolves, elk numbers would have rapidly increased, also causing damage to sage grouse food plants and cover. Fremont had seen large numbers of birds on the upper waters of the Green River in 1845 (Patterson 1952c, p. 19). In 1897, Huntington

considered that sage grouse were most abundant in near Fort Bridger and southward through the Green River Basin all the way to the Uinta Mountains in Utah (Patterson 1952c, p. 19). Carpenter described the birds as numerous near Fort Bridger and in 1905 Burnett described the birds as most abundant in the counties of Albany, Converse, Natrona, and Carbon (Bent 1932, p. 303, 308). The birds were so numerous in these areas that a hunter could kill hundreds in a single day, even without a dog (Bent 1932, p. 308). As late as the early 1940's, Eden Valley in Sweetwater County "was one of the areas of heaviest concentration" of sage grouse, containing so many birds that they interfered with farming operations nearby (Allred 1946b, 1949). Before agricultural development and ranching were widespread in Goshen Co., birds were present in such "great multitudes" that people gathered their eggs for table use (McDowell 1956). McDowell (1956) listed dam building, agriculture, ranching, overgrazing, and highways as threats to the bird – again, these threats have been recognized for many decades. Some of the earliest studies of sage grouse were undertaken in Wyoming. Girard worked in Sublette County, and Patterson's study areas were in northern Sweetwater Co., southeastern Sublette Co., and southwestern Fremont Co. – one site in the Eden Valley irrigation district and other was between Pacific Creek and Dry Sandy Creek (Patterson 1952c, p. 22, 39).

In Wyoming, most settlement occurred after completion of railway lines, delaying the demise of the bird. But, by the 1930's, populations had declined so much that hunting seasons had to be closed until the 1950's (Drut 1994, p. 20). Sage grouse populations have steadily declined since the 1950's. The state has relatively continuous harvest information for the last 40 years, including both overall harvest levels, and a measure reflecting hunter effort: (birds harvested) $(\text{hunter})^{-1}$ $(\text{day})^{-1}$ (Heath 1992). Both measures show large declines since the 1950's, and the hunter effort adjusted metric has declined by 40% from 1974 to 1989, indicating a major population decline (Heath 1992; Drut 1994, p. 12, 20). These declines are supported not only by declines in birds taken by hunters, but also by lek counts which show declines of about 40% in the last 20 years (Christiansen 2000, p. 12). Recent breeding numbers have declined by 17% (Connelly and Braun 1997, Table 1). Males per "active complex" (which presumably refers to a lek, or group of leks have declined drastically in the Laramie region. This metric reached a high of 99 in 1959 and was never under 30 until 1975. But after 1980, it has never been above 30, falling to a low of 11 in 1995, and increasing only slightly to 16 by 1998 decline (WSSGTC 1999, Wyoming section). Chicks per hen have increased somewhat, from 1.6 in 1996 to 2.1 in 1998 (WSSGTC 1999, Wyoming section). In the Green River and Lander areas, total males counted has increased from about 600 in 1996 to about 1,300 in 1999 (WSSGTC 1999, Wyoming section). The Wyoming report does not explain these data, and apparent increases in the 1999 report are "probably the result of more intensive surveys and [increased] precipitation" (WSSGTC 1999). Overall, Wyoming state biologists have termed the declines in the last 20 years as "alarming" (Christiansen 2000, p. 14).

Indeed, the Service itself realizes that sage grouse in Wyoming have "not returned to pre-drought population densities" and is concerned about "the rapid expansion of oil and gas developments in the Pinedale Anticline" in "prime sage grouse habitat" (Director, US Fish and Wildlife Service 1999a, 1999b). Even while emphasizing that Wyoming is the heart of the sage grouse range (id.), Service personnel have noted the risk to sage grouse in Wyoming. After an analysis of the preliminary data received from the Wyoming Game and Fish Dept., Dr. Deibert noted that "it doesn't look good" (Deibert 1999a). Thus, if sage grouse are in trouble in Wyoming, the heart of the range, the species is in even greater trouble elsewhere in what remains of its range. As is obvious from the rest of this status review, that is unfortunately the case.

The state of Wyoming has failed to conserve the species and is even less likely to act on behalf of sage grouse in the future. Perhaps the most egregious example of political meddling in biological resource management is the imposition of a gag order on the Wyoming Dept. of Game and Fish (Collins 2000). Scientists and experts within the agency are no longer allowed to comment on federal or other actions which will impact sage grouse without political interference. All comments must go through a special committee set up by the governor, the Office of Federal lands Policy (OFLP). It is not very likely that the Governor's committee will conduct peer review – they lack the expertise and training; instead, the biologists' analyses will be subjected to political review. As one example of the degree of political scrutiny, Wyoming Game and Fish biologists are not allowed to use the word "'recommend,' even in a technical sense * * * [not] in any context" (Collins 2000, p. 2). Previously, the state's Office of Federal Lands Policy (OFLP) had "delet[ed] entire sections" of some of the analyses by Game and Fish biologists (Collins 2000, p. 2), who had to careful tailor the wording to keep their comments in the letters. Now, the OFLP has complete control over whether biological analyses will be given to federal agencies at all – no negotiating by Game and Fish is allowed (Collins 2000, p. 2). "Obviously, the process forces the federal agencies, or any of the public, to work harder at seeing what state agencies really say about any given project" (Collins 2000, p. 2). Game and Fish biologists are specifically forbidden to "Advance, promote or draw conclusions" (Collins 2000, Attachment, item 7.b) or to use "negative…language" (Collins 2000, Attachment, item 7.a). Interestingly, the gag order comes just as huge areas of sage grouse habitat are about to be subjected to coal bed methane leasing. Of course, such political interference with wildlife agencies is not limited to Wyoming – government scientists have frequently been attacked by their political overlords, as the numerous examples in Wilkinson (1998) make clear.

Natural gas development on the Pinedale Mesa could "impact sage grouse over a large geographic area," and destruction of winter habitat in the area could affect sage grouse "throughout the region," as far away as a 94 km radius from the Mesa (Lyon 2000, p. 99) – i.e. an area of over 27,000 km^2.

Although Wyoming has the largest areas of sagebrush in North America (Sundstrom, et al. 1973), virtually all of that area has been degraded. Grazing and development are major threats in Wyoming (Drut 1994, p. 20). * * *

Idaho Population Assessment

At one time, Idaho was a stronghold for sage grouse and contained numerous large populations. At least 6 expeditions entered what is now Idaho in the 1800's and published their reports. Lewis and Clark passed north of the range of sage grouse in Idaho, following the Clearwater River (Moulten 1983a, 1983b; Merriam 1891, p. 4). In 1834, Townsend crossed the Snake River plains and noted the large numbers of grouse there (Merriam 1891, p. 4). Later, various railroad surveys entered the area, but made few natural history reports, and the next survey of biological resources in southern Idaho was made in 1872 by the 16 year old Merriam who accompanied the Hayden expedition as a naturalist (Merriam 1891, p. 4-5). Robert Ridgeway (often spelled "Ridgway") made the next foray into the City of Rocks area when he accompanied Clarence King (Ridgeway 1877). Bendire entered the area next, during his explorations of southeastern Oregon (Bendire 1877). Merriam re-entered the area in 1890 on a biological reconnaissance and published his report in the North American Fauna series (Merriam 1891). Merriam found "large flocks" of sage grouse (Merriam 1891, p. 13) and noted that the birds were "abundant" and normally seen in flocks of a "dozen or more" (Merriam 1891, p. 93). Sage grouse were common in the Teton Basin, along the Henry Fork of the Snake River, and at

Henry Lake (Merriam 1891, p. 93). Merriam also noted that other species – which are now greatly reduced, such as Brewer's Sparrows and Sage Sparrows – were abundant or common in the area (Merriam 1891, p. 103).

Merriam also noted the extent of the sagebrush ecosystem in southern Idaho – the descriptions of habitat suggest that sage grouse existed in "large numbers" (Rich 1985b). Sagebrush extended throughout the Lemhi River and Birch Creek valleys, reaching "up over the foothills" to the mountains (Merriam 1891, p. 8-9), reached a point 5 km north of the post-office of Clyde in the Little Lost River (Merriam 1891, p. 12), extended almost the entire length of the Phsimeroi Valley to within 5 km of the divide at 1,950 m. in elevation (Merriam 1891, p. 12), covered the entire Challis River valley "at all levels" (Merriam 1891, p. 15), extended from a few miles below Hailey in the Big Wood River valley out onto the plains (Merriam 1891, p. 16), covered the valley (or basin) at the head of the Salmon River and extended to the Stanley Basin (Merriam 1891, p. 17), and occupied the "main part of the Big Lost River and Antelope Valleys" (Merriam 1891, p. 16). The west border of the Antelope Valley was composed of "rounded and grassy" mountains (Merriam 1891, p. 15). In sum, Merriam describes the lobes of a vast sea of sagebrush, which has now largely been transformed into an agro-industrial complex, interspersed with cheatgrass and areas degraded by grazing. Over 70% of the original sagebrush habitat has been converted and what remains is heavily degraded "by overgrazing, fires, and intrusion of exotic grasses" (Cade 1999). By 1949, cheatgrass was a dominant in 4 million acres of shrub and grasslands, the principal herbaceous species in another 2 million acres, and had invaded 10 to 15 million acres in Idaho (Stewart and Hull 1949).

In Fremont County, birds were found at Spencer, Kilgore, Sheridan Creek, and near Highbridge by Rust in 1916 (Burleigh 1972, p. 87). Sage grouse were a common resident at Grays Lake (Burleigh 1972, p. 87). In Minidoka County, sage grouse were already declining somewhat by the turn of the century (Burleigh 1972, p. 87). Davis reported similarly from near Riddle in Owyhee county, describing the birds as previously common but scarce by 1934 (Burleigh 1972, p. 87).

During the mid-1990's, sage grouse populations were believed to be stable (Drut 1994, p. 12). However, recent breeding numbers have declined by 40% (Connelly and Braun 1997, Table 1). Sage grouse populations in Idaho appear to be at record lows (Idaho Sage Grouse Task Force 1997). BLM recognizes that all monitored sage grouse populations in Idaho have undergone a "significant long-term decline" (Foster and Olendorff 1999). Sage grouse in the upper Snake River plains have "declined significantly over the past 40 years" (Leonard, et al. 2000).

Fire, livestock grazing and agriculture have greatly altered or eliminated significant expanses of upland habitats (Saab and Groves 1992). From 1980 to 1992, 20% of Idaho's shrub-steppe rangelands burned, and were then invaded by exotic annual plants. Fire and habitat conversion to low value agricultural products has created "concern about the status of sage grouse" in Clark and Fremont counties (Nelle 1998, p. 5). Populations have declined significantly between the 1950's and 1990's (Crowley and Connelly 1996). In one study area (Red Road), the number of leks declined from 18 to 4, lek attendance declined by 37%, and hunting data mirror these trends (Nelle 1998, p. 7). These declines are related to habitat destruction and degradation. In Clark, Fremont, and Jefferson counties, at least 186,694 ha were sprayed with herbicides such as 2,4-D, and after this chemical was banned, deliberate burning of sage grouse habitat destroyed 36,444 ha, while wild fires destroyed another 80,264 ha (Crowley and Connelly 1996; Nelle 1998, p. 7).

Sagebrush has been reduced by more than 60% in Idaho (Campbell 2000b). Remaining

sage grouse habitat in southern Idaho is "clearly inferior" to that in the higher elevations of Idaho and Colorado because it has less annual precipitation and a depauperate herbaceous flora (Rich 1985a). Along major highways, such as Interstates 84 and 86, and US 30, huge areas of sagebrush have been converted into agricultural fields (personal obs. by author). Unfortunately, this region was formerly the least fragmented of all sagebrush areas in the state. North of the town of Arco, sagebrush habitat is fragmented into long fingers by forest intrusion (Tisdale, et al. 1969, Fig. 4). West of the city of Pocatello, sagebrush habitat is fragmented by forest and juniper woodland intrusion (Tisdale, et al. 1969, Fig. 4). Idaho riparian habitats are "under increased pressure from livestock grazing, logging, water management and recreation", and note that more than 90 percent of the original riparian habitat in the West has been eliminated by flood control and irrigation projects" (Saab and Groves 1992). Catastrophic floods in 1983, damaged large amounts of riparian areas. These floods were exacerbated by roading and grazing of large areas which reduced stream bank stability and increased runoff by removing vegetation and compacting soil (Hiatt 2000).

Rich (1985a) found that population numbers plummeted in southern Idaho from 1950 to 1985: his Fig. 2 shows Idaho population numbers in the 1980's that are less than half those in the 1970's. The Idaho Dept. of Fish and Game (IDFG) believed that sage grouse populations in the state were stable as of 1994 (letter cited in Drut 1994, p. 19). IDFG does have concerns about conversion of sagebrush to agriculture and grazing (letter cited in Drut 1994, p. 19). The Magic Valley area in south-central Idaho once had 279 leks, but now only 50 are active – a reduction of 82% (Mattise 1995). Likewise, counts of birds at leks have plummeted from 1,600 in 1987 to only 400 birds in 1998 (Owyhee County Local Sage Grouse Working Group 1998). Sage grouse populations in south-central Idaho have declined at about the same rate as those in Oregon – about 40% to 50% from the 1940's to 1980's (Rich 1985b). Such declines are typical of the entire state (Welch, draft manuscript, Ch. II, p. 14).

Demographic data show similar declines, for example, chick mortality has increased alarmingly. Chicks per hen has decreased from 2.3 to 1.7, below the replacement rate needed for populations to grow or remain stable, "suggesting a problem with chick survival" (Owyhee County Local Sage Grouse Working Group 1998). Sage grouse are declining rapidly in Idaho – many study areas have decreased by 80% in the last 15 years (Weidensaul 2001, p. 61 citing Connelly). The "black hole" is chick survival Weidensaul 2001, p. 61 quoting Connelly).

Hunting harvests are down 39% from the 5 year mean Idaho Upland Game - Summary of Estimated Statewide Harvest, Table 1 ().

Sage grouse face major threats in Idaho, and these threats are ongoing. Habitat conversion is a severe and ongoing problem in Idaho. Boise is the largest city in Idaho, and is the second fastest growing city in the entire United States with about as many housing starts per year as the entire San Francisco Bay Area. Boise is also one of the worst cities in the US in terms of sprawl. Much of this sprawl impacts the remaining sage grouse habitat that was not already converted to agriculture (these agricultural lands themselves are also impacted by urban sprawl). In 1998 alone, "over 3 million acres of sage grouse habitat [were] converted to agriculture" (US Fish and Wildlife Service 1998, p. 2 of Attachment). The acreage converted to other uses is "among the most productive and best habitat, thus magnifying the impact" (Owyhee County Local Sage Grouse Working Group 1998). Owyhee County is now home to the largest cattle feedlot in the nation, and the largest hog farm in the nation is planned for that county. The hog farm, a major industrial operation, will require over 140 miles of new roads. Additionally, USAF is vastly expanding the bombing range in the most remote areas of sage grouse habitat in the

county. Fires have caused massive damage to sage grouse habitat in Idaho. Surprisingly, 5 times as much acreage of sagebrush is being destroyed in prescribed burns as opposed to wildfires (Owyhee County Local Sage Grouse Working Group 1998). In the 1990's, and average of 6,000 acres were burned each year; and during the 1980's, about 57,000 acres were burned (Owyhee County Local Sage Grouse Working Group 1998). Fire is rapidly converting sagebrush habitat to exotic annual grasslands in southwest Idaho (Knick and Rotenberry 1999b). The US Air Force has plans to conduct bombing exercises on sage grouse habitat in Owyhee County in southern Idaho (Commons 2000b). The Air Force proposes to build a number of sites ranging in size from ¼ acre to 5 acres, with an extensive road network, construction of buildings and installation of barbed wire fences (Commons 2000b).

Montana Population Assessment

At one time, Montana was a haven for huge flocks of sage grouse. Sage grouse were widespread in the state, and were recorded by numerous early explorers. Members of the Lewis and Clark Expedition observed sage grouse along the Marias river north of present day Great Falls (Cutright 1969), and early explorers killed the bird along the Milk River (Coues 1874). Knowles (undated) presents an annotated bibliography of the published accounts from these early expeditions. In the 1920's, sage grouse were so plentiful that they "darkened the sky" (Eustace 1995). Even as late as 1964 hunters were able to take nearly 100,000 birds annually; but, by 1999 only 4,000 males could be counted in the entire state, even though the state wildlife agency greatly increased its attempts to find leks in an attempt to ward off a listing (Auchly 2000, p. 9-10). Large numbers of sage grouse were found locally as late as the 1970's and 1980's. Cade (1999) recalled that he often saw thousands of birds per day in 1984 at the foot of the Beaverhead Mountains in Clark County, but saw none by 1999, even when employing multiple dogs.

These drastic population declines are related to habitat conversion to agriculture and habitat degradation by grazing. Nearly 1 million acres of sage grouse habitat were converted to agricultural croplands between 1954 and 1987 (Eustace 1995). Sagebrush once occurred throughout most of Montana, often as a mixture of sagebrush and grasses. By the 1970's sagebrush was restricted to several large islands and additional smaller isolates spread across the southern half of the state (Morris, et al. 1976). As early as 1912, some local populations of sage grouse were extirpated in Montana (Saunders 1912). By the 1930's, "agricultural development, including livestock grazing, resulted in an estimated 50 percent decrease in the bird's original habitat" (Martin and Pyrah 1971, p. 135-136, Fig. 1). The geographic range did not change much between 1941 and 1970, and the bird was found in 39 counties (Martin and Pyrah 1971, p. 135). However, populations declined in the mid-1940s and continued downward for several years, despite closure of hunting seasons for 7 years, from 1945 to 1951 (Martin and Pyrah 1971, p. 137). Hunting was revived in 1952, but the birds had not sufficiently recovered so that season lengths could exceed 3 days until 1955 (Martin and Pyrah 1971, p. 139). Hunting regulation was relaxed in 1963 and the number of birds harvested greatly increased, only to crash to less than 1/3 of 1964's numbers in 1965 (Martin and Pyrah 1971, p. 140). This again suggests that hunting is not purely replacement mortality. The number of birds harvested fluctuated between 29,000 and 57,000 from 1966 to 1969.

By 1975, over 10% of all habitat in Montana had been converted into useless range areas (Johnsgard 1983, Wallestad 1975a). In some areas, such as Meagher County, nearly 50% of habitat had been destroyed by conversion to cropland (Johnsgard 1983). Habitat conversion is a severe problem throughout Montana. In just the 5 counties that contain most of the sage grouse

habitat north of the Missouri River, nearly a million acres of rangeland were converted to cropland between 1954 and 1987" (Eustace 1995, p. 24 citing Montana Fish, Wildlife and Parks biologist Ray Mule).

By the early 1990's, density had increased by 10% to 25% from previous levels except in the northeast portions of the state, where estimated populations had decreased by 20%. These decreases were attributed to dry weather (letter from Montana Dept. of Fish, Wildlife and Parks, cited in Drut 1994, p. 19, p. 40).

Harvest levels were 16,178 in 1989, and 20,456 in 1990; however, those levels are depressed from harvest levels of years ago (Drut 1994, p. 19) and harvest levels continue to decline (WSSGTC 1999, Montana section). Harvest was only 8,000 birds in 1993, the lowest in 36 years of record keeping (Eustace 1995). Populations were thought to be declining in local areas as late as the mid-1990's Drut 1994, p. 12). The Montana Dept. of Fish, Wildlife and Parks (MDFWP) believes that distribution has not changed recently, but is concerned about habitat fragmentation and reduced population numbers in south central Montana (letter cited by Drut 1994, p. 19). Independent scientists are less sanguine: recent breeding numbers have declined by 30% in eastern Montana and 32% in southwestern Montana (Connelly and Braun 1997, Table 1).

Montana reports increases in the number of males counted; however, the average males per lek has declined since 1989, and this metric has increased only moderately from the lows of 1993 (WSSGTC 1999, Montana section). Thus, the increase in the count of males, coupled with declining harvest levels indicate that sage grouse are probably decreasing in Montana. Apparent increases in the 1999 report are "probably the result of more intensive surveys and [increased] precipitation" (WSSGTC 1999).

SE-MT

Southeast Montana consists of the counties of Bighorn, Carter, Custer, Dawson, Fallon, Garfield, Powder River, Prairie, Richland, Rosebud, Treasure, Wibaux, and McCone, corresponding to Montana Dept. of Fish, Wildlife and Parks (FWP) Region 7, covering 81,050 km^2 of land area (Denson 1997). The best available data for this area show extremely low densities of sage grouse, and leks that are so small that they are near abandonment. A further complication is that 75% of the land in Region 7 is in private ownership area (Denson 1997), so that sage grouse are unprotected by statute and regulation. Over 9% of Region 7 has been converted to croplands (Denson 1997, p. 4) and only about 52% of the area remained in sagebrush cover by the early 1980's (Denson 1997, p. 4). Juniper is invading sage grouse habitat in this area (Denson 1997, p. 4).

In 1992 and 1993, the BLM and FWP inventoried 78,240 acres (31,662 ha) of land in Rosebud and Fallon counties, but were able to find only 7 sage grouse leks in this entire area (Tribby 1994, p. 2). Moreover, only an average of 9.3 males/lek were observed, and no lek had more than 12 males. Thus, only about 9.3 * 7 = 65 males were found, representing a density of 8.3 males per 10,000 acres (or about 0.5 males/$mile^2$). The density of leks was less than 0.06 leks/$mile^2$. BLM and the Montana FWP also inventoried 321,320 acres in Rosebud and Custer counties in 1992 but found only 327 males on 20 leks, 15 of which were on private land and thus unprotected by law (Tribby 1992, Table 1). This gives a density of 0.65 males/$mile^2$, and 0.04 leks/$mile^2$. The agencies also inventoried 167,201 acres in Garfield County, yet found only 4 leks with 47 males on them (Tribby 1992, Table 3). This gives densities of 0.18 males/$mile^2$ and of

0.01 leks/mile^2 – both are even worse than the other areas in southeast Montana.

By 1996, the hunting harvest had fallen from 2,034 birds in 1995 to 1,504 birds, a decline of 26%. In all of Region 7 – covering over 31,000 square miles – only 328 leks remained by 1996, a density of 0.01 leks/mile^2. Of those leks, only 22 were known to be active (Denson 1997). Denson (1997, p. 22) notes that the estimate of 328 leks – as small as that number is – contains "leks which have had no birds present for a period of 5 years or longer." If the true number of active leks is near this latter figure, then sage grouse are in imminent danger of extirpation. Even if the number of leks exceeds 300 in Region 7, sage grouse are threatened with extinction. Thus, these data show that all surveyed areas of southeast Montana have such small and sparse sage grouse populations that they are near extinction.

SW-MT

In southwest Montana and southeast Idaho, every measure of sage grouse abundance shows the birds to be in a long decline that began in the 1950's (Crowley and Connelly 1996). These declines are closely correlated with sagebrush manipulations in the area. Over 186,000 hectares of sagebrush have been degraded in just 4 counties since the 1950's (Crowley and Connelly 1996, 133). In some areas, more sagebrush was converted or degraded in the 1980's than in the 1960's and 1970's combined (Crowley and Connelly 1996). Most of the damage to sagebrush habitat was from controlled burns and spraying operations, but about 30% is from wild fires (Crowley and Connelly 1996, p. 133). Statistically significant declines in lek attendance occurred in the 2 breeding seasons following sagebrush manipulation and agricultural activity (Crowley and Connelly 1996). The overall breeding population in this entire region has now reached a "critically low level" (Crowley and Connelly 1996, 131) and only 437 males were counted on leks in 1983 (Crowley and Connelly 1996, p. 133). The best sage grouse populations in southwest Montana are in Beaverhead County, which accounted for 71% of the sage grouse killed by hunters in the 7 counties making up Fish and Game District Three (Anonymous 1978). From 1967 to 1979, hunters were able to take between 3,000 and 8,700 sage grouse from this area. However, low forb cover "is a widespread problem" and results from "longterm livestock abuse and soil loss" (Anonymous 1978). By 1972, the sage grouse population in this area had fallen to only about half their numbers in 1963, and at the Mud Lake area, numbers were only 20% of their 1963 values (Anonymous 1978, Fig. 1).

Numbers have continued to fall, and by 1998, only 1,500 grouse could be located in the most important core areas of the county (Schmidt 1998, Table 1). This is a total density of both males and females of only 10.9 individuals/mile^2 in this huge 137 mile^2 area. This small number of sage grouse was found even though a combination of trained dogs and human observers combed an area of 35,483 hectares by 4wd truck, snow machine and on foot, leading the researchers to "believe[] that the survey method was very effective" (Schmidt 1998, p. 1). Thus, the best available data show that the sage grouse population in the best sage grouse areas in southwest Montana are in severe decline.

The reason for the decline in sage grouse in Beaverhead County is not hard to discover: the survey area suffers from "over browsing by [domestic] sheep and vegetation manipulation," causing parts of the "sage grouse habitat to be in very poor condition" (Schmidt 1998). Other portions of the survey area had "over-mature and decadent" sagebrush, caused by "excessive grazing by sheep" and "small and isolated" stands of sagebrush (Schmidt 1998). Development is a serious problem: "numerous fences intersect the surveyed sage flats" and "probably contribute to a significant percentage" of sage grouse mortality (Schmidt 1998). Even without systematic

fence surveys, an "incidental check of a fence line" revealed 5 fatal fence strikes by grouse, and 2 others that were not immediately fatal (Schmidt 1998). The researchers felt the number of grouse found to be only a small fraction of those dying from fence collisions, because grouse remains often landed 40 to 70 feet away from a fence (too far to be seen from near the fence), and because wounded grouse walk away to die elsewhere. Agricultural development has apparently created "an artificially high concentration of eagles attracted to calving operations" and this probably "adds considerably" to sage grouse mortality (Schmidt 1998). Sage grouse in southwest Montana are also threatened by subdivision and the placement of houses or trailers in sage flats (Schmidt 1998). Besides the avoidance of buildings, this also exposes birds to "marauding dogs, cats, and children" (Schmidt 1998). This is a particularly strong threat in parts of the "picture-postcard" west, such as southwest Montana.

BLM is not managing its lands to conserve sage grouse. Although BLM admitted that "declines in the occurrence and distribution" of sage grouse "are apparent on the Hansen Creek allotment" it still allocated 413 AUMs of grazing for that area (BLM 1999a, p. 3). Even worse, after a rancher protested this decision, BLM actually increased the grazing pressure to 481 AUMs (BLM 1999b, p. 4). This occurred even though BLM admitted that sage grouse had "declined considerably since the mid-1960's" and that "recent harvest [by hunters] is but a fraction of the historic harvest" (BLM 1999b, p. 2). Today, sage grouse are present in only low densities in the Simpson Creek area (Hockett 1999). This results from "heavy livestock use" and the "permanent diversion of flows from Simpson Creek" for agriculture (Hockett 1999). There is "heavy trampling" by livestock in the area and "forage conflict[s]" between livestock and wildlife species, causing forbs to be "conspicuously absent" (Hockett 1999). An important sage grouse lek is subject to "intensive use" by livestock allowed to graze the area in early spring, causing "direct conflict" with sage grouse (Hockett 1999).

South-central Montana

In south-central Montana, sage grouse populations have declined tremendously. Only 55 leks have been found in a huge area encompassing 5 counties near Billings (Carbon, Golden Valley, Musselshell, Sweet Grass, and Yellowstone counties); moreover, despite increased search effort, only 879 sage grouse (apparently both males and females) were found in this entire area (Newell 1993). Worse, declines are rapid and substantial: counts in Golden Valley County declined by 52% from 1988 to 1993, and counts declined 60% in Musselshell County over the same period (Newell 1993). The magnitude of these declines is characteristic of this region – of the 34 leks censused since 1981, the number of sage grouse dropped from 1,032 in 1981 to only 642 in 1992 (Newell 1993). On the Billings Resource Area, only 110 leks remain and only 28 of those are on federal lands where some legal protections exist (Billings Resource Area, BLM 1983a, 1983b).

North-central Montana

The best available data show that few sage grouse exist in the Havre BLM area. In 1980, the Missouri Breaks area contained 15 leks and the North Blaine area contained only 10 leks (Gniadek 1980). The entire distance from Fort Peck to Havre was surveyed in 1983 and 1984 and only 8 leks were found – near the Phillips County and Valley County line (Stoneberg 1984). The survey was undertaken in connection with the construction of a large powerline, and it is unlikely that these leks still exist.

Threat Analysis

A wide variety of threats affect sage grouse. Most threats are anthropogenic (human caused), although some are natural or only indirectly caused by human activities. As one example, juniper and pinyon pine invasion is a threat that appears natural until one realizes that the spread of these species into sagebrush habitats is primarily driven by cattle grazing, fire suppression, and anthropogenic climate change. These latter two effects are also related in part to cattle grazing – for example, cattle are a major source of methane inputs to the atmosphere and methane is a gas that strongly influences climate change (de Hann, et al. 1996). Although vehicular and power plant CO_2 emissions receive the bulk of the attention in the popular news media, methane has 21 times the radiative absorption capacity of CO_2 (Kauffman and Pyke 2001, p. 47). Anthropogenic impacts are qualitatively different from natural disturbances because "human impacts tend to be chronic," cumulative and persistent (Aplet and Keeton 1999). It is perhaps not surprising that anthropogenic threats to sage grouse are so serious. Anthropogenic threats endanger many species – perhaps most of the species extant. This is to be expected because approximately 40% of all net primary productivity (NPP) for the entire terrestrial surface of Earth is sequestered for human use (Vitousek, et al. 1986). NPP is roughly the food supply for all animals and decomposers (Ehrlich and Wilson 1991). Sage grouse face most threats throughout their range and all range-wide threats are caused either directly or indirectly by humans. In most areas, sage grouse are in danger of extinction because of these threats. In a few relatively small areas of Wyoming and perhaps Montana, sage grouse remain in sufficient numbers that they are threatened but are probably not endangered at present. However, sage grouse densities are low everywhere and the status of the bird could rapidly decline to endangered throughout the entire range.

The major threats to sage grouse are not new. Scientists and other commentators have warned about the effects of cattle grazing and habitat conversion to farming and settlements for over a century. Grinnell noted the effects of "cultivation and thick settlement" in California, as did Finley in Oregon (Hornaday 1916, p. 201-203). Most threats operate range-wide. One exception is the development of water sources such as reservoirs. Reservoirs, though numerous, have affected relatively localized areas – unfortunately, those areas are in what was formerly the best late summer and fall habitat.

Sage grouse once occurred virtually everywhere there was sagebrush. They have declined primarily because of loss and degradation of habitat by livestock operations, elimination of sagebrush for agriculture, and land development (Hamerstrom and Hamerstrom 1961; Tirhi 1995; Hoffmann 1991; Hays, et al. 1998; Livingston 1998; Schroeder 1998c). Sage grouse populations began declining from 1900 to 1915, when livestock utilization of sagebrush shrub-steppe was heavy (Patterson 1952c). In the 1950's and 1960's, land management agencies adopted a policy of aggressive sagebrush control in order to convert sagebrush cover types to grasses for livestock forage. Chaining, frequent fire, and herbicide treatments reduced sagebrush by several million acres and sage grouse numbers plummeted drastically (Call 1979, Mattise 1995). Conversion of sagebrush types to grassland has been criticized as a management practice for livestock that is detrimental to wildlife (Johnsgard 1973, 1983; Schneegas 1967; Wallestad 1975a). Call (1979) stated that:

> Any land use practice which has as its objective the permanent elimination of sagebrush and establishment of grasses in the Mountain West will ultimately reduce the collective carrying capacity of that range for livestock, elk, mule deer, antelope [pronghorn], sage

grouse, and many smaller species of wildlife.

Sage grouse, like 85% of the species analyzed by Wilcove, et al. (1998), are primarily threatened by habitat degradation and destruction. Indeed, habitat destruction is "the most significant cause of endangerment" for birds as a group (King 1977, p. 10, evaluating IUCN Red Book listings; accord Collar, et al. (1994)). Every category of habitat destruction and degradation identified by Wilcove, et al. (1998), with the exception of logging, is also a threat to sage grouse. The categories identified by Wilcove, et al. (1998) include: agriculture, livestock grazing, mining and oil and gas exploration and development, logging, infrastructure development, road construction and maintenance, military activities, outdoor recreation, off road vehicle use and developments, water developments, dams, pollutants (including pesticides, herbicides, and pollutants from mining and oil and gas developments), land conversion, and disruption of natural fire ecology. In the western United States, regions with a high degree of species endangerment are associated with "rangeland" ecosystems, predominantly "shrub/brush range systems" (Flather, et al. 1994, p. 21).

Sage grouse have one of the lowest population recruitment rates of any upland game bird in North America, further reducing the ability of populations to recover. Loss of habitat, predation, drought, and poor weather conditions during hatching and brooding periods have been cited as factors leading to poor recruitment (Mattise 1995). Autenrieth, et al. (1982) ; Braun, et al. (1977); Call (1979); Dalke, et al. (1963) and the Western States Sage Grouse Technical Committee (WSSGTC 1999) provide guidelines for management of sage grouse and their habitat. The WSSGTC guidelines are the most recent. Unfortunately, they "represent a series of compromises" and lack specificity (Braun 2001a). Worse, these guidelines ignore important landscape effects which severely threaten sage grouse populations.

It is particularly important to analyze threats in combination, and not merely separately. Threats in combination can have synergistic effects (the cumulative effect can be greater than the additive sum of the parts). Such synergy of effects is so common in ecology that it is discussed in major texts (e.g. Meffe and Carroll 1997, p. 152-154), and such situations are common in birds – one striking example is that of the Heath Hen (Simberloff 1986b). Porter, et al. (1984) demonstrated a method of statistical analysis to simplify the analysis of such complex interactions. Importantly, many threats are correlated. For example, military training exercises are both directly harmful to the birds, and also increase the likelihood of fire. Fire damages habitat directly by destroying sagebrush, and also enhances invasion of cheatgrass (Knick 1998). Threats can inhibit population processes even without direct death or injury to the birds. For example, sage grouse may practice behavioral avoidance of intrusive threats such as noise sources, antennas, transmission towers or other raptor perches. This avoidance can disrupt dispersal patterns, foreclose the use of traditional lek sites, or otherwise reduce population viability even without noticeable increases in mortality rates near the intrusion. The amount of habitat affected by such factors is huge, and is continually increasing.

As detailed in previous sections of this review, sage grouse possess certain demographic, physiological and ecological characteristics that render them susceptible to extinction and extremely difficult to reestablish after extirpation. Likewise, sage grouse habitat is easily damaged, and recovers only slowly if at all from damage. These sections are included as threats to the species by reference in this petition and the Service is requested to give its comprehensive consideration to the suite of characteristics rendering sage grouse susceptible to population declines and extinction.

Dr. Braun, perhaps the foremost expert on sage grouse, believes that habitat conversion,

habitat fragmentation and habitat degradation are the major threat categories to sage grouse (Braun 1999a, p. 1). Predation and other threats act because of the widespread effects of these three threat categories (Braun 1999a, p. 1).

The Service recognizes the importance of these threats: “high intensity grazing is incompatible with nest success” needed to ensure sage grouse population viability; habitat fragmentation can have “significant impacts” and will affect “oil and gas exploration and drilling, mining, road construction” and recreation; “habitat removal has been locally significant,” and conversion of habitat to agricultural uses “will need to cease” if sage grouse are listed (US Fish and Wildlife Service 1998, p. 2 of Attachment).

A species must be listed if it "is endangered or threatened" because of any “natural or manmade factors affecting its continued existence " 50 C.F.R.§ 424.11(c)(5); 16 U.S.C. § 1533(a)(1)(E). This section of the ESA is meant to incorporate any factors not explicitly listed in the four sections preceding that section in the statute. The Secretary must conduct a "review of the species' status." 50 C.F.R. § 424.11(c). The determination to list the species must be made "solely on the basis of the best scientific and commercial data." 16 U.S.C. § 1533(b)(1)(A); 50 C.F.R. § 424.11(b). The Service “cannot ignore available biological information.” Connor v. Buford, 848 F.2d 1441, 1454 (9th Cir. 1988). The Secretary may not consider actual or "possible economic or other impacts" in the listing decision. 50 C.F.R. § 424.11(b). To make the Service’s task easier, and to insure prompt action on the petition, Petitioners have prepared a very thorough and comprehensive status review for the Service. Petitioners incorporate all parts of this review, particularly the section designated “Population Mechanisms and Vulnerability” and its sub-sections, into the threat analysis as “other natural or manmade factors affecting” the continued existence of this species.

Effects on Sage Grouse Habitat and Range

A species must be listed if it "is endangered or threatened" because of "present or threatened destruction, modification, or curtailment of its habitat or range." 50 C.F.R.§ 424.11(c)(1); 16 U.S.C. § 1533(a)(1)(A). The Secretary must conduct a "review of the species' status." 50 C.F.R. § 424.11(c). The determination to list the species must be made "solely on the basis of the best scientific and commercial data." 16 U.S.C. § 1533(b)(1)(A); 50 C.F.R. § 424.11(b). The Secretary may not consider actual or "possible economic or other impacts" in the listing decision. 50 C.F.R. § 424.11(b).

The range of sage grouse has been significantly curtailed in historic times. Much of the extant sagebrush will not be available to sage grouse because it is (1) degraded, and (2) even if not degraded, is too small, or (3) is subject to proximity effects (too close to powerlines, roads, or trees) for sage grouse to use. Habitat may also be subject to proximity effects if it is too far away from another habitat type for sage grouse to use, or to use without significant predation or other dangers. These range contractions are ongoing, and are virtually certain in the future. Virtually all sage grouse habitat has been degraded and much has been destroyed (Connelly and Braun 1997; Braun 1998a, 1999a; Paige and Ritter 1999). The threats which have produced habitat degradation are ongoing, and additional habitat modification and degradation is certain. Many, but not all threats, are anthropogenic. Human impacts tend to be chronic, arising from cumulative and persistent actions over broad areas (Aplet and Keeton 1999; Johnson, et al. 1994).

Various studies have attempted to assess the condition of the shrub and grassland ecosystem types in the western United States and none has been of much scientific validity (Noss

and Cooperrider 1994, Donahue 1999). The Environmental Protection Agency is currently attempting to develop an Environmental Monitoring and Assessment Program for these arid lands as well as other ecosystem types. What is clear however, is that sage grouse are almost literally evaporating from a vast landscape like water in a very large, but shallow container.

Grazing

Grazing of domestic livestock has affected the entire range of the sage grouse, and grazing with its associated livestock operations is the number one range-wide threat to the continued existence of the species. BLM acknowledges that grazing is the major activity affecting wildlife habitat on its lands (USDI 1994, Draft EIS, p. 25-27). As Dr. Clait Braun, perhaps the single most expert sage grouse scientist, put it:

> When one considers exotic plants, changed community structure, and changed plant height, the number 1 factor affecting sage grouse has been domestic livestock grazing – and lack of grazing management – have had the most long-term negative impacts on sage grouse abundance (habitat degradation). Braun (2001g).

Livestock grazing is clearly linked to sage grouse declines (Patterson 1952c, p. 274) as well as to declines or extinction of other species. Livestock grazing has negatively affected many gamebirds (Brown 1978) as well as other birds (Brown 1978, p. 483). Grazing is the predominant land use on 70% of the land in the 11 states west of the 100th meridian (Cooperrider 1991). The impacts and extent of grazing on sage grouse are widely documented (e.g. Yocom 1956, Dobkin 1995, Autenrieth, et al. 1977; Klebenow 1982). No sage grouse habitat is known to have escaped degradation by livestock grazing (Braun 1998a). The US Dept. of Interior has noted that "although only about 10% of the sagebrush steppe that dominates the Intermountain West has been converted to anthropologic habitats, more than 90% of this community is degraded by livestock grazing" (Noss, et al. 1995).

Grazing is so damaging in the arid West that critics have repeatedly called for its complete elimination (Forsling 1963, Donahue 1999). Current grazing management is unlikely to improve these BLM lands (USDI 1994a), yet BLM has implemented few if any changes to date.

Grazing effects can be categorized into two major groupings. First, grazing directly affects vegetation structure, soil characteristics, and other habitat characteristics. Second, when lands – even public lands – are used for grazing, they are usually altered by one or more "treatments" to produce more grass and forb cover for the livestock and to reduce shrubs, such as sagebrush. These treatments involve a vast agro-industrial infrastructure of fences, roads, dams, water developments, powerlines, vegetation manipulations and more.

Ungrazed sagebrush steppe in the Intermountain West has declined by 98% or more since Euro-American settlement (Noss and Peters 1995, table 1; Noss, et al. 1995). Nearly half of the shrub-steppe of eastern Oregon, western Idaho, and the northern Great Basin has been completely destroyed (Noss and Peters 1995, p. 58). Worse, the region of sage grouse habitat in eastern Washington has been almost completely wiped out (Noss and Peters 1995, p. 57-58).

Livestock grazing in the arid West brought about sudden and immediate change to native ecosystems. In the American West, grazing by livestock began in the 1840's – some Texans drove cattle to California by way of Wyoming, Utah, and Nevada to fill the beef market created by the 1849 gold rush (Brown 1994, p. 43). In December of 1866, Nelson Story ended a long trail drive from Ft. Worth near Livingston on the Yellowstone River, thus starting the cattle industry in Montana (Brown 1994, p. 313). A range herd was established near Ft. Laramie in

1868, and large numbers of cattle were driven from the northwest into Wyoming at least as early as 1876 (Brown 1994, p. 313). By 1878, thousands of cattle occupied central Wyoming, and Johnson County was organized. Grazing increased rapidly throughout the West in the 1870's, and peaked around 1890 (Young and Sparks 1985; Saab, et al. 1995). By that time, native perennials grasses "were, for all practical purposes, no longer present on southern Idaho ranges," native forbs began to disappear, and topsoil loss was significant (Quinney 2000, p. 93). In the Interior Columbia Basin, grazing has caused "extensive soil losses from upland habitats" (Quigley and Arbelbide 1997b, p. 460). By 1900, much rangeland had been altered by the combination of high intensity livestock grazing and extreme drought (Yensen 1981, Saab, et al. 1995). By 1870, cattle had so reduced native plant communities that hunter-gatherer Native Americans could no longer obtain adequate food from wild lands (Steward 1938, Basin-Plateau Aboriginal Socio-political groups).

As Saab, et al. (1995) noted "Major changes in native shrub-steppe vegetation, particularly the rapid loss of forbs and grasses took as little as 10-15 years under severe overgrazing that accompanied early settlement of the West (Kennedy and Doten 1901, Cottam and Stewart 1940, McNaughton 1979, West 1979)." Trimble (1989) described the rapidity of degradation: "it took just fifteen years from the start of grazing before the best grasslands in the sagebrush desert were grazed out." Domestic livestock grazing has caused major changes in plant species composition of shrub-steppe habitats including loss of cryptogram layer, loss of native grasses, reduced perennial grass cover, reduced forb cover, increased shrub cover, and invasion by exotic species, particularly cheatgrass (Saab, et al. 1995, 2001). In the Columbia Plateau region of Oregon and Washington, livestock grazing has caused "widespread and severe impacts on vegetation structure and composition," the "spread of exotic plants," and has detrimentally affected riparian areas (Altman and Holmes 2000, p. 10).

Indeed, livestock grazing is the most widespread influence on native ecosystems of western North America (Fleischner 1994, Wagner 1978, Crumpacker 1984). In 16 western states, approximately 165 million acres of BLM land (94% of the total BLM land) and 103 million acres of USFS land are grazed by 7 million head of livestock, primarily cattle (Fleischner 1994, GAO 1988b) and on 70% of all lands in the west (GAO 1988b). Approximately 70% of the of the West is grazed, and this figure includes the entire area of lakes, rivers, forests, parking lots and urbanized areas, thus the percentage of grassland and shrubland is vastly greater (Crumpacker 1984; Fleischner 1999, p. 64). Even 35% of all wilderness areas have active livestock grazing allotments (Reed, et al. 1989). The 35% figure represents an average over the entire US, so the figure for the West is probably substantially higher. Effects on wildlife are severe: Smith (1977) found that grazing is "the single most important factor limiting wildlife production in the West," and Cooperrider (1991) noted that grazing is "one of the primary threats to biological diversity." The effects of grazing and livestock operations have been devastating to sage grouse.

Grazing changes habitat structural characteristics and species composition in both upland and riparian sites, spreads exotic invasive species, and causes erosion, degradation, and shrub encroachment into riparian areas (Rasmussen and Griner 1938; Patterson 1952c; Autenrieth, et al. 1982; Klebenow 1982, 1985; Call and Maser 1985, Belsky, et al. 1999). Grazing has rendered many areas unsuitable for sage grouse. Of even greater concern is that these areas may have been permanently damaged, and may not be able to return to their former vegetative composition because of grazing (Autenrieth 1981, Laycock 1991). Even light grazing is known to put stress on the herbaceous plants favored by livestock, and required by sage grouse (West 1996). Thus,

even light grazing has the potential to reduce food quality for sage grouse.

The grazing of domestic livestock is not comparable to the use of an area by native herbivores, such as bison or Pleistocene herbivores (Sierra Nevada Ecosystem Project 1997, p. 114). First, much of the range of sage grouse did not overlap with that of bison (*Bison bison*) (Reynolds, et al. 1982; Van Vuren 1987; Van Vuren and Deitz 1993). Bison primarily occurred in short-grass and long-grass prairies east of the range of sage grouse, and were not common in the Great Basin (Mack and Thompson 1982, Daubenmire 1988). Livestock grazing is particularly destructive in these bunch grass dominated areas as these grasses did not evolve in conjunction with grazing pressure (unlike rhizomatous grasses in the prairies of the Great Plains and in Africa). Consequently, bunch grasses — which formerly predominated in the Intermountain West — lack the ability to reproduce after grazing destroys the seed heads, respond poorly after close cropping of the plant body, and are susceptible to trampling damage.

Second, bison ranged widely in those areas where they did occur. Cattle, however, concentrate on gentle slopes near water (Van Vuren 1982) – these are precisely the areas needed by sage grouse for critical life history stages, such as brooding (Gill 1965a, 1965b; Savage 1969a, Klebenow 1969). Third, grazing by domestic livestock is repetitive, with annual or biennial grazing periods of varying timing and length (Braun 1998a). Fourth, bison and most native ungulates browse rather than graze and often do so in the dormant season – however characterized, bison eat primarily grass rather than forbs (Pieper 1994; Crawford Area Conservation Plan, CACP 1998, p. 4). Introduced species, such as cattle, often graze rather than browse, and do so during the season of active growth for grasses and forbs. Fifth, bison select and consume rougher, drier forage than do cattle (Geist 1996, Lott 1991a, Norland 1984, Wuerthner 1998, p. 374-375).

The canard that domestic cattle merely substitute for the effects of bison has been well debunked, as the above citations show (see also Donahue 1999). Surprisingly, the BLM has subscribed to this replacement notion, at least with respect to grasslands (USDI 1994a).

The scientific literature is replete with studies showing the serious ecological costs of grazing domestic livestock in arid ecosystems (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; Belsky, et al. 1999). Grazed sites may have only one-third the species richness of ungrazed sites (Reynolds and Trost 1979, 1980; Rummell 1951). Removal of livestock can double grass densities, but an area may take 110 years to recover (Gardner 1950). Webb and Stielstra (1979) found that grazing caused the aboveground biomass of annuals to decrease by 60% and decreased the above ground biomass of perennial shrubs by 16% to 29%. Grazing is known to deleteriously affect bird species (Mosconi and Hutto 1982), in part due to indirect effects on habitat structure (Fleischner 1994).

The amount of grazing on public lands is under-estimated by the standard measure of grazing intensity, the animal unit month (AUM), essentially the forage consumed by a cow and its calf in one month. Many, if not most, of the existing grazing allocations by public agencies were determined in the mid-1950's and were based on cows that ranged in size from about 850 to 1000 pounds. In the last 40 years, however, genetic techniques have been used to breed significantly larger cattle, which now often have body masses of 1,350 pounds or more (GBCP 1997, p. 43). This factor alone is a 35% to 59% increase. Moreover, the calves are also larger, and mature more rapidly (GBCP 1997, p. 43). These two factors increase the plant consumption for each cow and calf, so that the consumption today may approach twice that per AUM when grazing allocations were determined. Even if the grazing allocations today did not exceed those

of the mid-1950's, those previous allocations were too high. This is evident from the historic decline of sage grouse populations throughout the west and from the condition of BLM lands.

However, cattle grazing allocations – measured as AUMs – have actually increased in states with sage grouse (Rich 2001). The "**total number of cattle AUMs on public land in sage grouse states is actually higher in 2000 than it was in 1949**" contradicting the conventional wisdom that they have declined (Rich 2000, emphasis in original). Instead, "the impacts are just being spread more uniformly across the West through fencing, pipelines, and spring development" (Rich 2001). But it is precisely this dispersion of effect away from riparian areas and into the uplands that is so damaging to sage grouse – "it is certainly causing more habitat destruction in the uplands" (Rich 2001, Duke 1999). Worse, as the AUMs have increased, the grazing impact has increased even more, because the area available for grazing has been reduced – "land has been fenced out of riparian areas and weeds are taking tens of thousands of acres out of use" (Rich 2001). The "net impact is a substantially higher density of cattle on the remaining lands" (Rich 2001). The "bottom line is clear – perhaps it is no surprise that we are losing grouse" (Rich 2001). Worse, management for "rangeland health" or for "good grazing" is likely detrimental to sage grouse because such management aims to produce more livestock forage, i.e. "graminoids" prefer grasses rather than forbs (M. A. Smith 2000).

Domestic livestock grazing reduces water infiltration rates, reduces cover of herbaceous plants and litter, disturbs and compacts soils (creating microsites for invasion of exotics such as cheatgrass), and increases soil erosion, which reduces the productivity of vegetation. A large and robust literature exists on these alterations of ecosystem processes, much of it based on exclosure studies and other experimental manipulations. Unfortunately, many of these studies involved areas too small to understand ecosystems processes or lasted only a few years (Saab, et al. 1995). Exclosures should be several hundred hectares in size (Rotenberry 1998, p. 270), and studies need to continue for decades. Belsky and Blumenthal (1997) recently reviewed this literature.

Grazing retards vegetative recovery from fires, grazing itself, revegetation after strip mining and from other disturbances. Grazing can also completely prevent any vegetative recovery after a disturbance, permanently altering the ecosystem to one of lower productivity and lower vegetative cover, reduced biomass and biodiversity, soil deterioration, and other aspects of desertification (Sheridan 1981, Noss and Cooperrider 1994). Overgrazing is "the most potent desertification force, in terms of total acreage affected, within the United States" (Sheridan 1981). An estimated 1.1 million mile^2 (36.8% of North America's arid lands) have already undergone "severe desertification," and desertification of an additional 10,500 mile^2 has been "very severe" (Sheridan 1981). Moreover, twice that area is threatened with desertification (Sheridan 1981). Indeed, there are few lands that have not undergone at least some desertification (Noss and Cooperrider 1994) and all sage grouse habitat has been degraded if not destroyed (Connelly and Braun 1997; Braun 1998a, 1999a; Paige and Ritter 1999).

Even when livestock are not present at the time of sage grouse use of an area, they remove and stress food and cover plants that the grouse will need either later in the year or in the next breeding season. These plants may not regrow at all, or may not regrow to sufficient height, density or nutrient composition in time for sage grouse to make use of them.

Hens with broods avoid meadows where grazing has caused steep, eroded stream banks, dense shrub cover, and low forb availability (Klebenow 1985). Patterson (1952c) noted the decline in sage grouse use of excessively grazed areas. Many grazed areas need active restoration to be adequate for sage grouse (Autenrieth, et al. 1982; Klebenow 1985). Sage grouse sometimes feed in meadows that are maintained for grazing (Evans 1986), and this has lead some incautious

observers to claim that grazing therefore benefits sage grouse. Grazed meadows are usually located in the most productive locales and would thus be chosen by sage grouse whether they when grazed or not. Evans (1986) apparently did not control for this factor in his thesis. Moreover, sage grouse have few other places to feed since the uplands have been heavily degraded by decades of livestock use.

In many areas, the dates at which livestock are released onto public land (BLM and USFS) conflicts with the nesting and early-brood rearing of sage grouse (GBCP 1997, p. 42). These life history stages have been identified as of critical importance to sage grouse (GBCP 1997). Such conflicts are no doubt common throughout the range of sage grouse.

Riparian areas, which are critical for brood-rearing, are heavily grazed in the arid lands that form the range of the sage grouse (GBCP 1997, p. 43). These critical riparian areas have been impacted by livestock grazing (GBCP 1997, p. 42). Grazing has also caused plant communities to shift to species that tolerate heavy grazing, and caused heavy infestations of undesirable plants such as Canada thistle, Scotch thistle, and stinging nettle, (GBCP 1997, p. 42). Gully formation has also led to loss of surface moisture and vegetation (GBCP 1997, p. 42). The Service recognizes that "high intensity grazing is incompatible with nest success" needed to ensure sage grouse population viability (US Fish and Wildlife Service 1998, p. 2 of Attachment).

Domestic livestock are not the only grazing or browsing mammals posing potential threats to sage grouse. Horses (*Equus caballas*) were extirpated from their center of origin, North America, at the end of the Pleistocene (Martin and Klein 1984). Grass and shrubland ecosystems evolved without horses (and without the many other large mammals that went extinct at that time) during the Holocene. Horses were reintroduced to North America by the Spanish and quickly adopted by Native Americans by about 1690 (Haines 1970, 1971). Reintroduced horses are believed to have intensively grazed some areas of the West at that time, including eastern Washington (Harris and Chaney 1984). Grazing by feral ("wild") horses continues today. In localized areas, feral horses have greatly reduced forbs and grasses (West 2000, p. 17). Feral horses are protected by federal statute and about 24,000 feral horses occur in 103 herd management areas (Nevada State Office, BLM 2000a, p. 8). Management is still possible, although the effort and expense to reduce herds to levels that do not damage sagebrush ecosystems can be considerable. * * *

In localized areas, such as some southerly portions of the Greater Yellowstone ecosystem, grazing and browsing by native ungulates can negatively alter sage grouse habitat (Singer and Renkin 1995, Singer and Harter 1996, Singer, et al. 1998a, Singer, et al. 1998a, Wambolt 1998). Reintroduction of native predators, such as wolves, rapidly restores sage grouse habitat by suppressing ungulate foraging and movements. * * *

Recovery time of habitat once grazing is halted can require decades or centuries. However, removal or reduction of cattle grazing is known to result in increases of herbaceous vegetation (Ellison 1960a, 1960b; Sneva, et al. 1984; Miller, et al. 1993, p. 126). Grazing also leads to feedback loops in shrub and grassland ecosystems, and these feedbacks damage sage grouse. For example, grazing increases the frequency and severity of grasshopper outbreaks. Managers then use more pesticides to control the grasshoppers, harming sage grouse, which are important controls on grasshoppers (Johnson 1987). Grasshoppers then proliferate even more, amplifying the feedback cycle. Interaction effects abound in such systems – for example, the overgrazing starves sage grouse, putting them into poor nutritional status, where they are likely more susceptible to pesticide effects. The Service will need to thoroughly evaluate the magnitude of all such interactions and feedback effects.

Apologists for livestock interests often note that heavy grazing in the past may be affecting ecosystem health more than current grazing. Even if correct, this assertion is irrelevant to a listing determination – if the effects on sage grouse habitat create threats or endangerment then listing is required, even if the ultimate causes of those threats are in the past. Second, because ecosytems have been degraded and destabilized, even lower levels of grazing in the present can produce severe effects.

This section discusses the effects of grazing *per se*. However, it is important to realize that and livestock operations have many more negative effects besides those due to grazing, and such losses of sage grouse have been documented (SMBCP 1998, p. 29). For example, in order to graze an area with domestic cattle, the area will usually be fenced, water developments will be installed, and unintended effects will also result, such as the invasion of exotic plants and insects, soil erosion, lowering of water tables and the dewatering of wetlands. Thus grazing cannot be thought of as merely a few cattle or sheep as depicted in a gentle pastoral painting. Instead, these effects result from the conversion of native ecosystems to agro-industrial uses, and are discussed in other sections below.

Direct Trampling Effects

Trampling is possible on nests, eggs, chicks, and adults. Although, slow-moving dim-witted livestock are unlikely to present much of a threat to chicks or adults, they will disturb birds and trample nests. Trampling of nests has been a concern since the early part of this century (Hornaday 1916, p. 188). Trampling is a known problem for a wide variety of bird species wherever livestock congregate (Fondell 1997). A particularly severe problem is the trampling of wet meadow areas needed by juveniles. Livestock trampling of such areas – often exacerbated by "development" of springs and seeps typically renders these highly productive areas into little more than mud holes filled with cattle excrement and devoid of plant life (R. H. Braun 1986; Low and Berlin 1984). Another severe effect is the trailing of large numbers of livestock across areas to move them from one range to another. Such trailing can cause "significant impacts on nesting hens and young broods," besides the destruction of vegetation is causes (Call and Maser 1985, p. 17).

Whether because of direct trampling or from disturbance effects, sheep are known cause extremely high rates of nest abandonment (Call 1979, p. 30). Livestock also [*compact*] soil by trampling (Adams, et al. 1982). Soil compaction is a significant problem in the Columbia Plateau, and affects water percolation, runoff, and soil nutrient levels (Altman and Holmes 2000, p. 8). Spring grazing is particularly damaging because it disturbs birds that are nesting and rearing broods. Even if grazing provided benefits (such as putative control of cheatgrass) these direct negative impacts will likely overwhelm any benefits.

Trampling of Vegetation

Livestock trample both sagebrush and grasses and forbs that sage grouse need for both food and shelter. Trampling by livestock is especially damaging to juvenile sagebrush plants (Owens and Norton 1990). Trampling of vegetation by grazing livestock is detrimental to most upland wildlife (Fleischner 1994, Belsky and Blumenthal 1997). Cattle generally trample riparian areas first, moving into the uplands after they have depleted the valley bottoms and areas near water sources (Stoddard, et al. 1975). However, removal of cattle from near streams to protect fish would force cattle to make greater use of uplands. Uplands are sage grouse habitat in general, and upland meadows containing mesic sites such as streams, wet meadows, and springs

provide critical summer and fall habitat for sage grouse, especially in arid areas (Savage 1969b, Oakleaf 1971, Autenrieth, et al. 1982). Nonetheless, USFS intends to "attract cattle away from the streams" in order to protect "sensitive riparian areas" (Duncan 1999, p. 2). USFS does not explain why it does not simply reduce or eliminate cattle grazing to protect all the public's lands and wildlife.

Livestock trample and damage cryptogamic soil crusts (variously known as microbiotic, microphytic, or cryptobiotic crusts). Crusts have been so reduced that it is now difficult to determine their exact range and role in sagebrush communities (Mack and Thompson 1982, St. Clair, et al. 1993). Cryptogamic crusts improve soil stability, productivity, and moisture retention, moderate extreme temperatures at the soil surface, and enhance seedling establishment of vascular plants (Belnap and Gardner 1993; Harper and Pendleton 1993; Johansen, et al., 1993; St. Clair, et al., 1993), thus contributing to high ecological integrity of shrub-steppe habitats. Cryptogamic crusts also inhibit cheatgrass establishment by about 50%, even when seed sources are nearby (Kaltenecker, et al. 1999; Belnap, et al. 2001).

Even light grazing can harm sage grouse in areas with a history of overgrazing, because the recovery of grasses and forbs may be greatly slowed or prevented (Blake 1970; Klebenow 1982, 1985; Autenrieth, et al. 1982; Winward 1991a). For example, on the YTC in Washington, grazing degraded soils, water quality, vegetation, and sage grouse habitat from 1960 through 1995 (Nissen 1989, CH_2M-Hill 1996, Livingston 1998). Most springs have been developed to supply water for livestock, and impacts are concentrated on sensitive wetland vegetation. Most riparian areas and meadows have not yet recovered from the grazing (Livingston 1998).

Intensive grazing is common throughout the range of the sage grouse. For example, in Washington, intensive grazing occurs throughout the counties with the bulk of the current sage grouse range (Yakima, Grant, and Douglas counties). These 3 counties contained an average of 297,876 cattle between 1986 and 1995 (Tirhi 1995), nor has grazing been reduced over time (Tirhi 1995).

Other federal agencies have recognized the importance of preventing trampling by domestic livestock. BLM recently canceled grazing permits on the 276,125 acre Granite Mountains Grazing Allotment in the Mojave National Preserve because of trampling concerns.

Removal of Food Plants

Forbs and other understory plants are critical, not only for their direct food value to sage grouse chicks but also because these forb plants provide food sources for insects which are a critical dietary component for sage grouse chicks during their early developmental period. Even light grazing tends to remove preferred food plants of sage grouse, while heavy grazing can create virtually barren spaces between sagebrush plants (Daubenmire 1942, p. 62). As the cryptogamic crust, and forb and grass understory is denuded, sagebrush plants increase in size, abundance and canopy closure often occurs (Daubenmire 1942, p. 62), a condition which has sometimes been dubbed "overmature" sagebrush.

Competition from cattle for native grasses is a threat to the desert tortoise, which has very low metabolic needs compared to an endotherm such as the sage grouse (Holing 1986). Thus, livestock competition with sage grouse may cause greater effects on the bird. Another important factor is that grazing alters the competitive balances of shrubs, grasses, and forbs in shrub-steppe ecosystems. Grazing allows shrubs to out-compete grasses and forbs, and allows canopy closure of shrubs (Klebenow 1969), preventing re-establishment of the forb and grass understory, even after grazers have been removed from the area. Livestock are known to convert herbaceous plant

communities to woody plants and remove native bunchgrasses (Archer 1994; Fleischner 1994; Ohmart 1996; Belsky, et al. 1999; Belsky and Gelbard 2000).

A wide variety of studies confirm the reduction in forbs and grasses caused by grazing in sage grouse habitat (Klebenow 1969, Autenrieth 1981, Call and Maser 1985, Wakkinen 1990, Gregg 1992). Even moderate grazing in spring can reduce or eliminate bunchgrasses by preventing seed set (Paige and Ritter 1999). Some studies have used direct comparison of control and manipulation sites: Pearson (1965) found that an area left ungrazed for about 11 years had 45% more top growth than an area that had been grazed for 70 years. Crawford and Coggins (1998) found that grazing had a highly statistically significant effect on ground cover, including forbs. Grazing interacted significantly with precipitation, which was also a significant predictor of ground cover (Crawford and Coggins 1998). Forb cover increased 3-fold and grass cover increased by about 2.5 to 3 fold in low sagebrush and Wyoming big sagebrush areas (Crawford and Coggins 1998, Table 6, p. 30). Simply put, removing cattle increased herbaceous vegetation and sage grouse productivity (Crawford and Coggins 1998).

Even "proper grazing practices" create conflicts with sage grouse needs because of the removal of herbaceous vegetation (Miller and Eddleman 2000, p. 25). This a particular problem in nesting areas. In some cases, cattle have grazed so intensively on sage grouse winter ranges in Oregon and elsewhere that the actual structure of the sagebrush has been altered, which harms grouse during winters with deep snow (Call 1979; Call and Maser 1985, p. 17)

Removal of Cover Plants

Forbs and grasses near the nest provide wind shelter, radiative shelter or shading, and visual concealment (Webb 1993a, 1993b). Besides removing food plants and altering competitive relations among plants, grazing directly harms sage grouse by removing the sheltering plants near the nest (Webb 1993b). These impacts are known to harm both nesting success and chick survival (Klebenow 1969; Hein, et al. 1980; Autenrieth 1981; Call and Maser 1985; Wakkinen 1990; Crawford and Delong 1993; Gregg, et al. 1994; Sveum 1995). Grazing removes the tall, dense grass cover needed by nesting sage grouse and increases predation at the nest (Crawford and Delong 1993; Gregg, et al. 1994). Crawford and Carver (2000) found that areas that were not grazed for several years had significantly more tall residual grass cover at sage grouse nests, and consequently nest success was 4 times higher than in areas that were grazed. Sage grouse avoid grazed shrub-steppe during the nesting season (NWEA 1999, p. 32 citing Schroeder in prep.) and many grazed areas in Washington no longer support sage grouse (NWEA 1999).

Alteration of Ecosystem Processes

Grazing also affects plant community composition by fostering interspecific competition between plants tolerant of grazing and those less tolerant. Miller, et al. (1993) suggest that these alterations in the competitive balance in the plant community may be one of the most important pathways of habitat degradation in the shrub-steppe.

Grazing is known to cause large increases in small herbivore populations, such as grasshoppers and jackrabbits (Miller, et al. 1993, p. 130). Grazing creates microsites for germination of invasive weed seeds, such as cheatgrass. Despite much talk about using livestock to "trample native seeds into the soil" for germination, there is little data to support such a notion (Miller, et al. 1993, p. 130). Indeed, it is precisely such microsites that favor cheatgrass. It is obvious that such processes would be superfluous for native plants, since they did not evolve with large mammals.

Grazing alters nutrient cycles, water cycles, fire return intervals, and energy flow (Miller, et al. 1993, p. 130). Grazing also reduces competition of grasses and forbs with tree seedlings, promoting tree establishment (Belsky and Blumenthal 1997). Grazing is a primary factor in the juniper and pinyon pine invasion.

Some have advocated spring grazing by cattle to reduce cheatgrass infestation or for other management purposes. However, cattle grazing in the spring will also damage native herbs (West 2000, p. 18). Fences would be needed to prevent cattle from spreading cheatgrass and to prevent destruction of native forbs and grasses outside the target area. Besides the extreme cost and likelihood of further spreading cheatgrass during fencing operations, the fences needed to control such grazing will directly harm any nearby sage grouse through mechanical impact and by serving as raptor perches. Spring grazing is poorly studied as a cheatgrass control mechanism, is expensive, and bear serious risks to native vegetation.

Invasion of Exotics

Livestock grazing is known to destabilize plant communities by increasing their susceptibility to invasion by exotic alien species (Fleischner 1994). Livestock help spread exotics by (1) dispersing their seeds in fur, in mud on their hooves, and in dung, (2) creation of microsites for establishment of cheatgrass (*Bromus tectorum*) and other exotics (Gould 1951, Mack 1981), and (3) by reducing the competition from native species by eating them (Fleischner 1994). Alien grass invasions in North America are closely associated with grazing (D'Antonio and Vitousek 1992). Basin big sagebrush and Wyoming sagebrush communities are highly susceptible to cheatgrass invasion (Miller and Eddleman 2000, p. 21). Once invaded, sagebrush communities are nearly impossible to recover or restore. The entire Great Basin is "an endangered landscape" and no successful restoration of sagebrush grasslands has ever been accomplished (Christensen 2000, quoting James Young, a scientist with the US Agricultural Research Service).

Livestock are also known to severely degrade cryptogamic crusts (Fleischner 1994). Cryptogamic crusts (which consist of bacteria, blue-green algae, fungi, mosses and lichens) are important in providing favorable sites for the germination of vascular plants (St. Clair, et al. 1984) and have important effects on soil hydrology (Fleischner 1994), on stabilization against wind and water erosion, on retention of soil moisture, on reduction of wind erosion (Belnap 2000, p. 57), and on promoting equable soil temperature regimes (Belnap 1993, 1994; St. Clair and Johansen 1993; Kaltenecker 1997). Crusts are also known to enhance the survival and biomass of native perennials in cool deserts (Belnap 2000). Once damaged, cryptogamic crusts can require 50 to 100 years to recover (St. Clair and Johansen 1993). Intact cryptogamic crusts prevent invasion by cheatgrass and similar species. Invasive annuals, such as cheatgrass, typically invade interstitial areas between native plants that were once occupied by soil crusts (Pyke 2000, p. 43). Soil crusts are easily damaged by livestock and human trampling, ORVs, and mining activities (Belnap 2000, p. 57).

Numerous studies show that livestock grazing contributes to both the invasion and dominance of noxious weeds (Lacey 1987, Bedunah 1992, Hobbs and Huenneke 1992, Dwire, et al. 1999). Grazing is directly implicated in the spread of knapweed (*Centaurea* spp.) and cheatgrass (*Bromus tectorum*) (Hoffmann 1991, Drut 1994). Cattle can transport invasive plant seeds and other pest propagules into nearly all areas, except those with the steepest slopes and areas farthest from water (Daubenmire 1970, Belsky and Gelbard 2000). A single cow can transport over 900,000 viable seeds per season (Dore and Raymond 1942). Other studies confirm

the ability of cattle to transport viable seeds in dung and on their coats (review by Belsky and Gelbard 2000). Besides promoting the invasion of noxious species, cattle create an environment that is susceptible to invasion (review by Belsky and Gelbard 2000).

Cryptogamic crusts also help prevent cheatgrass invasion and prevent the spread of wildfire (Kaltenecker 1997). Once damaged, crusts may not recover for over a decade, even with complete elimination of livestock (Cole 1990; Belnap 1993; St. Clair and Johansen 1993; Kaltenecker 1997).

Crested wheatgrass (*Agropyron desertorum; Agropyron cristatum*) plantings damage sage grouse habitat by replacing plants used for food, shelter and concealment such as sagebrush and forbs (Beck 1975a, 1975b), and by altering the fire regime. Crested wheatgrass was seeded throughout the sagebrush region by BLM and private parties because it was more tolerant of grazing than native grasses, which had been largely degraded by livestock grazing before crested wheatgrass was planted (D'Antonio and Vitousek 1992, p. 66). Crested wheatgrass competes with sagebrush for phosphorus and can inhibit sagebrush growth (D'Antonio and Vitousek 1992, p. 70). Sage grouse have occasionally used areas planted with crested wheatgrass as lekking grounds. The use of crested wheatgrass areas for lekking is attributable to the high site tenacity in this bird. For example, sage grouse also lek on the airport runway in Jackson, Wyoming. It is unlikely that sage grouse prefer crested wheatgrass for lekking or for any other need (see the numerous citations in the Rangeland "Improvements" section). The Oregon BLM acknowledges that native plantings ought to be used (BLM 1999c). Unfortunately, land management agencies have not had the forethought and stable funding base needed to ensure that sufficiently large stores of native grass and forb seeds are available, and are currently using exotics to revegetate areas due to the lack of native seed stores. Use of native seeds collected in the wild presents another problem: most wild collected seeds contain cheatgrass and risk spread of cheatgrass into uninfected areas (Pyke 2000, p. 46). Crested wheatgrass stands often persist for several decades and can invade native grasslands, especially where the native grasses are stressed by drought or cattle grazing (Utah Agricultural Experiment Station 1996).

Degradation of Soil Quality

Soil quality is a primary factor determining the quantity and type of potential vegetation on a given site. Reduction of the herbaceous understory in sagebrush ecosystems renders soils more vulnerable to both wind and water erosion (GBCP 1997, p. 39). Wind erosion can be a particularly strong erosive effect within the range of sage grouse. Soil compaction and erosion from ORVs, livestock use, and other trampling effects decreases water availability to plants, destroys soil crusts, alters nutrient cycles, and accelerates soil erosion (Belnap 1995a). Soil erosion alters soil quality – and hence vegetative characteristics – by decreasing soil fertility and the depth of the top layers of soil. Soil fertility is affected by reduced organic matter, reduced moisture retention after precipitation, and increased soil compaction. These factors, in turn, are strongly affected by grazing, vehicle use, and water developments. In the Gunnison Basin, top soil has already been lost in many areas, and has impacted critical nesting and brooding areas (GBCP 1997, p. 39). Such effects are likely throughout the range of sage grouse. Cold deserts, such as sagebrush areas, are particularly susceptible to soil damage from surface disturbances and recovery requires centuries (Belnap 1995a).

Fences

Fencing is often used for livestock operations and to delineate property boundaries. Fencing may vary from a few strands of barbed wire to a woven mesh. Even a stranded barbed wire fence will kill sage grouse. This writer has seen dead birds caught on stranded barbed wire

fence, as have other observers (Call and Maser 1985; Braun 1998a; Dove Creek Conservation Plan, DCCP 1998, p. 23). Even worse is a woven mesh fence that does not permit the birds to pass through by walking, their preferred mode of locomotion (GBCP 1997, p. 48, SMBCP 1998, p. 22). Sage grouse are particularly susceptible to fence collisions because they "usually fly fast and direct" at just a few feet above the ground (Wilkinson 2001b, p. 1). Sage grouse apparently do not become accustomed to fencing (Wilkinson 2001b, p. 1). Fences located along ridgelines or in swales, or near leks are likely to be most hazardous to sage grouse – unfortunately, fences are often located along ridgelines because of ease of construction (Wilkinson 2001b, p. 1). Young grouse are often killed by flying into fences (Trueblood 1954). In Utah, fencing killed at least 36 birds in only 3 months (Call and Maser 1985). In southwest Montana, "numerous fences intersect the surveyed sage flats" and "probably contribute to a significant percentage" of sage grouse mortality (Schmidt 1998). Even without systematic fence surveys, an "incidental check of a fence line" revealed 5 fatal fence strikes by grouse, and 2 others that were not immediately fatal (Schmidt 1998). Over a 6 year study in Utah, collisions with fences caused 18% of the mortality – the largest source of mortality after raptor predation (Wilkinson 2001a, p. 3 of attachment 7). The researchers felt that the number of grouse found were only a small fraction of those dying from fence collisions, because grouse remains often landed 40 to 70 feet away from a fence (too far to be seen from near the fence), and because wounded grouse walk away to die elsewhere. Marking fences with colored tape or cloth strips was recommended by Call and Maser (1985), but these markers do not last, and no data exist to support their efficacy. BLM biologists who have studied fencing effects on sage grouse are "not aware of any research that has been completed that concludes that mitigation actions have successfully minimized sage grouse collisions with fences and other structures" (Wilkinson 2001b, p. 1). Moreover, mistakes are often made, exposing sage grouse to unmarked fences (G. Miller 2001). Sage grouse often collide with fences soon after they are erected (G. Miller 2001). Mortality from fence collisions "is an all too common problem" and a study by Danvir found fence collisions as a major cause of adult sage grouse mortality, second only to raptor predation (Mike Stamm in G. Miller 2001). Fence removal is a prerequisite for sage grouse recovery. Fences have often been installed to keep cattle out of riparian area, and these fencing projects have often been pursued "with blinders on" as to their effects on sage grouse (Wilkinson 2001a, p. 3 of attachment 3). The solution is to close these areas to grazing entirely, protecting both fish and birds.

Vertical elements in the landscape, such as fence posts, serve as perches for aerial predators such as raptors and nest and chick predators, such as corvids. Corvids are known to be more common along linear strings of such vertical elements because they serve as perches or as nest sites (Knight and Kawashima 1993). There "are no mitigation possibilities" to prevent raptors and corvids from perching on fence wires (Wilkinson 2001a, p. 1 of attachment 3).

Livestock and other uses, including maintenance, often cause trails along the fence line. Such trails provide travel corridors for predators, increasing the risk to sage grouse populations (Braun 1998a). Fence posts also provide perches for avian predators (SMBCP 1998, p. 22; DCCP 1998, p. 23). Sage grouse are known to avoid fences (Braun 1998a); thus fences serve to fragment habitat.

Some have suggested that grazing could be used as a management "tool to enhance sage grouse habitat," suggesting that grazing could be used in fenced meadows to reduce old vegetation" (Beck and Mitchell 2000). Besides the fallacy of assuming that "old vegetation" needs to be removed by an exotic import that never existed on this continent during the times of highest sage grouse abundance, Beck and Mitchell's suggested use requires the use of fences

which are prominently displayed in a photograph on page 999 of their article. Fences act both as raptor perches and as barriers that kill or maim flying sage grouse. The suggested "cure" is worse than the problem. Cattle and sheep grazing "are tools that do more harm than good" Strassmann (1987, p. 42), and this applies even more strongly to the infrastructure of industrial agriculture needed to support livestock management. This is a significant threat because over 31,000 miles of fencing has been constructed on BLM lands in states with sage grouse habitat (Wilkinson 2001a, p. 1). Moreover, many additional miles of fence have been constructed to keep livestock out of the millions of acres of sagebrush that have burned since 1997 (Wilkinson 2001a, p. 1).

Conversion of Habitat

Conversion of habitat to other uses, such as agriculture or housing, completely eliminates that habitat. Consequently, sage grouse are extirpated from that area (Swenson, et al. 1987). Even minor reductions in area from habitat conversion can cause large reductions in sage grouse populations – when 16% of sagebrush steppe was ploughed, sage grouse populations declined by 73% (Swenson, et al. 1987). Worse, conversion is a permanent habitat change and precludes restoration or recovery of populations (unless one contemplates completely plowing up fields, burning down suburban houses, and replanting sagebrush). As such, these are the only threats that are likely to be greater than livestock grazing. Conversion of habitat has limited the amount of habitat available to sage grouse throughout their range (Pyrah 1971, Wallestad 1971, Martin 1976) and probably exceeds livestock operations as a threat in Colorado, Washington, and perhaps in Idaho (Hays, et al. 1998). Habitat conversion impacts all life history stages of sage grouse (Rogers 1964). Settlement of, and agriculture on, sage grouse habitat began in the mid-1800s and was enhanced by passage of the series of acts known as the Homestead Acts, beginning in 1862 (Todd and Elmore 1997). Much of the land originally homesteaded was ploughed and the sagebrush removed. Some of this land reverted to the public domain after agriculture and homesteading failed. Irrigation projects, including both taxpayer subsidized large dams on major rivers, and small dams on streams, made irrigation water unusually cheap. Consequently, irrigated agriculture in the shrub-steppe has converted many thousands of acres of sage grouse habitat into low value crops.

Habitat can also be converted by the invasion of exotic alien species, such as cheatgrass. Initially, these species merely degrade habitat, but after a period of time some invasions can destroy sage grouse habitat, rendering it totally unsuitable for the birds. Destruction of sagebrush and intentional seedings of non-native species can also convert habitat, and is further analyzed below under the topic "Rangeland 'Improvements.'" Such conversion of habitat by cheatgrass and intentional destruction is estimated to have occurred over 10% of native sagebrush steppe (West 1988, 1996).

Agriculture is the most widespread form of habitat destruction for all species, followed by commercial development (Wilcove, et al. 1998). For sage grouse, agriculture (including grazing) is clearly the most widespread threat to the species existence, with development being the worst threat in some relatively local areas, such as near urban centers and in scenic areas near roads. Habitat conversion has been overwhelming in some areas, such as the Snake River Plain in Idaho, various valleys in Utah, and the eastern California and western Nevada region. In Oregon and Washington, the Columbia Plateau has had nearly half its habitat converted to agriculture (Altman and Holmes 2000, p. 9), and most of that agriculture consists of low value products used as cattle fodder.

Vast areas of natural communities have been converted to anthropocentric land uses, especially for agriculture. In 1989, USDA Soil Conservation Service analyses showed that

cropland accounted for 421 million acres, and pastureland for 132 million acres (Langner and Flather 1994, p. 14). Although much of that conversion took place in the East and Midwest, native grasslands are known to have suffered much higher conversion rates than have forests (Langner and Flather 1994, p. 14). Much agriculture does not produce food for human consumption, but instead merely feeds cattle. Approximately 37% of the Columbia Basin has been converted from native vegetation to agricultural use (Quigley and Arbelbide 1997b, p. 459). "Agricultural and urban development, livestock herbivory, the introduction of exotic plants, and changes in disturbance regimes have resulted in unprecedented changes." (Quigley and Arbelbide 1997b, p. 765). Habitat conversion is probably the major cause of sage grouse declines in Washington and some parts of Colorado, exceeding even grazing and livestock operations in those areas. About 2 million acres of sagebrush habitat on federal lands have been sprayed, chained or otherwise damaged in an attempt to convert them to livestock pastures, and the amount of habitat in private ownership that has been damaged or destroyed in this manner is even greater (Vale 1974). Between 1952 and 1977 alone, 2.5 million ha of sagebrush habitat were destroyed by conversion to livestock range (Ellis 1985).

In many areas, large water reservoirs have been created, destroying vital sage grouse habitat. Such reservoirs are often placed in areas that were formerly wet meadows or other types of wetlands that are crucial for sage grouse reproduction, particularly in drought years.

* * *

Habitat Conversion to Agriculture

It is not surprising that agriculture, including grazing, is so damaging to sage grouse: agriculture is the key variable explaining the endangerment patterns not only of birds as a group, but of mammals and plants as well (Dobson, et al. 1997). Wilcove, et al. (1998) identified habitat loss as the single greatest threat to biodiversity, as have virtually all other authors (Noss, et al. 1995, p. 2; Noss and Peters 1995, p. 45; Ehrlich and Ehrlich 1981; Ehrlich and Wilson 1991; Diamond 1984a, 1984b). Of the habitat required by sage grouse, 98% or more has been degraded since Euro-American settlement (Noss and Peters 1995, table 1; Noss, et al. 1995) and 10% of native sagebrush steppe has been converted to agricultural crops (West 1988, 1996). Habitat conversion to agriculture is the primary cause for sage grouse declines in Washington (Hoffmann 1991). Habitat losses due to farming have been problems since the early part of last century (Hornaday 1916, p. 188). Today, most basin big sagebrush communities have been converted to cultivation (Bunting, et al. 1987).

Besides the direct removal of habitat, agricultural fields serve as barriers to dispersal and isolate populations (Mader, et al. 1990; Mader 1984). By attracting birds into areas with little predator cover, fields may also create high risk "kill zones." Agricultural conversion is also accompanied by the vast infrastructure of modern corporate agriculture – fences, electrical wires and poles, herbicides, and water developments – all are threats to sage grouse.

Croplands cannot support sage grouse populations, although sage grouse may feed at the margins of alfalfa or bean fields if adequate shrub cover is nearby. In other areas, habitat has been converted to vast grasslands, often with exotic alien grass species that sage grouse cannot use. Even when native grasses are planted, sage grouse cannot use areas without shrub cover. Federal land management agencies, such as the BLM, have been particularly at fault for such habitat conversion.

Throughout the Columbia River Basin and Snake River Plains, dryland farming, made economically viable by subsidized irrigation water delivery from dams, has resulted in the

destruction of immense expanses of sage grouse habitat. Ironically, this has occurred concurrently with the destruction of salmon runs by the same dams. Today, these once extensive shrub-steppe ecosystems exist only as tattered remnants of fragmented landscape in a sea of development, grazing lands, and agricultural fields.

Development and Habitat Conversion to Suburbs and Ranchettes

Suburbanzation (including dispersed ranchettes and vacation homes) as well as the buildings and home sites of working ranches also directly remove habitat. Braun (1998a) suggested that ranch buildings affected about 1% of sage grouse habitat, but that because of their proximity to water and the best soils, the negative impacts to sage grouse populations would be much greater than the proportion occupied. Braun (1998a) estimated that 3% to 5% of sage grouse habitat in Colorado had been negatively impacted by towns and urban development, and this estimate is probably reasonable for most other states as well. Development is implicated in the extirpation of Gunnison sage grouse from the Iron springs mesa area of San Miguel County, Colo. (Brigham 1995b). Suburbanzation also tends to occur near water, where higher quality soils are located, so its population impacts are also likely to be larger than the amount of habitat affected.

The Intermountain West, which contains the bulk of sage grouse habitat, is the fastest growing area of the country, and has a population growth rate that is greater than that of Mexico (Knight 1997). For example, between 1969 and 1987, 19% of the ranchland in Park County, WY was platted for subdivision, while the rates were 16% in Teton County, ID and 23% in Gallatin County, MT (Knight 1997). Moreover, suburbanization rates are disproportionately greater than population growth. In Idaho, Oregon, Washington, and western Montana – all states with the largest sage grouse populations – the area of developed land grew faster than population in the decade leading up to 1992 (Durning 1996, p. 26). The amounts of habitat that are degraded by suburbanization can be startling – Braun (1998a) found that in some Colorado counties, 50% of available sage grouse habitat is under development for ranchettes. This estimate may not apply to all states or to all areas, yet every western state has areas of extremely high population growth and the west is the fastest growing part of the country. Only one western state, Oregon, has land use controls and urban growth boundaries. However, even in Oregon, these land use controls are frequently violated in the part of the state containing sagebrush and sage grouse. Worse, Oregon's land use controls have not demonstrably reduced conversion of either natural areas or of agricultural lands (Kline and Alig 1999).

Suburbanization also unleashes large numbers of domestic pets, which can prey upon or otherwise disturb both adult birds and their young. Domestic dogs (*Canis familiaris*) and cats (*Felis catus*) commonly forage along edge habitats near human dwellings (Oehler and Litvaitis 1996) and this may be a problem in shrub-steppe habitats as well. Developments not only remove habitat, they also constitute threats to moving sage grouse. Sage grouse have been observed to fly into windows (Hays, et al. 1998 citing Connelly, personal communication).

Suburbs do not exist in a vacuum, but are tied to urban centers by networks of roads, powerlines, and pipelines. This infrastructure also affects sage grouse, by directly removing their habitat, by degrading adjacent habitat, and by fragmenting habitat. In the Gunnison Basin, development of subdivisions is one of the greatest potential threats to Gunnison sage grouse habitat (GBCP 1997, p. 47).

Sage grouse avoid areas within 0.5 mile of occupied dwellings (DCCP 1998, p. 20). Other studies have also noted declines in sage grouse use of an area after residential

development. Hupp (1987b) found that leks in hay meadows were abandoned after nearby development. Given this proximity effect, it is relatively easy to delete these habitat areas from GIS based maps.

Mining as Habitat Conversion

Mining, particularly strip mining, directly eliminates habitat. Mining operations also release a diversity of pollutants, many of them toxic, and create additional roads and additional traffic on existing roads. Surveys and explorations for mineral, oil, gas, and coal deposits also entail habitat degradation. If the area is adequately reclaimed, sage grouse may be able to reestablish populations after some decades, but only if migration corridors from population source areas are available (see Braun 1998a).

However, it is difficult to establish sagebrush and forbs on reclaimed areas after mining. Sagebrush reestablishment by direct seeding is not reliable (Schuman, et al. 1998). Reestablishment by transplanting is expensive. Stockpiling of topsoil during mining – even for periods as short as 6 months – destroys mycorrhizae that sagebrush require and causes significant nutrient depletion (Schuman, et al. 1998). Other problems include competition from herbaceous species, particularly invasive exotics. Sagebrush will not reseed naturally unless the seed source is very close – a 100 meter distance reduces establishment by half (Schuman, et al. 1998). Researchers studying 14 different "reclaimed" coal strip mined sites were able to find only 3 sites with adequate shrub densities for sage grouse, even after 10 years or more (Olson, et al. 2000). Moreover, Braun (1998a) found that there was no evidence that sage grouse populations were able to reach their previous numbers on reclaimed sites, and the Gunnison sage grouse suffers from the effects of past mining (GBCP 1997, p. 47).

Spatial Analysis of Habitat Conversion

Remote sensing data can be used to gain fairly accurate estimates of the amount of landscape currently in agriculture, suburbanized, or mined. Indeed, wholesale habitat conversion is the threat that is most susceptible to spatial analysis, because of the ease of acquiring geo-data via remote sensing. The amount of landscape that was formerly sage grouse habitat can be estimated from potential natural vegetation mapping, and the fraction of potential habitat that might not have been available in historical times because of disturbance induced displacements from its potential seral stage (e.g. by fire) can be estimated by paleoecological techniques, such as pollen counts. Many of these data probably already exist, and a good portion of those data may be in spatial form, suitable for use in a Geographic Information System (GIS). GIS is now commonly used for resource conservation and reserve design (ASPRS/ACSM/RT 1992). A habitat quality model suitable for remote sensing (thematic mapper) and GIS applications has already been developed (Homer, et al. 1993; Edelmann, et al. 1998). Their model does not appear to include any landscape features such as proximity analysis, barriers, shape ratios or other characteristics, but is an important first step. For example, the Interior Columbia Basin Ecosystem Management Plan (ICBEMP) generated a wealth of spatial data that may be applicable to sage grouse habitat studies, even though that data probably overestimates the availability of habitat to particular wildlife species. Thus, the degree of habitat conversion can be estimated fairly accurately without a great deal of effort. Nonetheless, a higher priority may exist for population viability analysis and habitat fragmentation studies of those populations still existing, than for studies of the importance of previous effects on population decline.

Landscape data on habitat types and land uses will be important for recovery planning.

Such datasets are available from a number of sources. Most USFS data are collected for forestry, such as Timber Survey maps based on aerial photointerpretation, and more recent GIS products. However, Dr. Bruce Welch at the Shrub Sciences Laboratory USFS Rocky Mountain Research Station in Provo, Utah is working on a monograph of big sagebrush to be published as a General Technical Report. Several chapters are in draft form (see Welch, draft manuscripts) but a chapter on the extent and condition of sagebrush is not yet completed (Welch 1999). Pipeline and utility companies often have maps of their facilities in GIS form. BLM has variable coverage of habitat and vegetation maps, and has not yet gathered comprehensive GIS information, but a project is underway (T. Rich, personal communication). Similarly, USGS-BRD (Biological Resources Div., US Geological Survey) has land use and land cover maps, and has a GIS project underway (S. Knick, personal communication). The EPA compiles ecoregion maps and the Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS) has soil type maps, although agricultural use mapping is not comprehensive. NRCS has also compiled a National Resources Inventory, which contains information on land uses. State natural heritage programs also have various data, often in GIS form. These and other sources are described by Scott, et al. (1993, p. 15-16) and in more recent sources. Many states have completed or are near completion of GAP analysis, and various GIS layers will be useful for sage grouse habitat analysis and protection. In Idaho, GAP analysis shows that protecting sage grouse would also protect large numbers of other vertebrates that are currently unprotected (Kiester, et al. 1996). The same is likely to be true in other states. GAP analysis is not a panacea however. Two major limitations on the use of GAP analysis are that location data for species typically lack specificity and that data layers on species distributions are typically mere estimates of habitat affinities (Schwartz 1999, p. 98).

Pursuant to Executive Order 12906, the Federal Geographic Data Committee (FGDC) of USGS has set up a Clearinghouse for geospatial data. It appears that little or no sage grouse habitat information is accessible from that site, however. Similarly, USGS personnel are attempting to inventory and systemize existing GIS data sets relevant to sage grouse and sagebrush shrub-steppe ecosystems (Knick, personal communication).

Rangeland "Improvements"

Much of the shrub-steppe grassland and desert biome used by sage grouse is often popularly termed "rangeland," as though its only or proper use were for the ranging of livestock. This terminology is to be avoided. Rangeland is an anthropocentric type of land use, not an ecosystem type (cf. Welch, draft manuscript, Ch. II, p. 35). Treatment of these areas to kill or control sagebrush and increase the amount of grass for foraging livestock has been, and remains, common. Treatments include the use of defoliants and other herbicides and pesticides, blading (bulldozing of sagebrush), chaining (dragging a heavy chain between two vehicles to mechanically kill of remove sagebrush), fire, and various other methods (Pechanec, et al. 1954a). The BLM alone has “treated” (destroyed) sagebrush on over 1.8 million ha (Miller and Eddleman 2000, sum of values in table 5, p. 20); when the figure for private lands is added, the total is astounding. These methods result in the complete destruction of habit – sprays kill 99% of all sagebrush and chaining kills about 90% of sagebrush (Vale 1974). Sagebrush eradication efforts have continued for many decades – they are even mentioned in Rachel Carson’s Silent Spring (Carson 1962, p. 65). To add insult to the injury caused to the public’s wildlife, ranchers do not even pay the majority of the costs of such projects – BLM uses appropriations from the general treasury for “soil and watershed protection” to fund much of each project (Vale 1974). State wildlife agencies have often expressed concern over such projects (Christensen 1968, Vale

1974) but they have continued anyway.

Often, sagebrush is removed to allow for the growing of crested wheatgrass (*Agropyron cristatum*) for livestock forage (Drut 1994, p. 21). Such treatments have been frequently studied and all studies have shown that effects on sage grouse are detrimental (Rogers 1964; Klebenow 1970; Martin 1970a; Pyrah 1970a, 1971; Wallestad 1971, 1975a, 1975b, Braun, et al. 1977). "Crested wheatgrass has no nutritive value to sage grouse" and "attracts few insects that can be used by sage grouse" (Braun 2000b). Additionally, it provides "little cover value or structure" for sage grouse (Braun 2000b) because of its short height even when mature. Conversion of native sagebrush shrublands to seed grass deprives sage grouse of a key habitat component for 7 years to 30 years or more (Braun 2000b).

Grazing can also act as a type of treatment (Braun 1998a). At best grazing treatments are neutral – there are no demonstrated instances where "positive impacts [from livestock grazing] are apparent" (Braun 1998c). Not surprisingly, this sort of habitat degradation is devastating to sage grouse populations. Sage grouse will alter their use of, or completely avoid, treated areas (see, e.g. Braun, et al. 1976, 1977). Braun (1998a) estimates that at least half of sage grouse habitat has been treated in this manner, and suggests further that this is merely a conservative estimate.

Depending upon the severity of degradation after "treatment," and the edaphic characteristics of the area, sage grouse use will be altered for a minimum of 2 or 3 years, to more than 30 years (Braun 1998a). In fact, there is no guarantee that "treated" areas will ever recover, as a severe enough degradation in these arid areas can alter the endpoints of plant community succession, resulting in a new clisere.

As with fire, the scale and pattern of areas affected across the landscape is of paramount importance to effects on the birds. Small scale brush removal that leaves twice as much area in sagebrush as is converted, may be a benefit to sage grouse in some areas (Braun 1998a). Large scale brush removal (more than 100 ha blocks), especially when coupled with the seeding of exotic grasses, severely degrades sage grouse habitat (Blaisdell, et al. 1982; Lancaster, et al. 1987).

Invasive Species

Overall, invasive species are a major cause of species extinction, second only to habitat loss (Flather, et al. 1994; Wilcove, et al. 1998). An exotic "invader" is any organism that is able to colonize and persist in an area where it has never existed before (Mooney and Drake 1986). Similar definitions have been offered by Pres. Executive Order 13112, and by the Service (invasives.FWS.gov). The US Office of Technology Assessment estimated that at least 4,500 alien species have invaded the United States and established sustainable populations here (Office of Technology Assessment 1993; Campa and Hanaburgh 1999). Invasions by exotic species can reduce biodiversity, spread disease and alter ecosystem processes and constitute serious threats to native ecosystems (Liebhold, et al. 1995; Vitousek, et al. 1996). Invasive species can alter ecosystem processes and components by disrupting normal rates of system level resource supply, altering trophic structures, and altering disturbance regimes (D'Antonio and Vitousek 1992, p. 64). They also can destroy wildlife habitat and damage agricultural crops, rangelands, forests and wildlands (Vitousek, et al. 1996).

Sagebrush habitats and other plant communities in the Great Basin are "highly susceptible to invasion" because annuals in these areas did not evolve to tolerate "intensive grazing" (J. A. Young, et al. 1972, p. 194), that is now rampant in the West. Invasion of alien plant species "is a major threat to remaining sagebrush habitats and in some areas overshadows

all other concerns" (Paige and Ritter 1999). Invasive species have "taken over" more than 25 million acres of public land in the Great Basin alone (BLM 2000a), are spreading through grass and shrublands at rapid rates, and these rates are increasing in many areas (Quigley and Arbelbide 1997c). Infestations of noxious weeds alone are increasing by at least 14% annually (R. Johnson, et al. 1999, p. 13). This invasion of arid and semi-arid lands is "unprecedented" and "threatens native ecosystems" while "reduc[ing] the success of restoration" (Allen 1995). Over 860 exotic plant species have invaded the Pacific Northwest (Rice 1994 in Quigley and Arbelbide 1997c). Invasive plant species have a large effect on sage grouse in many areas, including the Gunnison Basin (GBCP 1997, p. 41). Invasion of exotics continues at epidemic rates, estimated as 2,200 ha/day on federal lands alone, and control strategies have been ineffective (BLM 1996a). "Noxious (exotic) weed spread is expected to accelerate dramatically" (Quigley and Cole 1997) and these noxious weeds are changing rangelands, leaving less habitat for wildlife. There are "at least 46 species" of "weeds" capable of entering and thriving in sagebrush ecosystems – 20 of these are classified as "highly invasive" and "competitive" (Pyke 2000, p. 43). Not all invasive alien species appear on state or federal noxious weeds lists – in some cases, control is so difficult or economically burdensome that regulatory powers have simply given up on control (Pyke 2000, p. 45). This abdication of responsibility – though the frustration is perhaps understandable – constitutes an inadequate regulatory mechanism.

Alien species affect other threats to sage grouse, and in turn, are affected by other threats – particularly livestock grazing – discussed in this review. Attempts to control invasive species can expose the birds, and plants they need for food and cover, to herbicides, pesticides, and endocrine disrupters. Alien species are often associated with agricultural lands and invade natural areas from agricultural lands (Janzen 1986; Alberts, et al. 1993; Smallwood 1994). Livestock are a known vector for the spread of alien exotics.

The term Invasive Species can also be applied to native species that escape natural biological controls. For example, overgrazing, drought, and destruction of competitors and predators by pesticide spraying contribute to grasshopper outbreaks (Lockwood, et al. 1988). Such outbreaks can affect the amount of forage available to sage grouse. Domestic livestock are the most damaging alien species in western North America, with the possible exception of hominids *per se*, but both are discussed in their own sections of this review.

The Great Basin has been permanently altered by alien species (Pellant 1990), thus recovery of sage grouse populations in areas from which they have been extirpated may be impossible, and the little remaining habitat must be conserved at all costs. The introduction of exotic plants (for example, annual grasses, and annual, biennial, or perennial forbs) and their establishment resulted in the replacement of native cover types and structures, primarily in the dry grass, dry shrub, cool shrub, and riparian areas (Quigley and Arbelbide 1997b, p. 459). West (2000, p. 19) provided some mechanisms explaining both the irreversibility of invasions and the "rolling tide" of invasive replacements: "shrub-centered islands of [soil] fertility" are destroyed by the interactions of fire, soil erosion, and tillage. The resulting annual grasslands are much less productive. "Similar invasions happened in the Middle East several millennia ago" and "many other more noxious weeds" from the Middle East could find their way here, resulting in a "downward spiral of further degradation." West's allusion to the Middle East is particularly disturbing when one considers the vast advance of the Sahara desert in recent times. The process resembles the well-known taxon cycles of island biology: North America is the island, and is repeatedly invaded by aliens species, each one degrading habitat and rendering the island more susceptible to future invasions by even more deleterious alien species.

Invasions by exotic organisms are facilitated by disturbance (Elton 1958 (reprinted 2000), Mooney and Drake 1986). Disturbance to the soil surface, such as is caused by cattle, is known to facilitate the establishment and spread of cheatgrass and medusahead wildrye (*Taeniatherum asperum*) (Nevada State Office, BLM 2000a, p. 7). Pickett and White (1985a) defined disturbance as any discrete temporal event that disrupts ecosystem, community or population structure and changes resources availability or the physical environment. Grime (1979) views disturbance as any process that removes or damages biomass. The disturbance caused by roads, ORVs, and livestock grazing allows exotic invaders access to undisturbed ecosystems. Creation of microsites favorable to seed germination is a significant effect facilitation invasion by cheatgrass and other plant species.

Agriculture, including livestock grazing, is the principal source of nonnative plant introductions (Miller, et al. 1994; Pieper 1994). As the USGS notes, one of the most important factors "making an ecological community susceptible to invasion by nonindigenous species is the level of human-induced disturbance" (Williams and Meffe 1998, p. 120; Hobbs 1989). Livestock grazing and other threats have substantially increased the invasibility of sage grouse habitats. For example, creation of microsites by grazing and other soil disturbing activities is a major factor in the invasion of alien plants into shrub-steppe ecosystems (Mack 1981). The entire Intermountain steppe region, which includes much of the range of the sage grouse, is "now largely dominated" by the effects of exotics, which were introduced and spread by "exotic animals," such as domestic livestock (Rosentretter 1994). Other such effects of grazing are discussed in more detail above in the section entitled "Invasion of Exotics" under the "Grazing" topic. Utility corridors can also allow dispersal by invasive species. Fragmentation creates more edge, allowing invasion by wind dispersal and other means. Roads and off-road vehicle use enhance the spread of alien species by carrying their seeds, spores, instars, or other dispersal or resting stages deep into fragments. In the Gunnison Basin, invasion of cheatgrass is particularly evident along roads (GBCP 1997, p. 41). Alien species, especially cheatgrass, can alter fire regimes to the point that sagebrush can no longer exist in an area. Furthermore, cheatgrass is extremely difficult to eliminate from an area – invaded areas may permanently cease to be sage grouse habitat.

Despite the known culpability of livestock in the dispersal and promotion of many invasive species, curtailment of livestock grazing is apparently not part of the BLM's proposed solution to the invasive species problem (BLM 2000a, see "Actions" sections, p. 29-34). Instead, the BLM proposes to spend huge amounts of money to spray herbicides, promote fire, and other such treatments. Unless sage grouse are listed before BLM undertakes such widespread activities, their needs are certain to be given little consideration, as has been made abundantly clear from previous BLM activities. The US National Strategy for Invasive Plant Management has as its first goal the "effective prevention of the spread of invasive plants" (Pyke 2000, p. 44; FICMNEW 1997a, 1997b). This cannot be achieved unless vectors for invasive plant spread such as cattle, ORVs, hikers and others are not allowed access from cheatgrass infested areas to unaffected areas. Yet, BLM has done nothing to limit such access, and BLM's grazing policy in particular violates the Invasive Plant National Strategy. Some invasive plants, such as halogeton and Russian thistle require continued disturbance to maintain dominance. Cattle grazing and off-road vehicle (ORV) use are primary disturbances, but again BLM has taken no actions to curb these disturbances.

Cheatgrass Invasion

Cheatgrass (*Bromus tectorum*) can alter fire regimes, and outcompetes native grasses and forbs (Kauffman 1990a, 1990b). Seedling establishment of native perennials is limited by cheatgrass competition (J. A. Young 1994a, 1994b). Cheatgrass invasion following fire in shrub-steppe habitats in the northern and western Great Basin and Interior Columbia Basin has triggered drastic changes in arid land ecosystems (Whisenant 1990). Native shrub-steppe ecosystems are being converted to simplistic annual grasslands (Billings 1994). The range of sage grouse is completely encompassed by that of cheatgrass (Rich 1985b).

Cheatgrass invasion and its attendant alteration of fire return intervals strongly reduces cryptogamic soil cover and reduces plant species biodiversity (Whisenant 1990, p. 9). Eventually, cheatgrass creates a non-diverse uniform annual grassland which carries fire so frequently that shrubs and perennials cannot co-exist (Whisenant 1990). Even without destroying the upper canopy of sagebrush, cheatgrass can displace native forbs and grasses in the understory that are a "critical habitat component for sage grouse" (Hemstrom, et al. undated, p. 3). Before cheatgrass invasion, fires were not common, and intervals between burns were 60 to 110 years; after cheatgrass invasion, fire return intervals are now often less than 5 years (Whisenant 1990). In Yellowstone National Park, pre-settlement fire return intervals were 32 to 70 years in sagebrush-grass areas (Wright, et al. 1979, p. 4). Big sagebrush is easily killed by fire and does not resprout (Blaisdell 1953b, Pellant 1990). Cheatgrass has already invaded 40 million hectares (Mack 1981; D'Antonio and Vitousek 1992, p. 75) and threatens to dominate 25 million hectares (62 million acres), or more than half of the West's sagebrush region (Rich 1996, Paige and Ritter 1999). Together with medusahead wildrye (*Taeniatherum asperum*), cheatgrass will dominate 30 million hectares in the Intermountain West alone (Pellant and Hall 1994). Cheatgrass invasion is perhaps the most significant plant invasion in North America (D'Antonio and Vitousek 1992, p. 75), yet BLM has done virtually nothing to stop it, and the agency's grazing, off-road vehicle (ORV), and road use policies actively advance the spread of cheatgrass. Cheatgrass can invade and establish itself in areas that have been grazed for only one or two seasons and persist for 40 years or more (Driscoll 1964). There are no known treatments that can eliminate cheatgrass over the large expanses it has invaded. The cost to reduce cheatgrass problems is large and limits the ability to maintain the ecosystems involved (Roberts 1990). Attempts to reduce cheatgrass are complicated by the ability of cheatgrass to outcompete native grasses (Meyer, et al. 2000, p. 70). Attempts at cheatgrass control have included tilling the soil, herbicide application, and early-season burning – all control methods are "either hazardous, expensive, or disruptive to remnant perennials and soil" (Meyer, et al. 2000, p. 70). Existing control strategies are also of limited effectiveness (Meyer, et al. 2000, p. 70).

These changes are irreversible or will require centuries to reverse (USGS 1999). State wildlife agencies in Idaho and Nevada have recognized the loss of large tracts of sage grouse habitat from cheatgrass (Drut 1994, p. 21). Both cheatgrass and Spotted Knapweed (*Centaurea maculosa)* are widespread in the sage grouse habitat of Washington. Knapweed is prevalent throughout the West, and diffuse and spotted knapweed have infested more than 3,500,000 acres in Oregon, Washington, Montana, and Idaho. Knapweed has a severe effect on the grasslands of the intermountain west. Knapweed out-competes native grasses, damages wildlife habitat and cattle rangelands, and contributes to erosion (Lacey, et al. 1997). Knapweed spreads, in large part, via movement of seeds on vehicles along roadways.

Cheatgrass was apparently introduced into North America from Eurasia sometime during the mid-1800's, and was first noted in the Great Basin in the late 1800's (Miller, et al. 1993, p.

122). Cheatgrass invaded and spread with the degradation of arid ecosystems by livestock grazing (D'Antonio and Vitousek 1992, p. 65, 74). Grazing apparently facilitated the invasion of many other exotics, including medusahead wildrye (*Taeniatherum asperum*) and red brome (*Bromus rubens*). Cheatgrass spread so rapidly as to escape recording (Leopold 1941), now dominates more than 41 million ha (100 million acres) in the Intermountain West, and forms virtual monocultures in former sage grouse habitat in many parts of Oregon, Idaho, Utah, Nevada, and Wyoming (Billings 1990). Cheatgrass threatens the entire sagebrush ecosystem, and thereby endangers sage grouse throughout its entire range (Billings 1990). Although its most significant effect is the alteration of natural fire regimes and consequent destruction of sagebrush, cheatgrass also alters pools and flows of both energy and nutrients (Christian and Wilson 1999). Moreover, cheatgrass may be favored by increased atmospheric CO2 levels (Billings 1990). Yet even cheatgrass stands can be invaded by other exotic annual species – medusahead wildrye (*Taeniatherum asperum*) can outcompete and invade cheatgrass and is even less desirable because it is more flammable than cheatgrass (Hironaka 1994). One biologist stated that sage grouse will not dance (display) in medusahead wildrye (Fred Taylor, Oregon BLM cited in Anonymous 2001). The spread of medusahead is "adversely impacting sage grouse habitat" (Nevada State Office, BLM 2000a, p. 7).

Other invasive exotics, such as red brome (*Bromus rubens*), medusahead wildrye (*Taeniatherum asperum*), yellow star thistle (*Centaurea solstitialis*), knapweed (*Centaurea* spp.), tumble mustard (*Sisymbrium altissimum*), leafy spurge (*Euphobia escula*) and halogeton (*Halogeton glomeratus*), also threaten sage grouse habitat (Yensen 1981, West 1996). Leafy spurge has infested 2.5 million to 3 million acres in North America and is found in nearly every county within the range of sage grouse (Dunn 1979; Lajeunesse 1999). Leafy spurge thrives in disturbed areas, including croplands and pastures, and is highly competitive, displacing native vegetation (Lajeunesse 1999, p. 250). Leafy spurge is spread by the hooves of livestock, and in livestock feed and crop seeds (Lajeunesse 1999, p. 253).

Cryptogamic crusts are affected by cheatgrass and other invasive plants (J. A. Young 1992, Kaltenecker 1997). Both cheatgrass and knapweed increase soil erosion (Lacey, et al. 1988), increase fire risk (Hays, et al. 1998) and reduce the diversity and quality of sagebrush ecosystems for sage grouse and other wildlife (CH_2M-Hill 1996).

Today, cheatgrass threatens to dominate or completely convert 25 million hectares (62 million acres) – over half of the sagebrush region in the West (Rich 1996). Cheatgrass enhances the invasion of other exotics. For example, litter from cheatgrass enhances water availability by microclimatic alterations in the litter cover, favoring germination of several alien species (D'Antonio and Vitousek 1992, p. 72). Over 40 million hectares have already been invaded (Mack 1989, Whisenant 1990). Halogeton has been termed "the most problematic product of prolonged, chronic abuse of grazing on public lands" (Young and Evans 1988). Medusahead (*Taeniatherum asperum*) is another pyrogenic alien species that threatens native grass and shrub ecosystems (Pellant 1990), as is *Bromus rubens*, red brome (Hunter 1990). Both species are spreading. Yellow star thistle has been reported in 23 of the lower 48 states, and is of special concern in the Snake River Basin. Yellow star thistle establishes monoculture stands on south facing slopes and in newly disturbed soils. Once established, it can out-compete native perennials. It has no value for native wildlife.

A particularly chilling and immediate threat to sage grouse is that cheatgrass now appears to be invading higher elevation areas, even as high as the pinyon-juniper elevational belt (D'Antonio and Vitousek 1992, p. 75). Many scientists formerly believed that as cheatgrass

invaded upwards from lower elevations and juniper and pinyon invaded downward from higher elevations, there would nevertheless be a middle elevation of sagebrush that would serve as a refuge for sage grouse, even though reduced in size. This is not a correct assumption. Billings (1990, p. 307) interprets the information provided by Young, et al. (1972) as showing the invasion of cheatgrass into "all sagebrush-grass vegetation types" in the northwestern Great Basin, "especially at the lower elevations." Cheatgrass has already invaded pine, hemlock, fir and other coniferous forests (Pierson and Mack 1990a, 1990b; Rice and Mack 1991c). It appears that the elevational ranges of cheatgrass and juniper already overlap (Billings 1990, p. 318-319), thus elimination of all sage grouse habitat appears certain without prompt remedial action – there are no elevational refugia.

Deliberate Plant Species Introductions

Non-native species, such as crested wheatgrass (*Agropyron desertorum*) have also been deliberately introduced into sage grouse habitat for erosion control, improved livestock grazing, or other purposes. These species compete with native plants but detrimentally affect sage grouse (Eissenstat and Caldwell 1988, Lesica and DeLuca 1996). Crested wheatgrass has been planted on thousands of acres of lands that were formerly excellent shrub-steppe sage grouse habitat. A large portion of CRP lands in Washington is planted with crested wheatgrass with attendant loss of sage grouse habitat (Schroeder 1998c; Hays, et al. 1998). Such plantings of exotic grass species in the West result in decreased insect and bird diversity (Campa and Hanaburgh 1999, p. 208), decreased bird species numbers (Olson 1974, Reynolds and Trost 1979), decreased numbers of small mammals (Reynolds and Trost 1979), and decreased numbers of reptiles (Reynolds 1979). Overall, the establishment of annual grasslands in sagebrush areas is "very detrimental to sagebrush habitat integrity" (Beck and Mitchell 2000, Young and Longland 1996). Across the Columbia Plateau, "Kentucky Bluegrass [] has spread to many riparian areas, forming a sod [that excludes] many other herbaceous species" (Altman and Holmes 2000, p. 9).

Once established, introduced species are difficult to remove. In north-eastern California, crested wheatgrass seedings were plowed and native herbs were planted. Unfortunately, aggressive annuals such as yellow star thistle soon dominated the area (West 2000, p. 19; citing Young, USDA ARS).

Juniper and Pinyon Pine Invasion

In many areas, native tree species have invaded former sagebrush shrub-steppe because of fire suppression and cattle grazing (Tisdale and Hironaka 1981). Sagebrush dominated areas will not be adequate sage grouse habitat if they contain juniper, pinyon, or other trees serving as raptor perches. Such areas serve as "kill zones" for sage grouse, which avoid areas within 100 m of pinyon pine or juniper trees (Commons, et al. 1999; accord Hanf, et al. 1994). In winter, where habitat may be severely limited, sage grouse may be forced to come within 40 m of trees. Sage grouse also avoid similar structural features such as power poles, fences, etc. (see Predation section). Braun notes that sage grouse will attempt to stay ½ mile from trees if they are within visual range and will stay 100 m away from trees unless forced to forage or seek winter shelter that is only available closer to a tree (Braun 2000c). Tree invasion of shrub habitats is widespread throughout the Great Basin, and in the Yellowstone area and southwestern Montana sagebrush and grasslands are being "heavily invaded" by trees (Gruell 1985, p. 104).

Juniper and pinyon trees can also dewater areas and destroy wet meadows and riparian areas needed for sage grouse especially during the critical brooding periods. Because sage grouse

avoid areas with trees, areas invaded by juniper – even those with sagebrush and forb cover – are not habitat; and may serve as dispersal barriers, limiting gene flow. Pinyon-juniper forests (woodlands) cover 50 million acres in the West (Meeuwig 1983).

Juniper invasion of sagebrush habitats has been explosive. Historically, juniper on the Columbia Plateau was primarily restricted to rocky ridgelines where fire was rare (Altman and Holmes 2000, p. 7). At study plots on Steens Mountain (in eastern Oregon), juniper populations now show exponential growth (Miller, et al. 1993, p. 121, fig. 9; Miller and Rose 1995, p. 40, fig. 1). One species, Western Juniper (*Juniperus occidentalis*), now covers 8.5 million acres in Oregon, 3 million acres in northeastern California, 500,000 acres in Idaho and Nevada, and parts of Washington State (EOARC 2000). Pinyon pine and other species have also invaded other parts of sage grouse habitat.

One major cause of juniper expansion is grazing, which reduces fuel for fires and led to a shift from native perennial grasses to shrubs and cheatgrass (Oregon Department of Fish and Wildlife 1994; West and Van Pelt 1987; Burkhardt and Tisdale 1976; Eddleman 1987; Miller and Wigand 1994). As with earlier expansions of pinyon-juniper communities in the Southwest and Great Basin, juniper expansion is due to livestock grazing, climate change (see particularly Shafer, et al. 2001) and reductions in fire frequency (Ellison 1960a, 1960b; Burkhardt and Tisdale 1976; Young and Evans 1981; Eddleman 1987; Neilson 1987; Evans 1988; Miller and Wigand 1994). Juniper expansion occurred just as large numbers of livestock were introduced into the region (both beginning in the late 1800's) indicating that livestock grazing and the concomitant reduction in fire frequency (due to loss of fine fuels from grazing) are the major causes of the expansion. Livestock grazing is the driving variable: overgrazing causes reduction in fine fuels that help initiate and propagate fires. The reduction in fire frequency allows juniper to spread (Ferry, et al. 1995). Burkhardt and Tisdale (1976) maintained that juniper invasion resulted from fire suppression alone, not overgrazing, but did not analyze the role of cryptogamic crusts. These crusts prevent juniper seedling growth, but are easily destroyed by grazing livestock. Most recently, Miller and Rose (1999) maintain that fire suppression, more mesic climatic conditions, and livestock introduction accounted for the spread of juniper. Thus, despite ongoing juniper eradication by range managers since the mid-1900's, juniper has continued to expand (Bolsinger 1989, Belsky 1996). As long as BLM continues its current management practices and continues to allow widespread grazing, juniper will continue to expand. However, juniper may continue to expand, albeit at a slower rate, even if cattle were permanently banned from the entire West because of climate change (Shafer, et al. 2001). In fact, Shafer, et al. (2001) found that climate change alone will cause virtually complete invasion of sagebrush habitats by the end of this century. This will inevitably cause extinction of sage grouse.

The beginning of rapid expansion of western juniper over the last century correlates closely to the introduction of intensive livestock grazing in the Great Basin (Miller and Wigand 1994). Although active fire suppression was uncommon in the Great Basin until the 1940's, grazing from the 1880's on led to a reduction of fire because it reduced the grasses which fueled fires in the region (Miller and Wigand 1994; West and Van Pelt 1987). Over the last century, livestock grazing and fire control have allowed juniper to move from rocky outcroppings and shallow soils to more productive sites. Even low-level grazing weakens herbaceous plants so that they can no longer out compete and exclude juniper seedlings and saplings (Belsky 1996). In addition, although juniper berries are unpalatable to cows, livestock help disperse juniper seeds by kicking them around with their hooves (Burkhardt and Tisdale 1976).

The relationship between grazing and juniper invasion is also supported by the unusual

situation of "the Island." "The Island" is actually a 250-acre peninsula in central Oregon just southwest of Madras where the Deschutes River meets the Crooked River (Driscoll 1964). The Island was formed 10,000 to 15,000 years ago and has been relatively undisturbed by humans, due to 700-foot cliffs and difficult access (Driscoll 1964). The only serious human-caused disturbance was sheep grazing for two successive summers sometime between 1922 and 1928 (Driscoll 1964). Wildfire has been common and there is evidence that where juniper burned it has been slow to reestablish itself (Driscoll 1964). By the 1960's, juniper, though present, were relatively sparse, occurring in clumps and comprising only ten percent of the vegetation in the one segment of the Island and four percent in the other (Driscoll 1964). Today, juniper has spread only slightly in the area (pers. obs.). Although there is some cheatgrass present, it is only 1.7% on the wheatgrass association compared to thirty percent in a comparable area on the nearby mainland (Driscoll 1964). Cheatgrass is concentrated near the access trail to the area (pers. obs.). Native perennials which are present on the Island are nearly or completely eliminated on the mainland area, and sagebrush comprises only 8.5% of the vegetation on the Island compared to 15% on the mainland (Driscoll 1964). The reduced invasion of juniper and cheatgrass is the result of reduced livestock grazing in the area.

Juniper seedlings do best under sagebrush or other shrubs, especially on the north side of such vegetation (Burkhardt and Tisdale 1976). Grazing has led to both a reduction of perennial grasses and an increase in sagebrush and other shrubs, helping to give juniper a foothold (Miller and Wigand 1994, Eddleman 1987, Burkhardt and Tisdale 1976). Cheatgrass and other noxious weeds often replace western junipers after juniper eradication takes place (Evans and Young 1987, Oregon Dept. Fish and Wildlife 1994). Because these weed species are non-native and contribute to undesirable fire, they are far worse than the original juniper woodlands.

The Oregon Dept. of Fish and Wildlife (ODFW) notes that complete rest from livestock grazing for twenty years without juniper cutting caused spontaneous die-back of juniper and produced the stated goals of juniper eradication – improvement in watershed conditions and restoration of riparian areas (ODFW 1994). ODFW thus recommends that "[i]n many cases, partial or complete rest from grazing will be necessary" in order to properly recover the soil and flora of the ecosystem (ODFW 1994). Caution must be exercised in juniper and pinyon pine removal. Both species are native to the West and have persisted throughout the Pleistocene. Removal should only target areas in which these species have invaded in the past 150 years. Otherwise, juniper dependent bird species could be imperiled, necessitating additional listing and recovery actions. A number of species rely upon juniper and are also candidates for listing, or are treated as vulnerable, critical, sensitive, or special status species by federal and state agencies. These species include: ferruginous hawk, loggerhead shrike, Northern sagebrush lizard, Pacific Townsend's big-eared bat, burrowing owl, sharptail snake, and Pacific pallid bat.

Reservoirs and Water Developments

Besides their effect on agricultural conversion, reservoirs and water developments have directly inundated large amounts of riparian areas needed by sage grouse (Braun 1998a) and dried up riparian habitat in other areas (Horsfall 1932). Water developments have diverted entire streams from their channels, and irrigation has caused alkali poisoning of vegetation (Call 1979, p. 6). Fluctuating water levels and recreation site developments near reservoirs have also affected upland habitat that sage grouse need throughout the year. Data on such areas are easily gathered by remote sensing, as noted elsewhere, but have not been compiled or analyzed in terms of sage grouse habitat reduction (Braun 1998a).

Reservoirs greater than 100 acres in size are known to negatively impact the birds

(SMBCP 1998, p. 24). Large reservoirs can directly kill sage grouse. Sage grouse are incapable of lengthy sustained flight, and birds have drowned in large reservoirs because of their inability to fly over them (Braun 1998a). Even small dams can harm sage grouse by changing needed wetlands and riparian areas into open water. There are "thousands of small dams in the [Interior Columbia] Basin" alone (Quigley and Arbelbide 1997a, p. 63) and tens of thousands across the range of sage grouse.

Water developments can also concentrate water and soil moisture. Sage grouse do not require open water, but do require forbs. Riparian zones in grasslands and shrublands typically have a wide ring of forbs and other riparian vegetation surrounding the water source because of the gentle slope near the seep or spring (Thomas, et al. 1979, p. 5). Water developments, by spatially concentrating water and soil moisture, replace the large ring of forb cover surrounding a water source with a sharp edge of transition from brush to wet areas, having little or no forb cover. Sage grouse often do not use water developments at all (Connelly and Reese 1999).

Stream irrigation or groundwater pumping for livestock or other uses, can cause a very large cone of depression and lowering of water tables. These effects, in turn, can cause decreased vigor and nutritive quality in shrubs such as sagebrush, conversion of meadows to shrubland or desert, and the elimination of wet sinks, springs, and riparian areas.

Even small water developments such as stock tanks, and the dewatering of small streams to fill these tanks, can cause negative impacts to sage grouse. The range of the bird is covered with numerous such projects, which have had a serious impact on its abundance and range. Tanks and troughs can drown wildlife if they are not equipped with escape ramps. All sizes of artificial water impoundments drown wet meadows and other required habitat which must be in close proximity to other habitat elements. Smaller water projects will only provide net positive benefits if they create additional wet meadow habitat (and if such habitat is limiting in the area). Indeed, water "catchments or guzzlers have not been shown to benefit sage grouse populations" (Braun 1998c, p. 4). Instead, such water developments lower water tables and channel water away from succulent vegetation areas such as wet meadows that sage grouse do require. As Jack Ward Thomas and others summarized it: "development of seeps and springs for livestock usually lessens the habitat value for wildlife" (Thomas, et al. 1979, p. 12). Moreover, water developments outside the riparian zone can harm riparian areas by changes in surface water quality, water quantity, and hydrological impacts (Buckhouse 1975). Past agency management – "business as usual" has harmed "many riparian wildlife and fish habitats" (Thomas, et al. 1979, p. 13). McAuliffe (1997) summarized water developments by noting that they were not conservation solutions, merely illusions.

Logging

Logging may be a threat to sage grouse by removing cover needed for microclimatic buffering from wind in winter habitat. Because the effects of trees on blocking wind can extend for hundreds of feet from an edge (Geiger 1965), sheltering effects cannot be analyzed by merely noting that no trees exist in an area. Instead, a proximity analysis must be performed. Logging is not a major threat to sage grouse, and logging or other removal of recently invaded juniper or other conifers into sagebrush areas may be required for sage grouse recovery.

Predation

Most predation on sage grouse takes place as nest predation or on chicks (Braun 1975, Autenrieth 1986, Bergerud 1988b). However, predation of females about to breed may be most important, because the reproductive adult is destroyed together with all offspring that would have otherwise been produced. Sage grouse are particularly susceptible to predation because of their

ground nesting and lekking habit (Hartzler 1974, Bergerud 1988b). Hens are more likely to encounter predators during the lekking period, perhaps because daily movements are increased (Gibson and Bachman 1992). This threat will be exacerbated when leks are spaced far from each other on the landscape, or when raptor perches such as powerlines, trees, or fence posts are common. One study found a mortality rate of 39% (n = 7 mortalities) on leks during the spring raptor migration (Jones and Braun 1994). Moreover, the sagebrush shrub-steppe contains a wide variety of both aerial and ground hunting predators and little in the way of concealing vegetative structure. Hartzler (1974) found that ground predators were observed less often than aerial predators, but killed more grouse.

Predator impacts are large in sage grouse, which lack adequate habitat, particularly grass cover, throughout their range. Such impacts have been demonstrated by predator removal experiments, which substantially increased hatchling success but did not increase breeding population size (Cote and Sutherland 1997). Overall, the effects of predation on sage grouse population viability are important because females and eggs or nestlings are often preyed upon. Predation of females and their eggs or chicks is most likely in areas of fragmented habitat, and degraded habitat which lacks a substantial forb and grass cover for concealment (Rasmussen and Griner 1938, Klebenow 1969, Wakkinen 1990, Webb 1993b). Bird eggs are more likely to be predated by avian predators when overhead cover from surrounding vegetation is low, independent of the effects of mammalian predators or human disturbance (Dwernychuk and Boag 1972). Adult males are more susceptible to predation than are adult females (Braun 1995e). Because of the lekking habit, this has important effects on the loss of genetic diversity. A small number of males carry out virtually all breeding, thus any loss of males to predation (or hunting) significantly reduces genetic diversity in the population, thereby increasing extinction risk. Moreover, dominant males are more susceptible to predation during display than are other males (Ellis 1984). Sage grouse may thus be an exception to the finding by Lande (1988a, 1988b) that demographic effects are often more immediately critical in population viability than are genetic effects (see also Lande 1995 for a later examination of the import of genetic effects on extinction). Predator impacts are particularly important because most sage grouse now exist in small populations, isolated from other populations by fragmentation (Commons, et al. 1996a).

Many interacting threats will be joined at the nexus of predation. Reduction of forbs in nesting areas by cattle will not only reduce food for sage grouse chicks, but also expose the chicks and the incubating female to detection by predators (Webb 1993b; Gregg, et al. 1994; Delong, et al. 1995; Sveum, et al. 1998a, 1998b). Crawford and Delong (1993) and Delong, et al. (1995) found that artificial nests placed in areas with dense, tall residual grass cover experienced far less predation than nests in areas with less grass cover. Other studies have also showed the importance of forbs and grasses in providing concealment to nesting birds and their nests (Gregg 1992, Gregg, et al. 1994). Lack of adequate nesting and brooding cover account for high juvenile losses in many regions (Kindschy 1986). Predation is reduced when adequate grasses and forbs are present to conceal nests (Gregg, et al. 1994; DCCP 1998, p. 25), thus restriction of grazing reduces predation losses. Braun (1995e, p. 2) summarized it well: "management of herbaceous cover within sagebrush [areas] is the most effective method to reduce nest predation of sage grouse."

Studies that examine only effects on reduction of food sources from decreased forb cover will under-predict population effects. Low recruitment has been noted in sage grouse populations, and predation of juvenile sage grouse has been cited as a major factor in sage grouse population declines. Ground squirrels and badgers can destroy up to half of yearly nest and egg

production (DCCP 1998, p. 25). Grazing favors various ground squirrel species (Fagerstone and Ramey 1996; Sampson 1952). In one Colorado study, grazing severely altered the vegetation after a drought, and nest predation by Richardson's ground squirrels was the greatest cause of nest loss (Giesen 1995). A decline in preferred prey may also result in increased predation on sage grouse. Kindschy (1986) suggested that in southeastern Oregon, a decline in black-tailed jackrabbit (*Lepus californicus*) numbers may have caused predators to switch to sage grouse as their primary prey. In the Gunnison Basin, predation may be the primary cause of low recruitment on the remaining habitat in the area (GBCP 1997, p. 49).

Predators on adult and juvenile sage grouse include: fox, coyote (*Canis latrans*) (Kindschy 1986), bobcat (*Lynx rufus*) (Bailey 1981, Kindschy 1986), badger (*Taxidea taxus*) (Kindschy 1986), various falcons (Falconidae) including small kestrels (Pennycuick, et al. 1994; Schroeder, et al. 1999a, p. 10), and hawks, kites, and eagles (Accipitridae) (Beck 1975a, 1975b, Dunkle 1977, Kindschy 1986, Phillips and Beske 1990). Golden eagles are a common predator near powerlines, which they use as perches, and are an important predator of sage grouse in the Gunnison Basin (Crawford Area Conservation Plan, CACP 1998, p. 47). Raptors and other avian predators may exert their greatest effect when perches are available (Schneider and Braun 1991, Bevanger 1994, Braun 1998a). Young chicks need to eat frequently, and perched predators can easily disrupt foraging bouts for substantial periods of time. Chicks also lack thermoregulatory abilities during inclement weather conditions, which are frequent in the shrub-steppe. Perching predators can disrupt the ability of chicks to obtain shading, wind or precipitation shelter and brooding from the female. Land management agencies have failed to consider the important effects of structures and other perches on juvenile sage grouse and have instead only considered effects on lek activities. High voltage powerlines provide the highest perches and hence the greatest sight distances for avian predators. Wooden utility poles and many pine trees are somewhat shorter, so the 1 km distance to either side of a high voltage tower may be reduced for such perches. Next in height are juniper and pinyon pines, followed by road signs and fence posts. An estimate of the sight distances for perching raptors (and hence avoidance distances for sage grouse) can be obtained from simple trigonometric formulae for these shorter perches. The use of automatic cameras has revealed that many birds experience nest predation from what were formerly thought to be unlikely sources, and sage grouse are no exception. Nest cameras in Wyoming revealed egg predation by badgers and bull elk, as well as by magpies and more conventional sources (Holloran 1999, p. 110, 112). Cow elk were present at nests but did not predate them, suggesting that the nutritional stress of antler development (Robbins 1983) drove calcium specific nutritional hungers and hence egg predation (Holloran 1999, p. 112).

Coyote predation appears to be a concern for some sage grouse populations (GBCP 1997, p. 49); however, the actual amount of coyote predation on sage grouse may not be large: only 3% of coyote dietary components consists of "all birds,' while 70-90% of the dietary component consists of rabbits and rodents (US Fish and Wildlife Service 1997). It is unclear whether these data are based on stomach contents analysis. In a Wyoming study, coyotes were responsible for only 11% of 47 predated nests, while ground squirrels predated 42% of the nests, and badgers and magpies predated 36% and 11%, respectively (Patterson 1952c). A significant percentage of coyote diets consist of sage grouse nest predators such as ground squirrels, thus coyotes may function to reduce, rather than increase, sage grouse losses. One Wyoming Game and Fish biologist noted that coyotes are "not a particularly effective nest predator, and they "control numbers of red fox which are much more effective nest predators" (Christiansen 2000).

Crows and ravens (*Corvus spp.*) and magpies (*Pica spp*.) predate nests and juvenile birds

(Kindschy 1986) and are attracted by dump sites and livestock feeding operations (YTC CA 1994). Ravens have increased in both the Great Basin and the Basin and Range provinces (Boarman and Berry 1995). Coyotes, ground squirrels (*Spermophilus spp*.), weasels (*Mustela spp*.) and badgers are the most important mammalian nest predators (Johnsgard 1973, Drut 1994, p. 22). Among bird species, magpies and ravens commonly prey on sage grouse nests (Hulet, et al. 1986; Johnsgard 1983; Wallestad 1975a). Three separate studies show that ravens are more common near highways than in open areas, and are most numerous near powerlines (Boarman and Berry 1995). Yearlings sage grouse have higher nest predation rates than adults (Petersen 1980b). Ground squirrels and weasels can predate up to 50% of the yearly nest and egg production (GBCP 1997, p. 49). Near suburbs and ranchettes, domestic pets such as dogs can predate all age classes, while domestic cats can predate nests, chicks, and juvenile birds and disrupt adult activities.

The Oregon Dept. of Fish and Wildlife proposed that predation was the limiting factor on sage grouse populations. The Idaho Dept. of Fish and Game requested that the Wildlife Services unit of the Animal and Plant Health Inspection Service (APHIS) help them assess predation impacts on sage grouse. Wildlife "Services" is an administrative unit in the USDA that spends public funds to kill the public's wildlife to benefit domestic livestock and other interests. It was formerly called Animal Damage Control (ADC), but bureaucrats changed its name after a series of media exposés by major news outlets. Wildlife Services issued an Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) regarding its predator killing operations in Idaho (APHIS 1999). The document is replete with NEPA violations, and completely ignores the effects of livestock, powerlines and other factors in altering predator-prey balances. Without citation to any source, the EA claims that predation is sometimes "one of the most important limiting factors on sage grouse populations" and claims that because livestock were grazed decades ago when sage grouse populations were higher, grazing cannot be a factor causing reduction in sage grouse, and therefore, predation must be the cause of these declines. Besides the logical faux pas, this assertion completely ignores the cumulative impacts of grazing over the years, although the agency is required by law to consider such impacts. The agency actions were recently overturned in federal court.

Scientific studies have also been conducted on predation. Gregg (1992) found, as have others, that nest predation effects are highly dependent on the cover surrounding the nest. Similar finding were reviewed in Webb (1993b) and Drut (1994, p. 22). Similarly, misguided suggestions to restore sage grouse by employing predator control have been made (Collinge 1999, Drut 1994, p. 22). These suggestions ignore the effects of habitat structure on predation rates, besides the great cost required for predator control campaigns (Drut 1994, p. 22). Moreover, predator control will not improve hen or chick nutrition. Predator control has been generally ineffective in conserving avian populations in numerous species (King, et al. 1976; Cote and Sutherland 1997) and there is no reason to believe it will help conserve sage grouse. In fact, where predator control (approximately 100 coyotes killed per year) has been evaluated, "there was no difference in nest success between predator controlled[] and uncontrolled areas" (Holloran 1999, p. 15). This has not stopped various entities from blaming predators as a convenient and politically unprotected scapegoat for sage grouse declines. Recovery planning should focus on effective measures, such as habitat restoration.

Anthropogenic effects greatly exacerbate predation on sage grouse by [1] altering habitat to prevent concealment, [2] reducing forbs and thereby increasing foraging time and hence exposure to predators, [3] artificially enhancing predator populations by providing alternate food

sources such as road kill and garbage dumps, [4] providing perches for aerial predators, and [5] removing top carnivores such as wolves and coyotes, which allows the proliferation of meso-predators such as fox and ground squirrels. For example, ravens and raptors are more abundant along roads and powerlines (Knight and Kawashima 1993). Agricultural development creates artificially high concentrations of eagles and other predators that are attracted to calving operations (Schmidt 1998). This probably adds considerably to sage grouse mortality in winter and perhaps spring (Schmidt 1998). Schmidt felt such artificially elevated eagle predation to be the largest single winter mortality factor in southwest Montana. Agricultural developments, such as winter calving operations, also attract other predators. Schmidt (1998) found an "abnormally large fox population" in agriculturally dominated riparian bottoms. The situation in Strawberry Valley, Utah shows that indirect effects can be very important. Construction of a reservoir at Strawberry Valley and fish stocking provided an alternate food source for red fox, a non-native predator. The fox also prey on nesting sage grouse and have caused "almost complete reproductive failure" of sage grouse (Bambrough, et al. 2000a). The fox also feed on road kill (caused by the construction of roads to the reservoir and high use by recreationists), and on trash and fish entrails discarded by fishermen. Coyotes, a natural predator of fox, have been removed to favor sheep growers and other livestock interests. Artificial sources of food, such as livestock feeding operations, landfills, and garbage dumps have greatly increased the number of predators, as have various landscape changes allowing predators greater access to interior habitat (Andelt and Knowlton 1987, Toweill and Anthony 1988, Stiehl and Trautwein 1991b). A concise illustration of ways human activities have concentrated and increased predator numbers, and altered habitat to reduce grouse defenses and enhance predator effectiveness is presented by Bergerud (1988c).

Some predators of sage grouse may be protected by one or more wildlife laws, such as the Migratory Bird Treaty Act (MBTA), 16 U.S.C. § 703 - § 711 (ravens, magpies, eagles) or the Eagle Protection Act, 16 U.S.C. § 668(a) as well as the ESA. These statutes should present no significant management problems, however, because predation is easily manipulated through habitat alteration. Nest monitoring by automated cameras have generated a number of anecdotal and informal reports of ungulates eating sage grouse eggs. In many areas, ungulate populations are abnormally high due to lack of wolves and management for big-game hunting. The extent of this factor is unknown and systematic studies have not yet been completed.

Predators are a convenient scapegoat for entities wishing to deflect attention away from the real causes of sage grouse decline. Sage grouse coexisted with predators for millennia, and predators did not significantly reduce sage grouse populations until severe anthropogenic habitat alteration occurred post-settlement. The most important factors affecting predation rates, and hence population size and persistence are habitat quality and habitat quantity, particularly cover (Braun 1998a; SMBCP 1998, p. 24). Instead of blaming predators, attention should be directed to habitat degradation that allows predators to more easily locate and capture sage grouse and their eggs and chicks. This habitat degradation is the result of grazing and livestock operations. Besides its high cost (Schroeder and Baydack 2001) predator control, especially by poisoning, has widespread impacts on protected predator species and on domestic pets. Calls for widespread poisoning of predators (e.g. Collinge 1999) are misguided and predator control should be restricted to only the most imminently endangered populations (Schroeder and Baydack 2001), if it is used at all. Proactive management for sage grouse will obviate any needs for predator control.

Competition

Sage grouse probably do not compete much with other birds. The most sympatric related species, Columbian Sharp-tailed Grouse (*Tympanuchus phasianellas columbianus*) no longer overlaps much with sage grouse as the range of sharptails has been reduced by 90% (Klott and Lindzey 1990). Moreover, the two species select different habitats within their ranges (Klott and Lindzey 1990).

A greater danger from competition may arise when alien exotics, such as pheasants or quail, are introduced into sage grouse habitat. Pheasants are known egg-dumpers, and such laying of their eggs in sage grouse nests will reduce sage grouse hatching rates even if the sage grouse hen does not abandon the entire nest. Competition for food is most likely in wet meadows and riparian areas where sage grouse and pheasant habitat preferences overlap. Unfortunately, such areas are critical for sage grouse especially in drought years.

* * *

The greatest competition with sage grouse for food plants such as shrubs and forbs, comes from livestock grazing. Grazing also reduces insect forage for sage grouse by removing insect habitat and insect food plants. Livestock also trample cover, trample nests, and create microsites which favor the invasion of alien exotic weeds. Because these latter effects do not increase livestock populations, they are properly considered disturbance (0, - interactions) rather than competition (-,-). Livestock effects on sage grouse are discussed in more detail elsewhere in this review.

Noise, Acoustic Interference, and Disturbance

Noise can interfere with sage grouse mating displays (Morton 1975), reduce their ability to detect predators, and cause the birds to move away from the noise source (Witkin 1977, Wiley and Richards 1978, Richards and Wiley 1980). During lekking, male mating success is strongly related to two different acoustical components of display (Gibson 1996a, 1996b; Gibson and Bradbury 1985), thus noise can have profound effects on population viability. Contact enhancement between the hen and newly hatched chicks is mediated by acoustical signals (Girard 1937, Patterson 1952c). Therefore, noise effects will be particularly important during the brooding period.

Noise and other disturbances are known to cause physiological stress in wildlife (Geist 1978) but the effects may not appear for days, weeks or months after the disturbance event (Gutzwiller 1991). Such stresses exacerbate the effects of disease and competition (Gutzwiller 1991), and stress, particularly if prolonged, can cause decreases in lifespan or in reproductive output (Geist 1978). Disease susceptibility is apparently mediated by immunosuppression, acting either via glucocorticosteroid levels and adrenal activity or via cortisol mediated pathways (Van Mourik, et al. 1985). Wildlife exposed to disturbance are known to experience reduced weight gain (a particular problem for overwintering sage grouse exposed to snowmobiles), higher mortality, and reduced productivity (Titus and van Druff 1981, Gutzwiller 1991), as well as nesting failures (Boeker and Ray 1971), reduced nesting success (Wiley 1975, White and Thurow 1985), displacement, and alterations in wintering distribution, summer home ranges, activity areas, and behavior (Stalmaster and Newman 1978; Andersen, et al. 1990; Fyfe 1969; Enderson and Craig 1974; Portnoy 1974; Swenson 1975; Zarn 1974; Dunstan 1968).

There are numerous noise and disturbance sources affecting sage grouse. Traffic on roadways, off-road vehicle (ORV) and snowmobile use, oil and gas wells, and concentrations of livestock can all interfere with acoustic signals by sage grouse (GBCP 1997, p. 22; White and Thurow 1985). These activities are also likely to disturb the birds in a more active behavioral

sense – birds will flush, become nervous, or abandon areas where these activities occur if they can hear or see the activities. Mining activities completely eliminated all sign of raptors from an area (Anderson undated). Numerous studies of various birds species show that recreational activity and the presence of humans reduces nest success (Anderson undated).

ORVs present particular problems with respect to disturbance. Supervision and enforcement of snowmobile use is virtually impossible if the area is large (Malaher 1967). The same is true of other ORVs – operators can simply drive around any closure notices or barriers because there is no forest cover to constrain the routes taken. Often abuses involve several snowmobiles and even aircraft, all in communication by two-way radio (Malaher 1967). Military operations can also severely disturb wildlife. Gunfire, even from 0.22 caliber weapons affect wildlife (White and Thurow 1985). Roads also cause noise effects from passing traffic that can disrupt lek activities, inhibiting mating. Braun (1998a) estimated that noise effects would be disruptive as far away as 1 km from a road.

Frequency effects are likely important for sage grouse. Schroeder, et al. (1999a, p. 6) present sonogram plots for both species, showing that significant acoustical output is present from nearly 0 to 8 kHz (the upper frequency limit for most son graph equipment). Other sonograms are found in Gibson, et al. (1991). Thus, acoustical interference can obscure behavioral signals at a wide range of frequencies. Data comparing the frequency spectra of noise sources to the detection ability of sage grouse at each frequency are lacking. The transmission of different sound frequencies through forest habitats types has been determined (Wiley and Richards 1978, Richards and Wiley 1980), but the attenuation of noise spectra over sagebrush areas has not been determined. However, it is highly likely that all frequencies of noise will travel much greater distances from the source over sagebrush than through forested areas, because sagebrush areas have no height of leaves and branches to attenuate noise spectra.

Very low frequency (infrasonic) sound is easily detectable by at least some species of birds (Kreithen and Quine 1979, Dooling 1982) and forms a component of sage grouse mating displays (Schroeder, et al. 1999a). Low frequency sounds also propagate for great distances (Marten and Marler 1977, Morton 1975, Witkin 1977, Wiley and Richards 1978). Thus, such sources as artillery fire, seismic exploration explosions, mining, and drilling may be particularly disturbing to the birds. High frequency noises may disturb contact enhancement or warning signal functions between females and their broods or among juveniles. These calls are described as having a high frequency sound ("see-ah") by numerous authors (Girard 1937; Batterson and Morse 1948; Schroeder, et al. 1999a). Typically, high frequency sounds follow line of sight paths, or nearly so, and can easily be reflected from environmental substrates.

There appear to have been few quantitative studies of the effects of noise conducted on sage grouse. Thus, the best available scientific data are in the GBCP (1997, e.g. p. 22) and are obtained by analogy to other species. Most studies of noise effects on birds appear to have been conducted on raptors and the results of such studies have been variable. Studies on raptors and other predators may not be particularly relevant to prey species such as sage grouse. Prey must remain alert to predators, and are likely to have behavioral responses to abrupt sensory stimuli (startle responses) that disrupt feeding, courtship, or other important behaviors. Studies of other avian prey species appear to have centered on geese. There are no data on noise propagation, or on signal detection showing differences in the habitats between geese and sage grouse. Such studies appear to be appropriate guides to effects of noise on sage grouse because, like sage grouse, geese occupy open habitats, nest and forage on the ground (although the water and land mix is quite different), and face threats from both aerial and ground based predators.

Disturbance increases movements and avoidance behavior in wildlife (Bleich, et al. 1990, 1994; Côté 1996). Wildlife exposed to ORVs alter feeding and activity behaviors, stay in cover more often, and flee more easily from disturbances (Yarmoloy, et al. 1988). In various wildlife species, disturbance can also cause social disruption, including disruption of broods and consequent increases in brood mortality (Bartelt 1987, Côté 1996). Wildlife do not habituate to disturbances such as humans on foot, or low level helicopter or fixed-wing aircraft flights (Bunch and Workman 1993), and such disturbances are known to disrupt important breeding, feeding, and social behaviors in a variety of wildlife (Dwyer and Tanner 1992). Other prey species, such as geese, respond adversely to people, boats, hunting activities, aircraft (Owens 1977, Kramer, et al. 1979), loud noises (Owens 1977), and automobile traffic (Madsen 1985) with aircraft causing particular disturbance (Miller 1994). Geese can be driven away from preferred areas when aircraft approach, and aircraft disturbance can cause significant weight loss (Miller 1994). Wildlife react to helicopter noise at levels as low as 60 db, A weighted, and show strong reactions at 77 dbA (Luz and Smith 1976). Helicopter disturbance is known to have serious effects on brant (Derksen, et al. 1992). Construction of airfields to service oil well and other energy extraction developments has been a long-standing disturbance factor affecting sage grouse (Patterson 1952c, p. 281). Large swaths of sagebrush are often destroyed during construction and operation of such airfields (Patterson 1952c, p. 281). Future energy developments in sage grouse habitat, such as the plans for coal bed methane developments, will entail additional airfields and other infrastructure, greatly harming sage grouse. Sage grouse crouch or "squat down" when initially approached by aircraft (Russi 1998), and "almost invariably" flee an area when small airplanes fly overhead (Wong 2000, citing Robert Gibson). Because sage grouse rely on cryptic coloration and inactivity to evade predators, forced movements from disturbance are likely to greatly increase predation rates, and hence reduce population persistence (Wong 2000).

Breeding male passerines, particularly older experienced males, avoid roads: densities of breeding males within 200 m of a highway can be 40% less than densities of comparable habitat further away (Reijnen and Foppen 1994). For all sex and age classes, 7 of 12 studied grassland bird species showed reduced densities near roads, and density reductions occurred as far away as 1.7 km from highways (Reijnen, et al. 1996). Density reductions were correlated with noise effects, not visual effects (Reijnen, et al. 1995).

Even low noise levels can obscure important signals that sage grouse attempt to detect – for example, the wind whistling through a raptor's wings as it stoops to dive is one such signal that sage grouse need to detect quickly and accurately. Besides any effects caused while the noise source is operating, noise exposure can reduce the capability to detect acoustic signals (partial deafness) for an extensive period after the exposure or permanently (Dr. Howard Wilshire, quoted in ABC News 1999). There is an extensive human literature on such effects, which are likely to affect both mating activities and predator detection. Such effects are likely to be particularly strong in sage grouse because of the high importance of acoustic signals in their mating displays, and because they are highly susceptible to predation.

Finally, little is known about visual disturbances as distinct from acoustic ones. However, it is likely that a visual disturbance will be accompanied by noise and the disturbance effects from the combined stimuli will be enhanced. Sage grouse are more disturbed by the presence of fixed wing aircraft than by helicopters (M. Morse 1980). This has been noted for other birds and probably results from the visual resemblance of fixed wing aircraft to raptors.

The types of disturbance to lekking sage grouse have received some study. In a study in

California, most disturbances were human caused (on foot, in vehicles, and human associated livestock and pets), totaling 29 of 82 incidents. (Hall and Haney 1997, p. 10). Other major disturbances were caused by pronghorn (*Antilocapra americana*, popularly termed "antelope" or "goats") which accounted for 18 of 82 incidents and Golden Eagles (25/82) and other raptors (5/82) (Hall and Haney 1997, p. 10). The raptor disturbance was greatly increased by human caused effects – powerlines had been strung through the area, increasing the number of perch sites for raptors (Hall and Haney 1997, p. 25). Likewise, human built roads in the area probably increased the disturbance by coyotes (7/82) and ravens (1/82) (Hall and Haney 1997, p. 26).

An important concern is that there appear to be synergistic interactions among disturbance sources. Visual stimuli often potentiate the effects of auditory disturbances (Taylor, et al. 1962). Thus, effects from two different disturbances are greater than if they were merely additive.

Fire

Direct fire-related mortality of sage grouse has not been documented in the literature; however, fire has strong and complex effects on sage grouse habitat. Jorgensen (1990) assembled a literature review of fire effects in sagebrush habitats, as has the USFS (Howard 1996). Prior to settlement, wildfire was the major disturbance agent in shrub-steppe habitats (CH2M-Hill 1996), but fire return intervals may have been fairly lengthy in many or most sagebrush habitats (Winward 1985, Braun 1987a), matching those in Ponderosa Pine forests (Gruell 1985, p. 103). Most species of sagebrush are killed by fire (Winward 1985; Peterson 1995; Wright, et al. 1979). Big sagebrush does not resprout after a fire and is highly susceptible to fire injury (Wright, et al. 1979, p. 7). However, early explorers found sagebrush to be both widespread and abundant in the west (Townsend 1839; Fremont 1845; Thwaites 1959; Tisdale, et al. 1969; Gambel 1974a, 1974b, 1974c; Vale 1975; Evans 1997). These vast sage lands could not have existed if stand replacement fires had been frequent. Tisdale and Hironaka (1981) suggested that fires were uncommon in the drier sagebrush types, and more frequent in areas with higher fuel loads. Within the entire interior Columbia Basin, Barrett, et al. (1997, p. 15) estimate that only 4% of the area burned annually in pre-settlement times. This is an average over all elevations of sagebrush-grass associations, and the burn rate for many sagebrush areas would have been lower. The entire sagebrush landscape cannot be treated as homogenous; instead, fire histories undoubtedly vary with elevation and with species and sub-species sagebrush composition (R. Rosentretter, personal communication), and so will the effects of fire. Together with overgrazing, fires caused by settlers are implicated in the reduction of sagebrush and of native grass and forb understories (Tisdale and Hironaka 1981). In the last several decades, probably most fires have been deliberately set to increase forage for livestock (Bunting, et al. 1987).

Depending on habitat quality before the fire and the type of fire, fire can be beneficial or harmful to sage grouse, but most fires are likely harmful. Sage grouse use sagebrush of different age classes and stand structures as lekking, nesting, brooding, and wintering grounds. Neither expansive dense sagebrush nor expansive open areas constitute optimal sage grouse habitat: Klebenow (1972) reported that in three summers of sampling, no sage grouse were observed in large acreage, dense sagebrush in southern Idaho. Besides its effects on food supplies and cover, fire interferes with movement patterns: Fischer, et al. (1997, p. 89) found that burned areas significantly altered migration. Nelle (1998) studied 20 previously burned areas in the Snake River Plains, a low elevation area in southern Idaho. Burning had long-term harmful effects on sage grouse habitat and after 14 years, sagebrush areas failed to return to pre-burn conditions (Nelle 1998, p. iii). Habitat requires many years to recover from fire – more than 20 years for

nesting habitat in Idaho (Nelle, et al. 2000) – over 32 years for habitat in Montana (Wambolt, et al. 2001).

Fire that creates a mosaic of sagebrush of different ages and structures should often benefit sage grouse (Klebenow 1972). Newly burned areas interspersed with patches of sagebrush offer increased forb production while providing nesting and brooding cover (Blaisdell 1953b; Mangan and Autenrieth 1986; R. C. Martin 1990). The younger age classes of sagebrush that establish after fire offer more nutritious and palatable browse than do old sagebrush stands (Gates and Eng 1984). Additionally, burns can provide new lekking sites: sage grouse have established leks on burns in areas where open cover was lacking before fire. Sage grouse show lek and fidelity (Connelly, et al. 1994a, p. 73), and may not use burns as lekking grounds if a sufficient number of old leks are present (Benson, et al. 1991). Moreover, fire may not benefit sage grouse in drier areas: Connelly, et al. (1994a) found that forbs did not increase, and insect populations declined, after a controlled burn in xeric sagebrush habitat. Many forbs are damaged by fire (Wright, et al. 1979, p. 7). Rabbitbrush (*Chrysothamnus spp*.) is usually enhanced by fire (Wright, et al. 1979, p. 72) and this could lead to it outcompeting sagebrush seedlings as they attempt to recolonize burned areas. Braun (1987a) notes that fire is unlikely to have been a predominant ecological force in xeric areas due to the lack of fine fuels.

Fire always removes a certain amount of sage grouse food and cover. Fire initially reduces insect populations (Bock and Bock 1991, Fischer 1994) which are required by young chicks (Johnson and Boyce 1990). Griner (1939) noted that burning resulted in a decline in sage grouse in Utah. If the burn is small in relationship to the surrounding area, it will probably enhance sage grouse habitat. Fire that destroys large tracts of sagebrush, or destroys key winter habitat, can be harmful (Klebenow 1969, 1972). However, large-acreage fires do not always harm sage grouse. A 17,250-acre (6,900-ha) wildfire in mountain big sagebrush in southern Idaho burned in a mosaic pattern, leaving many unburned islands. The wildfire occurred at an ebb in the sage grouse population, so nesting sites were not limiting in the first postfire nesting season. Overall effect of the wildfire on the sage grouse population was apparently neutral: the sage grouse population increased after the fire, but this was part of a regional trend of sage grouse increase following several years of low reproduction. Martin (1990) suggested that had nesting habitat been limiting, the large-acreage fire probably would have adversely affected the sage grouse population. Pseudo-replication experiments showed that fire caused a loss of leks, and a decline in attendance of individuals at leks (Connelly, et al. 2000c, p. 93).

However, suppression of natural fires along with cattle grazing allows invasion of pinyon pine (*Pinus spp.*) and juniper (*Juniperus spp.*) into sagebrush areas (Miller and Wigand 1994; Miller and Rose 1995; Belsky 1996; Davenport, et al. 1998). Raptors and corvids use the trees as perches, and expansion of pinyon and juniper into sage grouse habitat reduces the use of these areas by sage grouse, because of increased predation (Commons, et al. 1999). By the 1980's, juniper and pinyon had spread across approximately 125,482 square miles in semi-arid regions of the western United States (Herbel 1984).

Some sagebrush species (*A. cana*, *A. filifolia*) can resprout after burning, suggesting that they evolved with fire (Braun 1998a). Big sagebrush (*A. tridentata*) is killed after burning and cannot resprout (Wright, et al. 1979), suggesting that it did not evolve with fire (Braun 1998a). Fire return intervals also differ among sagebrush species and sub-species. Natural fire return intervals are reported to be 12 to 25 years in mountain big sagebrush (*A. tridentata ssp. vaseyana*) communities, but range from 50 to 100 years in more arid sagebrush community types (Miller and Eddleman 2000, p. 17). Today, fires burn much more frequently. Moreover, even

areas previously thought to be "fire tolerant" have lost sage grouse habitat from fires (D. Pulliam 1999).

Cheatgrass and other non-palatable species can invade after a fire (Pickford 1932, Stewart and Hull 1949). Once present, cheatgrass alters fire regimes to the point that many sagebrush stands are eradicated (GBCP 1997, p. 41). In the Snake River birds of prey National Conservation Area, continued cattle grazing has exacerbated cheatgrass invasion. Consequently, over 54% of the shrublands in this area have been destroyed (USGS 1999). Once cheatgrass is established, it is extremely difficult to remove and can prevent sagebrush from recolonizing an area – the endpoint of community succession has been altered (see Invasive Species section). Land managers are partly to blame for habitat conversion: after a burn areas are often seeded to crested wheatgrass instead of native vegetation, and are thus eliminated as sage grouse habitat (Wallestad 1971, Martin 1976, Braun, et al. 1977). Fire also increases soil erosion because the ground cover is removed (Blaisdell, et al. 1982, p. 19). In southern Idaho, 20% to 40% of the sage grouse habitat has been lost in just "the last 5 years due to range fires" (Healy 2001, quoting Saether-Blair). In the last 3 years, over 500,000 acres have burned in southern Idaho (Healy 2001 quoting Pellant).

Destruction of habitat by fire is increased by other anthropogenic threats for two reasons. First, fire ignitions are much more likely when humans and their developments are present in sage grouse habitats. Roads, off-road vehicle (ORV) use, oil and gas or coal developments, suburbanization, unattended campfires, agricultural operations, and other human activities can greatly increase fire risk. Fires in forests or woodlands can also spread into sagebrush areas. Second, human caused fragmentation of shrublands greatly increases cheatgrass invasion as does cattle grazing. Large, unfragmented shrubland patches are significantly less likely to be destroyed by fire than are fragmented areas (Knick and Rotenberry 2000, p. 226). Rotenberry (1998) noted that fire (often mediated by invasive species) was primarily responsible for the loss of all pristine native shrubland, whether fragmented or not (Young and Evans 1978; E. B. Allen 1988).

Individuals hired as "fire ecologists" by BLM and other land management agencies often have a psychological "love of the drip torch." Agencies will need to foster a modern and prudent ecological attitude towards the use of fire, if sage grouse and other sagebrush obligates are to be saved. The "yearn to burn" will need to be justified with hard data and rigorous analyses (quoted remarks are from a BLM biologist who wishes to remain anonymous). Moreover, fire control in sagebrush areas must be adequately funded. Idaho BLM biologist Signe Saether-Blair stated that resources were being allocated to fight forest fires, while ignoring sagebrush areas, and Idaho state Fish and Game biologist Jack Connelly stated that fire was "annihilating sage grouse habitat" (Salt Lake Tribune, Aug. 18, 2000).

Nearly all lands on which sage grouse currently occur are subject to a mandate to reintroduce fire – the Federal Wildland Fire Management Policy and Program Review (USDI and USDA 1995) requires burning consistent with land management plans. These plans and this policy may need to be recalibrated to ensure sage grouse viability. Moreover, sagebrush is not always included in reseeding mixtures following burns and crested wheatgrass, which has no value for sage grouse, is "often planted in lieu of native species" (Nevada State Office, BLM 2000a, p. 7). The National Fire Plan, which covers both USFS and BLM lands, could be catastrophic for remaining sage grouse populations unless prescribed burns are carefully considered and controlled.

Maps of recent fires in sage grouse range are available from the National Interagency Fire

Center (NIFC) at http://www.fs.fed.us/eng/rsac/fire_maps.html. The maps are based on remote sensing spectroradiometric data, and fire pixels are geolocated to an accuracy of 500 meters. The satellites carrying these instruments were launched in 1999, so historic data are not available. However, various land management agencies no doubt have fire data and maps that could be georeferenced to more carefully examine habitat loss. Some states have also compiled maps showing the locations of recent fires. Nevada has prepared a map showing the large fires that have burned large amounts of sage grouse habitat in 1999 and 2000. In just the year 2000, 2% of the entire state burned. The fraction of sage grouse habitat that burned is likely much greater; moreover, fires have burned large holes in sage grouse habitat areas turning them into doughnut shaped fragments with large amounts of edge and reduced landscape integrity. Such fire induced fragmentation is shown in maps of sage grouse habitat and recent fires in Nevada.

Temporal Fire Regimes

Fire regimes can be roughly divided into three temporal periods. The earliest period would be wholly natural and occurs before aboriginal human populations reached North America. During this longest period, fires were most likely influenced by warming and drying continental interior climates characteristic of the post-Pleistocene. The middle period includes the time of Native Americans and may begin 15,000 to perhaps 50,000 years ago. Fire was probably somewhat more common during this period because of anthropogenic origin; however, fires may have been less intense because increased fire frequency reduced fuel loads. Sage grouse are known to have been extremely abundant at the close of the middle period, so Native American land management practices and hunting cannot have had especially severe negative effects on these populations. Nonetheless, Native American fire practices were apparently a potent ecological force (Miller, et al. 1993) and may have benefited sage grouse by creating mosaics of forbs and grasses, and reducing canopy closure of sagebrush. Miller, et al. (1993) review some of the relevant studies for this period. Fire intervals are poorly known but probably did not exceed 30 to 50 years in most areas (Bunting, et al. 1987, Bunting 1994). In southern Idaho, fire return intervals are thought to have been 20 to 25 years in wetter regions, and 60 to 110 years in arid shrub-steppe (Tisdale and Hironaka 1981). Fires were probably patchy and small in extent except in very dry years. In Nevada, fires may not have been important in determining vegetation type (Paige and Ritter 1999, p. 6 citing McQueen).

A third fire regime begins with the introduction of livestock and the white settlement of the west, which introduced profound changes to the sagebrush shrub-steppe (Miller, et al. 1993). Areas of brush have been burned by prescribed fires, and accidental fires are more common as sparks from vehicles, commercial, industrial, and home cooking and heating uses escape control. At the same time, other areas have undergone fire suppression due to removal of fire fuels by livestock grazing, and have been invaded by conifer species. It is in this latter period that severe declines in sage grouse populations have occurred.

Overlaid across all three periods is some degree of climate change, including global warming in the last few decades, perhaps some effect of the Little Ice Age in the west a few centuries ago, and episodic drought. Climatic events from the early Holocene or late Pleistocene may exert effects on present day western landscapes.

Burning of grasslands at the sagebrush-pinyon-juniper interface probably prevented the spread of conifers into sagebrush areas (Bunting 1994, Evans and Workman 1994). Fire would not have burned uniformly and large areas went unburned for decades (Winward 1984, Braun 1987a). Of particular importance is that natural fires in the past did not operate the same way as

fires do at present. Today, fires burn much larger areas, and burned areas often have large numbers of confined livestock grazing soon after the fire passes (GBCP 1997, p. 42). Another factor today is that cheatgrass invasions have likely altered fire return times for many areas. Finally, fire suppression has allowed invasion by western juniper (*Juniperus occidentalis*) and increased canopy cover by sagebrush (Kauffman 1990a, 1990b). These vegetative changes have reduced grass and forb cover, an essential habitat component for sage grouse (Winward 1991a).

Today, fires occur much more frequently than previously, tend to occur most commonly during spring and fall (rather than mid-summer), and individual fires are vastly larger than was previously the case (West 2000, Fig. 2).

Use of Fire

Howard (1996) called for a diversity of sagebrush habitat, in terms of sage grouse food and cover, as a management objective. Klebenow (1972) recommends burning sagebrush on a rotational basis to create sage grouse habitat. Different patches should be burned each year or every few years, with as long as 20 years between burning each patch. Benson, et al. (1991) recommend burning in patches of less than 100 acres in size. Because livestock may concentrate in small burns, livestock should be excluded from the burns. Fire sometimes enhances forb production (Cook, et al. 1994) and sage grouse may respond to this by foraging in burned areas (Pyle and Crawford 1996). However, sage grouse avoid large burned areas without remnant sagebrush (Benson, et al. 1991) and increases in forb production are not always obtained (Pyle 1993).

No general, overall benefits of fire to sage grouse have been documented, and some disagreement exists among the sage grouse experts in various state wildlife agencies and universities as to the benefits of fire to sage grouse. This may well result from elevational and other edaphic differences in sage grouse habitat in the respective states, and the degree and imminence of threats from cheatgrass invasion. This disagreement needs to be resolved so that management plans for use or containment of fire to improve habitat and recover sage grouse can be developed. A large body of fire effects data has been developed for forests and some of those general concepts may be applicable to sagebrush shrub-steppe. It is safe to say that fire must be used in a very careful and well monitored fashion if it is to be encouraged at all (Benson, et al. 1991; Fischer, et al. 1997; Connelly and Braun 1997; Connelly, et al. 1998a). Gains expected in multi-aged vegetative mosaics must be balanced with both potential loss of sagebrush *per se* and the risk of cheatgrass invasion. The total area burned by both wild fire and prescribed fire at 10 year intervals is unknown, but appears to be increasing (Connelly and Braun 1997).

Controlled or prescribed burns are dangerous because they often escape controls and become uncontrolled. However, BLM does not maintain statistics on how many prescribed fires burn out of control. Prediction of fire spread and intensity is particularly difficult in sagebrush areas because the fuels are discontinuous and not uniform (J. K. Brown 1982, p. 1). BLM formerly used green stripping (interruption of native or other flammable vegetation with non-flammable vegetation to form fire breaks) to reduce fire spread. However, the alien species used and the reduction and fragmentation of habitat militates against continued use of green stripping. BLM employees have stated that the use of green stripping has been suspended (Rotenberry 1998, p. 267, quoting Singe Sather-Blair).

Use of fire should be disfavored in the entire historic range of sage grouse until additional research establishes that it is both a safe and an effective management tool. This is particularly true for low elevation areas, where cheatgrass invasion appears most dangerous. However,

absolute prohibitions against fire may slow recovery of forbs, which appear to be severely limiting on sage grouse populations. Forb restoration depends most strongly on elimination of grazing. However, prescribed burns in small mosaics has been suggested to accelerate forb recovery (Wirth 2000). Such burns will only be effective if an "adequate pre-burn forb community" already exists in the area to be burned (Wirth 2000). Greenhouse experiments failed to support the hypothesis of accelerated forb recovery from fire (Wirth and Pyke 1999).

If there is a single area of management actions that requires the combined consultation of state and federal wildlife biologists, academic and independent specialists, and plant ecologists, it is the use of fire in sage grouse habitat. This might be accomplished without a listing, but is much more likely if a listing were made.

Fire on Leks and Nesting Grounds

Fire that occurs outside the mating season will probably not affect postfire sage grouse use of the grounds for mating. Fall wildfires on sage grouse leks in southern Idaho had no effect on sage grouse use of the leks the next breeding season (Martin 1990). Areas immediately surrounding leks, however, are heavily used as nesting grounds, and fire in areas surrounding leks may have a negative impact on consequent use of the surrounding areas by hens. Wallestad and Pyrah (1974) recommend that sagebrush within 1.9 miles (3.2 km) of a lek not be burned in order to protect nesting habitat. This recommendation may be most applicable to areas where nesting habitat is limited, however. Also, it is now established that nesting often takes place at substantially greater distances from the lek than was believed in 1974, at the time of the Wallestad and Pyrah study (Autenrieth 1981; Wakkinen 1990; Hanf, et al. 1994; Schroeder, et al. 1999a, p. 17). There will often be a lag effect of behavioral responses to habitat manipulation for species such as sage grouse that exhibit site fidelity (Wiens 1985a). This can complicate analysis of the effects of fire. However, sage grouse selected unburned areas within a large burn for nesting, indicating that fire removed nesting cover for sage grouse (Connelly, et al. 1994a).

Gates and Eng (1984) noted that on their southern Idaho study site, which was surrounded by 120 square miles (300 km^2) of Wyoming big sagebrush, nesting habitat was plentiful. While their summer-fall prescribed fires did burn near several established leks, the fires also created an open area that sage grouse used as a lekking ground the next spring. The fire treatment apparently did not deter hens from using grounds adjacent to the burns for nesting and brooding. Most radio-collared sage grouse hens nested within 3 miles (5 km) of the lek on which they were captured the year before fire treatment. In the first summer postfire, 5 of 11 collared hens moved their brood into agricultural areas adjacent to the burn. Broods apparently made little use of the burns as foraging areas. Schlatterer (1960) and Dalke, et al. (1963) noted that following unintentional fire, sage grouse used small burned openings as leks. To create openings in homogeneous sagebrush, Klebenow (1972) recommended small fires, 1 to 10 acres (0.4-4 ha) in size.

The USFS does not recommend spring fire on sage grouse nesting grounds (Howard 1996, Autenrieth, et al. 1982; Mangan and Autenrieth 1985). USFS does not recommend the use of fire on the nesting grounds in any season if nesting habitat is limited (Howard 1996; Autenrieth, et al. 1982).

Brooding Areas

Fall spot fires burning several patches of a few acres can result in suitable brood rearing areas by increasing forb availability. Spot burns along edges of meadows where sagebrush is

encroaching may also enhance brood rearing areas if adequate sagebrush-meadow ecotone is left to provide cover (Howard 1996, Autenrieth, et al. 1982). Martin (1990) noted that in southern Idaho, broods neither preferred nor avoided large burned areas ($P<0.05$). Fire in brooding areas is known to reduce food supplies for chicks (Fischer, et al. 1996a)

Wintering Areas

Klebenow (1972) does not recommend burning in winter habitat. Autenrieth, et al. (1982) recommend that fire in winter-use areas be applied cautiously: what may appear as an excess of sagebrush in summer may provide only minimal amounts of sagebrush in winter. They recommend that prior to burning, winter sage grouse distribution during peak snow conditions should be assessed so that key wintering grounds are not depleted by fire. Fire directly reduces the amount of winter habitat for sage grouse (Robertson 1991, Fischer 1994). Because wintering birds feed solely on sagebrush leaves, and require sagebrush for shelter, there is no benefit to burning in winter habitat. Burning in wintering areas should be prohibited.

Roads

Besides the obvious collision induced mortality of sage grouse, roads eliminate habitat directly because the road surface itself and the band of altered vegetation on both sides of the road and its drainage structures do not support the needed habitat characteristics for sage grouse. Roads also induce noise effects from passing traffic that can disrupt lek activities, inhibiting mating. Braun (1998a) estimated that noise effects would be disruptive as far away 1 km from a road. Additionally, raptors may use road signs and utility poles along roads as perches (Bevanger 1994). Roads also restrict movements of sage grouse and remove culturally transmitted knowledge of traditional movements from the population (SMBCP 1998, p. 22; Cultural Inheritance section of this review). Roads are particularly pernicious in their fragmenting effects on populations because they constitute linear isolating elements in the landscape – there may be no way to transit a landscape without crossing a road. Many of the effects of roads are also present for railroad lines. Roads are typically built along drainages (Miller and Eddleman 2000, p. 23) and thus differentially affect riparian areas, which are critical habitat for sage grouse.

Biologists have been concerned about the effects of roads on sage grouse since the early part of the last century. Howell (1917) feared that roads would cause local extinctions of sage grouse populations. Horsfall (1932) was particularly concerned about the rate of extirpation caused, in part, by roads. Traffic on roads, particularly paved roads or graveled through routes, causes direct sage grouse mortality by mechanical impact, or can disrupt energy budgets and behavioral activities when they must evade speeding traffic. "Large numbers of sage grouse are killed annually by vehicular traffic" (Patterson 1952c, p. 280). If the numbers of sage grouse killed by traffic collisions are fewer today than in Patterson's time that merely reflects the fact that there are far fewer sage grouse to be killed today. Vehicular speed is the primary factor in wildlife-vehicle collisions (Gunther, et al. 1998). Bean (1941) counted 11 sage grouse killed by automobiles in a small area and this mortality factor has surely increased with time and higher traffic speeds (Hays, et al. 1998 citing Schroeder, personal communication). Martin (1942) found 22 sage grouse killed in just 115 miles of travel – multiplied by the tens of thousands of miles of highways in the range, this is a very large "kill zone" for the bird. Sage grouse often prefer to walk to reach useable habitats except when snow cover increases their conspicuousness (GBCP 1997, p. 48, SMBCP 1998, p. 22). This form of locomotion greatly increases their danger from traffic. Sage grouse are highly susceptible to roadways which fragment populations (Patterson 1952c, Aldridge 1998a, 1998b). In studies conducted in the Gunnison and San Miguel Basins of

Colorado, all primary and many secondary roads reduce the size of sage grouse populations (GBCP 1997, p. 47, SMBCP 1998, p. 22). Roads are known to reduce the reproductive success of many bird species. Distance from a road is correlated with nest success in sage grouse – unsuccessful hens nested an average of only 268m from a road, while successful hens nested an average of over 1 km from a road (Lyon 2000, p. 56).

Sage grouse use roads to dust bathe which makes them particularly susceptible to vehicular collisions (Bean 1941). Sage grouse will also dust bathe along the margins of paved roads, so it is not only dirt or gravel roads that pose a hazard. It is unknown whether roads also serve as an attractant as a source of digestive grit, as they do for other birds. However, low traffic roads may be used as leks and thereby attract sage grouse which are then at risk of sporadic vehicular collisions. Chicks and hens tend to "forage along roads" (Barber 1991, p. 37), thus exposing them to traffic as well as to "avian and terrestrial predators" (Barber 1991, p. 37).

Roads also serve to greatly increase human impacts such as hunting, poaching, and recreational use. Generalist predators, such as coyote (*Canis latrans*) frequently hunt along roads in forests (May and Norton 1996) and may be attracted to roads in the shrub-steppe. Roads greatly increase the invasion of alien species. In the Gunnison Basin, invasion of cheatgrass is particularly evident along roads (GBCP 1997, p. 41). The danger of roads to sage grouse has long been recognized: As long ago as 1942 a Wyoming biologist expressed concern over sage grouse killed by automobiles, suggesting that Wyoming's thousands of miles of highways "undoubtedly account[ed] for many thousands of bird casualties in the course of a year" (Martin 1942, p. 9).

Finally, roads cause increased kill rates of animals and increase the visual prominence of carcasses, inflating the numbers of raptors, corvids, and other scavengers along the roadside (Knight and Kawashima 1993). Such secondary impacts then increase predation and disturbance of sage grouse (Hall and Haney 1997, p. 26). Three separate studies show that ravens are more common near highways than in open areas (Boarman and Berry 1995). Corvids are also more common where linear rights of way, such as roads, parallel each other (Knight, et al. 1995b).

Roads also alter ecosystem structure by facilitating the transport and growth of invasive species. Roads foster the entry of exotic plants by providing access for dispersal through human activities. Livestock often travel along roads, and vehicles are major transport mechanisms that spread exotic plants. When a vehicle drives through a weed infested area, seeds or other plant parts often become lodged in the tire treads and undercarriage. Propagules can travel for miles before becoming dislodged in uninfested areas (Cale and Hobbs 1991; BLM 1993c; Sheley, et al. 1997). As one example, the arrival of tansy ragwort (Se*necio jacobaea)* in Montana is directly attributed to seeds moving in on logging equipment from Oregon (Kollmeyer 1997). Tansy Ragwort is a noxious Eurasian weed that is toxic to livestock, and can outcompete native vegetation. Tansy thrives in grasslands and disturbed sites, including the compacted soil of roadbeds (Kollmeyer 1997).

Soil disturbance plays a major role in the spread of exotic plants (Elton 1958 (reprinted 2000), Mooney and Drake 1986, Hobbs and Huenneke 1992, Pickett and White 1985b). Soil disturbance caused by road building changes the microclimate of the area, allowing opportunistic exotic plants to colonize. Two studies on experimental soil disturbance (Kotanen 1997; Zink, et al. 1996) showed that when soil was excavated and biomass removed, exotic plant species colonized quickly and completely, outcompeting native vegetation. Johnstone (1986) notes that plant invasion is caused by removing a barrier that previously excluded a plant from a site. An exotic seed or propagule can lie dormant as a seed or maintain itself as a suppressed seedling

until a disturbance destroys or weakens its native competitors. The exotic then enters a growth and reproductive phase, spreading throughout the area. Roads clearly remove barriers (vegetation/biomass) that exclude some exotic plants from a site. Roads produce soil compaction which can persist for decades after use of a road ends, inhibiting plant growth and altering heat storage and water vapor transport on and near the road (Trombulak and Frissell 2000). Traffic on roads, particularly unpaved ones, causes dust mobilization which inhibits plant growth and nutrition – in some cases the entire structure of the plant community is altered (Trombulak and Frissell 2000).

Roads facilitate invasions by exotic pests and pathogens. As with exotic plants, disturbance can cause "outbreaks" of exotic pests and pathogens. For example, an exotic species may be present at low levels and not drastically impact the ecosystem. With human disturbance, outbreaks can occur where one or two species rise to higher levels of abundance than in undisturbed areas (Dobson and May 1986). Roads also alter microclimates, causing outbreaks that can have serious ecological implications. Roads also provide access for intentional or unintentional human introduction of exotics, besides the stresses they exert on native species (Trombulak and Frissell 2000). Humans sometimes introduce exotics purposefully for erosion control along or near roadsides (Trombulak and Frissell 2000). Oyler-McCance (1999) found that the two most important variables explaining sage grouse use of a patch were distance from a paved road and area size. Distance to a road is a particularly strong effect: regardless of area size, each patch must be greater than 1,000 m from a road to have a greater than 50% chance of occupancy by sage grouse.

Roads directly affect over 20% or the land area of the United States (Forman 2000). The effects of roads can never be fully mitigated unless the road is completely removed and revegetated (Trombulak and Frissell 2000). Roads are persistent landscape features that constitute threats to sage grouse for long periods of time.

Off-Road Vehicles

The Geological Society of America convened a special committee of experts to assess the effects of off-road vehicles (ORVs). That expert committee found that off-road vehicle (ORV) use caused “severe physical and biological consequences” (Wilshire, et al. 1977). Dr. Wilshire, at that time a USGS employee, was attacked by administrators within USGS and Interior, such as Charles Kay (Principal Deputy Assistant Secretary for Policy, Budget and Administration of the Interior Department), and a gag order was issued prohibiting contact with conservation groups (Wilkinson 1998, p. 323-328). Many studies confirm that ORVs cause significant harm to desert areas (e.g. Eckert, et al. 1979; Webb and Wilshire 1983). This damage occurs even when ORV use is minimal (Iverson, et al. 1981). In 1995, the US Government Accounting Office (GAO) studied the impacts of ORVs, and found that land management agencies such as BLM were not complying with Executive Orders 11644 and 11989; for example, monitoring of ORVs was casual and ineffective rather than systematic, “adverse impacts were seldom being documented,” and corrective actions were not implemented or even “prioritized” for action (excerpted in Wilkinson 1998, p. 310).

ORVs are [*a favorite toy of some recreationists*]. ORVs are also used to some extent for industrial operations, for example, in oil and gas exploration, and by ranchers and farmers. For sage grouse, both wheeled vehicles (small ATVs as well as larger SUVs) and snowmobiles are of concern. ORVs cause alterations of grass and forb cover and reduce plant species diversity (Clampitt 1993). ORV operation is a well known cause of soil compaction and erosion, reduced water infiltration rates, and negative effects on vegetation (Adams, et al. 1982; Eckert, et al.

1979; Iverson, et al. 1981). In arid lands, the soils are “exceptionally vulnerable to ORV attack” (Sheridan 1979). Many of the effects of ORVs are discussed further in the section Military Operations.

Even light use of a truck on a shrub landscape can damage vegetation and soils (Vollmer, et al. 1976; Iverson, et al. 1981). Not surprisingly, ORV use causes decreased diversity, density and biomass of breeding birds, and ORVs have a negative effect on desert wildlife over large areas (Bury, et al. 1977). Even moderate ORV use is known to cause substantially reduced bird densities (Bury, et al., 1977; Luckenbach 1978). Affected areas can take “centuries or millennia” to recover, or may not recover at all (Wilshire, et al. 1977; Iverson, et al. 1981). In the Gunnison Basin, ORV use is "increasing and expanding into more and more sagebrush and riparian areas" (GBCP 1997, p. 50). Besides damage to vegetation, even slight ORV use increases the amount and frequency of water runoff and erosion, decreases soil porosity, infiltration capacity, effectiveness of soil stabilizers, and hydraulic resistance to overland water flow (Iverson, et al. 1981). ORVs and other motorized vehicles tend to travel in valley bottoms, which are particularly critical to grouse because these areas are one of the most important feeding areas for young birds (GBCP 1997, p. 50). Roads and trails formed by ORVs become corridors for predators and for invasive plant species (GBCP 1997, p. 50).

ORV use also is a major cause of invasion of weed seeds and other pests into grass and shrub lands (Tyser and Worley 1992, Hobbs and Humphries 1995, BLM 1996a). Seeds commonly lodge in the vehicle’s chassis and can be transported “hundreds of miles” (Pyke 2000, p. 46). Landscape scale is important in understanding the invasion of weeds, and ORVs and livestock are of primary importance in introducing weeds from roadsides into grass and shrub land areas away from roads (Belsky and Gelbard 2000). Extant native grasses, forbs, and shrubs will be destroyed by even moderate ORV use, and even tree roots can be undermined, or damaged by soil compaction even though damage is not apparent (Wilshire, et al. 1977).

Snowmobile use harms wildlife, vegetation and soils. Because of their high noise levels and extreme speed, snowmobiles harass sage grouse and other wildlife far from roadheads or other entry points, causing increased metabolic rates and stress responses. ORVs present particular problems with respect to disturbance. Supervision and enforcement of snowmobile use is virtually impossible if the area is large (Malaher 1967). Often abuses involve several snowmobiles and even aircraft, all in communication by two-way radio (Malaher 1967). During the winter months, sage grouse are especially vulnerable to this harassment because they are already burdened by increased levels of stress due to low temperatures, inclement weather, reduced food supply, and the need to gain weight for the energetically demanding breeding season. Snowmobile use can also cause disruption in movement patterns, making it more difficult to locate reliable food sources. These impacts are best understood and documented for ungulates (Cain, et al., 1997; Parker, et al. 1984; Moen, et al. 1982; Severinghaus and Tullar 1975); nevertheless, many other wildlife species suffer the same sorts of direct impacts from exposure to and harassment by snowmobiles. It is certain that sage grouse within the range of snowmobile use will be harassed by noise and visual impacts. Accumulation of snowmobile exposures over the course of a winter or several seasons can result in significant long-term wildlife displacement and expanded home ranges, increasing winter stresses and energy expenditures. In many winter areas, sage grouse have very limited suitable habitat available. As a consequence, wildlife often suffer increased winter mortality in areas where snowmobiles are used, even in low intensities (Berwick 1968; Bury 1978; DeMarchi 1975; Dorrance, et al. 1975; Neumann and Merriam 1972).

In winter, snowmobile and other ORV use can cause significant damage to both exposed and unexposed vegetation. Abrasion and breakage of seedlings, shrubs, and other exposed vegetation is common (Neumann and Merriam 1972; Rongstad 1980; Ryerson, et al. 1977). Similarly, shallow roots and rhizomes (such as are found in sagebrush) can be crushed or otherwise damaged. Especially on steeper slopes, and particularly when snow levels are low, snowmobile use can lead to considerable soil erosion. For example, increased sedimentation and turbidity is known to occur both in the immediate area and throughout the watershed (Aasheim 1980). Repeated snowmobile use can lead to changes in plant density and species composition and set back seral stages (Aasheim 1980, Wanek and Schumacher 1975), and the associated loss of vegetative cover generally leads to increased soil erosion (Montana Fish, Wildlife and Parks 1993). Because ORVs generate pollution levels hundreds of times those of a modern automobile, there is significant opportunity for vegetation damage from air pollution in basins with stable air masses.

Snowmobile-induced snow compaction is implicated in numerous environmental impacts. These impacts are often overlooked, and rarely appear in NEPA documentation. For instance, snow compaction can cause considerable below-surface vegetation damage (Neumann and Merriam 1972). Significant reductions in soil temperatures may also result from snow compaction (Aasheim 1980, Rongstad 1980). This reduced soil temperature retards both soil microbial activity and seed germination (Keddy, et al. 1979). These temperature impacts may be exacerbated by physical effects from compaction of the underlying soil layers, making it more difficult for the seedling to mechanically push through material layers surrounding it. Snow compaction is also responsible for numerous and severe impacts to sage grouse because they depend on subnivean spaces (the spaces between the snowpack and the ground surface) for winter survival. Compaction lowers temperatures in subnivean spaces, which in turn leads to increased metabolic rates, and thus, increased mortality. In some cases, compaction restricts movement to the point of asphyxiation. When snow is compacted, grouse must work harder to dig for vegetation (Fancy and White 1985), increasing their energetic demand and increasing the amount of time they are exposed to harsh conditions and predators on the snow surface. Snow compaction by snowmobiles also increases the mobility of terrestrial predators such as coyotes, bobcat, and red fox (Neumann and Merriam 1972). Finally, because most of the snow compaction occurs on the first snowmobile pass, even minimal use of any area can cause considerable damage (Aasheim 1980; Gabrielson and Smith 1995; Keddy, et al. 1979). Snow compaction often retards melting of snow, altering vegetative phenology, besides leading to muddy trails and roads, which are then highly susceptible to significant damage and enlargement. For the same reason, snow compaction can lead to altered melting and discharge regimes, further increasing soil erosion (Montana Fish, Wildlife and Parks 1993). Smith (1996) recently summarized snowmobile impacts.

ORV use is accelerating and as BLM states, has shown a “dramatic increase” in just the last few years (ABC News 1999). Over half of all ORV use takes place on BLM lands (Donahue 1999, p. 187). Other federal lands are also experiencing rapid increases in ORV use (ABC News 1999). In Wyoming, one driver recently ran his vehicle “right into the middle” of a strutting ground (High Country News, May 10, 1999, Vol. 31, No. 9, p. 15).

Military Operations

The range of the sage grouse contains a large number of military bases and training areas, exacerbating the problem of habitat destruction as well as direct effects on the birds from noise and visual disturbances, and from nest destruction. Military operations include troop movements,

cross-country operation of tracked and wheeled vehicles, military overflights (often very close to the ground), live firing exercises of small arms and artillery, the dropping of both live and dead (dummy) bombs, stationing of mechanized and armored combat forces, and construction of various temporary and permanent installations with their associated utility needs. The deleterious effects of ground based military operations are concentrated in the best sage grouse habitat, because both sage grouse and military trainers prefer areas with slopes of less than 10% which comprise a limited subset of lands in many areas of sage grouse habitat, particularly on the YTC in Washington (Cadwell, et al. 1997; Livingston 1998). Generally speaking, the best soils, best vegetation, and most critical habitat are in valley bottoms with slopes of less than 10%. For example, on the YTC, such areas include Selah Creek and Cold Creek, where military training activities are also concentrated.

Use of tracked vehicles ("tanks") can cause even greater damage than use of ORVs. Both operations in a straight line and turning or stopping of the vehicle (causing divots) are significant causes of erosion, sagebrush destruction and understory destruction (Watts 1998). Effects on cryptogamic crust are particularly severe (Watts 1998). Both vehicle and foot traffic are known to compact soils, increase erosion, reduce vegetative cover, facilitate the spread of alien plants, and increase fire frequency (Watts 1998). Use of tracked vehicles also results in greater fragmentation, and smaller, more closely spaced shrub patches as well as increased cheatgrass invasion (Knick and Rotenberry 1997). Moreover, these effects are documented on the ground at the YTC as affecting the sage grouse in Washington (Eberhardt and Hoffmann 1991, Stephan, et al. 1996; Livingston 1998).

Firing of tracer bullets and use of pyrotechnic devices are major sources of fire (YTC CA 1994, p. 4, section VI.H). Troop training also involves the excavation of soil for foxholes, latrines, and other uses, and the establishment of bivouacs, which damage vegetation.

Sage grouse are particularly vulnerable to human disturbance at nests and lek sites. Females are known to abandon nests and possibly their broods if disrupted by foot traffic such as troops, by vehicles, or by explosions and noise (Livingston 1998). In Washington, several important leks on the YTC are located on or adjacent to roads (Livingston 1998). These leks are likely to be abandoned if vehicles drive on the roads while sage grouse are displaying or mating. Sage grouse on the YTC have a number of unusual behaviors, such as large home ranges, atypical and extensive movements, and the seeking of areas with low levels of human disturbance, that are likely related to disturbance by military training operations (Eberhardt and Hoffmann 1991).

Military operations can also degrade habitat, and areas used for military operations for any appreciable length of time often have low levels of sagebrush cover (Cadwell, et al. 1996; Sveum, et al. 1998a). Further loss of sagebrush is particularly endangering to the birds, yet is more likely than in other areas because of the likelihood that military operations will set off fires. Even a single training exercise can do tremendous damage to sage grouse habitat. In 1995, the YTC conducted an exercise termed Cascade Sage, which impacted approximately 14% of the big sagebrush in sage grouse primary habitat, and immediately killed 1.7% of all sagebrush plants in the area, and severely damaged 7.8% of all sagebrush plants in the area (Cadwell, et al. 1996). Damaged plants, of course, may die later on, and do not provide needed cover for sage grouse, which declined following the exercise (Cadwell, et al. 1996). These deleterious effects are not unusual: training by the Washington Army National Guard in 1996 caused similar levels of habitat destruction (Stephan, et al. 1996). Nor are these isolated instances: training exercises on the scale of Cascade Sage are planned to reoccur regularly in future years. Such negative impacts

will have serious cumulative effects on sage grouse. Cadwell, et al. (1996) estimated that exercises of this scale will reduce sage grouse habitat by nearly 1% per year at the YTC, a loss of 133 hectares every year. Additional losses of sagebrush are expected due to training related fires and natural mortality. Cadwell, et al. (1996) estimate that sagebrush cover would decline to merely 5.4% after 25 years of such biannual training, which is well below even the minimal level needed to support sage grouse. Stephan, et al. (1996) presented similar estimates of cumulative habitat loss from military training. However, because of the genetic and demographic factors discussed elsewhere for the YTC group of birds, this group of birds is unlikely to persist that long even without military training exercises at the projected levels. The YTC birds need habitat restoration to have any chance of survival, not habitat destruction.

Instead of mitigation or reduction of training levels, however, they are projected to increase significantly. In 1994, authorities approved a dramatic increase in military activity on the YTC from the stationing there of 2 brigades of heavy combat forces. These forces will conduct combat training operations on 49,000 acres per year, creating 89,500 miles of off-road tracked vehicles (tanks and other heavy armored vehicles such as personnel carriers) miles each year (US Army 1994).

Sage grouse habitat receives little protection on the YTC. Less than 10% of sage grouse habitat is located in light use zones established by the Cultural and Natural Resources Management Plan for the YTC, and most areas of critical habitat are used heavily during training (CH_2M-Hill 1996). The Army has proposed some voluntary actions and mitigation measures on the YTC; however, even if these actions are carried out completely, they will be woefully inadequate to conserve the grouse.

Use of tracked vehicles in military operations causes extreme fragmentation, resulting in small, closely spaced shrub patches (Knick and Rotenberry 1997). Training exercises cause repeated re-ignitions of fires at closely spaced time intervals, preventing sagebrush from reestablishing itself and causing irretrievable loss of habitat (Knick and Rotenberry 1997).

Oil and Gas Operations, Mining, and Prospecting

Prospecting and operations for oil and gas, mining, and other such resource development typically involves the use of ground vehicles and road construction. Prospecting often involves setting off underground explosions that can interfere with the low frequency mating vocalizations of male sage grouse and otherwise disturb the birds. It is known that "sage grouse use decline[s] markedly" in areas with coal, oil and gas installations (BLM undated, b, p. 33). Oil field development causes sage grouse populations to "decrease dramatically" (Braun 1987a). As oil fields mature, there is some evidence that they become less harmful to sage grouse; however, there "is no doubt that refineries, pumping stations, gasification plants, and associated developments have permanent negative impacts on sage grouse populations" (Braun 1987a). Moreover, any type of intensive development greatly increases poaching – Bay (1989) estimated a 3x increase in game violations in such areas.

Exploration activities cause noise, road creation, and disturbance that may have long-term effects (Braun 1987a). Hens from areas where leks were disturbed by natural gas development had lower nest initiation rates, traveled twice as far to reach nest sites, and were more sensitive to nest cover than hens from leks that were not disturbed (Lyon 2000). This is particularly troubling because BLM and other land management agencies attempt to mitigate disturbance by protection areas within 2 miles (or even less) of a lek. But it is precisely these areas in which females will attempt to nest farther than 2 miles from a lek (Lyon 2000, p. 23). The use of low-flying helicopters, in an attempt to avoid ground disturbing activities, can also

enhance the dispersal of weed seeds, as well as create high noise levels that interfere with sage grouse activities. Aircraft over-flights are apt to be particularly disturbing to prey species such as sage grouse, as explained elsewhere in this review.

Well pads and roads drastically harm nesting success. Only 67% of hens captured near disturbance sites such as well pads or roads attempted to nest as opposed to 89% of hens in a less disturbed area (Christiansen 2000, p. 14). Moreover, only 47% of sage grouse remained within 2 miles of the disturbance sites as opposed to 89% of the birds in the less disturbed area (Christiansen 2000, p. 14). Combined, these effects reduce the number of chicks hatched by more than half (Christiansen 2000, p. 14). As significant as these results are, they underestimate the true effects of such disturbances because the birds in the control areas were nonetheless disturbed by capture and census techniques as well as other potential effects.

Besides oil and gas development, the West has been subjected to extensive industrialization in the past several decades, including the leasing of vast areas for the strip mining of coal, synthetic fuels development, coal bed methane development and similar schemes. These resource development activities require an infrastructure which is harmful to sage grouse. For example, oil and gas field facilities such as powerlines, treater stacks and storage tanks create raptor perches which greatly increase predation on sage grouse and produces sage grouse avoidance of large areas near each facility even in the absence of any predation. Moreover, human activity around facilities increases the incidence of poaching and road kill, and noise and movement causes avoidance behaviors in sage grouse.

Coal bed methane development will be especially pernicious. BLM projects that 80,000 wells will occupy the Powder River Basin of Wyoming within the next decade (Clifford 2001, p. 10). Each well disturbs approximately 4 acres on each 80 acre parcel, and well pumps add noise as well as nitrous oxide and other air pollutants over a large area (Clifford 2001, p. 10). Each well has a road, a power line and poles, and a wastewater disposal pipeline (Clifford 2001, p. 11). Heavy vehicle traffic on the roads is required, as well as attendant road construction (Clifford 2001, p. 10). Each well produces large quantities of wastewater, which is laden with Mg, Ca, and Na salts (Clifford 2001, p. 10). Thus, the coal bed methane development expected in Wyoming will destroy large amounts of the best remaining sage grouse habitat. The state of Wyoming has invited industry to drill on state lands that are checkerboarded with BLM lands in each township to avoid federal environmental impact analyses (Clifford 2001, p. 11). Coal bed methane development also entails the pumping of large quantities of ground water onto the surface. Besides the potential damages from ground water depetion, surface effects such as flooding and wet soils kill or damage sagebrush, thereby destroying sage grouse habitat (Ganskopp 1986).

Braun, et al. (2002) recently summarized some, but not all impacts of coal bed methane (CBM) development: “Impacts to sage-grouse from CBM development include direct loss of habitats from all production activities along with indirect affects from new power lines and significantly higher amounts human activity, both during initial development and during production.” Coal bed methane development has begun in the Powder River Basin of Wyoming, and with development of the entire project, “over 50 % of the known sage-grouse range will be either directly or indirectly affected” (Braun, et al. 2002). Moreover, leks within ¼ mile of a CBM well, compressor station, or power line have “significantly fewer males/lek” and/or “the rate of growth is much lower when compared to other less disturbed leks” (Braun, et al. 2002). These effects are likely to persist for decades: sage grouse have not occupied leks even 15 years after disturbance for oil and gas development (Braun, et al. 2002). CBM development is

especially pernicious because "severe consequences to sage-grouse" are likely; however, knowledge of those effects will "most likely come too late to result in any major initiatives to protect the birds or their habitats" (Braun, et al. 2002).

Surface coal mining directly destroys habitat and disturbs grouse. Braun (1987a) cites 5 separate studies, all "clearly demonstrat[ing] that development of surface coal mines negatively impacted sage grouse habitats and populations." Sage grouse impacted by mining were apparently unable to successfully re-establish off site and appear to be "lost from the population at a high rate" (Braun 1987a). Other types of mining also threaten sage grouse. Shaft mining can lead to the poisoning of riparian areas from leaks of heavy metals and other pollutants. Open pit mines, which are especially numerous in Nevada, damage substantial areas of habitat and pollute riparian areas. Cyanide heap leach mines can be especially disastrous to wildlife. Open pit mines also lead to tremendous amounts of dewatering of vegetation – one mine alone (the Betze-post mine in Nevada) has pumped over 100,000 acre-feet of water, enough to support a city of nearly one-half million people. Mining can expose birds to contaminants such as cadmium. Although such exposures are likely to be low in sage grouse, herbivorous species are particularly susceptible to this toxin (Dillon 2000b). Other toxins from mining activities are likely to reach sage grouse in air or water. Toxins leach from mines even when they have been abandoned. Shaft mines are not often considered threats to sage grouse; however, the many thousands of such mines within the range of sage grouse (Seattle Post-Intelligencer 2001a), and the likelihood of contamination of critical habitats such as riparian and wet areas downstream from mines means that this assumption needs to be re-evaluated. Water sources in large areas of sage grouse habitat have been contaminated by metals from mining (Seattle Post-Intelligencer 2001b), and the full extent of the contamination is not known because USGS mapping efforts were suppressed by government officials (Seattle Post-Intelligencer 2001b).

Utility Corridors and Powerlines

Pipelines, electrical transmission lines, telephone lines, and the like cause degradation of natural vegetation, soil disturbance, and the hydrological regime (Artz 1989). Recovery times for vegetation on these areas are 30 to 100 years or even longer (Artz 1989). Pipeline construction can probably be managed so as not to permanently disrupt sage grouse activities. This will require narrow disturbance zones, reseeding or replanting of native vegetation, construction limited to seasons when sage grouse are not using the area, and effective closure of roads and trails nearby.

Utility poles also represent perches for aerial predators and can serve as a behavioral deterrent to migration. Three separate studies show that ravens are most numerous near powerlines (Boarman and Berry 1995). However, the greatest danger to sage grouse near powerlines comes from raptors which use the poles as perches, providing excellent point from which to sight prey. Typically, such poles range from 13 m to over 20 m in height (Hall and Haney 1997, p. 11). Utility poles and their lines can permanently disrupt sage grouse populations (Graul 1980; Ellis 1984, 1987). Sage grouse are known to reduce their use of areas near powerlines, and powerlines also produce fragmentation effects and reductions in security of sage grouse (Braun 1998a). Powerlines serve as a barrier to dispersal (Ellis 1987). In both Utah and Colorado, studies have documented the loss of all leks visible to perching raptors on powerline poles (GBCP 1997, p. 47; DCCP 1998, p. 23). Other data, including pellet counts and radio-tracking data, also support the magnitude of the effects on sage grouse. Negative effects on sage grouse extend as far away as 20 km from the powerline itself (Hall and Haney 1997, p. 25). These are much greater distances than can be accounted for by visual impacts alone (Hall and

Haney 1997, p. 25). Powerlines are a severe threat to sage grouse and powerlines corridors as wide as 1 mile serve as death zones for the species through out the entire length of the powerline. Any vertical element that can serve as a raptor perch will affect sage grouse. This is not limited to powerline or telephone poles, but also includes trees (live or dead), microwave towers, military and civilian radar installations, cell phone towers, oil rigs, and similar infrastructure. These vertical elements in the landscape serve as perches for aerial predators, such as raptors, and nest and chick predators, such as corvids. Corvids are known to be more common along powerlines because they serve as perches and as nest sites (Knight and Kawashima 1993).

Powerlines also directly harm sage grouse because the birds collide with them, as do other species (Herbert, et al. 1995). The dangers of overhead wires to birds have long been recognized, and predate the invention of the telephone (Coues 1876). Sage grouse are known to fly into powerlines (Hays, et al. 1998 citing Connelly, personal communication). Neyer (1977) found the carcasses of 8 sage grouse who were "doubtless collision victims" based on the severe mutilation of the bodies. Borell (1939) observed sage grouse killed by telephone wires, and Trueblood (1954), Call (1979) and Blankenship (personal communication, cited in Hall and Haney 1997) also found such effects. In less than 4 km of powerline in Montana, 18 sage grouse carcasses were found – all within 10 m of the powerline pathway (Wilkinson 2001a, p. 1 of attachment 2). Consequently, power distribution lines even in remote areas, constitute a hazard to nearby sage grouse populations (Wilkinson 2001a, p. 1 of attachment 2). BLM biologists have had poor success in getting powerline companies to install flight diverters on their lines (Wilkinson 2001a, p. 2 of attachment 2). The protections of the ESA would ensure compliance with needed sage grouse safety measures.

Many of the data on utility corridors have probably been put into spatial form, and the remote sensing and GIS techniques noted elsewhere in this document are easily applicable to this issue. The "effects of powerlines on sage grouse are severe" (GBCP 1997, p. 47, SMBCP 1998, p. 21). Sage grouse "avoid powerlines when possible" (DCCP 1998, p. 23). Paradoxically, utility companies have often tried to create raptor perch sites to enhance wildlife, and land management agencies promote the practice (Maser, et al. 1979, 1983, 1984).

A pole design that eliminates perch sites for raptors may reduce the impact of power lines on sage grouse (Braun 1998a); however, sage grouse avoid powerlines even when raptors are not perched on them (Braun 2000f; Braun, personal communication, cited in Hall and Haney 1997). Sage grouse have not returned to leks near powerlines even when the recently installed poles were retrofitted with devices which prevent raptors from perching (Hall and Haney 1997, p. 24). Thus, mitigation becomes much more costly, and rerouting or burial will be required for many powerlines.

Rapid growth of fiber optic cable communications is occurring throughout the United States. Because these cables are typically buried, they do not serve as raptor perches. Soil disturbance from cable trench digging facilitates invasion of exotic plants and removes sagebrush. However, the footprint for such trenches is relatively narrow, reducing the import of sagebrush removal. Siting of cellular communications towers and other facilities is also rapidly increasing in the United States. Such towers provide raptor perches and eliminate useable habitat. If cell telephone towers or cable corridors are placed adjacent to roads, they are likely to cause little additional harm to sage grouse.

Weather Effects

By weather, this review adopts the conventional view that weather encompasses relatively short-term changes in such variables as precipitation, temperature, wind, and solar

insolation, while climate refers to longer-term changes in these factors. Weather events have direct effects on adult birds (Walsberg 1978, 1983a, 1983b; Walsberg and King 1978b; Gessaman and Worthen 1982; Root 1988a, 1988b), their eggs (Walsberg and King 1978a; Webb and King 1983a) and chicks (Webb and King 1983b). For sage grouse, weather events can reduce breeding populations by 50% (letter from Montana Dept. of Fish, Wildlife and Parks, cited in Drut 1994, p. 19, p. 40). Wet and cool conditions during the spring nesting and early brooding seasons can reduce productivity (Weichel and Hjertaas 1992). In combination with other factors, such as habitat fragmentation, grazing, and hunting, such episodic weather events as heavy rain, snowfall, or hail could easily cause multiple population extirpations within the range of the sage grouse.

Episodic weather events can also alter habitat and vegetation structure and are a recognized element in plant survival (Nelson and Tiernan 1983). Successive wet years can cause shrub die-offs across large areas (Wallace and Nelson 1990), thus destroying sage grouse habitat. Drought can also damage sagebrush. The winter of 1976-77 had nearly the lowest precipitation in recorded history and "extensive areas" of sagebrush were killed, producing the "most extensive winter injury of indigenous plants ever recorded in the United States" (Nelson and Tiernan 1983, p. 1, 15).

Climate Change and Global Warming

Climate refers to long term changes in weather. The greenhouse effect is the term used to describe the trapping of heat in planetary atmospheres by various gases. This effect is essentially unrelated to ozone layer depletion. The greenhouse effect is minimal on Mars, strong on Venus, and moderate, but apparently increasing, on Earth. Carbon dioxide (CO_2) is estimated to account for about 49% of the contribution to the greenhouse effect on Earth (Hansen, et al. 1988). Methane, nitrogen oxides (NO_x), and chloroflurocarbons (CFCs) are the main gases accounting for the remainder of the greenhouse effect (Hansen, et al. 1988). Peters and Lovejoy (1992) described global warming as the most ominous of all potential threats to biodiversity. Grover (1990) and Kareiva, et al. (1992) discuss biotic effects of global warming. Regional temperature changes can be much more extreme" than changes in global averages (Root and Schneider 1993). Interestingly, livestock are estimated to account for 15% of methane inputs to the atmosphere – each cow emits 400 liters of methane per day because it farts or belches every 90 seconds. When summed over the number of cattle on Earth, this is a very large amount of methane.

Regardless of the sources of the greenhouse effect or how significantly the greenhouse effect itself contributes to planetary warming, the warming trends are real and could have severe effects on sage grouse and their habitat. Sage grouse have several of the factors identified by Herman and Scott (1992) rendering species vulnerable to global warming effects. Prairie has been retreating westward in recent times (T. Webb 1981), and this is likely occurring with sagebrush as well, reducing the habitat available to sage grouse. Some contractions in sage grouse distribution may already be partly caused by global warming – the possibility has never been rigorously examined. Climate change is "almost certain to become" a threat to many species "in the foreseeable future due to increasing concentrations of greenhouse gases from fossil-fuel use, land-use changes, and agriculture" (Wilcove, et al. 1998). Indeed, it appears that the ranges of some species are already being affected by global warming (Parmesan 1996). The inland West is "particularly vulnerable to global warming and to extreme moisture stress" (Covington, et al. 1994). Climate change will continue and worse, will accelerate in the future

(IPCC 1996, McCarty 2001).

Although the predicted magnitudes of warming are severe, "it is the predicted rate of temperature change that poses the greatest threat to biodiversity" (Morse, et al. 1995). Climate change has been and is projected to be "rapid," and the "ability of species to survive rapid climate change may partially depend on the rate at which they can migrate to newly suitable areas" (Morse, et al. 1995). However, sage grouse migration rates are largely irrelevant because the required habitat will not trend northward sufficiently rapidly to avoid extinction.

The World Meteorological Organization's Intergovernmental Panel on Climate Change (IPCC) estimates that the central portion of North America, including the range of the sage grouse, will warm 2 ^{o}C to 4 ^{o}C by 2030 (Houghton 1990). Other models predict even greater warming of 4 ^{o}C to 7 ^{o}C (Morse, et al. 1995). Soil moisture is predicted to decline by 15% to 20% (Houghton 1990). Even intermediate warming trends, which will occur sooner, will cause a broad array of negative impacts on sage grouse and their habitat, including increased length and severity of droughts. Warming would push the entire area suitable for sage grouse and their required habitat northward. Fragmentation interacts with climate change to restrict migration because of barriers to movement (Peters and Darling 1985). Even if sage grouse were able to establish new ranges on new habitat, most of that habitat would then be in Canada, not in the United States, and the birds' status in the United States – the *sine qua non* of the Endangered Species Act – would be in even greater jeopardy.

Equilibrial general circulation models predict greater drought and decreased summer soil moisture within 50 years (Ferguson 1997) – a threat that is thus easily foreseeable. Semi-arid and arid ecosystems are considered among the most sensitive because these ecosystems often are water-limited and have marginal nutrient reserves (Shriner and Street 2001). The entire range of big sagebrush in North America will decline to only 41% of its present range (R. S. Thompson, et al. 1998, Table 2) and most of the present range will be occupied by expanding creosotebush, *Larrea tridentata* (Shafer, et al. 2001, p. 18). Warming will lead to increased invasion of alien plants (Morse, et al. 1995), such as cheatgrass. Thus, sage grouse habitat – already degraded, fragmented and reduced – will contract and fragment even more. As cheatgrass spreads at lower elevations and juniper and pinyon pine increase at higher elevations (both exacerbated by climatic change) the narrow elevational ring of sage grouse habitat will shrink, further exposing the birds and their habitat to increasing direct threats from climatic and weather events. Moreover, variability of precipitation has increased (Tsonis 1996). The effects on sage grouse could be severe because it is the population lows that are of concern for extinction risk, and such lows are exacerbated by drought years.

Sage grouse will be extinct or nearly extinct in the United States because their habitat will be almost entirely extirpated from juniper invasion. Juniper invasion is greatly enhanced by climate change. It is not the changes in temperature that are important in juniper invasion; instead, it is the direct physiological effect of increased CO2 on plant metabolism. This effect alone will cause extinction or near extinction within 90 years. Shafer, et al. (2001) used three different response surface models to predict future plant distributions as a result of climate change. The response surface models rely upon three bioclimatic variables which are well correlated with, and good predictors of, plant species distributions in North America. Continental distributions for these and many other taxa "are largely controlled by macro-climatic variables" (Shafer, et al. 2001; Woodward 1987). The models assume a 1% per year compound increases in atmospheric CO_2 and changes in SO_4 aerosols. These changes match those of the midrange scenario prepared by the World Meteorological Organization Intergovernmental Panel on

Climate Change (IPCC IS92a). If less conservative climate change scenarios had been used, complete extinction of sage grouse and sagebrush would be even more likely. All three models gave very similar results, and all three models show that the range of big sagebrush (*Artemisia tridentata*) in the United States will decline by approximately 99% or more – only a few small patches will remain in parts of central Utah and Colorado (Shafer, et al. 2001, fig. 5; Shafer 2000). The impacts on sage grouse will be even greater as they must migrate to the remaining sagebrush patches and will be prevented from doing so by numerous natural and anthropogenic barriers. Notably, these models do not incorporate the impact of juniper expansion or cheatgrass invasion. These impacts will exacerbate range contraction (Shafer, et al. 2001, p. 18). Climate change will, of course, impact other sagebrush species, grasses and forbs in varying measure.

The Endangered Species Act requires a listing as threatened if a distinct population segment of a vertebrate, a species, or sub-species is "likely to become" endangered within the "foreseeable future throughout all or a significant portion of its range…." 16 U.S.C. § 1532(20); 50 C.F.R.§ 81.1(l). Here, the outcome is not merely foreseeable, it is predictable, and has already been predicted. Moreover, endangerment will not merely occur within a significant portion of the range; instead, it will occur, and is occurring, throughout the entirety of the range.

As Shafer, et al. (2001) point out, their work is necessarily imprecise. However, even if the predictions are inaccurate by 100%, the habitat available to sage grouse in the United States will still be so small as to cause endangerment. Further, it is just as likely that the model under predicts range reductions as that it over predicts them. Climate change alone will thus cause extinction of sage grouse in the United States, if not in 90 years then in 200 years, all species, sub-species and population segments of sage grouse will become in danger of extinction in every part of its range long before that.

Climate change will also accelerate invasion and habitat conversion by exotic annual grasses. Red brome and annual desert grasses (presumably including its congener, cheatgrass) produce more biomass and seeds when exposed to increasing CO2 levels (Smith, et al. 2000). This response is "dramatically" greater than that of native plants, and is expected to shorten fire cycles from 75 years or longer to as little as 4 to 7 years (Trent 2001, quoting a co-author, Jeff Seaman, from Smith, et al. 2000).

But climate change will not operate alone. Instead, it will operate in combination with other threats, such as degradation from cattle grazing, conversion to agriculture and other development, and landscape threats such as oil and gas development and electric powerline and cell telephone tower sitting. These threats in combination will eliminate this formerly abundant species in a much shorter time than climate change alone. When the various threats are considered in combination, the outlook for this bird is grim indeed.

Ozone Layer Depletion

Thinning of the layer of ozone in the Earth's atmosphere removes the primary barrier to the transmission of ultraviolet rays (UV). Increases in high energy UV radiation can damage plant tissues (thereby inhibiting plant growth and vigor and affecting photosynthesis), can cause thinning of avian eggshells, and can affect insect production (GBCP 1997, p. 45). Thus ozone depletion can affect sage grouse directly, as well as by reducing their food supply. Effects on eggs and young chicks will be particularly strong in areas where livestock grazing has removed radiative cover from nesting areas (Webb 1993b).

Sage grouse are particularly susceptible to increased UV radiation caused by ozone depletion because they live in areas that typically have low cloud cover, and at high altitudes where less atmosphere exists to filter out UV radiation. Ozone depletion could threaten the sage

grouse in the foreseeable future across their entire range.

Air Pollution

Several Clean Air Act non-attainment areas (i.e. polluted air sheds) lie within the range of sage grouse, including one along the northern California and Nevada state lines, and one in northern Utah (Schoettle, et al. 1999, p. 4, Fig. 1). Power plants constructed in the area produce a number of harmful emissions including sulphur compounds that can produce significant environmental effects. Sulphur emissions are a "regional issue because the sulphur may travel 1,000 km in a few days" (Schoettle, et al. 1999, p. 5).

Sulphur dioxide (SO_2) and other pollutants can affect both vascular plants and, especially, cryptogamic crusts (Schoettle, et al. 1999, p. 33). Studies have shown that cryptogamic crusts are being affected by air pollutants, and these impacts include electrolyte leakage, chlorophyll degradation, and reductions in nitrogen fixation (Belnap 1991). Effects on cryptogamic crusts are of particular concern in arid environments such as sage grouse habitat because these lands "depend on the integrity of cryptogamic crusts for soil stabilization" (Schoettle, et al. 1999, p. 49) and nitrogen fixation by crusts contributes nitrogen to higher plants (Belnap 2000). Indeed, crusts are critical to both these ecosystem functions and are an essential component of arid ecosystems (Belnap and Lange 2001). A general review of the effects of air pollutants on arid lands is given by Mangis, et al. (1991).

Sulphur oxide (SO_x) and nitrogen oxide (NO_x) emission sources are common throughout the range of the sage grouse (Schoettle, et al. 1999, p. 8-9). This may come as a surprise to the many, as the West has not traditionally been thought of as having significant air emissions. However, industrial facilities have proliferated in recent years, as have vehicular sources. Consequently, "even remote areas are subject to high concentrations of [air] pollutants" (Scruggs 1991). Nearly every county within the range of the sage grouse has SO_x and NO_x sources producing hundreds of tons, and in some cases thousands of tons, of emissions per year (Schoettle, et al. 1999, p. 8-9). Another potentially important emissions source for NO_x is agriculture – "air emissions from fertilized agricultural land may be substantial," yet such emissions "are not accounted in the NO_x inventory" (Schoettle, et al. 1999, p. 41).

Ozone (O_3) emissions are increasing and are particularly damaging because ozone is a known phytotoxin and can "threaten remote ecosystems and resources far from pollutant sources" (Schoettle, et al. 1999, p. 10). Even if ozone does not kill plants outright, it can weaken native vegetation sufficiently to allow invasion by alien plant species. Indeed, "ozone has the greatest potential of any air pollutant to directly reduce growth and vigor of vegetation" in the Interior Columbia Basin (Schoettle, et al. 1999, p. 43).

Acid Precipitation

Acid precipitation – often termed acid rain – can occur as rain, snow, or particulate fallout carried by any type of precipitation. It occurs when nitrogen or sulfur oxides are released into the atmosphere. Vehicle emissions are the major source of nitrogen oxides and industrial plants are the major source of sulfur oxides.

The susceptibility of certain organisms such as lichens to acid precipitation is quite high. The susceptibility of sagebrush, forbs and grasses used by sage grouse is not clear. What is important in analyzing acid precipitation is not whether the absolute amounts generated in the west are comparable to the amounts generated in the mid-western and eastern United States. Instead, it is whether the susceptibility of sagebrush, forbs and other plants needed by sage

grouse is within the range of acid precipitation reaching them. Concentrations of automobiles and trucks in Los Angeles, the San Francisco Bay Area, Denver, Salt Lake City and other cities as well as smelters and power plants such as those located in the Four Corners area and in Colorado may be generating acid precipitation in quantities sufficient to harm sagebrush, grasses or forbs needed by sage grouse.

Effects of Chemical and Radiological Agents

Use of herbicides, pesticides, and other chemical agents is known to have damaged sage grouse populations, even though the phenomenon has been little studied. Thus, effects on sage grouse are surely larger than have been reported, and limitations on the use of various chemical agents will be required to recover the bird. Both herbicides and insecticides are consumed by, and will often be bioaccumulated in insects, which are an important food source for both chicks and pre-laying hens. Thus, the most susceptible life-history stages of the bird are exposed to chemical agents (Schroeder, et al. 1999a, p. 17). Some organophosphates are known to have killed numerous young birds while leaving adults alive (Blus and Henny 1997). Sage grouse are known to have suffered mortality from strychnine-laced rodent bait, toxaphene, Aldrin and chlordane (Post 1951, Carver 1997).

Like humans, wildlife are subjected to a mix of numerous synthetic chemicals. Synergistic effects of this mixture may exceed the effects of individual contaminants by several orders of magnitude (Arnold, et al. 1996; Colborn 1995). Besides the effects of synergistic mixtures of contaminants, and the effects on susceptible life history stages, the manner in which chemical agents are tested also tends to underestimate effects in nature. Chemicals are routinely administered to well fed and well watered, healthy animals. In contrast, wildlife often go hungry, experience water stress, disease and parasite loads, face mechanical injury and immuno-challenges, often in combination – all while being subjected to chronic or acute exposures to chemical agents.

Besides the effects on habitat, water sources can be contaminated by spraying of nearby fields that drain into the water source. Breakdown of chemicals in dry soils may be particularly slow, due to lack of microbial activity in low moisture environments.

For decades the West has been used as a dumping ground for the Nation's hazardous wastes and for the siting of ultra-hazadardous facilities, such as nuclear weapons factories. To some extent, such activities have benefited sage grouse and other wildlife by excluding most other human activities. For example, the INEEL (Idaho National Engineering and Environmental Laboratory, formerly INEL) has excluded hunting and grazing because of national security concerns associated with Naval nuclear reactor and other research at the site. Hunters and other trespassers have been confronted by Naval sharpshooters perched in helicopters and other security personnel (C. Peterson, personal communication), which likely dampens some of the pleasures of poaching. Consequently, this area has been rested from grazing for approximately 50 years, and habitat and populations are both markedly superior to the surrounding area.

However, sage grouse in this area are radioactive (Connelly and Markhamer 1983). In other areas, habitat has been removed for hazardous waste dumps and production facilitates, and both sage grouse and humans are at substantial risk. For example, central Utah contains perhaps the nation's greatest concentration of hazardous facilities, including the worst emitter of toxic chemicals in the nation (Fedarko 2000, p. 116), an incinerator for nerve gas and other chemical weapons, several bombing ranges, fallout from nuclear weapons tests, radioactive mine tailings, and chemical weapons testing areas (Fedarko 2000). The area is also expected to store nuclear reactor waste fuel rods (Fedarko 2000, p. 122). Sage grouse have also been directly killed in

accidents. On March 13, 1968 an F-4 Phantom military aircraft released 2,730 pounds of VX nerve gas in central Utah, killing large numbers of sage grouse as well as every other animal in the area (Fedarko 2000, p. 124). Many other such ultra-hazardous activities occur in other parts of sage grouse habitat in Nevada, Utah, Washington, and Oregon.

Effects of Herbicides

A variety of chemical herbicides have been used to remove sagebrush and other shrubs in sage grouse areas. Besides any direct effects on the birds, such chemicals are used to target habitat that the birds need. Herbicides are also used for weed control. Common herbicides used have been 2, 4-D, 2, 4, 5-T, and Tebuthiuron, often labeled as Spike 20 or Grasslan (Braun 1998b). Use of 2, 4-D was curtailed in the late 1970's but is now increasing again, as is that of Tebuthiuron (Braun 1998b). Despite the deep affection for Tebuthiuron by BLM and some other land management agencies, Braun (1998b) noted that no study has ever "demonstrate[d] any positive responses by sage grouse to any Tebuthiuron treatment anywhere in sage grouse range." Moreover, Braun examined several Tebuthiuron treated areas and found all of them to be harmful to sage grouse, at least over the short time frame of the studies conducted (Braun 1998b). Consequently, he recommended that his state agency (Colo. Div. Wildlife) not support its use at all or allow its use on state lands (Braun 1998b). Treatment of large patches (200 or more ha in size) is particularly deleterious to sage grouse (Braun and Beck 1996). Tebuthiuron is particularly damaging to sagebrush and forbs, both critical habitat components for sage grouse (Braun 1998c, p. 3). Tebuthiuron has a higher persistence time in soil and thus may be more damaging to sage grouse habitat than even 2, 4-D (Braun 1987a). Tebuthiuron is known to cause pancreatic dysfunction in vertebrates and affect digestion (Emmerich 1985). It is also more likely to be transported in runoff and subsurface waters than most other herbicides (Emmerich 1985). Worse, it can persist in soil for many years – the half-life can exceed 5 years (Emmerich 1985). Many forbs are especially vulnerable to herbicides such as 2,4-D, but these "effects have been ignored by many range scientists in their efforts to increase production of grass (Blaisdell, et al. 1982, p. 20) – the grass, of course, is destined for livestock.

Despite the lack of data showing benefits to wildlife, millions of acres have been sprayed with these herbicides since the early 1960's, and Braun (1998a) estimates that more than 25% of all sagebrush areas has been affected. About 91,000 km^2 of rangelands were sprayed between 1985 and 1990 for grasshopper control alone (Johnson and Boyce 1990). Martin and Pyrah (1971, p. 137) and Martin (1965) describe the effects of treatment of a 1,700 acre area with herbicide. Over a 3 year study after the spraying, a total of 15 sage grouse were found in sprayed areas, while 400 sage grouse were found in unsprayed areas (Martin 1965, Table III). Sprayed areas constituted 90% of the total area, but yielded only 4% of the observations of sage grouse. The difference was related to alterations in the vegetative cover of the sprayed areas. Over 90% of the sage grouse that were in the sprayed strips were within 30 m. of an unsprayed area (Martin 1965). On the YTC in Washington, hundreds or thousands of acres are sprayed with Picloram or 2, 4-D to control knapweed (Cochran 1998).

Higby (1969a) reported the extirpation of an entire wintering population of 1,000 birds from spraying in Wyoming. Moreover, the area was not repopulated for 5 years. After sagebrush was sprayed in the late 1950's in the Gunnison Basin, lek counts declined to about one-third of their former numbers near the treated area but did not decline in other areas (Hupp 1987b, p. 87, Fig. 13; Rogers 1964). Similarly, a 12,000 acre extent of sagebrush in Oregon was sprayed with 2,4-D to eliminate sagebrush. The program was effective – and winter range for 1,000 sage

grouse was destroyed (Call and Maser 1985, p. 13). Effects from sagebrush spraying persist for at least 10 years (Braun and Beck 1996).

Wallestad (1975a) and Blus, et al. (1989) have noted the detrimental effects on sage grouse populations from contamination by spraying of herbicides and pesticides. Both authors discuss die-offs of birds using agricultural lands for foraging caused by chemical spraying. Besides their acute effects, many herbicides have chronic effects, and can act as endocrine disrupters. It is clear from the studies above that herbicide spraying completely destroys habitat for sage grouse. Habitat may not recover for decades after spraying.

Effects of Animal Pesticides

Pesticides have been used to kill various insects occurring in sage grouse habitat areas, including Mormon crickets, mosquitoes, and grasshoppers. Pesticides harm sage grouse populations by depleting their food supply, by acute poisoning, by chronic poisoning, and perhaps by disrupting neuronal and endocrinological systems affecting immune function, development and behavior. Sage grouse chicks die of malnutrition if deprived of sufficient numbers of insects, and spraying of pesticides has been implicated in declines of other (Johnson and Boyce 1990). The amount of sage grouse habitat exposed to pesticide contamination is unknown as is the magnitude of pesticide spraying; however, Johnson and Boyce (1990) estimated that over 5 million acres were sprayed between 1980 and 1985 to control just one insect species, the grasshopper. Carbamate pesticides are known to harm sage grouse (Blus, et al. 1989). Blus, et al. (1989) documented the direct mortality of sage grouse from organophosphate insecticides used on cultivated crops. Birds experienced significant depression of brain cholinesterase levels (Blus, et al. 1989). Malathion and dieldrin are known to be toxic to a closely related species, the sharp-tailed grouse (McEwen and Brown 1966), and toxaphene can kill sage grouse (Hill 1984). Sublethal levels of toxicants increased susceptibility to predators in species closely related to sage grouse (McEwen and Brown 1966).

Sage grouse kills from organophosphate insecticides have also been noted in southeastern Idaho (Mondecar, et al. 1987; Blus, et al. 1989). Sage grouse entered potato and alfalfa fields that had been treated. Sage grouse that fed on sprayed alfalfa fields were especially susceptible; however, even use of the sprayed alfalfa fields for roosting or loafing caused severe effects (Wallestad 1975b; Blus, et al. 1989). Mere occupation of sprayed potato fields also caused death or severely adverse effects (Blus, et al. 1989). Sage grouse are likely most susceptible to pesticide effects during periods when energy is withdrawn from lipid stores, such as during breeding displays for males (Hupp and Braun 1989a) and egg formation for females. Birds often feed in or near croplands and there are reports that “large numbers of sage grouse died” at the interface of croplands and sagebrush (Blus and Connelly 1998). Pesticides and other contaminants cause increased variation in per capita growth rates of populations (Meyer and Boyce 1994). Sage grouse populations will be especially variable as juvenile birds are particularly susceptible to pesticide induced reductions of insect prey (Meyer and Boyce 1994). These variations increase the risk of extinction and of genetic drift.

Pesticides render habitat unsuitable for sage grouse by destroying the insect food supply needed for critical life history stages. Additionally, many pesticides have chronic effects, and can act as endocrine disruptors. After a thorough review of thousands of BLM and other agency documents, [*the author*] have seen virtually no analysis of ways to reduce the impacts of pesticides on sage grouse, although such mitigation techniques are known (Stiehl and Trautwein 1991a).

Even low doses of organochlorine pesticides are known to alter important behaviors in birds, such as aggression levels, alertness, discriminatory behaviors and territorial activity (Jeffries 1973). Organophosphide pesticides are known to cause such sub-lethal effects as weight loss, reduced visual acuity, auditory detection, vigilance, food seeking behaviors, offspring caretaking, and greater susceptibility to environmental stressors, including weather effects (Grue, et al. 1983). Thus, low doses can cause death or reproductive decrements by acting synergistically with other, natural effects in the birds environment. These threats are continuing (Blus and Connelly 1998).

Effects of Endocrine Disrupters

A number of chemical compounds, some otherwise thought to be benign, have been implicated as causing subtle, but long-lasting effects, including behavioral alterations, and disruption of development. Behavioral alterations include aberrant behavior of birds during nesting (Mac 2000) – of particular import for sage grouse viability. Importantly, these effects are hypothesized to occur at concentrations several orders of magnitude below those at which either acute or chronic effects are known from conventional chemical agents. A second important concern is that effects are believed to have occurred at concentrations below detectability limits, even using the most modern analytical techniques, such as HPLC (high performance liquid chromatography) or mass spectrometry. The US Geological Survey noted that such compounds can act by mimicking natural estrogens in the body, as well as by altering the action of other sex hormones, and glucocorticoids and thyroxine (Mac 2000). In humans, large reductions in sperm counts have been attributed to endocrine disruptors, as have the recent increases in cancers of the prostrate, breast, and ovaries – all tissues which are sensitive to sex hormones (Mac 2000). Effects of these compounds have been demonstrated in birds and are known to produce transgenerational effects (Colborn, et al. 1993; Facemire, et al. 1995). Effects are a particular concern during embryonic development and endocrine disruptors " can permanently modify the organization of the reproductive, immune, and nervous systems" (Guillette, et al. 1995).

Sage grouse in areas that have been treated with Tebuthiuron (Spike) have been observed engaging in atypical behaviors. For example, during a period when most males were flocking, "one male [was] consistently alone in an area where sagebrush has been treated with Spike" (Brigham 1995a). Further, a male was observed sitting out "in the open" in "the heat of the day" even though a big sagebrush bush provided shade only 50 meters away (Brigham 1995a). Although anecdotal, such observations may reflect contaminant mediated behavioral alterations with powerful effects on individual fitness and population persistence.

Natural Factors and Environmental Variation

Environmental variation in climate, food sources, and predators is high in the areas used by sage grouse. The climate is "highly variable," causing many threats, such as grazing and fires, to act like disturbances to the ecosystem (Eddleman and Doescher 2000). The "key functional elements" of disturbance have great temporal variation (Eddleman and Doescher 2000). This contributes to significant environmental stochasticity making it even more likely that small populations of these birds will become extirpated.

Sage grouse ranges are generally xeric with high evapotranspiration rates except in northern latitudes, and low rainfall, ranging from 15 to 32 cm per year. Available moisture for plant growth is highly variable, and drought is common both seasonally and for periods lasting for several years (Palmer 1965, Braun 1998a). Drought periods seem to often exacerbate declines in sage grouse populations (Patterson 1952c, p. 68-69; Connelly and Braun 1997). Drought is

believed to reduce grass and forb cover, much as grazing does, causing increased detection by predators, and decreased food availability both of forbs directly and of insects which eat and make use of the forb cover (Klebenow and Gray 1968; Peterson 1970b; Drut, et al. 1994a, 1994b; Gregg, et al. 1994; Fischer, et al. 1996b). Factors affecting populations interact, and if a major drought occurs at a time when habitat has been severely degraded by grazing and other effects, the effects on sage grouse populations could be catastrophic. Drought is known to reduce forb cover at brooding sites and cause low production of young (J. R. Young 1994b, p. 45). One prediction from global warming models is increased drought in continental interiors, such as the range of the sage grouse.

Drought impacts both plants and insect populations that sage grouse depend upon for food and cover. Drought – even severe drought occurring over multiple years – is a natural feature of the climatic regime in the habitat of sage grouse. The Service must consider the effects of such episodic events in evaluating the risk to remaining sage grouse populations. Both nesting success of females and brood survival decline severely during years with low soil moisture (GBCP 1997, p. 45). This effect is compounded if land management practices remain unchanged during years with low soil moisture (GBCP 1997, p. 45). These effects of reproductive persist into future years – the year after a drought, there will be fewer yearling males on leks (FWS, undated, b).

Fragmentation

Fragmentation is discussed extensively elsewhere in this review, and is also known to affect social behavior in vertebrates (D. R. Webb 1981). Webb postulated that the increase in agonistic behavior, and the decrease in amicable behavior seen in fragmented areas was caused by the difficulty of juvenile dispersal to new areas, and was unrelated to such factors as elevation, foraging time, and other non-landscape factors. Habitat fragmentation could cause similar behavioral alteration in sage grouse. For example, if juvenile sage grouse experience difficulty in dispersing to new habitat patches because of fragmentation, then the number of males at a given lek may increase. Researchers would see more males per lek, and assume that beneficial effects were taking place in that population. However, increased male density could instead lead to increased fights among birds, or such large displays that females would make incorrect choices of potential mates. Although data are lacking on the issue of crowding, it is one that must be considered for listing decisions, designation of critical habitat, and the crafting of recovery plans.

Oyler-McCance (1999) found that the two most important variables explaining sage grouse use of a patch were distance from a paved road and area size. Habitat fragmentation is increasing in the Interior Columbia Basin, the Klamath Basin and the Great Basin – particularly in upland areas that form the vast majority of sage grouse habitat (Quigley and Arbelbide 1997b, p. 761).

Habitat Recovery Time

Both sage grouse populations and their habitat evince lags in their response to improved conditions (Schroeder 2001a, p. 8). As previously discussed, sage grouse habitat may not be able to recover from certain events, such as cheatgrass invasion which can cause the complete eradication of sagebrush in an area. Other past effects include the extremely heavy grazing of the west, which took place between the late 1800's and World War II, off-road vehicle (ORV) use, and military exercises. Depletion of vegetation and loss of soil by erosion are grazing effects that may prevent full recovery of the ecosystem. Unfortunately, heavy grazing continues today. Much sagebrush habitat has been treated with herbicides such as 2, 4-D, which leads to establishment

of rabbitbrush (*Chrysothamnus* spp.) rather than regrowth of sagebrush. Overgrazing and other events may have already irreversibly altered sagebrush habitat (Patterson 1952c, Yocom 1956, Autenrieth, et al. 1977; Autenrieth 1981). Even significant recovery of sagebrush steppe from desertification is "highly questionable" (West 2000, p. 20). Even complete cessation of grazing, as advocated by Kerr (1998b) and others, may not reverse degradation in some areas because the state of degradation has exceed recovery thresholds (West 2000, p. 20). Besides lag times due to various biotic interactions among species, soil formation is exceedingly slow in arid areas – taking 5,000 to 10,000 years (Belnap 2000, p. 58).

In arid and semi-arid lands, such as sage grouse habitat, forces such as grazing disturbance or altered fire regimes can cause vegetation to cross a threshold, or transition point. Once crossed, removal of the disturbance will not necessarily result in a transition to a higher successional state without substantial inputs, and does not follow classic patterns of plant succession. Examples of this are cheatgrass/medusahead monocultures (Quigley and Arbelbide 1997b, p. 766). "Most current period arid and semi-arid rangeland [areas] remain stable at one or more lower (less advanced) successional states for long periods of time" (Quigley and Arbelbide 1997b, p. 765). Much of the "sagebrush-grass area has been so modified by past use that restoration to the natural condition will not be possible during the foreseeable future, even under intensive management" (Blaisdell, et al. 1982, p. 14). Even wetter areas, such as riparian meadows require many years to recover – Dobkin, et al. (1998) studied plots after 30 years of grazing exclusion and noted that restoration "will not happen quickly." USFS researchers have also found that riparian areas often require many years to recover (Clary, et al. 1996).

Both forbs and grasses lag the removal of stressors. On Hart Mountain National Antelope [pronghorn] Refuge, elimination of grazing in 1991 led to improvements in forb covers after a lag of a few years, but only after a series of very wet years (Crawford and Drut 1993). * * * Nest initiation did increase (Crawford and Drut 1993, p. 9), suggesting that females were nutrient starved by reduction in forb coverage caused by cattle grazing. In west-central Utah, herbaceous vegetation did not recover even after 13 years after removal of livestock (West, et al. 1984). In more mesic areas, vegetation can recover more easily. The basal cover of perennial grasses increased by a factor of 19 after removal of cattle for 25 years (Anderson and Holte 1981).

Once removed or degraded, sagebrush is difficult to reestablish (Medin and Ferguson 1972). Sagebrush has low emergence and poor seedling vigor (Eddleman 1977, 1980). Wiens (1976, p. 89) summarized the recovery time of sagebrush habitats as "notoriously slow." Even if sagebrush shrub-steppe areas can recover and reestablish themselves as good sage grouse habitat, the time this may take can be so long – 100 years or more – that sage grouse populations will not be able to persist long enough for habitat recovery to occur. The lag in sage grouse recovery may also add to the lag in habitat recovery – even if sage grouse populations are able to maintain some viability in a degraded area, the local population is unlikely to be capable of serving as a source population in a landscape sense for many decades. The Service must consider the many decades required to restore habitat in its assessment of threats to the grouse because areas of habitat will continue to be degraded and eliminated before other areas can recover and sage grouse can reestablish populations in those areas.

The most recent research on recovery times in arid areas indicates that full ecosystem recovery may not occur for literally thousands of years (Lovich and Bainbridge 1999). In the Gunnison Basin, the "long-term health of the ecosystem may have been altered, possibly irreversibly, affecting [] carrying capacity" (GBCP 1997, p. 43). Thus, significant amounts of sage grouse habitat may have been lost forever.

"Even under themes [management scenarios] where aggressive restoration activities are planned… it is thought that the deterioration and loss of sagebrush habitat will outpace restoration success" (Saab and Rich 1997, p. 16).

Even if livestock are removed from an area, the presence of invasive weeds, overly dense stands of sagebrush, or heavy browsing by rodents and rabbits can inhibit recovery of grasses and forbs (Tisdale and Hironaka 1981). For native grasses, recovery times can also be very long – bluebunch wheatgrass will not recover from even a single season of heavy grazing for 8 years, even under the best management practices (Anderson 1991). In northwestern New Mexico, there has been no significant increases in grass cover at Chaco Canyon National Historical Park despite over 50 years of grazing exclusion (Hobbs and Huenneke 1992; Pieper 1994).

After fire, many sagebrush species do not resprout and must re-establish by seed set. This process is very slow (Britton and Clark 1985) and 30 years or more may be required to regain pre-burn sagebrush densities (Harniss and Murray 1973, Tisdale and Hironaka 1981). This time interval may be even greater in areas with lower precipitation or higher potential evapotranspiration, such as eastern Washington (Griner 1939, Pyrah 1963, Call and Maser 1985, Drut 1994). For sagebrush habitat, “a full century may be required for a landscape to recover fully” (Rotenberry 1998, p. 268).

Over Utilization of the Species

A species must be listed if it "is endangered or threatened" because of "over utilization for commercial, recreational, scientific, or educational purposes." 50 C.F.R.§ 424.11(c)(2); 16 U.S.C. § 1533(a)(1)(B). The Secretary must conduct a "review of the species' status." 50 C.F.R.§§ 424.11(c). The determination to list the species must be made "solely on the basis of the best scientific and commercial data." 16 U.S.C. § 1533(b)(1)(A); 50 C.F.R.§ 424.11(b). The Secretary may not consider actual or "possible economic or other impacts" in the listing decision. 50 C.F.R.§ 424.11 (b).

Hunting

Sage grouse are a popular game bird. Sage grouse hunting is regulated in those states where it is allowed, and has not generally been cited as a factor in recent sage grouse declines (Autenrieth, et al. 1982; Blaisdell, et al. 1982; Johnsgard 1973, 1983). However, at least one former advocate of sage grouse hunting and a recognized expert on sage grouse, Dr. Clait Braun, now feels that hunting policy for this bird may have “negatively impacted” the species (Braun 1995d, p. 2). A thorough analysis, presented below, indicates that hunting is likely a significant factor in populations that are small, sparsely distributed, or concentrated in few areas (such as near riparian areas). * * *

Excessive hunting was likely a major factor causing early declines in sage grouse populations (Girard 1937, Batterson and Morse 1948). In historic times, sage grouse were considered a primary game species and hunting was so heavy that wagon loads of birds were carried out (Girard 1937, Rasmussen and Griner 1938, Patterson 1952c). However, analyses of habitat degradation by grazing had not been undertaken at that time, so it is unclear exactly how much of these early declines were due to hunting and how much was caused by habitat degradation. Indeed, the importance of habitat quality on wildlife populations was not widely appreciated until the efforts of Leopold (1933). Hunting mortality can depress populations well below carrying capacity (Gibson 1998).

Unfortunately, the states where hunting is allowed have powerful motivations to maintain hunting, not only in terms of direct financial benefit to their Game Programs, but also in terms of general economic benefit and prestige. It is possible that some states would fail to properly regulate hunting or other effects on the birds and their habitat. The very low population recruitment of these birds and the extraordinarily slow recovery of upland desert and shrub-steppe habitat areas also bode ill for population recovery. Even if all threats to the birds were immediately halted, many populations would likely go extinct, and others would not recover for decades, perhaps centuries. Scientists in state agencies are able to obtain some limited population data from hunting, and may favor hunting for this reason. However, the data collected are of low quality and are subject to various errors and biases.

Hunting may reduce sage grouse population size (Zunino 1987). However, low levels of hunting in large and dense sage grouse populations, particularly when restricted to birds that are not likely to breed, is probably not an important factor in reducing population sizes (Braun and Beck 1983, 1996). The problem is that the levels of harvest permitted are not proven to involve the take of merely "surplus" birds and thus are unlikely to constitute merely replacive mortality (Schroeder 2001a). Moreover, natural mortality of adults in summer and autumn is low (Schroeder 2001a, p. 7), and effects of hunting are likely to be difficult to document, even if significant (Schroeder 2001a, p. 7). Crawford and Lutz (1985) and Klebenow, et al. (1990) have particularly cautioned against heavy hunting harvest, and against harvest in years of poor productivity.

Hunting as Replacive Mortality

Of particular importance to the effects of hunting on sage grouse population viability is whether hunting truly replaces other mortality factors that would operate before the particular individual would have bred. The notion that hunting merely compensates for other mortality factors dates back at least to the time of Allen (1954, p. 131). Bergerud (1988c, section 16.3) suggested otherwise, particularly with respect to overwinter mortality. However, data for sage grouse are lacking. Crawford (1982a) noted that the notion that hunting constituted merely replacive mortality was based on studies of other gallinaceous birds, which are less susceptible to the effects of hunting than are sage grouse. For example, sage grouse congregate in wet areas and at water holes, and are easier to hunt than other upland game birds (Crawford 1982a). Hunting is known to constitute additive mortality for ptarmigan, a close relative of sage grouse (Braun 1995d, p. 3). If the sage grouse population subjected to hunting is large and hunting effort is low, then hunting mortality may be largely compensatory for other mortality factors (Crawford 1982a, p. 376). However, if populations are not large, if hunting effort is not low, or if hunting takes or causes disruption to breeding birds, then this threshold will be exceeded and hunting will not merely substitute for other forms of mortality. The fact that populations increased after hunting seasons were closed in Colorado and other states (discussed in the "Population Assessment" section), strongly argues against the notion that hunting merely substitutes for other forms of mortality.

More recent studies have also implicated hunting as a significant threat to sage grouse. In a long term study in Nevada, Klebenow, et al. (1990) found that during a time of population increase, grouse populations on unhunted areas increased by about 7 times the amount on hunted areas (Drut 1994, p. 19). Johnson and Braun (1999) used matrix projection models to incorporate age structure in assessing the impacts of hunting on sage grouse populations. Although not a full viability analysis (for example, the study did not include the effects of genetic or environmental

stochasticity), their results did show that hunting should be allowed only if juvenile and adult survivorship are sufficiently high that survival rates do not limit population increase, because hunting mortality is probably additive only above some threshold level (Johnson and Braun 1999). But, it is precisely juvenile survivorship that is usually cited as the bottleneck in declining sage grouse populations. Hunting typically takes mostly naïve, juvenile birds and therefore hunting is highly unlikely to constitute mortality that merely replaces other mortality factors. Hunting also tends to reduce population productivity because "a critical part of the population, adult females, usually constitutes a large proportion of the kill" (Crawford and Swanson 1999, p. 8). Moreover, hunting differentially affects females (Connelly, et al. 2000a, 2000b).

If hunting is allowed, area restrictions must be adjusted seasonally and yearly. In Wyoming, significant take of successfully reproducing hens occurred because hens concentrated in riparian areas late in the season, exposing them to hunters (Christiansen 2000, p. 12). Such concentration in riparian areas will occur earlier in the season in years with low moisture. Moreover, vigilant enforcement will be needed to ensure that hunters stay out of closed areas – such violations are common.

The Service will need to be extremely cautious in evaluating which areas of sage grouse range can be opened to hunting after the bird is listed. Hunting is known to exacerbate Allee effects and increase extinction risk (see Allee Effects section, and Dennis 1989). Once habitat is restored and population productivity is high, quite large hunting takes should be supportable – perhaps even in the range of those related in early historical accounts elsewhere in this review. Real world data, and thorough analysis should be required before hunting is allowed – hunting should be halted until more is done to justify it than inherent biases or hopeful guesses.

Surprisingly, nearly all states allow hunting of sage grouse, even those where populations are declining rapidly and have reached extremely low levels (e.g. Utah). There are no data or analyses showing that a huntable surplus exists in any sage grouse; instead, management agencies have merely assumed that hunting will not harm population dynamics. This suggests mis-management of the wildlife resource because of political pressure within the states. If true, then the states have violated the public trust and the wildlife trust.

Poaching

Poaching is the intentional taking of birds out of season or the intentional taking of more birds than are allowed by hunting regulations. Importantly, poaching levels are not measured by the techniques used by state wildlife agencies to monitor hunting levels. Thus, few reliable estimates of the loss of birds to poaching are available. However, in Colorado, poaching has occurred in all months of the year, and is greatest in winter and in big game season (Oct. and Nov.) when more hunters are afield and the birds are concentrated (GBCP 1997, p. 48; DCCP 1998, p. 27). Roads and the use of ORVs greatly increase the level of poaching.

Incidental Take from Hunting other Species

Inadvertent killing of sage grouse by hunters looking for other birds can be a significant problem for small populations. Open seasons for other upland game birds such as chukar, pheasant, quail, and other grouse species will expose sage grouse to mortality when the open hunting areas are within the range of sage grouse. Sage grouse may also be misidentified and shot by hunters of other birds such as chukar and other partridges, pheasant, grouse and quail (YTC CA 1994). Some degree of incidental killing of sage grouse is known to occur from the hunting of blue grouse in Colorado (Toolen 1999b).

Hunting of other birds in an area inhabited by sage grouse may also disturb sage grouse even if they are not shot. Moreover, open seasons for other birds may afford an alibi for poachers or otherwise operate to conceal or obscure their operations.

Falconry

Sage grouse are a preferred prey species for many types of falconry. The extent of direct take by falconers is not known, but Braun (2000g) estimated it as fewer than 500 birds per year across the entire range of the bird. Falconry can also act as a disturbance to sage grouse and this can be a greater threat than direct killing of the bird (Braun 2000g). Falconry should not be allowed when sage grouse are winter stressed, on or near leks, or engaged in other breeding activities such as nesting (Braun 2000g). However, there are some falconers who fly their falcons at precisely those times, thus regulation is needed. The state of Colorado has such regulations (with the support of falconers), but most states do not. Currently, falconers "do not have a bag limit," and sometimes "take 50 to 60 birds a YEAR!" (Deibert 1999d, emphasis in original). The falconers "like coming to Wyoming because of the lack of restrictions" (Deibert 1999d). The Service should carefully evaluate this threat, and actively seek further information surfaces during the listing process. Afterwards, carefully controlled falconry – like other carefully restricted hunting – is a good candidate for an incidental take permit.

Bird Watching and Recreational Use

The only direct recreational use of sage grouse at present is viewing, particularly of lekking birds. Nonconsumptive uses, such as bird watching, are not always benign. Humans could disrupt lekking activities and hence mating if they – or their domestic pets – approach leks too closely. The same disruptions can occur near nest sites, but the implications could be worse, as hens have already invested considerable nutrient stores into egg production, and inadequate time for locating another nest site and relaying may exist in that season. Disturbance at a lek can reduce mating opportunities and cause decreased production (Call 1979) or even abandonment of the lek. Sage grouse flush more easily at leks subject to extensive human viewing (Braun 1987a). If humans approach a lek on foot, birds may avoid the lek for the rest of the day (Call 1979). Quiet observation from enclosed vehicles does not appear to disrupt lekking activities. However, tourists often leave their vehicles to get a closer look at the birds. State wildlife agencies appear to follow an informal policy of having a "sacrifice" lek near an all weather road to which the inquiring public is directed for viewing. Other lek locations are generally not revealed to the public. * * * Disruption of nesting or lekking activities are most likely near suburban areas, areas populated by ranchettes, and popular recreation areas. Roads greatly increase disturbance in any area. For example, disturbance in the Gunnison Basin is a concern (GBCP 1997, p. 49-50) and disturbance has occurred at the Foster Flats lek near Frenchglen, Oregon (Armstrong 1988), yet the BLM has not posted a sign warning tourists to stay in their vehicles.

Recreational activities can also affect sage grouse indirectly. One example is the near extirpation of sage grouse at Strawberry Valley, UT (discussed in the Predation section). There, the infrastructure for concentrated recreational use caused accumulations of trash, greater road use led to increased road kill, and stocking of fish led to a proliferation of fish entrails – all attracted red fox. The fox then disturbed and preyed on sage grouse nests leading to almost complete reproductive failure of the sage grouse population (Bambrough, et al. 2000a).

Agricultural Operations

Mowing or plowing can directly kill sage grouse, especially young birds (DCCP 1998, p. 28). "Sagebrush beating throughout entire pastures has eliminated sage grouse use in those

pastures in the short term" (Braun 1997b). These practices also alter habitats and make them unsuitable for the birds. Pesticide and other agricultural impacts are discussed elsewhere in this review.

Road Kill of Sage Grouse

Road kill of sage grouse has not been estimated; however, death of other animals from motor vehicle collisions is an important mortality factor. There is no reason to suppose that this is not important in sage grouse, especially when the number of roads fragmenting sage grouse habitat and the preference of the birds to walk is considered. Roads are a major threat both directly and in terms of habitat fragmentation and are discussed elsewhere in this review.

Scientific and Educational Purposes

Concerns have been expressed regarding the effects of scientific study on the birds, particularly with respect to lekking activities and nesting (SMBCP 1998, p. 24). Study of the birds often involves capture and marking of the birds, and may involve fitting the birds with radio transmitters. Radio transmitters are known to increase the energetic burden on passerines by about 10% (Caccamise and Hedin 1985), and likely do so to a lesser extent for sage grouse. Capture techniques include spotlighting, hand capture, use of long handled nets, and walk-in traps. All techniques involve some stress to the birds, and repeated disturbance of lekking birds causes them to become more wary and flush more easily (GBCP 1997, p. 50). Because sage grouse have extremely strong site tenacity, especially for lekking areas, the fact that they return to a lek after capture and marking (SMBCP 1998, p. 24) does not mean that they have not been severely stressed. It may be possible to examine blood corticosteroid levels to determine the degree of stress from capture and marking operations. Certainly, such methods will be needed to recover populations.

Disease and Parasitism

A species must be listed if it "is endangered or threatened" because of "disease or predation." 50 C.F.R.§ 424.11(c)(3); 16 U.S.C. § 1533(a)(1)(C). The Secretary must conduct a "review of the species' status." 50 C.F.R.§ 424.11(c). The determination to list the species must be made "solely on the basis of the best scientific and commercial data." 16 U.S.C. § 1533(b)(1)(A); 50 C.F.R.§ 424.11(b). The Secretary may not consider actual or "possible economic or other impacts" in the listing decision. 50 C.F.R.§ 424.11 (b).

Girard (1937) and Batterson and Morse (1948) suggested that disease caused local declines in sage grouse populations. Stoddard and Kay ascribed a marked drop in 1932 in populations of birds in Utah to parasites (Lords 1951). Other scientists suggesting that disease and parasitism adversely affected populations include Grover (1944), and Honess and Post (1968). Thorne (1969) and Thorne, et al. (1982) summarized a number of diseases and parasites that threaten sage grouse. Disease outbreaks are commonly associated with drying water holes causing high bird densities (Wallestad 1975a). Death was generally caused by coccidiosis, which is the most prevalent disease affecting sage grouse (F. Simon 1940, Thorne 1969). Coccidiosis is episodic, not continuously epidemic in sage grouse (Honess 1947). Coccidiosis is transmitted by the protists *Eimera angusta* and *E. centrocerci* in contaminated water, and is more prevalent near drying water holes where the birds are concentrated (F. Simon 1940). Coccidiosis epidemics occurred in Montana during July and August when water was limited (Wallestad 1975a) and during drought in Wyoming (Scott 1942). Symptoms of coccidiosis include weakness, inability to fly, emaciation, and diarrhea leading to death (Autenrieth 1986). Maggots and beetles, which

feed on sage grouse droppings and are then consumed by sage grouse, are common disease vectors (Grover 1944). *Plasmodium* and several other hematozoa are known to occur in sage grouse, including those in Colorado (Stabler, et al. 1966, 1974, 1977, 1981).

Crowding of birds, and consequent increases in disease spread, will also likely result from loss of habitat and from fragmentation (Meffe and Carroll 1997, p. 290). Such crowding will further expose birds to transmission of disease vectors, increasing the risk (Friend 1995, p. 404; YTC CA 1994). Crowding also harms habitat quality by fecal contamination and damage to vegetation (Friend 1995, p. 404). Furthermore, birds in a weakened physiological state or under behavioral stress are more susceptible to diseases and parasites. Gabrielson and Jewett (1940, p. 218) suggested that the near extirpation of the Oregon population on Hart Mountain was because of disease.

Numerous parasites are identified with sage grouse and include tapeworms (*Raillietina spp.),* protozoans (such as *Eimeria spp.),* and ticks (*Haemaphyalis spp*.). Other diseases affecting sage grouse include salmonellosis, botulism or limberneck, aspergillosis, avian tuberculosis and pasturellosis (Thorne 1969). As early as 1954, Edminster noted that at least 8 species of endoparasites and 4 species of ectoparasites were known to infect sage grouse (Edminster 1954, p. 126). Two parasites in the genus *Eimeria* were known to cause epizootics (id.).

Disease outbreaks need not kill or even cause severe physiological effects in individual birds to reduce population viability. For example, even mild malaria outbreaks can affect reproduction because male sage grouse infected with malaria attend leks significantly less frequently during the mating season (Boyce 1990). Females appear to avoid infected males during mating (Johnson and Boyce 1991; Spurrier 1989; Spurrier, et al. 1991). Thus, the sexual selection advantages of the lekking habit can easily become disrupted by even mild disease effects on individuals. As sage grouse populations become smaller and more isolated, disease threat will increase.

Exotic bird species such as quail and pheasants are often introduced for hunting. Such introductions carry substantial risk of disease and parasite spread to sage grouse. For example, the Colo. Div. of Wildlife "allows releases of exotic/introduced species which are known to be carriers of parasites/diseases harmful to sage grouse into habitats where sage grouse live" (Braun 1999a, p. 1). Moreover, introductions of sage grouse to other parts of the range can introduce potentially lethal diseases to existing birds (Davidson and Nettles 1992).

Of all the threats to sage grouse, disease and parasitism are among the most poorly studied. Disease can have severe effects on population persistence: in a 1941-42 study near Craig, Colo., disease accounted for 68% of all mortality (Sage Grouse Meeting Notes 1997, p. 8). The second greatest mortality source was unknown (14%), followed by a suite of direct anthropogenic causes (highway kill, telephone wire, and mower), which totaled 9%, equaling predation (id.).

Disease interacts with other threats – for example, small population size caused reduced variation in the major histocompatibility complex in cheetahs, and 50-60% mortality was documented in only 3 years from corona virus (O'Brien and Evermann 1988). Enhanced susceptibility to infectious disease or parasites is likely to be a common result from small population size.

Other threats, such as livestock operations, agriculture and development, are known to have extremely negative effects on sage grouse, and are novel threats unlike disease which grouse have faced for millions of years. Nonetheless, anthropogenic effects such as introductions of pheasants and other exotics, immunosuppression caused by chemical exposures, and crowding

may be causing exacerbated disease effects on sage grouse.

Inadequacy of Existing Regulatory Mechanisms

A species must be listed if it "is endangered or threatened" because of "the inadequacy of existing regulatory mechanisms." 50 C.F.R.§ 424.11(c)(4); 16 U.S.C. § 1533(a)(1)(D). The Secretary must conduct a "review of the species' status." 50 C.F.R. § 424.11(c). The determination to list the species must be made "solely on the basis of the best scientific and commercial data." 16 U.S.C. § 1533(b)(1)(A); 50 C.F.R.§ 424.11(b). The Secretary may not consider actual or "possible economic or other impacts" in the listing decision. 50 C.F.R. § 424.11 (b).

Sage grouse are or were game species in every state within their range. That a game species could be so reduced in numbers and habitat as to be endangered shows that something is terribly wrong with management. In May and June 2000, biologists from several states met together with USFS, BLM, and US FWS representatives to form a "Sage Grouse Framework Team" and discuss sage grouse issues. The notes from this meeting are instructive regarding the mis-management of sage grouse. Team members considered whether to conduct a "Conservation Assessment" on sage grouse, but decided that "disadvantages" of such an assessment would be that it could "give [the] listing process a 'leg up'" and could "become the basis for other listing petitions" (Sage Grouse Framework Team 2000, p. 4-5). Thus, public employees and biologists have affirmatively avoided searching for the facts on sage grouse in order to avoid a potential listing under the ESA. In evaluating petitions to list sage grouse, the Service must consider these biases against federal law, and against the basic preconditions of scientific inquiry, as threats to the species from the states, from the federal land management agencies, and from within the Service itself.

Just as fragmentation has affected the populations and habitat of the sage grouse, the existing management and regulation of the bird and its habitat is fragmented among a diverse assortment of private, state and federal entities. The best habitat is located on private lands or has been converted into housing, agricultural fields, towns, and mini-ranchettes. In the Interior Columbia Basin, only about half of the habitat is on federal lands (Raphael, et al. 2000, p. TER 69). Most of the upland habitat is on BLM lands, but management of the bird itself is under state jurisdiction. Although the states control hunting, they do not have authority over the land base constituting the bird's habitat. Most states lack state Endangered Species Acts. [*Most*] state endangered species acts that do exist are toothless and do not constitute regulatory mechanisms. State wildlife agencies have often been remiss in failing to comment on NEPA documentation for actions on federal lands affecting sage grouse. When they have commented, federal agencies have affirmatively disregarded or deliberately misconstrued state agency comments (see comments re: the Oregon Dept. Fish and Wildlife elsewhere in this review).

Thus, the management of the species is as fragmented as is the range of the bird, if not more so. Sage grouse management is replete with examples of poor communication and competition among different agencies, bureaucratic inertia, lack of landscape management, and other ills that Grumbine (1990b) has previously summarized and critiqued.

Only a listing under the ESA has the power to bring in all parties, all actions, and all land management agencies to discuss these threats and recover the species. Otherwise, the present fragmentation of management ("cumulative space effects," *sensu* Meffe and Carroll 1997, p. 380) will fail to conserve the species. Only a listing under the federal ESA can assure coordination of these diverse entities which each have some jurisdiction over sage grouse.

Existing regulatory mechanisms are virtually non-existent and existing management is inadequate to conserve the bird. Although sage grouse inhabit an environment subject to extraordinary variation, management plans lack the flexibility to adjust to such fluctuations. For example, the effects of drought on sage grouse populations can be severe (GBCP 1997, p. 45) and are compounded if land management practices remain unchanged during years with low soil moisture (GBCP 1997, p. 45). Despite this, there are no regulatory mechanisms or management plans that require the alteration of land management practices in drought years.

Besides the lack of an adequate regulatory framework, existing management within the range of the sage grouse is undesirable. The grasslands, shrublands and "deserts" that make up the range of this species "are poorly represented in United States reserves" (Cooperrider 1991, p. 46). Moreover, most protected lands in the United States were not established to conserve biodiversity (Noss and Cooperrider 1994, Graf 1990)…. Many species in this region are declining or endangered. As but one example, 16 bird species in the Columbia Plateau have "significant" recent or long-term declining population trends and others have been extirpated from parts of the region or the entire area (Altman and Holmes 2000, p. i).

In 1995, the state of Colorado and the US Dept. of the Interior entered into a memorandum of agreement regarding management of the many native species that are in trouble in Colorado (Colorado MOA 1995). In 1999, state entities (the Western Association of Fish and Wildlife Agencies), the BLM, USFS, and FWS drafted a range-wide Memorandum of Understanding (MOU) concerning sage grouse. This MOU was drafted to promote conservation planning, habitat management, and species management (Stiver 2000). The MOU is in no way a regulatory mechanism, and was drafted specifically to avoid any regulatory language. Minutes from the 1999 meeting of the Western Association of Fish and Wildlife Agencies (WAFWA), show that the BLM and USFS emphasized their "inability to agree to any language that was, or could be perceived as, decisional" (Farschon 1999). No on the ground actions have taken place, progress is slow, and so far, the only action has been meetings to develop a "resource toolbox" to help write conservation plans (Stiver 2000). * * * These Memoranda require no action other than cooperation and collaboration between state and federal agencies. * * *

Several states have formed local working groups to develop management plans for sage grouse (Hemker 2000). These working group plans are subject to all the inadequacies discussed elsewhere for the Colorado conservation plans, with the additional caveat that most other working groups have not even put together conservation plans yet. These plans are only advisory and voluntary, their reliance on consensus means that the lowest common denominator controls the process and result – not the welfare of the species that is purportedly to be conserved – and, to the extent that they are time consuming and defocus the efforts of agencies, they harm rather than help sage grouse.

The habitats inhabited by sage grouse are a little-loved landscape, and consequently, little protection has been established for this eco-region. Storms, et al. (1998) conducted a GAP analysis of the Columbia Plateau and Wyoming basin. This area covers most of the range of the sage grouse and nearly all of what has been termed the "core" states of Oregon, Idaho, and Wyoming. Less than 4% of this vast region has been protected with management focusing on biodiversity (Storms, et al. 1998). Worse, only 2.5% of the *Artemisia tridentata* land cover class is protected (Storms, et al. 1998, table 1).

Among the many other problems in management, existing management agencies are "too slow to respond with effective mitigation" when events call for it (Braun 1999a, p. 1). In particular, agencies are unwilling to adequately manage domestic livestock grazing and are

unwilling to reduce "elk/deer numbers" when necessary (Braun 1999a, p. 1). For decades, federal land management agencies improperly managed wildlife on the public's lands, relying on such "clichés" as "good range management is good wildlife management," which federal agency biologists have pointed out will not suffice (Maser and Thomas 1983, p. 2). Federal agency personnel have long been ruled by a mind set to convert "soil, sunshine, and moisture" into "livestock production" and prevent these resources from "being squandered in the production of sagebrush." (Astroth and Frischknecht 1984, p. 1 quoting Woodward). Personnel were exhorted to question how long they would "let this sort of thing continue" and to devote their efforts to converting these ecosystems of "undesirable plant species, particularly sagebrush" into "rangelands" that can "best contribute to livestock production" (Astroth and Frischknecht 1984, p. 1, 27). That Woodward voiced these sentiments in 1948 is perhaps excusable. That Astroth and Frischknecht voiced the same sentiments in 1984 is reprehensible – such avoidance of multiple use considerations is illegal. FLPMA and NFMA required multiple use of these lands long before Astroth and Frischknecht revealed their antipathy for wild ecosystems. Even when reference is made to relict vegetation areas that are ungrazed, agency personnel have been careful to note that "this does not mean that pristine condition is the management objective;" instead, any remaining pristine areas to serve "only as a guide" to what an area is capable of supporting (Blaisdell, et al. 1982, p. 12). Other federal agency biologists have noted that "it is time to concede that the production of livestock has more intense, widespread influence on wildlife than any technique applied by a wildlife biologist to enhance habitat" (Maser and Thomas 1983, p. 5).

On federal lands, specific statutes apply to various agencies that manage the public lands. Besides the ESA itself, only two relevant statutes extend across agency land boundaries: the National Environmental Policy Act and the Clean Water Act. * * * Multiple-use land management agencies typically have organic acts relating to how they manage the public's land that they are allowed to administer. For the BLM, the Federal Lands Policy and Management Act (FLPMA) applies, and for the Forest Service, the National Forest Management Act (NFMA) applies.

The Service cannot reasonably rely on NEPA, FLPMA, NFMA and other laws to conserve the species because these laws are not adhered to by federal agencies. Just as is the case with the Service, hundreds – if not thousands – of federal judges have ruled that the BLM, the Forest Service and other land management agencies have broken the nation's environmental laws. In many other cases, plaintiffs have not been successful in getting courts to reach the merits of a case because of a plethora of procedural, deferential, and jurisdictional hurdles that shield federal agencies from judicial review. The erection of doctrines barring or hampering citizens from court contributes to the inadequacy of existing regulatory mechanisms. The Service must consider the track record of agency protections and the ability of citizens to review agency action when determining the adequacy of regulatory mechanisms. * * *

Other agencies with sage grouse populations or habitat have no particular mandate to protect the species. These agencies include various branches of the Dept. of Defense, the Bureau of Reclamation, and others. They are governed by no substantive statutes requiring wildlife protection. Thus, the protection of the ESA is especially critical on these lands. Some agencies and entities have acted not to preserve and restore sage grouse so much as to prevent a petition under the ESA. The numerous conservation plans are examples of such efforts. Another, particularly troubling, example is an offer by the head of the National Fish and Wildlife Foundation (which receives public tax money) to help the FWS "forestall[]" a petition to list

sage grouse (Eno 1998).

National Environmental Policy Act (NEPA)

The National Environmental Policy Act of 1969 (NEPA, 42 U.S.C. § 4321 – et seq., Pub. Law No. 91-190) is merely a procedural act and requires no substantive outcome. Vermont Yankee Nuclear Power Corp. v. NRDC, 435 U.S. 519 (1978). It thus does not constitute a regulatory mechanism. Moreover, because substantial declines in sage grouse populations have occurred since NEPA was first passed in 1969 it has clearly been inadequate to conserve the species. Congress recognized the inadequacy of existing statutes when it passed the Endangered Species Act in 1973.

National Forest Management Act (NFMA)

The National Forest Management Act (NFMA, 16 U.S.C. § 1600 – et. seq., Pub. Law No. 94-588, 90 Stat. 2949, as amended) governs actions of the US Forest Service on the public lands it administers. One NFMA provision requires that the Forest Service "provide for diversity of plant and animal communities," 16 U.S.C. § 1604(g)(3)(B). To carry out its statutory duty, the Forest Service promulgated an administrative regulation that requires maintenance of the viability of vertebrate species on its lands (36 C.F.R.§ 219.19). The Forest Service has not maintained the viability of vertebrate species, including the spotted owl, nor has the Forest Service maintained biodiversity on the lands it manages. For example, several botanists were forced to sue the agency because forest plans did not rely on well-understood landscape ecology concepts (Mlot 1992). As late as the 1990s, scientists noted that the Forest Service "abysmally misunderstood, misconstrued, or missed altogether" vast amounts of information on the effects of fragmentation from the 1970s and 1980s (Mlot 1992). Although this information had been in the scientific literature for "20 to 25 years" before forest plans came out, and was "widely accepted scientifically," the plans did not incorporate that information. A Justice Dept. attorney, who represented the Forest Service in the ensuing litigation, stated that that was "how government works. They're going to be behind the curve" (Mlot 1992). Unlike the FWS, the Forest Service is not required to use the best available science, leading to mis-management of rare species. Moreover, the viability requirement has been weakened by several court decisions that have given overweening deference to the USFS even when the top population biologists in the world disagreed (Inland Empire Public Lands Council v. United States Forest Service, 88 F.3d 754, 760 (9th Cir. 1996)), and have allowed USFS to substitute mere habitat quantity for population viability (Sierra Club v. Marita, 46 F.3d 606, 619-20 (7th Cir. 1995)). * * * Ultimately, there is simply not sufficient habitat on USFS lands to preserve the sage grouse, no matter how well USFS acted as a steward.

Federal Lands Policy and Management Act (FLPMA)

The Federal Lands Policy and Management Act of 1976 (FLPMA, 43 U.S.C. 1701- et seq., Pub. Law No. 90-2743) governs BLM actions. Unlike NFMA, FLPMA contains no requirement to preserve the viability of any species, and has largely evolved into merely a usage planning act. There is a non-discretionary duty to ensure that the Secretary of the Interior shall prevent, by regulation or otherwise, unnecessary or undue degradation of the public lands. 43 U.S.C. § 1732; Sierra Club v. Hodel, 848 F.2d 1068 (10th Cir. 1988). However, this provision is difficult to enforce, and common law doctrines of judicial deference to administrative agencies allow the BLM itself to determine whether degradation is occurring and whether any degradation is necessary – for example, to fulfill the desire of the agency to allow cattle grazing, mining or oil and gas development. * * *

BLM is required to develop land use plans for the lands it manages. 43 U.S.C. § 1712(a). However, the agency has been given great latitude to manage for whatever goals it wishes, and these goals have primarily favored extractive economic uses over preservation of wildlife (Nolen 1996).

Other Federal Laws

The Public Rangelands Improvement Act (PIRA), 43 U.S.C. §§ 1901-1908, Pub. Law No. 94-514, recognized the degradation of grasslands, shrublands and other arid lands in the U.S. and required a national inventory of rangelands. However, PIRA requires no particular conservation efforts by any agency.

The Taylor Grazing Act, 43 U.S.C. §§ 315-316, June 28, 1934, as amended 1936, 1938, 1939, 1942, 1947, 1948, 1954 and 1976, was the first federal attempt to regulate grazing on the public's lands. The Taylor Grazing Act established grazing districts and permits for grazing, but as one legal scholar, George Coggins, noted "it causes far more problems than it solves." The vast declines in sage grouse have occurred under the operation of the Taylor Grazing Act.

The Sikes Act, 16 U.S.C. §§ 670a-670o, September 15, 1960 (74 Stat. 1052, Public Law 86-797), as amended 1968, 1974, 1978, 1982, 1986, 1988 and 1989) requires the development of conservation plans for wildlife on all public lands. BLM has not developed a comprehensive plan for sage grouse, and the species has declined under the operation of the Sikes Act.

Enforcement

Multiple use land management agencies, such as the BLM and Forest Service, may be structurally incapable of adequately managing species at risk. One important reason for this arises from the agency mission to provide for extractive commercial interests such as grazing and mining, as well as recreational interests such as off-road vehicle (ORV) use that have strong support from large industrial manufacturers. Such uses are often at odds with wildlife protection, and agencies often fall prey to the familiar phenomenon of administrative "capture" by the interests it is supposed to be regulating: "controls directed by a public regulator on the private sector…[but] in practice, the direction of interference or control is opposite … regulatory outputs tend to correspond to the interests of the regulated party…." (Mantic 1980, p. 14). This is the familiar problem of capture of a regulatory agency by the interests it is supposed to regulate (Davis and Pierce 1994), a phenomenon first systematically analyzed by Nobel Prize winning economist George Stigler.

Management on Bureau of Land Management (BLM) Lands

The Federal Land Policy and Management Act (FLPMA), 43 U.S.C. § 1701 – et seq. controls the activities of the Bureau of Land Management (BLM) in managing public lands under its purview. Notably, FLPMA does not contain a provision requiring that the viability of wildlife populations be protected (cf. NFMA). Sage grouse have declined significantly since FLPMA was enacted in 1976, thus it is obviously inadequate to protect the species. A former biologist with the Idaho Dept. of Fish and Game was not afraid to speak out regarding BLM management:

> It would be too optimistic to presume that BLM and the Forest Service will provide sufficient sage grouse habitat. [FLPMA] has done little but produce an array of alternatives for habitat-alteration proposals. Selecting the best alternative for wildlife is so rare that it is almost nonexistent. (Autenrieth 1986, p. 775).

Autenrieth also spoke about the cause of this mis-management:

> As long as livestock men dictate BLM and Forest Service policy and as long as

> the people of the United States subsidize ranchers … sage grouse and other wildlife will continue to decline. (Autenrieth 1986, p. 774).

Autenrieth's damning comments are as true today as 15 years ago. All that has changed is that sage grouse populations have declined drastically since his comments were made. The misadministration detailed here by BLM may result from the capture of the agency by extractive interests, as charged by scholars on public administration (Culhane 1981), legal commentators (Greeno 1990), and the agency's own employees (PEER 1994).

BLM is aware that sage grouse have declined 33% in just the last 30 years (BLM 2000f), and that virtually all actions undertaken by the agency present a "high" degree of risk to sage grouse populations (BLM, undated; BLM 2000f). Moreover, the agency acknowledges that sage grouse "have experienced significant population declines" and "widespread loss and degradation of sagebrush habitat across the West" (BLM 2000g). High officials within BLM are aware that "both habitat and populations have been reduced dramatically," and that sage grouse are now "at the lowest population levels ever recorded" (Daly 2001). BLM lists agricultural conversion, overgrazing by domestic livestock, invasion of exotic plants, water diversions, expansion of juniper and pinyon pine woodlands, fragmentation, and large, hot burning wildfires as threats (BLM 2000g). Fragmentation is a "problem, even for higher quality habitats" (BLM 2000g). But BLM has been remiss in taking conservation actions, or even halting actions that harm sage grouse. [*The author and*] petitioners have reviewed nearly one thousand BLM documents (254 of which are cited in the accompanying Bibliography) and not one provides adequate monitoring, evaluation, or consideration for sage grouse. Moreover, BLM states that it does not even ***know*** what the effects of grazing are on removal of grasses and shrubs, or what the effects of removal of grasses and forbs are on sage grouse (Hecker 2000). Yet, specific management recommendations for sage grouse are readily available (WSSGTC 1999, and prev. reports). Interestly, BLM has been "managing" grazing for over a century and has been managing sage grouse to extinction for decades. Braun, et al. (1994b) note that federal land management agencies have been "reluctant to alter management practices" when that would "conflict with commodity uses, such as livestock grazing." * * *

Moreover, BLM admits that sage grouse, along with numerous other grassland and shrubland species, are "losing ground" on the lands it manages (BLM 1992, p. 5). Apparently, BLM considers its duties to conserve sage grouse troublesome. * * * Numerous internal memoranda discuss the "problem" of sage grouse and ways to prevent a listing. One employee noted that his "brain wrestled all night with insoluble, nonsensical sage grouse problems of its own manufacture. Awoke exhausted" (Stamm 2000). Yet there is no need to manufacture nonsensical problems – BLM has created plenty of problems for, and threats to, sage grouse on the public lands it has mismanaged. Some of these problems may indeed be insoluble – cheatgrass expansion is one – but most are easily soluble by limiting both development and livestock grazing.

Riparian habitats are critical to sage grouse as well as to other fish and wildlife species. However, BLM concedes that broad recovery of riparian areas will not occur under current grazing management (USDI 1994a, Draft EIS, p. 3-32). The agency continues to destroy riparian habitats with water developments (Rich 1999).

To a large extent, these declines and the mis-management of sage grouse habitat by BLM have occurred while the "Western sage grouse" was a Candidate species. Yet, BLM's policy is to conserve Candidate species (BLM Manual 6840.06C) and to alter all proposed actions to prevent further declines and the need for listing of Candidate species. This is an internal policy, and not a

regulatory mechanism that the public can enforce, at least over much of the range of sage grouse. See Western Radio Services Co., Inc. v. Espy, 79 F.3d 896, 907 (9th Cir. 1996) cert. denied sub nom. Western Radio Services Co., Inc. v. Glickman, 117 S.Ct. 80, 136 L.Ed.2d 38, (1996). Because "enforcement of the law is what really counts," Evans v. Jeff D., 475 U.S. 717, 746 (1986) (J. Brennan, dissenting), the BLM has been able to destroy vast areas of sage grouse habitat without restraint and has made a mockery of its policy to conserve Candidate species. One need only compare the widespread declines in sage grouse on BLM administered lands with the length of time the species has been listed as a Candidate to see that this policy has in no way operated to conserve sage grouse and is no regulatory mechanism.

Not only has it not adequately protected sage grouse, the BLM has actively destroyed vast areas of habitat by conversion to agro-industrial livestock operations, for strip mining of coal resources, and has fragmented habitat with roads, powerlines, fences, oil and gas installations, and other industrial developments. The Western Association of Fish and Wildlife Agencies "has continually expressed concern about the management of western rangelands, most of which are administered by the Bureau of Land Management" (Braun 1987a). A common claim made by BLM employees is that sagebrush is "over-mature" or "decadent" and must be removed or degraded. * * * [*However,*] BLM has not established standards or definitions as to what constitutes "over-mature" or "decadent" sagebrush. These subjective impressions by BLM personnel appear to merely be window dressing to justify alteration of native ecosystems to provide forage for domestic livestock.

BLM is to designate certain areas as Areas of Critical Environmental Concern (ACEC) pursuant to 43 C.F.R.§ 1601.0-5, if special management is required to protect natural resources. However, only about 200 such areas have been designated (Williams and Campbell 1988). The areas designated have typically been very small and often limited to wilderness areas (Cooperrider 1991). Of course, wilderness areas are already protected, so designation of an ACEC within a wilderness area carries little political risk to the bureaucracy. Commentators have criticized BLM for its failure to designate ACECs (Campbell and Wald 1989).

There appears to be economic distortions in the management of funds by the BLM. The US Government Accounting Office found that BLM directs only 3% of its total appropriation to wildlife habitat management, and instead directs 34% of its budget to its three consumptive programs: range, timber, and energy and minerals (GAO 1988b). Such lack of funding constitutes additional evidence regarding the inadequacy of existing management programs.

The Bureau of Land Management has seriously mis-managed the public's lands: even when using the BLM's own definitions and rating system, over 68% of its lands are in "Unsatisfactory" condition (Wald and Alberswerth 1989, GAO 1991a). BLM mismanagement has been the subject of a large number of GAO reports, all of them critical. As Donahue points out, the mere titles of these reports constitute an indictment. Titles of GAO reports contain such excerpts as "more emphasis needed on declining and overstocked allotments," "widespread improvement will be needed," "monitoring has fallen short of requirements," and "database incomplete and inaccurate" (Donahue 1999, p. 56). These GAO reports are listed in the Bibliography of this petition and incorporated herein by reference. * * *

Some BLM offices have recognized that their management must change. For example, the Idaho State Office proposes to build exclosures around springs and wet meadow areas (Foster and Olendorff 1999). However, these exclosure will serve as raptor perches, creating a kill zone for sage grouse inside the area that was intended to be protected. Only removal of livestock from large areas will suffice to restore sage grouse. The same BLM memorandum suggests increasing

the use of herbicides to control noxious weeds, and notes the inconsistent and fragmented nature of management and GIS implementation (Foster and Olendorff 1999).

BLM has requested large amounts of funding to implement what it calls the Great Basin Restoration Initiative, a huge and expensive ($25 million per year) effort to reverse cheatgrass invasion and reduce fire frequencies (Tweit 2000, p. 70). If implemented, this effort may not improve sage grouse habitat, and could further damage habitat because it emphasizes the planting of non-native grasses on vast expanses of public land (Tweit 2000, p. 70). The Great Basin Restoration Initiative appears to be an effort to restore livestock forage only, not native biodiversity. Currently, BLM is allowed to use over 21 herbicides on western lands (Shaw and Monsen 2000, p. 66). BLM herbicide use is governed by an EIS pursuant to NEPA (BLM 1991b). The Great Basin Restoration Initiative may modify that EIS to allow even more herbicide use on public lands. Although herbicides can reduce cheatgrass invasion rates, they also risk numerous reproductive effects on sage grouse, other wildlife, and humans, and are likely to damage forbs and grasses needed by sage grouse. Moreover, BLM employees, as well as the public, doubt whether BLM can properly manage for wildlife on the public's lands without being forced to do so by an outside entity. As one BLM biologist put it "the only thing that gets under a manager is T&E" (name withheld by request).

BLM does not adequately monitor, plan for, or measure sage grouse populations or habitat parameters needed to restore the species. For example, state wildlife biologists have noted that "composition and density goals in BLM range plans are not expressed in terms compatible with the sage grouse guidelines" (Grandison and Welch 1987).

There has been no significant improvement in BLM lands – which form most of the range of the sage grouse – since 1950 (Donahue 1999, p. 50, 61-64). Congress noted these "deteriorat[ions] in quality" over "substantial portions" of BLM lands when it enacted FLPMA (43 U.S.C. § 1751(b)(1), codifying section 401(b)(1) of FLPMA). But, in the ensuing years, rangeland conditions have gotten worse. BLM admits that 43% of the uplands it administers are non-functioning or are functioning at risk (USDI 1994a, Draft EIS, p. 26). BLM admits that current grazing management is unlikely to improve these BLM lands (USDI 1994a), yet BLM has implemented few if any changes in grazing on lands within the range of the sage grouse. BLM also does not adequately enforce its own regulations against grazing trespass (Donahue 1999, p. 65). Thus, livestock grazing cannot be allowed even near sage grouse habitat much less inside it, if the species is to be conserved. * * *

BLM has promulgated a series of vague and elastic guidelines for management of its lands," which it terms "Standards of Rangeland Health" (BLM 1997a). Despite the acknowledgement that assessment and monitoring are "critical," little such monitoring [*is*] done. Worse, the "standards" are not objective or measurable standards at all, but instead are unverifiable narrative descriptions and subjective impressions, which are wholly unstandardized. Even these reports are rarely completed for the vast majority of the sagebrush ecosystems under BLM's purview. These guidelines appear to have been drawn to give BLM maximum bureaucratic *lebensraum*, rather than to improve the management of the public's lands. Meanwhile, BLM continues seedings as a "land treatment option," continues to "control" brush, and continues to build fences and water developments at a "steady pace" (Rich 1999).

* * *

BLM Management in California

BLM is updating its management plans in California. Recently, BLM appears to have

reduced grazing on allotments where sage grouse still exist during the current drought (Blankenship 2001b). But, BLM has only reduced grazing near leks (Halford 2001b). Grazing must be reduced in all areas used for foraging and nesting as well, and must be reduced over areas of unoccupied habitat to allow population increases. Moreover, grazing must be reduced during non-drought times to allow vegetation to increase when moisture is available. Neither USFS or LADWP has comparable standards for grazing management (Halford 2001b).

In 1991, BLM proceeded with actions that it knew would "moderately to heavily impact[]" the Long Valley sage grouse population even though it knew that sage grouse declines were widespread and severe (Bishop Resource Area, BLM 1991, p. 4-10). The California BLM state office recently completed an EIS for rangeland health, but this document gives virtually no consideration to the needs of sage grouse and mentions them only in a few brief sentences under other upland game species (California State Office, BLM 1998, p. 3-50). By BLM's own admission, most rangelands are not improving at all (California State Office, BLM 1998, appendix 7, table 5).

BLM Management in Colorado

BLM's treatment of Fruitland Mesa, an area of public land under its administration in Colorado, is well documented, and worthy of attention as an example of BLM management of sage grouse habitat. In 1983, the BLM conducted a "plow and seed" operation "for livestock grazing" (Anonymous 1995a) and to "increase livestock forage (Uncompahgre Basin Resource Area 1994, p. 4), thereby destroying large amounts of sage grouse habitat. Immediately thereafter, lek counts declined by 50% (Anonymous 1995b). Searchers were unable to see any sage grouse in the plow and seed areas (Ferguson 1986, p. 2) or even near the plow and seed areas (Bray 1981, p. 2). By 1994, BLM finally recognized that sage grouse had "declined sharply" in this "livestock emphasis area" and proposed to improve sage grouse habitat (Uncompahgre Basin Resource Area 1994; p. 5, p. 3). Unfortunately, BLM only proposed to enhance historic lek areas by brush beating, and completely ignored the need for winter habitat, nesting habitat, food sources, brooding habitat, and other components of sage grouse needs. The BLM assumed that since the use by cattle would be past "the peak time for the sage grouse breeding season" that "no direct conflicts" would ensue (Uncompahgre Basin Resource Area 1994, p. 3). Of course, not all sage grouse are finished breeding by the peak of the season, so substantial direct impacts would occur to late nesting birds, including any that had to renest because of predation or disturbance. Worse, BLM completely neglected the high likelihood of indirect impacts by cattle grazing: removal of vegetation, erosion, and others detailed elsewhere in this review. Declines continued, and by 1996, BLM planned to interseed grasses and forbs into the areas that had been plowed and seeded with non-native species for cattle (Uncompahgre Basin Resource Area 1996). Cattle grazing was now recognized as such a severe problem that BLM proposed to spend huge amounts of money to erect and maintain electric fences in this remote location to keep cattle away from sage grouse areas. In this document, the BLM also reveals its "ultimate mission" – to "prevent wildlife species from being listed under the ESA" (Uncompahgre Basin Resource Area 1996). BLM personnel regard the potential listing of Gunnison sage grouse under the ESA as a "train wreck" (Stiles 1996). Nonetheless, BLM agrees that the bird exists in very "low numbers," has a "limited range," and has declined range wide for over 40 years (Stiles 1996).

* * *

Fire is a serious threat to sage grouse. For example, over 20% of the fire starts in the

Uncompahgre area of Colorado are from human causes and fire has burned nearly 22,000 acres since 1989 (Uncompahgre Field Office Fire Management Plan 1999). Many fires are set intentionally by BLM, and its analysis of fire effects on sage grouse is inadequate. For example, despite the extreme danger to sage grouse habitat from fire, sage grouse habitat receives the second lowest of all precautionary classifications in the Uncompahgre fire plan, and "significant prescribed burning" is expected in these areas (Uncompahgre Field Office Fire Management Plan 1999, p. 7). Moreover, no analysis of fire return intervals or of the decades needed to restore sagebrush cover has been done. Instead, BLM appears to be using fire to remove oak and confers from these areas (Uncompahgre Field Office Fire Management Plan 1999). But this removal could be accomplished by other, safer means, such as the cutting of trees. Reduction of over-mature sagebrush could be achieved by mechanical means. The EA for the Uncompahgre fire plan also fails to consider the likelihood of fire escape, cheatgrass invasion, or the myriad other effects of burning on sage grouse habitat (Uncompahgre Field Office Fire Management Plan, Environmental Assessment 1999).

BLM Management in Oregon

The Oregon state office of BLM acknowledges that sage grouse habitat in Oregon has declined by 50% of its original range, and that populations have declined by 60% in the remaining range (Bradley 1999). Moreover, the BLM admits that the species is at risk in Oregon and Washington, and has proposed development of a sage grouse conservation strategy (Bradley 1999). BLM is also aware of the importance of nesting and wintering habitat, as well as the inadequacy of simply protecting areas within 2 miles of a lek (BLM 1999c).

Despite BLM's knowledge of the demise of sage grouse, the agency has done little to alter its land management actions in the state. BLM has generated numerous Resource Management Plans (RMPs) and Allotment Management Plans (AMPs), but the agency has avoided NEPA compliance by segmenting the various plans even though they are connected actions, and even though they all affect sage grouse. A listing under the ESA would put and end to this segmentation and refusal to assess effects rangewide. BLMs plans are inadequately monitored, and contain no provisions to measure vegetation density or height – or any other habitat components that are important for sage grouse. BLM allows grazing from June through October, apparently believing that this protects sage grouse. Of course, livestock still remove vegetation needed by sage grouse, particularly for the crucial growth and development periods, and for nesting the next spring. BLM also maintains an ORV area in known sage grouse habitat.

In the Prineville area, BLM has removed brush by "burning, brushbeating, herbicide spraying, or plowing of big sagebrush" (Prineville District, BLM 1989, p. 89). Only areas inside "important mule deer wintering grounds" are spared (Prineville District, BLM 1989, p. 89). Although well aware that sage grouse are in trouble, decreasing, and depend on sagebrush, the Prineville BLM is destroying habitat at a rapid rate. The Prineville BLM is also undertaking construction projects in sage grouse nesting areas (Prineville District, BLM 1989, p. 90). It claims it will mitigate the effects of construction disturbance by not conducting the work during nesting, but there are two problems with this scheme: the constructed edifice will remain through all seasons and will likely serve as a raptor perch, and construction will occur during the brooding season, which may be even more damaging than activities during the nesting season.

In the Deschutes area, BLM has increased grazing without any monitoring of vegetation or sage grouse habitat, even though the species was a candidate for listing at the time (Hanf 1991, p. 1). In the Leslie Ranch part of the Deschutes area, sage grouse numbers declined at a

rate that was statistically highly significant (Hanf 1991, p. 2). Worse, the magnitude of the declines was great – attachment 3 to the Hanf memorandum shows strong declines at most leks; only 2 leks increased, and the overall decline was -18% (Hanf 1991). This decline, in the professional opinion of BLM's own wildlife biologist "clearly reflects the deleterious impacts of heavy livestock grazing" (Hanf 1991). Despite its legal obligations, BLM has "not adhered to the management plan" even though this is even more critical during periods of drought (Hanf 1991, p. 3). Grazing by the permittee was even higher than the allowed amount (Hanf 1991). On the Leslie Ranches allotment, males declined by 58% from 1988 to 1991, leaving only 71 males in the area (Prineville District, BLM 1992a). But BLM proposes no enforceable standards for the future management of these areas. Instead, it promises it will monitor and provide flexible management (Prineville District, BLM 1992a). However, apparently no monitoring has been done, as BLM was unable to provide documents related to ongoing monitoring of sage grouse and their habitat in response to a FOIA request made in 1999. BLM is also pursuing management that it claims will increase sage grouse, but the actions undertaken are either not helpful to sage grouse or will harm them. Such inappropriate management actions include installation of guzzlers and water pipelines (Prineville District, BLM 1992b), which are not helpful to sage grouse and may deprive the birds of riparian vegetation by dewatering areas to run the guzzlers. BLM is also installing fences that serve as perches for aerial predators. Finally, BLM proposes to burn over 1,000 acres in the Leslie Ranches area, which poses a significant risk of fire escape and habitat destruction (Prineville District, BLM 1992b).

The Moffit Allotment contains one of the largest sage grouse leks on the Prineville District, as well as wintering areas and probable nesting grounds (Hanf 1989). Nonetheless, BLM allowed "heavy cattle use" that had "severe" effects on bitterbrush, removing 90% of the new years growth (Hanf 1989). All this occurred despite the BLM's Allotment Objectives to "improve ecological condition" and to "maintain or improve livestock forage" (Hanf 1989). So bad was the abuse in this allotment that the BLM's own wildlife biologist refused to sign the evaluation (Hanf 1989). This biologist was later harassed and transferred by BLM administrators.

In the Millican Valley in Deschutes County, BLM has undertaken extremely destructive actions, despite recognizing that the valley is "very important" for the "winter survival of sage grouse" (Prineville District, BLM; undated). BLM knew that the Millican Valley provided the only winter habitat during heavy snow years because of its "comparatively mild weather" and "fairly good sagebrush cover" (Prineville District, BLM; undated). In 1994, BLM promised to immediately implement actions to conserve sage grouse, but it has not done so – instead BLM appropriated lands for "use and development" which contributed to a "loss of sage grouse habitat" and did not mitigate these actions (Hanf 1995). These birds are "at risk of extirpation" (Hanf, et al. 1994, p. 10), making BLM's mismanagement even more bewildering. The only plausible explanation is that BLM administrators decided to sacrifice sage grouse to appease powerful off-road vehicle (ORV) interests in the county. Without the protection of the Act, such mis-management is certain to continue, and further waves of extinction will follow.

Despite the serious habitat loss in the Umatilla Basin of Oregon (described above), the BLM proposes to trade away a large block of nearly 3,000 acres of sage grouse habitat in a land exchange (Prineville District, BLM 1998, comment letter of Dec. 30, 1997 from Oregon DFW). Despite the concerns of ODFW, BLM's actions will severely reduce the already limited sage grouse habitat in Juniper Canyon, which is "one of the largest and most ecologically intact examples of the shrub-steppe/grassland habitat type" (id., p. 3 of letter). BLM later

"misinterpreted" the ODFW letter, necessitating an additional letter reiterating the state agency's previous points, most especially, that the proposed disposal of Juniper Canyon was ODFW's "primary concern" in the exchange (Prineville District, BLM 1998, comment letter of Feb. 18, 1998 from ODFW). BLM policy (Manual 6840, Special Status Species Management) "requires that BLM work with state agencies in achieving conservation goals" for sage grouse and similarly situated species (Bibles 1990, Attachment 1-1). BLM has not obeyed its own policy, has not given adequate deference to the state's valid concerns, and has sought to cloak its bad faith in the shroud of "misunderstanding." * * *

On the Burns BLM District, the agency has not "completed evaluations on Allotment Management Plans (AMPs) having sage grouse objectives" (Hanson 1999) despite the serious declines in sage grouse populations. Even when it issues management plans for allotments, BLM has not adequately evaluated sage grouse needs. For example, even though sage grouse are a "priority species," BLM stated that "no specific population or habitat data has been collected during the revaluation [sic] period" for the Pueblo Mountain Allotment, nor did BLM reduce the number of cattle on the allotment (Christiansen 1999, p. 5-6 of attachment).

Federal agency projects such as the Vale Project eliminated shrub cover from millions of acres of public lands in southeastern Oregon in the 1960's. By 1981, in the Burns and Vale districts alone, the BLM had altered native vegetation on 140,770 ha, had seeded alien annuals grasses on 211,682 ha, had built 4,469 miles of fence (exposing the remaining sage grouse to raptor predation), installed 477 cattle guards and built over 1,000 miles of roads (Maser and Thomas 1983, p. 11). The BLM also destroyed 749 springs, built 927 water tanks and 2,119 reservoirs, and laid nearly 800 miles of water pipe (Maser and Thomas 1983, p. 2). In brief, BLM attempted to convert the native ecosystem into an agro-industrial cattle factory, and every action taken was detrimental to sage grouse. Vale BLM proposals (such as the Bully Creek LAMP, BLM 2000c) continue to emphasize removal of sagebrush and other shrubs.

* * *

BLM Management in Montana

In Montana, BLM has not adequately protected habitat. Consequently, populations have declined sharply on BLM lands, as shown in the Population Assessment section.

There appears to be a policy to provide only partial protection of sage grouse lekking areas within either a few hundred feet or up to ¼ mile of a lek. Every NEPA document examined from numerous field offices limits protections in this way. In addition, BLM has undertaken a vast program of chisel plowing in Montana, ostensibly to remove club moss and encourage grass growth for livestock (Brubacker 1989). The state BLM office issued chisel plowing criteria that allow habitat destruction and disturbance up to 100 feet from known sage grouse leks (Brubacker 1989). Of course, if a lek area is not "known," it will be destroyed. But even if all leks were known, these criteria would allow destruction of all habitat for every other life history stage, thus decimating sage grouse populations. Indeed, a 100 foot buffer does not even allow adequate hiding cover to reduce predation losses on the lek.

As another example, BLM has applied No Surface Occupancy (NSO) stipulations for oil and gas operations and prospecting only within ¼ mile of leks and has only applied timing stipulations within 2 miles of leks (Miles City District, BLM 1992, p. 71; 1995, p. 38; Lewistown District, BLM 1998, p. 44). In 1988, BLM allowed drilling within 500 feet of all sage grouse leks in a blanket stipulation (MT-3109-1, attached to West HiLine RMP, BLM 1988).

Studies have shown that many birds nest much farther from leks than 2 miles. Also, noise and disturbance can easily carry more than ¼ mile. Worse, such stipulations provide absolutely no protection from raptors or corvids ranging many miles away from perches provided by installations, and winter, brooding, and fall habitats are completely unprotected by such stipulations. Two mile buffers are inadequate as many birds are known to nest beyond this range from leks. Also, such small buffers provide no protection for other habitat components during other parts of the life history. In 1990, BLM began requiring a 2 mile buffer, but only in the breeding season; moreover, maintenance and operations facilities were allowed even inside the buffer (State Director, MT BLM 1990). Finally, BLM appears not to have updated all plans to require even the inadequate 2 mile buffers.

Severe impacts to sage grouse habitat in Montana have resulted from BLM development activities. Past, present, and projected coal development cause "significant local impacts to wildlife" on over 1 million acres of land. These impacts occur "even if mitigation for the loss of wildlife habitat" is successful (Miles City District, BLM 1984, p. 112). The BLM rightly notes that the fact that "wildlife habitat would be destroyed" is "a significant impact" (id.). BLM also proposed destruction of sagebrush habitat by "mechanical treatments," range "improvements," and by allowing over 700,000 AUMs of grazing impacts (id., p. 113). BLM claims that the removal of needed food plants and vegetative shelter for sage grouse would somehow have "favorable impacts" (id.), although it does not offer any explanation for this surprising conclusion. BLM also proposed to construct over 100 miles of fencing, which serve as raptor and corvid perches, and to dispose of over 165,000 acres of the public's lands, which would expose any sage grouse there to development and other actions, unprotected by law (id., p. 114).

BLM has not considered the cumulative impacts of its actions on sage grouse. For example, the Malta Field Office has proposed and conducted multiple prescribed burns without considering the cumulative effects of these actions. One burn of 320 acres, on the South Alkali Creek Allotment # 5369 (Malta Field Office, BLM 1998a) is just a few miles from the Ferry Plant prescribed burn, but the actions are analyzed in complete isolation from each other (Malta Field Office, BLM 1998a). Protection under the ESA would assure that the effects of actions on federal, state, and private lands is analyzed together. The BLM also incorrectly assumed that burning outside the nesting season would not significantly affect sage grouse – of course, burning destroys habitat for decades (until sagebrush can grow back to adequate density and height), something the BLM characterized as "temporary" (Malta Field Office, BLM 1998a; 1998b). On the Guston Coulee allotment, the Malta Field Office admits that nearly half of the range is in only "fair" condition (a rating of fair indicates that the area is sufficiently degraded as to significantly affect sage grouse), while none of the allotment is in "excellent" condition (Malta Field Office, BLM, undated). Yet, BLM admits that the "entire allotment is considered crucial nesting habitat" because it is within 2 miles of a lek (id.).

BLM continues to rely on mythological notions, not data-based grazing management, such as the Savory method, aka "HRM, Holistic Resource Management" (Pike 1987). Gammon (1978), and Herbel (1974) have reviewed Savory's recommendations as well as other rotational grazing systems and found that they offer no advantage. Other studies criticizing Savory include Noss and Cooperrider (1994), Miller, et al. (1994), and particularly Belsky (2001). Grazing systems are, at best, minor effects on herbage production on rangelands – the major determinant of herbage production is the stocking rate (Van Poolen and Lacey 1979). BLM does not even apply HRM to meet rangewide sage grouse habitat restoration goals. For example, it has not considered any habitat component except nesting habitat, and then only within 1 mile of a lek

(Pike 1987). Indeed, BLM sage grouse habitat management is not designed to conserve the species, but only to "give as much consideration as is possible under the circumstances" to sage grouse and other birds that get in the way of livestock development – over 2/3 of the available forage goes to livestock (Malta District, BLM 1982).

In the Havre area, BLM has admitted that sage grouse "are a species of concern" because of "decline throughout their historic habitat" (Havre Field Office, BLM 1999, p. 12). Nonetheless, BLM proposed a prescribed burn which would harm this "crucial winter habitat for sage grouse" (id.) even though it admitted that "any loss of sagebrush … will have a negative impact on sage grouse" (Havre Field Office, BLM 1999, p. 24).

BLM appears to be misinformed about sage grouse requirements. For example, the Dillon, MT resource Area proposed to protect sage grouse by fencing "meadow sites to exclude livestock" (Dillon Resource Area, BLM 1979, WL-22.1). However, fences serve as raptor perches and this would harm sage grouse by creating a "death zone" within hundreds of feet of each fence post. BLM also intends to protect sage grouse by restricting mining in winter and spring – but only on what BLM terms "crucial" sage grouse winter ranges (Dillon Resource Area, BLM 1979, WL-5.12). Although BLM underlined the term crucial to ensure that mining and other disturbances could still occur on all other winter range, it did not define the term. Moreover, BLM apparently did not recognize (or sought to conceal from the public) the obvious fact that mining destroys habitat no matter when it is conducted.

BLM provides little protection for or consideration of sage grouse. The Butte BLM Field Office has not evaluated allotments with sage grouse habitat under its Standards and Guidelines process, it does not have any activity plans with objectives for sage grouse, and it has not developed an allotment evaluation that addresses sage grouse (Good 1999). Not surprisingly, few sage grouse remain in the Butte area although sage grouse were "commonly seen until the last 10-15 years" (Butte Field Office, BLM 1998, 3-101). Intensive surveys failed to locate any sage grouse and the largest "flocks" that have been sighted consisted of only 3 individuals (Butte Field Office, BLM 1998, 3-101). This is not isolated neglect: The Billings resource area has proposed to enhance sage grouse habitat by constructing game bird watering devices, even though sage grouse do not require free water (Billings Resource Area, BLM 1983a, p. 27). Instead, sage grouse require the plants in wet meadow areas near seeps and springs – it is these areas that BLM destroys by installation of livestock watering devices.

BLM Management in Wyoming

"Sublette County is thought to contain some of the best sage grouse habitat in the state" (Wyoming BLM 1998). Yet BLM is permitting massive oil and gas development in this and other Wyoming counties, including Sweetwater, Carbon, Lincoln, and Uintah counties in southwestern Wyoming (Wyoming BLM 1998). In Sublette County alone, 100-200 leks are likely to be affected (Wyoming BLM 1998). Some oil fields are so densely developed that they have a well on every 40 acres (Wyoming BLM 1998). Leks are known to have been abandoned when oil wells were drilled as far away as ¾ mile from the lek (Wyoming BLM 1998). Yet, BLM has only applied ¼ mile restrictions on wells, even though it knew that adequate impact data was not available and was "not sufficient to address the legal challenge" to the BLM's massive development plans (Wyoming BLM 1998).

BLM Management in South Dakota

BLM lands in South Dakota are managed by the Montana state BLM office and suffer

from the same mis-management. Surface occupancy is allowed within 500 feet or ¼ mile of a lek, and no other protections are required (South Dakota Resource Area 1985, p. 69, 144).

Management on USFS Lands

Most sage grouse habitat is on BLM or private lands; nonetheless, lands managed by the US Forest Service (USFS), such as National Grasslands and the lower elevations of many National Forests, contain significant amounts of sage grouse habitat. A particular threat on lands administered by USFS is the rescissions bill which exempts grazing permit renewals from the requirements of NEPA analysis. Because these permits last for 10 years, significant damage to sage grouse can be done. As one USFS biologist put it, "most forests" are "rubber stamp renewing" grazing permit renewals. This is not an adequate regulatory mechanism.

Forest Service scientists have admitted that they do not conduct site-specific analyses of the impacts of management actions on wildlife – the demands of assessing impacts "preclude site-specific study" of those impacts (Toth and Baglien 1986, p. 255). The reasoning is circular, and the violations of NEPA seem clear. Such issues may also apply to BLM management actions. The Forest Service is a known scofflaw – one judge noted the "deliberate and systematic refusal by the Forest Service and FWS to comply with the laws protecting wildlife." Seattle Audubon Society v. Evans, 771 F. Supp. 1081, 1090 (W.D. Wash. 1991).

In Colorado, some National Forests, such as the Grand Mesa, Uncompahgre, and Gunnison National Forests, recognize sage grouse as a Management Indicator Species (MIS). For a MIS, the Forest Service must evaluate and state planning alternatives "in terms of both amount and quality of habitat and of animal population trends of the management indicator species." 36 C.F.R.§ 219.19(A)(2). However, various projects have been approved without evaluation of their effect on sage grouse, such as the Powerline Prescribed Burn. The Forest Service has also proposed projects to improve sage grouse habitat, but they involve fire and chemical treatment (rather than mechanical brush beating) and thus involve substantial risk to the grouse. The most important habitat improvement is to increase forb and grass cover by halting grazing, but the Forest Service has not proposed such actions. Instead, in its Gunnison Basin Range Project EA, the Forest Service has claimed that grazing levels on its lands do not harm sage grouse and that it will not restrict grazing. On the Beaverhead-Deerlodge National Forest in Montana, USFS has failed to track sage grouse populations or habitat quality for over 15 years while it has renewed livestock grazing permits.

Under regulations promulgated pursuant to NFMA, the USFS is required to assure the viability of vertebrates on USFS lands (36 C.F.R.§ 219.19). USFS has not maintained viable populations of sage grouse on its lands. In fact, sage grouse on the Crooked River National Grassland in central Oregon have been completely extirpated.

Clearly, the Forest Service is not giving adequate attention to sage grouse on National Forests or National Grasslands – one USFS biologist stated that "until [a species is] proposed for listing" or listed "probably nothing is going to happen" to promote its management.

One concern regarding the livestock management for fish species on federal lands is that rather than simply reduce or eliminate grazing, the Forest Service is attempting to "attract cattle away from streams" (Duncan 1999, p. 2), including studying the use of "off-stream water systems used to attract cattle away from the stream…." (Duncan 1999, p. 4). Inevitably, cattle will be attracted away from streams and into sage grouse habitat, thus degrading that habitat even more than its present damaged state. Such efforts are not limited to the Forest Service, but are threats on all lands, where managers attempt to improve riparian conditions while maintaining livestock.

In Oregon, only 50 to 75 sage grouse remain on the Ochoco National Forest. The Ochoco National Forest has paid little attention to sage grouse. In response to a FOIA request, the Ochoco National Forest was able to find only 3 documents dealing substantively with sage grouse (Cuddy 1999). The Crooked River National Grassland was unable to locate any documents (Cuddy 1999). Only a single lek (in the Mineral planning area) is known to the Forest Service on the Ochoco National Forest (Ochoco National Forest 1997). Biologists recommended that the Ochoco National Forest monitor habitat in Buck Springs area for sage grouse as early as 1990 – yet, after 10 years, this has not been done as no documents exist showing any monitoring (Cuddy 1999).

Sage grouse once covered what is now the Crooked River National Grassland, but after plowing and planting to crested wheatgrass by homesteaders in the 1930's and by the US Forest Service in the 1960's, sage grouse were extirpated from this entire area. The Forest Service has no plans for habitat restoration on the Crooked River National Grassland – instead, the agency allows some of the most intense grazing in the state of Oregon. Stocking rates are 2 or 3 times those of comparable BLM lands. This grazing regime prevents reestablishment of sage grouse habitat.

In California, the Forest Service has allowed renewal of grazing permits with little or no monitoring, despite knowing that this would cause "direct disturbance" to sage grouse, along with "competition for forage" and removal of much of the new growth of forbs and grasses "critical for juvenile" sage grouse (Inyo National Forest 1997a, p 18). So lax is the Forest Service's consideration of sage grouse needs that it proposed fencing as "beneficial to [sage] grouse" (Inyo National Forest 1997a, p 18). On the Dexter Creek allotment, the Forest Service allows sheep grazing, with similar disregard for, and lack of consideration of, the needs of sage grouse (Inyo National Forest 1997b).

Management on NPS Lands

Without the guidance of the Endangered Species Act, even the National Park Service has damaged sage grouse populations. Development of the Curecanti Recreation Area has caused brood habitat to become "almost totally lost," lek and nest habitats have been reduced, and winter habitat has been "reduced and/or compromised" (Braun 1999b, p. 1). At Black Canyon of the Gunnison National Monument, powerlines, raptor perches, pinyon/juniper invasion, interior fencing, and degraded sagebrush habitat are threats to the birds (Braun 1999b, p. 2).

Neither Black Canyon of the Gunnison National Monument nor Curecanti National Recreation Area has conducted or is conducting any research or other studies on the bird, and neither entity has a management plan for the species (NPS 1999c). Oddly, the NPS did not provide a copy of the letter written by Dr. Braun (Braun 1996b) in response to a FOIA request, instead claiming that it had no information regarding the bird. Two grant proposals have been submitted to conduct research on the Gunnison sage grouse, but support for even this minimal and late effort is "problematical at best" (NPS 1999c).

National Parks and Monuments

Sage grouse are not known to occur in any National Parks in any appreciable numbers. A few individuals exist in Grand Teton National Park. Grazing is still allowed in Grand Teton National Park, as well as [*as other*] units of the National Park system. Worse, the Parks in the Yellowstone area conduct land management activities to favor elk such as burning and brush clearing, which damage sage grouse habitat. Oddly, these activities continue even though elk

populations are so high that damage to vegetation is widespread.

Sage grouse were extirpated from Lava Beds National Monument shortly after the 1930's. NPS biologists recommended restoration of habitat and populations (Forsell 1961), but actions were never taken.

Management by the US Fish and Wildlife Service

It is not merely state and other federal agencies whose mis-management threatens sage grouse. The Service itself has mismanaged its ESA duties, including its listing responsibilities under section 4, as well as the lands in the National Refuge System. The Service has also sought to withhold documents regarding sage grouse from the public, in violation of the Freedom of Information Act (Ramirez 2001).

Management of Listing and other ESA Duties

* * *

The Service has not acted to uphold the ESA with respect to sage grouse. For example, the Service has affirmatively sought to undermine potential petitions and the listing procedure: "Mr. Ireland [a FWS employee based in Grand Junction, Colo.] is trying to keep all the players in the loop so a petition is not started" and is "trying to slow things down" (Summary of North Park Working Group Meeting 1999). Such actions are per se arbitrary and capricious and implicate violations of the Service's duties and trust responsibilities. Mr. Ireland then stated that conservation plans could provide some "relief or relaxation from [ESA] listing" (id., p. 2) and that after a listing "grazing will not be shut down at all" (id., p. 3). Service employees have discussed the significant impacts of a listing petition and the advantage of "being pro-active" to "divert potential litigation" (Parker 1998, attachment). The ESA mandates various affirmative duties on the FWS to evaluate threats to the species and to use the best available science in its evaluation, but employees have contemplated abrogating those duties. Personnel noted that if the sage grouse were petitioned range-wide, "US FWS could conclude [that the listing was] 'not warranted' if [the] petition [was] not good" (Anonymous FWS document 1999, p. 2, Rich Howard speaking). Almost immediately after the American Lands Alliance held a public meeting to discuss the plight of sage grouse, the Service held a conference call (Anonymous FWS document 1999). FWS employees discussed how to evaluate the danger to sage grouse but without moving towards protection for the species. As early as Jan. 1999, FWS intended to ensure that a sage grouse petition would be "going to [the] bottom of the pile" (Anonymous FWS document 1999, p. 3, Rich Howard speaking). FWS decided they would "have to call it [the status review] something else" to "keep [it] out of listing" procedures (Anonymous FWS document 1999, p. 3, Chuck Davis speaking). The FWS admitted that they already "have data" but "need synthesis" (Anonymous FWS document 1999, p. 3, Chuck Davis speaking). Although the Service has the data, it has taken no steps on its own to consider protection for sage grouse. The Service is not allowed to consider economic or any non-scientific issues when deciding on listing a species. Yet, the Service constructed a Regulatory Action Alert prior to the listing of the Washington population of sage grouse that discussed the "potential importance to industry" and which Congressional Districts were involved in the area covered by a listing (FWS 2001c).

* * *

Because these issues are raised in a rule-making petition pursuant to the Administrative Procedures Act, the Service must consider the degree to which its own legal violations constitute a threat to the species.

Management on National Wildlife Refuges

Most National Wildlife Refuges have been set up to produce waterfowl for hunters to shoot. Accordingly, the Refuge system has largely been operated as a series of duck farms, not as natural ecosystems. Most waterfowl refuges have a developed aspect with steep banks forming hard edges along the margins, rather than gentler slopes which would create the moist riparian soils that promote plant growth favored by sage grouse, particularly late in the brooding season. One refuge (Hart Mountain in Oregon) was set up to protect pronghorn (*Antilocapra americana*), an Artiodactyl that is the only species in its Family and occupies grasslands and shrublands. Proper management for pronghorn should also conserve sage grouse. * * * Sage grouse habitat quality [*has*] improved after grazing was eliminated [*from Hart Mountain*] (Crawford and Drut 1993).

Independent scientists have expressed numerous concerns regarding the failure of the National Wildlife Refuge system to protect various species of wildlife and biodiversity in general. Much of this criticism has centered on the failure to regulate cattle grazing and on pollution. Cattle grazing and haying occur at 123 National Wildlife Refuges. Few Refuges have voluntarily removed or even reduced grazing; instead, this has typically occurred only when directed by a federal judge. Grazing and haying consume 50% of refuge funds and 55% of staff time (Fleischner 1994). Strassmann (1983, 1987) showed that these activities directly impeded wildlife conservation. This grazing continues even though Strassmann (1987, p. 42) found that grazing does "more harm than good."

The fact that at least one National Wildlife Refuge (Kesterson, in California) had to be declassified because of water pollution (Ohlendorf 1990), and that other refuges, notably the Klamath Basin Refuges, are used for farming row crops of absolutely no benefit to wildlife, indicates that establishment of National Wildlife Refuges has not provided adequate protection to [*some*] wildlife or to the ecosystems on which they depend.

Conservation Reserve Program

The Conservation Reserve Program (CRP) was created by the Food Security Act of 1985, and allows land parcels to be set aside from agricultural production for temporary and indefinite time periods. Farmers need not keep land in the CRP and can remove land from the CRP when they wish. Economic incentives are provided to farmers to keep land in the program but as economic conditions change, farmers can opt out. These set asides have been used to enhance some parcels of sage grouse habitat, notably in Washington state. The CRP was designed to reduce soil erosion, not protect wildlife. Although better than nothing, such programs have numerous problems. One problem is that most of the acreage is in parcels of less than 100 acres, and often they become population sinks, rather than sources, for birds. Predators can easily find these small parcels amid the cultivated fields in which they are embedded. In some cases, cultivation or livestock feeding operations may even attract more predators to the area than would otherwise be the case. For example, ravens are attracted by the grain spread in livestock feeding operations. Once in the vicinity, it is easy for these nest predators to locate any sage grouse nests nearby. Furthermore, the CRP program is not based upon wildlife values. A 100 acre plot in the middle of a wheat field has tremendous edge effect, thereby allowing easy access for predators. Studies of CRP lands using GIS, remote sensing, and habitat modeling have shown that vegetation structure was unsuitable for game birds, resources needed by game birds were not present (resources that were not limiting on game birds were provided), and birds suffered nest disruption in CRP lands from agricultural operations, thus creating a population sink (Roseberry, et al. 1994).

The plantings on CRP lands provide little benefit to sage grouse – 87% of the program lands are planted in grasses, and 67% of those are exotics (Campa and Hanaburgh 1999, p. 211). The CRP program is also very costly. In Montana, the public actually spends more on "renting" CRP lands than it would cost to buy those lands (George Wuerthner, personal communication). As Wuerthner states: "Farmers typically get $50 an acre in Montana (payment varies from place to place in the country so it's more in places like Iowa). But they get this for ten years. [i.e.] 50 x 10 equals $500/acre over ten years. You can often buy this same land for $100-200 an acre outright. So we are paying far more than the land is ultimately worth and we get no guarantees that these lands won't be turned back into wheat fields or whatever in ten years." Economic analyses of the CRP in other states have not been conducted, but this expense ratio is probably typical for most Western states.

The CRP had more than 160,000 acres enrolled within the sage grouse range as of the late 1980's, including 60,000 acres in Douglas County (Hays, et al. 1998). The CRP appears to provide some benefit to sage grouse by providing some cover for nesting (NWEA 1999, p. 30 citing Schroeder, personal communication). The most beneficial CRP lands are those adjacent to remnant shrub-steppe patches. However, sage grouse habitat in Douglas County is still vulnerable (Hays, et al. 1998). Much of the habitat needed by sage grouse is not enrolled in the CRP, nor do the CRP lands offer protections adequate to conserve the grouse. Brush control, chemical spraying, and conversion of sagebrush areas continue, causing additional loss and degradation of sage grouse habitat (Tirhi 1995; Hays, et al. 1998). Many CRP lands have been planted with crested wheatgrass, which is rarely used by sage grouse or other wildlife (Hofmann and Dobler 1988).

Moreover, CRP protections are temporary. Thousands of hectares of habitat currently enrolled in the CRP could be converted to agricultural fields as soon as 10 year long contracts expire. Moreover, recently changed standards for CRP lands may "require replanting of significant acreage under existing contracts" (FWS 2001d, 66 Fed. Reg. 22984, 22993) – thus, further decreasing their value to wildlife. Perhaps most importantly – the CRP program has failed to halt the severe declines in sage grouse populations to date. There is thus no reason to expect that it will do so in the future. Finally, it is unclear whether the CRP program provides a significant benefit to wildlife or whether it is merely a politically motivated farm support program.

Management by the States

The states have a very poor record of conserving sage grouse. Significantly, state fish and wildlife departments typically believed sage grouse populations to be in much better shape than independent scientists who have studied the data. As but one example, ODFW published an analysis of sage grouse in Oregon, which came to significantly more optimistic conclusions than that of Drut (1994). As explained here, those conclusions are unwarranted.

Although many states have endangered species acts, these acts are weak and rarely have much impact on wildlife (George 1998). State conservation agreements are inadequate to conserve sage grouse. They are voluntary and unfunded or underfunded, and have a poor track record. Although states can regulate hunting, the majority of habitat is either on federal lands or on private lands. Instead of being able to regulate the species, state "wildlife agencies are relegated to an advisory role on habitat manipulation proposals and usually are left to minimizing detrimental impacts. Seldom, if ever, is a project designed to benefit wildlife." (Autenrieth 1986, p. 774). Thus, even if states were not in the thrall of extractive interests, they would be unable to conserve the birds, merely to lessen the damage.

State fish and wildlife agencies and their employees appear more concerned with protecting their "turf" than with conserving sage grouse. For example, state agencies have been concerned about "a federal takeover" of sage grouse by the US FWS, and an Idaho employee, "Jack Connolly [Connelly] expressed concern" that FWS was even considering a status review "because he felt it gave the NGO's [environmental groups] more ammunition to pursue a listing" (Deibert 1999c). This points up the lack of concern for conservation by state agencies and employees. It is perhaps not surprising that state agencies would be hostile to a listing under the ESA. When a game animal falls to such an imperiled status, it shows severe mis-management by the states, and as the states well recognize "demonstrates a failure by landowners, other agencies, and their own Department to do a good job in managing the resource" (Howard 1999, p. 2).

Following are summaries of selected states' management of sage grouse and sagebrush habitats.

Management in Oregon

The state of Oregon is widely regarded as having the preeminent land use planning system in the United States. Oregon's land use planning laws have been in place since 1973 and are a considerable source of state pride, as well as a source of controversy. Oregon has established urban growth boundaries (UGBs) and all urban development – as well as the extension of city services – are to take place within those boundaries. Development is restricted on rural and farm lands outside the UGBs. However, Oregon's land use planning was designed to cluster development and preserve farm lands and open space, not specifically to maintain wildlife habitat. That Oregon's land use planning laws are inadequate to assure conservation of sage grouse is evident from the significant declines that have occurred since land use planning was enacted. Moreover, the land use planning act is subject to alteration either by the legislature or by citizen initiative, and several attempts to reduce restrictions on development have been proposed. Finally, significant development has taken place in the eastern part of the state despite the presence of land use planning. Although it is not clear how much of this development has occurred in historical sage grouse habitat, it is precisely the drier, eastern portion of the state that once harbored large numbers of sage grouse.

Although the Oregon land use planning system is the most restrictive of any state's, it has failed to halt declines in sage grouse populations. Therefore, land use planning in other states can have no expectation of protecting sage grouse habitat.

The Oregon Dept. of Fish and Wildlife (ODFW) has a very poor track record of monitoring sage grouse populations and compiling that information. The agency has been aware for years that "much of our Oregon data is sketchy" (Denney 1980). Independent, outside sage grouse experts have noted this problem as well. ODFW apparently has not assessed habitat within the state at all. Moreover, the ODFW has been very reluctant to provide public records regarding sage grouse to the public, and has sought to delay and deny access at virtually every turn. This suggests that the agency has something to hide. Moreover, ODFW employees have attempted to deflect university research scientists from studying the effects of "livestock utilization of forage" on sage grouse (Lemos 1997, p. 1). The agency's attitude towards sage grouse is not one of conservation or of stewardship of a public resource. Rather than address threats to the existence of the sage grouse, ODFW employees instead regard potential action to protect sage grouse under the ESA as a "listing threat" (Van Dyke 1999, p. 1, 7). ODFW has not implemented a conservation strategy based on objective or impartial scientific research; instead, "the intent behind these [conservation strategy] efforts is to satisfy USFWS that the listing of the bird in Oregon is not necessary" (Van Dyke 1999, p. 2). The motivation behind ODFW make its

conclusions suspect, and the Service should carefully evaluate all analyses – much less opinion – from this agency.

Management in Utah

Utah lags far behind Colorado in its attempts to arrest the decline of the Gunnison sage grouse. A Conservation Agreement for species in San Juan County is still unfinished, and a draft has been circulated for review. Mapping and delineation of sage grouse use areas has not even been carried out. The state wildlife agency and the Utah field office plan to pay $3,000-$4,000 for a technician to delineate sage grouse use areas. This technician, who will be employed part-time (if hired at all) will have the additional responsibilities of working with private landowners to enhance sage grouse habitat, and will monitor usage of enhancement projects. This is a very ambitious use of the small amount of funding provided, and all these activities will obviously not get accomplished. Moreover, nothing at all is planned for other parts of the Gunnison sage grouse's historical range in other counties in Utah.

A draft "concept" of a conservation plan has been written (San Juan Draft Concept Plan 1997); however, there has been little action taken on its provisions. These provisions merely contemplate the gathering of information without any action being taken to protect the species. Indeed, the concept plan explicitly lists "enhancement of personal income" as a goal. A conservation agreement has also been drafted (Utah Draft Conservation Agreement 1998) but it is unclear whether it is based on the concept conservation plan. The conservation agreement includes a goal to enhance sage grouse habitat, but the actions associated with this goal primarily involve mapping and delineation of various habitat and use areas (Utah Draft Conservation Agreement 1998). The conservation agreement is thus far from any on the ground actions, and the only management actions called for are extremely vague and non-specific. Overall, the conservation agreement simply does not contemplate specific actions adequate to conserve the species, even if it were implemented in its entirety.

Management in Idaho

In 1996, the Idaho Dept. Fish and Game drafted conservation plans, which included actions to prevent further loss of sagebrush, to monitor effects of agricultural chemical use, and to reduce hunting pressure. These plans are not regulatory mechanisms and have not even been implemented (Cade 1999). Instead, even after 4 years, they are "still being discussed by local working groups," and the "original objectives for the year 2000 have been pushed into the indefinite future" (Cade 1999).

Management in Colorado

Colorado attempts to manage sage grouse by regulating hunting. No other state regulatory controls exist. Colorado does not have a comprehensive land use planning system, and has few controls on development of any sort. Thus, suburbanization and ranchettes are likely to continue to eliminate remaining sage grouse habitat.

Moreover, it appears that the Colorado Dept. of Wildlife (CDOW) has been remiss in its general management of sage grouse. As late as 1978, the CDOW had failed to implement any systematic population assessments (CACP 1998, p. 2). Instead the "searches and counts were sporadic," and the CDOW allocated personnel and funding elsewhere (CACP 1998, p. 2). This all occurred despite the fact that CDOW had been requested to document sage grouse status and trends as early as the 1950's (CACP 1998, p. 2). Perhaps an even more startling fact is that

Gunnison sage grouse hunting in the Crawford Area was not ended until 1994, even though the number of grouse had sunk to less than 90. CDOW personnel operate with only one eye on science – the other eye is fixed on politics. For example, one memorandum notes that even though a critical population will become extinct without active habitat management, the required habitat manipulation may nonetheless not be possible "considering the present political climate" (Braun 1995g, p. 1). These facts make assertions of conservation actions to take place in the future suspect – either the CDOW lacks the interest in conserving the species, or it lacks the power. In either event, prompt listing under the ESA is a necessity.

Threats from disease and parasites are imminent and ongoing. The Colo. Div. of Wildlife "allows releases of exotic/introduced species which are known to be carriers of parasites/diseases harmful to sage grouse into habitats where sage grouse live" (Braun 1999a, p. 1). Colorado does not have a comprehensive land use planning system, and has few controls on development of any sort. Thus, suburbanization and ranchettes are likely to continue to eliminate remaining sage grouse habitat.

Conservation Plans

Even though the present regulatory climate has brought sage grouse to the brink of extinction, neither federal nor state agencies have altered regulatory mechanisms within the range of the bird. Instead, federal or state agencies have begun to implement "conservation plans." State personnel admit that a major goal of such conservation plans is to "try to prevent Federal action concerning the grouse" (Wait 1997). If state wildlife agencies had made good faith efforts to actually conserve sage grouse populations attempts to write conservation plans with a goal to prevent Federal listing would not be needed.

To date, only a few conservation plans have been written (Braun 1996a). Indeed, there is still "reluctance" to "fully implement" conservation actions regarding grazing on some allotments in the Gunnison Basin (Braun 1996a). The conservation plans avoid conflicts over grazing by simply ignoring the issue. Instead, they assume that increased grass and forb production will – somehow – magically provide adequate habitat for both cattle and sage grouse. Conservation plans must be "exposed to public notice and comment" to be valid (Save Our Springs v. Babbitt, Civ. No. MO-96-CA-168 (W.D.Tex. 1997) at 9). Moreover, conservation plans must include "tangible steps to reduce the immediate threat to the species," and cannot rely on "promises of proposed future action" to preclude a listing (id.).

The Gunnison Basin, Colorado conservation plans form a framework for developing conservation actions. These consist of public education, research into causes of sage grouse declines, monitoring of populations, mapping and inventory of habitat, and similar assessments (Gunnison Basin Sage Grouse Conservation Plan 1997, p. 18). The conservation plans are thus useful tools to organize data collection and research, and may function to educate the public. They fall far short, however, of what is required to avoid a listing under the ESA. These conservation actions and conservation plans are not regulatory mechanisms, the actions do not yet exist, and both the plans and actions they contemplate are inadequate to insure conservation of the species. They thus fail each test for adequacy when considering a listing under the ESA.

The conservation plans do not themselves require the implementation of any actions, and needed actions have not been implemented. For example, the Gunnison Basin Sage Grouse Conservation Plan (GBCP) contemplates that implementation of actions under the plan will not be completed for 15 years (Gunnison Basin Sage Grouse Conservation Plan, GBCP 1997, p. 18). By then, Gunnison sage grouse will likely either be extinct or will be present in such small,

scattered populations that it will not be possible to prevent the extinction of the species. The GBCP itself recognizes this time lag problem with conservation measures, although it does nothing to alleviate the problem. The plan states, "it may take several years for an actual increase in cover, and the establishment of desirable species" after implementing a "vegetation management plan" (GBCP 1997, p. 19). The plans even admit that some actions could prove ineffective. For example, "a drought could negate or reduce the positive effects" of "vegetation management through improved livestock grazing" (GBCP 1997, p. 19). Despite this recognition, the plans do not provide for any safety margins or "fall-back" options in such cases. The San Miguel Basin Conservation Plan (SMBCP 1998) is so far merely an "outline of the Draft Conservation plan" (SMBCP 1998, front cover), and does not even estimate a time when conservation measures will be fully implemented except to note that it will "require a lengthy period" (SMBCP 1998, p. 16). The San Miguel plan merely establishes a wholly voluntary "process" and "framework" in which, someday perhaps, a true plan will be implemented. Similarly, participation by private landowners in the Crawford Area Conservation Plan (CACP) "will be strictly on a volunteer basis" (CACP 1998, p. iii). While these rosy speculations are appropriate for a children's fairy tale, they will not conserve the sage grouse. Such vague agreements require nothing, and have been uniformly rejected by every court that has examined the issue.

The conservation plans make no requirements on private landowners; instead, such action is purely voluntary (GBCP 1997, p. 19; SMBCP 1998, p. 3 "strictly voluntary"; CACP 1998, p. 3 "strictly voluntary"). Even if private lands are needed for conservation of the species, all land uses will be permitted, apparently including subdivision, because landowner participation is strictly voluntary.

Nor do the plans even assure funding for conservation actions: for example, the GBCP specifically contemplates that "[i]nadequate funding may preclude the completion of an action in a given period." In such cases, the "implementation sequence" would be adjusted" – that is, deferred (GBCP 1997, p. 19). The plans explicitly defer on the ground actions. For example, increased attempts to reduce poaching will not begin until 2009 (GBCP 1997, p. 20). Mitigation of utility corridors – which already exist – will not begin until 2006 (GBCP 1997, p. 20). Again, this deferral of action may itself be deferred if funding is inadequate (GBCP 1997, p. 19).

The plans are not regulatory mechanisms in any sense. "The process or mechanism [to implement the plan] is generally to rely on each [working group] member or entity to implement to the best of their ability actions for which they have responsibility." (GBCP 1997, p. 19). Thus, the actions in the plans are voluntary even if they are not explicitly deferred by the plan's timetable, or implicitly deferred by "inadequate funding." They will doubtless be deferred by the plans reliance on each entity being able to explain that they couldn't complete the actions for which they were responsible, but to the best of their ability, they did whatever they wanted. This is not a regulatory mechanism. The San Miguel Plan mentions the authority of the county to regulate land use but does not explain the limits of that authority or the degree to which it has been exercised in the past (SMBCP 1998, p. 29-30). In fact, one of the chief dangers to the bird is development (Braun 1998a). The county's authority over land development has not proven effective in the past. Thus, even if the authority to control land use were truly a regulatory mechanism, it has been shown inadequate. Without true regulations on land use, there is no guarantee that the county will exercise its authority in the future. The San Miguel Basin plans other assumptions also fail as adequate regulatory mechanisms. The plans impose no new regulatory scheme, instead relying on the same regulatory mechanisms – or lack thereof – that

have allowed the severe declines in Gunnison sage grouse. The San Miguel Basin plan does mention the authority of the FWS under the ESA, but this presupposes that the bird has been listed (SMBCP 1998, p. 30). Thus, the plans cannot function as adequate regulatory mechanisms sufficient to prevent listing of the bird – the only true regulatory mechanism is listing under the ESA. The San Miguel Basin plan also notes the establishment of Memoranda of Agreement and of Memoranda of Understanding among various federal agencies and between FWS and the state of Colorado (SMBCP 1998, p. 30). None of these qualify as regulatory mechanisms as a matter of law. Nor have the programs contemplated by the Memoranda even been drawn up and agreed to, much less implemented. The only regulatory program discussed at all by the San Miguel Basin plan is the ability of the Colorado Div. of Wildlife to regulate poaching and harassment (SMBCP 1998, p. 29). This has been ineffective to conserve the Gunnison sage grouse as seen by the severe declines in the bird. Moreover, it can only address one of many threats.

Even if all of the conservation plans were completely implemented immediately, they would prove inadequate to conserve the Gunnison sage grouse. The Gunnison Basin plan contemplates a minimum spring population goal of 867 males for a total of population of 2,601 grouse. The plan contemplates an "optimum" spring population goal of 1,200 males for a total of population of 3,600 grouse (GBCP 1997, p. 37). There are numerous problems with this scheme. First, although the plan acknowledges that the best scientific data now show that minimum viable population sizes of 5,000 are required to ensure against species extinction (GBCP 1997, citing Lande 1995), it does not incorporate this finding into its goals. Even the "optimum" of 3,600 birds is far short of an adequate population size, being only 72% of that number. The plan even acknowledges that in the past there may have been 10,000 birds in the Gunnison Basin, twice the number estimated in 1969 (GBCP 1977, p. 37). Thus, the 1969 population was already greatly reduced from its historic numbers and may have not been large enough to assure viability in any event. The San Miguel Basin plan does not contemplate that population size will reach that of a viable population from the already extremely small population present there (SMBCP 1998, p. 7). The San Miguel Basin plan hopes to achieve only 480 birds, even after 15 years. Even if it did achieve that goal, the genetic bottleneck effect found in small populations is likely to cause depressed reproductive success.

Second, the plans ignore effective population size (N_e) arising from the variance in reproductive contributions among male birds. As discussed previously, N_e for sage grouse is far lower than that for populations with random mating. This is well established in the scientific literature, and even appears in undergraduate textbooks, yet the plans do not account for this factor in their goals, even though the GBCP acknowledges that inbreeding depression is likely in Gunnison sage grouse (GBCP 1997, p. 6). Oddly, the San Miguel Basin plan, although written later than the Gunnison Basin plan, does not even acknowledge the reduction in effective population size. Instead, the San Miguel Basin plan makes an error in the opposite direction: it assumes that actual population sizes will be larger than the counted population because there are about "2 females for every male" (SMBCP 1998, p. 6). But the studies it bases this assertion on are not cited. The Crawford Area Conservation plan repeats this estimate, asserting that "studies across western North America" have found this to be the approximate sex ratio in spring (CACP 1998, p. 2). But, again no citations to the literature are given, and sex ratios of 1:1 are more likely in adult, breeding populations that are not hunted. It is not appropriate to use spring breeding numbers in any event as not all those grouse will breed.

Third, the plans make optimistic assumptions about the relation of the numbers of grouse counted to the actual numbers. As explained in the Methodology section above, Jenni and

Hartzler (1978) cautioned that evening counts at leks do not properly represent morning lek counts, yet the plans do not specify when lek counts will be made. Jenni and Hartzler (1978) also cautioned that hens visit multiple leks, multiple times, and thus counts of hens will generate overly optimistic population estimates. Counts of males at leks will not correctly represent population sizes (Jenni and Hartzler 1978, yet the plans all assert that their census numbers are conservative estimates.

Fourth, the plans rely on spring population sizes only. Not all grouse will mate, and not all females will successfully raise broods. Thus, spring population size alone is not an adequate measure of population viability; instead, spring census estimates represent the maximum number of birds present including "floaters" and other surplus birds from an evolutionary standpoint.

Fifth, the plans incorrectly assume that if a certain number of birds are present in a vast geographic area such as the Gunnison Basin, then those birds exist in a single population linked by gene flow. It is highly unlikely, however, that the grouse in the Gunnison Basin are a single population. Instead, they are almost surely fragmented into numerous small population isolates. In discussing "population" goals, the plans make no allowances for effects of habitat fragmentation on the birds, and instead only call for "well distributed" lek areas (GBCP 1997, p. 37). It is not the distribution of lek areas that is the problem. As explained above, a major problem causing endangerment is the fragmentation of habitat causing fragmentation of populations into small, isolated groups of birds that no longer experience gene flow with other isolates. The plans have not adopted any goals to reduce habitat fragmentation, and thus will surely fail to conserve the Gunnison sage grouse.

The ineffectiveness of these conservation plans, and their inadequacy as regulatory mechanisms is evident when viewing what the advocates of these plans list as their accomplishments. For example, the table of accomplishments for the plans lists few on the ground actions to restore habitat or even arrest the imminent and ongoing threats to the bird (Gunnison Sage Grouse Conservation Plan Accomplishments 1998). Instead, the type of accomplishments listed in this table include such things as selling T-shirts, lecturing to kindergarten and elementary school students, paying ranchers not to graze small areas of the public's land, mapping vegetation, and printing color brochures. Most of these are fun and worthwhile activities, but rather than act to conserve the grouse, they merely distract from needed actions. As such, they could form a useful adjunct to recovery plans once the species is listed – they cannot substitute for a listing. Much hard work and negotiation has gone into these plans. Yet, far from assuring the conservation of the species, the Sage Grouse Conservation Plans are plans for extinction of the sage grouse, simply because they are so ineffective.

In general, all of these conservation plans read as though they were concocted to advocate for minimal effects on established interest groups, and to paint the rosiest possible picture of the Gunnison sage grouse. The conservation plans do not present a sober assessment of the population status of the grouse, nor do they propose effective measures to arrest its alarming decline. In fact, at least some plans have "the potential for more harm than good" for sage grouse (Braun 2002a). This Plan identifies hunting, predators, and lack of grazing as threats, while it "turns a blind eye" to real threats, such as "housing developments, oil production, roads, timing of grazing, more fencing, more power lines, … Tebuthiuron, etc." (Braun 2002a). The North Park "Conservation" Plan "will not do any good" (Braun 2002a). Conservation Plans for Gunnison sage grouse are better, but have come "too late for Dove Creek, Glade Park/Pinon Mesa, and Poncha Pass" (Braun 2002a).

Taken together, or considered separately, the conservation plans for the sage grouse are

inadequate to conserve the species; because of their lack of enforceability and emphasis on protecting vested interests rather than protecting the grouse, they represent extinction plans for the sage grouse. Even worse, even if each conservation plan were completely effective, the extinction risk for the sage grouse would still be high. None of the conservation plans would provide connections among the isolated populations that are the subject of each individual plan. Thus, at best, the sage grouse would eventually consist of isolated and non-viable populations, each of which would then become extinct. As Storch (1997) noted in a study of several grouse species closely related to sage grouse: "attempts to stabilize a population below minimum viable population size will fail unless dispersal from neighboring populations occurs." Unfortunately, "travel corridors for sage grouse throughout their range are becoming restricted" thus preventing gene flow among these scattered isolates (Braun 1999a, p. 3).

Ultimately, conservation plans are literally that – mere plans. Actions on the ground must be taken if sage grouse are to be conserved. Importantly, the success of these actions must be quantitatively monitored if the effectiveness of the actions is to be assessed. Yet, land management agencies and wildlife agencies do not have adequate data collected to determine whether planned actions would be effective or not. As Lord Kelvin (the 19th Century scientist who united heat theory) once said: "when you measure … you know." The converse is also true.

Management by Private Parties

Within the historic range of the sage grouse, private land typically is more fertile, has more forb and grass cover, better soils, and has better hydrological status than public lands (SMBCP 1998, p. 25; DCCP 1998, p. 26). Private lands are typically those located near streams (SMBCP 1998, p. 25). It has been said that the public lands in the United States are those that no one wanted during the period of Western settlement and homesteading. It is thus not surprising that private lands impact sage grouse populations to a disproportionate degree.

Yet no regulatory mechanisms protect the birds on private lands (with the limited exception of hunting seasons). * * * Because private lands are so important to sage grouse (SMBCP 1998, p. 25), especially for the very limited early brood rearing habitat, even perfect conservation efforts on all federal lands would be unlikely to ensure the continued survival of the species. Thus, listing under the ESA is essential to conserve sage grouse species.

The Future for Sage Grouse

Vast decreases in distribution and population numbers of sage grouse have already taken place. The range has been greatly reduced by 60%, population numbers have plummeted by 90% or more, and the remaining range is highly fragmented. But worse is yet to come.

According to Dr. Clait Braun (2001h, 2001i), within approximately 20 years, the northern sage grouse will be completely eradicated from 5 more states and provinces: Alberta, Saskatchewan, Washington, North Dakota, and South Dakota. Additional extirpation will take place in other states and sage grouse will then persist only in "central Montana, central and western Wyoming, northern Colorado (2 counties), northern Utah (4 counties), northern Nevada, south central and eastern Oregon," and several disjunct populations in southern Idaho (Braun 2001i). As bad as this assessment sounds, it may be overly optimistic. For example, juniper invasion and fires are likely to extirpate sage grouse from south central Oregon in less than 20 years.

* * *

Gaps in Information Needed to Conserve the Species

"We know enough about sage grouse habitat requirements (extensively published) to manage rangelands to maintain or enhance sage grouse populations" (Braun 1999c). Additional research is not needed to begin restoration now. Nonetheless, scientists typically desire additional research on any topic. This is part of the culture of science, that additional knowledge is a worthy goal. In the present case, however, actions must be taken now to restore sage grouse populations and habitat, and there is no reason to wait. Although additional scientific study, particularly of habitat fragmentation and gene flow, is useful, it is not necessary. The Service must avoid the bureaucratic temptation to "study the problem to death" – something that will violate the ESA and cause the sage grouse to become extinct. Likewise, the Service must avoid the temptation to create a "false uncertainty" (sensu William Curtiss, personal communication 1996) that there is insufficient knowledge to conserve sage grouse, when the reality is that the threats and the steps needed to alleviate those threats are both quite clear. Even when information actually is incomplete, action to prevent extinction is required by the ESA. As Murphy and Noon (1991) admonished with respect to critical habitat: "failure to act because of incomplete information is imprudent."

Importance of Sage Grouse

Sage grouse have significant aesthetic value because of their vivid and unusual mating displays, and also possess unusual digestive and detoxification abilities which are of significant scientific interest and possible economic importance. Sage grouse are economically important in many rural counties (Loft 1998) and, of course, would be more economically important if there were more of them. Recreational value for bird watching and hunting is great. Moreover, because of their discovery by the Lewis and Clark expedition and the dependence on them as a food source by Indians and early pioneers, sage grouse possess significant historical importance. Their cultural significance to various Indian tribes is unquestioned, they may have religious significance to various tribes as well.

Contemporary understanding of ecological communities posits that the loss, removal, or reduction in numbers of individual species can cause dramatic changes in ecological communities, including the extinction of other species. Recently, Berlow (1999) showed that even weak ecological interactions can have important effects on ecological processes. Sage grouse may be strongly influenced by ant and beetle abundance as these prey species are critical in both juvenile nutrition and the nutrition of hens during the pre-laying period. Forbs are now widely acknowledged in the scientific literature as a critical component of sage grouse habitat because they serve as protein sources for hens and juveniles, as a physical vegetative feature that provides concealment from predators, and as a substrate and food source for insects, which sage grouse require at critical life history periods.

The converse is also true: sage grouse are important components of shrub-steppe ecosystems, and serve as prey for a wide variety of predators. The importance of sage grouse as competitors, mutualists, or disturbance sources is unknown, but any vertebrate formerly present is such huge numbers across such vast spaces was likely an important determinant of community structure and processes. Typically, ecosystem dynamics are driven in large part by a relatively "small number of biotic and abiotic variables on whose interactions the balance of [other] species are, in a sense, carried along" (Holling 1992, Lawton 1994, Perrings 1995). In the sagebrush shrub-steppe, it is sage grouse around which such interaction variables cluster.

Sage grouse can also serve an important role as what has sometimes been referred to as

"umbrella" species. By protecting the sage grouse, the Service would also be protecting a large number of sagebrush obligates and other species that use sagebrush habitats.

Similarly, protection of sage grouse would reduce the workload on the Service because protection of this species would obviate the need for additional protections on other species with similar habitat requirements. The Service would thus not need to address a potential avalanche of petitions to list the myriad species in this ecosystem type that will otherwise follow.

The Service is requested to consider the importance of protecting sage grouse in providing a means whereby the ecosystems upon which other endangered species and threatened species depend may be conserved.

Protection of Sagebrush Ecosystems

All state wildlife agencies agree that "sage grouse are an important indicator of the overall health" of "the sagebrush shrub-steppe ecosystem" (MOU 1995). Sage grouse are acknowledged to have "key herbivory functions" in the interior Columbia Basin (Quigley and Arbelbide 1997c, p. 1609). Highly placed BLM officials recognize that "hundreds of special status fish, wildlife, and plant species" in sagebrush ecosystems are "at risk" (Jauhola 2001). Petitioners request that the Service recognize and consider the importance of sage grouse as a keystone species, as an ecological dominant, and as an umbrella species, which can protect numerous other species in the western United States. Petitioners request that the Service incorporate such considerations into all aspects of its section 4 responsibilities under the Endangered Species Act. The effects of habitat degradation on sage grouse and other species in sagebrush ecosystems is not new. Carhart (1954) recognized that at least 4 species of birds were dependant on sagebrush, and other authors expressed concern even earlier (e.g. Hornaday 1916). Because of their area requirements, sage grouse can also function as a focal species, *sensu* Lambeck (1997). In Idaho, GAP analysis shows that protecting sage grouse would also protect large numbers of other vertebrates that are currently unprotected (Kiester, et al. 1996). The same is likely to be true in other states.

As the Oregon BLM has noted, sage grouse are a "good indicator of sagebrush habitat health." By protecting the sage grouse, the Service will also be protecting an entire ecosystem type, the sagebrush shrub-steppe, and the other species that depend on this ecosystem. This fulfills the statutory purpose of the Endangered Species Act, 'to provide a means whereby the ecosystems upon which endangered or threatened species depend may be conserved…." 16 U.S.C. § 1531(b). The Service recognizes that the conservation of such ecosystems is "a primary purpose of the Act." 59 Fed. Reg. 34273, Friday, July 1, 1994. The Service adopted the "Ecosystem Approach to Fish and Wildlife Conservation" on July 1, 1994, explaining that "species will be conserved best not by a species-by-species approach but by an ecosystem conservation strategy that transcends individual species." 59 Fed. Reg. 34273. By listing sage grouse under the protections of the ESA, the Service has a chance to comply with that policy. Moreover, the Service should take into consideration the importance of ecosystem conservation when assigning priorities in the listing process.

Sage grouse function as a "keystone food resource" (Terborgh 1986; Meffe and Carroll 1997) supporting many predator species in the sagebrush shrub-steppe. Sage grouse populations affect both predator populations and plant populations and community dynamics. Extinction or reduction in numbers of sage grouse could be a primary extinction or effect that necessarily causes multiple extinctions of numerous other species in sagebrush ecosystems because of food web interactions and other community level effects (Terborgh 1976, Wilcox and Murphy 1985).

As the National Biological Service noted, a "significant decline in a once-dominant or keystone species could have profound ecological ramifications," and these "ecosystems-wide effects could occur long before a pivotal species becomes rare enough for listing as endangered" (Noss, et al. 1995).

Sage grouse serve as both an indicator and as a key species affecting many other species in sagebrush shrub-steppe ecosystems. Among birds, the sage thrasher (*Oreoscoptes montanus*), Brewer's sparrow (*Spizella breweri*), and sage sparrow (*Amphispiza belli*) require big sagebrush habitat (Belthoff, et al. 1995; Reynolds and Trost 1981). These obligate species (Paige and Ritter 1999, p. 33-37) have habitat requirements similar to those of sage grouse (Welch, draft manuscript, Ch. II, p. 15) and there is a high degree of overlap between the source habitats for sage grouse and those for these species (Rich and Altman 2001). Fragmentation is significantly impacting these bird species (Knick and Rotenberry 1995b). Moreover, many grassland and shrub dwelling bird species have declined within the range of the sage grouse (Peterjohn, et al. 1995).

Protection of sage grouse is also highly likely to protect many rare plants. Rare plants are often found in the areas inhabited by sage grouse. For example, a BLM botanist lists a dozen or more rare plants in just the Mono area of California which the California Dept. of Fish and Game has ranked as threatened or very threatened (Halford 2001a).

Welch reviews a number of other sagebrush obligate species and their habitat requirements (Welch, draft manuscript, Ch. II, p. 15-18). For example, many mammals depend upon sagebrush ecosystems. Pygmy rabbits (*Sylvilagus idahoensis* or *Brachylagus idahoensis*) is also a sagebrush obligate (Green and Flinders 1980, Lyman 1991), as is the sagebrush vole (or sage vole) (*Lagurus curtatus*) (Maser 1974, Carroll and Genoways 1980, Larrison and Johnson 1973). Welch reviewed the literature on facultative associations of other mammals with big sagebrush (Welch, draft manuscript, Ch. II, Table 2.2 and p. 24-34) and of facultatively associated bird species (Welch, draft manuscript, Ch. II, Table 2.1). Numerous reptiles are also associated with big sagebrush (Welch, draft manuscript, Ch. II, Table 2.9). Protection of sage grouse would protect many other birds species such as loggerhead shrike (*Lanius ludovicianus*), sharp-tailed grouse (*Tympanuchus phasianellus*), sage sparrow (*Amphispiza belli*), Brewer's sparrow (*Spizella breweri*), sage thrasher (*Oreoscoptes montanus*), and green-tailed towhee (*Pipilo chlorurus*) which use sagebrush and shrub habitats (Altman and Holmes 2000, Appendix C) as well as other bird species that would benefit from restored habitats within shrub-steppe ecosystems, such as vesper sparrow (*Pooecetes gramineus*), long-billed curlew (*Numenius americanus*), black-throated sparrow (*Amphispiza bilineata*) and others (Altman and Holmes 2000, Appendix C). Many non-vertebrates are also obligate species of sagebrush, and Welch describes sagebrush as a "mini-ecosystem with big sagebrush as the keystone species," and one that includes 52 species of aphids, 10 or more species of parasitic hymenopterans feeding on the aphids, and an unknown number of ladybird beetles, fungi, lichens, moths and other insects, ants, and aphid species attending the ants (Welch, draft manuscript, Ch. III and p. 9). Many of the species already listed as threatened or endangered in the intermountain West "are associated with rangeland ecosystems" (Flather, et al. 1998). By protecting sage grouse, the Service will be protecting this entire ecosystem, thereby protected the myriad of species found there (Simons, et al. 1988; FWS 1995; Flather, et al. 1998). As BLM recognizes, "sage grouse are considered to be an umbrella species," so conservation of sagebrush habitats needed by sage grouse will benefit a multitude of other sagebrush habitat species of concern" (Nevada State Office, BLM 2000a, p. 8). Because of the large number of obligate species, and even larger number of facultatively

associated species, protection of the sagebrush shrub-steppe is thus "important for conservation of biodiversity" 59 Fed. Reg. 34274, Friday, July 1, 1994.

In the past, the Service has not considered ecosystem effects in its listing priorities because ecosystem "information is seldom available at the time a species is considered" (1983 Guidelines, 48 Fed. Reg. 43098, 43101, Sept. 21, 1983). Here, extensive information is provided to remove that barrier. The Service promised to consider "ecosystem importance" on an ad hoc basis (id.), and petitioners formally request such consideration here.

Status Review and Petition to List the Greater Sage Grouse (*Centrocercus urophasianus)* as Threatened or Endangered under the Endangered Species Act

ADDENDUM

The following new information concerning Greater Sage Grouse supplements the foregoing copyrighted status review and petition to list the species under the Endangered Species Act.

A. Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

A species must be listed if it "is endangered or threatened" because of "present or threatened destruction, modification, or curtailment of its habitat or range." 50 C.F.R.§ 424.11(c)(1); 16 U.S.C. § 1533(a)(1)(A). This section presents new and developing threats to sage grouse and sagebrush habitat.

- **Coalbed Methane Development.** Coalbed methane development (CBM) is presently scheduled on both private and public lands used by sage grouse across Montana, Wyoming and Colorado. CBM is a pervasive and highly destructive activity with both obvious impacts on sage grouse (habitat destruction and fragmentation) and more subtle effects, such as the potential disturbance to sage grouse nest initiation from traffic on CBM service roads.[3]

  Following is a summary of some impacts of CBM development on sage grouse:

  > "Impacts to sage-grouse from CBM development include direct loss of habitats from all production activities along with indirect affects from new power lines and significantly higher amounts human activity, both during initial development and during production." Coal bed methane development has begun in the Powder River Basin of Wyoming, and with development of the entire project, "over 50 % of the known sage-grouse range will be either directly or indirectly affected" (Braun, et al. 2002). Moreover, leks within ¼ mile of a CBM well, compressor station, or power line have "significantly fewer males/lek" and/or "the rate of growth is much lower when compared to other less disturbed leks" (Braun, et al. 2002). These effects are likely to persist for decades: sage grouse have not occupied leks even 15 years after disturbance for oil and gas development (Braun, et al. 2002). CBM development is especially pernicious because "severe consequences to sage-grouse" are likely; however, knowledge of those effects will "most likely come too late to result in any major initiatives to protect the birds or their habitats" (Braun, et al. 2002).[4]

- **Wind Energy Development.** Wind energy development is a burgeoning new use of public and private lands in the West. Energy companies are targeting federal public lands

[3] Lyon, A. G. and S. H. Anderson. 2003. Potential gas development impacts on sage grouse nest initiation and movement. Wildlife Society Bulletin 31(2): 486-491.

[4] Webb, R. 2002. Status Review of the Eastern sub-species of the Greater Sage Grouse (*Centrocercus urophasianus urophasianus*). Wildlife Protection Institute. Eugene, OR, *citing* Braun, C. E., O. O. Oedekoven, and C. L. Aldridge. 2002. Oil and Gas development in western North America: effects on sagebrush steppe avifauna with particular emphasis on sage-grouse. Trans. N. Amer. Wildl. and Nat. Res. 67: 337-349. {By agreement, American Lands Alliance may distribute copies of all or part of this status review and petition to further the organization's mission to "protect forest, grassland, desert and aquatic ecosystems; preserve biological diversity; restore landscape and watershed integrity; and promote environmental justice in connection with these goals."}

for "wind farms" that fragment habitat, disrupt migration, and introduce weeds to natural areas. The BLM is presently cooperating with an energy company from England to site wind turbines in pristine sage grouse habitat (including wintering areas) in Idaho.[5] Wind energy development is also planned in Wyoming and Nevada.[6]

The relatively sudden growth of the wind energy industry prompted the Service to issue a new set of guidelines for siting and installing wind turbines in 2003. However, according to one commentator, the Service' "voluntary guidelines and the discretionary enforcement described in this document is reminiscent of the impacts of other energy production and transmission facilities and infrastructure in this country."[7] The BLM has also proposed a programmatic EIS to evaluate wind energy on BLM lands, expanding and institutionalizing this new use on public lands, further burdening the native wildlife that live there.[8]

- **Domestic Livestock Grazing.** State and federal agencies continue to underestimate the effects of livestock grazing on sage grouse. For example, in its draft sage grouse strategy the BLM suggests that "[s]ome activities, such as … intensive livestock grazing practices, are of concern but less common today than in the past" (p. 5). Petitioners could not disagree more. Livestock grazing is perhaps the most pervasive and harmful impact on sage grouse and sagebrush habitat in the West.

  In addition to the extensive analysis of the effects of livestock grazing on sage grouse in the enclosed status reviews, the scientific literature has been recently augmented by relevant new studies and reviews describing the harmful impacts of grazing on arid landscapes in the West. Hockett (2002) provides a thorough review of livestock impacts on the herbaceous components of sage grouse habitat, demonstrating the overlap between livestock preferences and sage grouse foods critical to the bird's life cycle.[9] Stohlgren, et al. (2001) studied the ability of soil crusts to impede the spread of invasive weeds, and suggest that disturbance of fragile crusts (including from livestock) may facilitate further invasion of exotic plants.[10] Freilich et al. (2003) critiqued the concept of livestock grazing as a "conservation tool" and the belief that grazing is sustainable use of western landscapes.

  Recent research has also focused on the ecology and management of big sagebrush varieties. Since sage grouse depend on big sagebrush habitats, these papers are particularly relevant. Welch (2002) discovered that burned big sagebrush sites reseeded

[5] Fite, K., e-mail communication (May 3, 2003).
[6] Fite, K., e-mail communication (May 3, 2003).
[7] Moore, S., e-mail communication (July 11, 2003).
[8] 68 Fed. Reg. 59814 ("Notice of Intent To Prepare a Programmatic Environmental Impact Statement (EIS) To Evaluate Wind Energy Development on Western Public Lands Administered by the Bureau of Land Management").
[9] Hockett, G. A. 2002. Livestock impacts on the herbaceous components of sage grouse habitat: a review. Intermtn. J. Sciences 8(2): 105-114.
[10] Stohlgren, T. J., Y. Otsuki, C. A. Villa, et al. 2001. Patterns of plant invasions: a case example in native species hotspots and rare habitats. Biol. Invasions 3: 37-50.

with forage species support fewer birds than unburned sites.[11] Welch and Criddle (2003) then challenged the notion that big sagebrush should ever be burned, chained, or otherwise "controlled" to benefit livestock (and supposedly wildlife).[12] Aldridge (2002) suggested that land managers must protect and enhance sagebrush stands and increase overall sagebrush cover to improve nesting habitat for sage grouse.[13] Vander Haegen et al. (2002) and others studied the effect of vegetation structure on predation of sage grouse nests and suggested that nesting success is positively correlated to tall, dense forbs and sagebrush.[14] Finally, Oyler-McCance (2001) documented the loss of sagebrush-dominated areas in southwestern Colorado between the 1950s and 1990s and suggested that Gunnison sage grouse might become extinct if the trend continues.[15]

B. Disease or Predation

"Disease" is a factor the Service must consider when evaluating species for listing under the ESA. 50 C.F.R.§ 424.11(c)(3); 16 U.S.C. § 1533(a)(1)(C).

- **West Nile Encephalitis Virus.** The threat of West Nile encephalitis virus (WNEV) to sage grouse populations increased significantly in 2003. WNEV was first detected in sage grouse in Wyoming in summer 2003.[16] Concern about the potential impact of the disease on sage grouse prompted the Wyoming Department of Game and Fish to suspend sport hunting in northeast Wyoming.[17] At least twenty-two sage grouse have tested positive for WNEV in Wyoming and Montana to date.[18]

  It is probably inevitable that WNEV will soon spread to every state in the West (WNEV was recently discovered in Colorado, Nevada and Arizona). Experts do not understand how to contain WNEV, or what the long-term effects of the disease will be on sage grouse and other wildlife. However, it is expected that isolated and/or genetically limited sage grouse populations (e.g., Gunnison sage grouse) will be especially vulnerable to disease outbreaks.[19] Water holding ponds, a wasteful byproduct of coalbed methane development, may serve as breeding habitat for mosquitoes, a vector of WNEV.

[11] Welch, B. L. 2002. Bird Counts of Burned Versus Unburned Big Sagebrush Sites. RMRS-RN-16. USDA-Forest Service, Rocky Mountain Research Station. Provo, UT. (September 2002).
[12] Welch, B. L. and C. Criddle. 2003. Countering misinformation concerning big sagebrush. Research Paper RMRS-RP-40. USDA-Forest Service, Rocky Mountain Research Mountain Research Station. Odgen, UT.
[13] Aldridge, C. L. and M. R. Brigham. 2002. Sage-grouse nesting and brood habitat use in Southern Canada. J. Wildl. Manage. 66(2): 433-444.
[14] Vander Haegen, W. M., M. A. Schroeder, R. M. Degraaf. 2002. Predation on real and artificial nests in shrubsteppe landscapes fragmented by agriculture. Condor 104(3): 496-506; M. E. Watters, T. L. McLash, C. L. Aldridge, R. M. Brigham. 2002. The effect of vegetation structure on predation of artificial greater sage-grouse nests. Ecoscience 9(3): 314-319.
[15] Oyler-McCance, S. J., K. P. Burnham, C. E. Braun. 2001. Influence of changes in sagebrush on Gunnison sage grouse in southwestern Colorado. Southwestern Natur. 46(3): 323-331.
[16] Wyoming Department of Game and Fish. "West Nile Virus in Three Sage Grouse has G&F Increasing Testing, Restating Cautions" (press release). (Aug. 15, 2003).
[17] Wyoming Department of Game and Fish. "G&F Closes Sage Grouse Season in Johnson, Sheridan and Campbell Counties" (press release). (Sept. 11, 2003).
[18] Associated Press. "More sage grouse have tested positive for West Nile." Casper Star Tribune (Nov. 12, 2003).
[19] Gruver, M. *West Nile strikes sage grouse*. Casper Star Tribune (Aug. 12, 2003); BLM biologist (name withheld), pers. comm. (Sept. 22, 2003).

State and federal agency response to the WNEV outbreak in Montana and Wyoming have been inadequate to date. For example, although it is laudable that the Wyoming Department of Game and Fish suspended hunting in the Powder River Basin to protect sage grouse, hunters took only 75 birds in this area in 2002.[20] Meanwhile, BLM continues to permit widespread livestock grazing and coalbed methane development in the same area, activities that severely degrade sage grouse habitat. Given a representative swatch of sagebrush habitat in eastern Wyoming, sage grouse may be confronted by livestock grazing, CBM development (with associated construction of roads, fences, powerlines and settling ponds), off-road vehicle use, weed invasion, drought, and now the added stressor of WNEV.

C. Inadequacy of Existing Regulatory Mechanisms

A species must be listed if it "is endangered or threatened" because of "the inadequacy of existing regulatory mechanisms." 50 C.F.R.§ 424.11(c)(4); 16 U.S.C. § 1533(a)(1)(D). This section presents recent planning processes and new federal programs and policies that fail to conserve sage grouse and sagebrush habitat, and threaten to accelerate habitat loss or degradation both in the near- and long-term. Petitioners and others participated in these decisionmaking processes as advocates for sage grouse and habitat conservation without success.

- **Interior Columbia Basin Ecosystem Management Project (ICBEMP).** An ambitious multi-agency federal planning effort, ICBEMP covered over 140 million acres in the interior Columbia River Basin, the Upper Klamath, and parts of the Great Basin. However, even before the multi-million dollar, nine-year project was demoted by the Bush Administration to a mere memorandum of understanding,[21] it was apparent that ICBEMP would do almost nothing to reverse long-term damage to sagebrush ecosystems in the Columbia Basin. For example, ICBEMP proposed to reduce public lands grazing by only 3 percent in the Basin to conserve upland arid landscapes despite reports by ICBEMP scientists that demonstrated that, without wholesale changes in management, sage grouse will be extirpated from most of the planning area in 100 years.[22]

- **Bennett Hills Area of Critical Environmental Concern.** Although damaged by livestock grazing and threatened by offroad vehicle use, the Bennett Hills still represent the last, best tract of sagebrush habitat between Boise, Twin Falls, and Pocatello in central Idaho. Citizens' organizations and the Idaho Department of Fish and Game documented the area's importance to sage grouse and other wildlife, and submitted a

[20] Wyoming Department of Game and Fish. "G&F Closes Sage Grouse Season in Johnson, Sheridan and Campbell Counties" (press release). (Sept. 11, 2003).
[21] Interior Columbia Basin Ecosystem Management Project. Federal Land Agencies Adopt Science Strategy for Interior Columbia River Basin (press release). Feb. 19, 2003. Available at www.icbemp.gov/html/nr021903.pdf.
[22] *See* R. Webb. 2002. Status Review of the Eastern Sub-species of the Greater Sage Grouse (*Centrocercus urophasianus urophasianus*). Institute for Wildlife Protection. Eugene, OR: 78-80; *see also* M. J. Wisdom, M. W. Rowland, B. C. Wales, et al. 2002. Modeled effects of sagebrush-steppe restoration on greater sage-grouse in the Interior Columbia Basin, U.S.A. Cons. Biol. 16(5): 1223-1231; M. A. Hemstrom; M. J. Wisdom, W. J. Hann, et al. 2002. Sagebrush-steppe vegetation dynamics and restoration potential in the Interior Columbia Basin, U.S.A. Cons. Biol. 16(5): 1243-1255; M. J. Wisdom, B. C. Wales, M. M. Rowland, et al. 2002. Performance of greater sage-grouse models for conservation assessment in the Interior Columbia Basin, U.S.A. Cons. Biol. 16(5): 1232-1242.

citizens' proposal for a Bennett Hills Sagebrush Steppe ACEC to the BLM that would have designated more than 200,000 acres for protection. However, as the planning process was finally concluded the BLM proposed less than 1,200 acres for the Bennett Hills ACEC.

- **Forest Service Drought Policy.** Drought has known, negative effects on fish, wildlife, and native vegetation in the West. However, despite receiving a petition from citizen's groups in 2002 to the promulgate new rules for land management in times of drought,[23] the Forest Service (Intermountain Region) has failed to act, even as the current drought in the West persists.

- **Clean Water Act rulemaking redefining "waters of the United States."** In January 2003, the Environmental Protection Agency (EPA) proposed to restrict the definition of surface waters that fall under the purview of the Clean Water Act (CWA) by excluding certain "non-navigable" waters from EPA oversight, including sparse wet meadows, seeps and springs, and intermittent streams which are the lifeblood of sagebrush ecosystems. Removing these waters from CWA protection would hasten the decline of sage grouse, which depend on small mesic systems during the hot summer months. (The importance of riparian areas to sage grouse was highlighted in a recent publication by the National Academy of Sciences.[24]) While the Bush Administration has since rescinded the proposed administrative rule, it has not withdrawn related policy guidance ordering EPA and the Army Corps of Engineers not to require permits under the Clean Water Act for the pollution or destruction of wetlands that are located within a single state and are not associated with any navigable waterway.[25]

- **BLM Sixteen-state Vegetation Management Plan/Draft Environmental Impact Statement (EIS).** In autumn 2001, the BLM announced that it would prepare a "vegetation management" EIS for its proposal to spray invasive species ("noxious weed control") and log trees and chain shrubs ("fuels reduction") on millions of acres of agency lands in sixteen western states. It was clear that the BLM intended to avoid consideration of the *causes* of invasive species spread, and ignore the minimal actions needed to protect private property from brush-fed wildfire.

- **Energy Development.** The Bush Administration has prioritized energy development in Rocky Mountain states,[26] threatening millions of acres of sage grouse habitat. Coalbed methane (CBM) development is proposed for large parts of Wyoming and Montana, the heart of the sage grouse's range. The gas wells, compressor stations, services roads, pipes and powerlines associated with CBM development fragment habitat, introduce invasive species and disrupt migration patterns. Current plans call for 65 thousand new wells, 27

[23] Forest Guardians. Administrative Procedures Act Petition to Develop Regionwide Drought Policy (June 26, 2002). Copies available upon request.
[24] National Research Council. 2002. RIPARIAN AREAS: FUNCTIONS AND STRATEGIES FOR MANAGEMENT. National Academy Press. Washington, DC: 116 (Box 2-2).
[25] Pegg, J. R. Bush dumps controversial wetlands rule. Environmental News Service (Dec. 17, 2003).
[26] Arellano, K. Rockies' energy role to grow: U.S. will lean harder on region's vast natural gas reserves. Denver Post (Nov. 6, 2003).

thousand miles of roads, and 53 thousand miles of pipeline, powerlines, and utility corridors in the Powder River Basin alone, affecting an area over 80,000 square miles in size. (Draft/Final Environmental Impact Statement and Draft Planning Amendment for the Powder River Basin Oil and Gas Project (Wyoming) and Montana Statewide Draft/Final Oil and Gas Environmental Impact Statement and Amendment of the Powder River and Billings Resource Management Plans.)

Conventional gas development has also been prioritized in sage grouse habitat, with the concurrent construction of roads, utility corridors, and related facilities. Planning processes for thousands of new conventional wells are presently underway in Montana and Wyoming. Some plans would approve a minimum of 64 wells per square mile. This density could effectively eliminate sage grouse from the area.

- **BLM sage grouse management strategy.** In August 2003, the BLM issued a draft national Sage Grouse Habitat Conservation Strategy (draft strategy) for public review. Unfortunately, the BLM's draft strategy relies on state fish and wildlife agencies to conserve and recover sage grouse on private, state and federal lands—which may in fact exacerbate problems for the species. For example, we understand that the U.S. Fish and Wildlife Service recently notified the Wyoming Game and Fish Commission that its final statewide sage grouse management plan fails to meet minimum criteria for conservation adequacy in the Policy for Evaluation of Conservation Efforts when Making Listing Decisions ("PECE policy").[27] In some cases, local interests have even challenged the need for statewide management frameworks, claiming that state and federal agencies have been pressured by "high profile, minority interest environmental groups" to produce sage grouse management plans for a species that does not necessarily require such attention.[28] Others have simply lost faith in state management planning.[29]

  In some states the responsibility for developing sage grouse plans has been passed down to local working groups, so that key sage grouse policy in these states will be determined not by BLM and its partners, state agencies, professional biologists, university scientists and contractors, but by a collection of isolated working groups comprised mostly of industry representatives and other stake-holders seeking to preserve their respective interests in public lands. These local groups rely on consensus for decision-making, meaning that the lowest common denominator controls the process and result – not the welfare of the species that is purportedly to be conserved. The plans they produce are mostly unfunded, advisory and voluntary. Hemker and Braun (2001) warned of these weaknesses.[30]

  Current planning efforts in Idaho serve as an example. In 1997 the Idaho Department of Fish and Game passed the onus of sage grouse conservation planning onto five to seven

[27] BLM official (name withheld), pers. comm. (Aug. 21, 2003).
[28] Idaho BLM. (undated). Idaho BLM Response to "Weaknesses of the Draft Framework to Assist in Making Sensitive Species Habitat Assessments for BLM-Administered Public Lands in Idaho" written by Chad Gibson and John Romero. p. 8.
[29] Moore, T. "Grouse back in court; western listing possible." Capital Press (Nov. 14, 2003).
[30] Hemker, T. P. and C. E. Braun. 2001. Innovative approaches for development of conservation plans for sage grouse: examples from Idaho and Colorado. Trans. N. Amer. Wildl. and Nat. Res. Conf. 66: 456-463.

local working groups.[31] But these groups have suffered from irregular membership, conflicting goals, and stagnation. In summer 1999 the Upper Snake Sage Grouse Local Working Group was created and it adopted a group charter that declared all decisions would be made by consensus, described as "everyone agrees not to sabotage a decision" once it is made. By June 2000 many participants had expressed "frustration with the apparent lack of progress within the Local Working Group regarding determination of what public land management agencies and private landowners can/should 'do' to help increase Sage Grouse populations."[32] Several participants also "expressed concern regarding the lack of involvement of the higher levels of management from various land management agencies and the apparent, related lack of commitment to follow through on recommendations being developed by the Local Working Group."[33] In July 2000 the group facilitator had received phone calls "from individuals who were concerned about the possibility that the group would not be able to reach consensus and that agreements could be made (outside the room) that would jeopardize the group's efforts."[34] By 2002, after meeting for three years, the group was asking itself whether it should continue pursuing a conservation plan at all.

The draft national strategy (a "regulatory mechanism") for conserving and recovering sage grouse is inadequate to save the species. The BLM's own conflicting mandates compromise its participation in local, state and federal planning processes and may even worsen the paralysis that has stricken these efforts. The agency is presently torn between serving multiple publics, while being presented with new science from both independent and government scientists predicting disastrous consequences for sage grouse from past—and current—management practices. Current BLM management schemes (as dictated by Congress) often prioritize resource use over habitat conservation and restoration, forcing the agency to preserve some level of resource use in sage grouse recovery plans even when it might harm the species. Listing the species under ESA will elevate conservation of sage grouse above other agency mandates.

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[31] _____. Upper Snake Sage Grouse Working Group Draft Plan for Increasing Sage Grouse Populations, p. 2. (no date) ("The Idaho Department of Fish and Game published a Sage Grouse Management Plan in 1997 that called for the development of local working groups throughout the state to develop local management plans for increasing sage grouse populations.")

[32] _____. Upper Snake Sage Grouse Working Group, June 12, 2000 Group Memory, p. 2.

[33] _____. Upper Snake Sage Grouse Working Group, June 12, 2000 Group Memory, p. 1.

[34] _____. Upper Snake Sage Grouse Working Group, July 14, 2000 Group Memory, p. 1.

D. Other Natural or Man-made Factors Affecting the Species' Continued Existence

Petitioners present "other natural or manmade factors affecting" the continued existence of sage grouse here in accordance with federal statute and regulation. 50 C.F.R.§ 424.11(c)(5); 16 U.S.C. § 1533(a)(1)(E).

- **Drought.** The current drought in the West has created new and emerging problems in the sagebrush steppe. More than 197,000 acres of sagebrush in the Uinta Basin in Utah has died or was stressed from drought in 2003,[35] rendering it uninhabitable to sage grouse and other wildlife. At least thirty percent of sagebrush in the Gunnison Basin in Colorado—the last, best Gunnison sage grouse habitat—died from extended drought in 2003.[36] Drought has affected sagebrush habitats in most of the West, including Montana, Wyoming, Colorado, Nevada and Oregon.

  While the Forest Service has ignored citizen petitions to promulgate new policies for managing public resources in time of drought, the BLM's draft sage grouse strategy also provides no guidance for management plans to contend with acute and long-term drought (drought is only mentioned as a problem, then ignored in the remainder of the document concerning management planning). The draft strategy states that "[in times of drought] timely adjustments in use during drought can allow for plant regrowth on uplands, in wet meadows and riparian areas, and can maintain the improved condition of rangeland made under more normal precipitation." Yet, in the midst of severe drought in the Uinta Basin, grazing permittees were allowed to continue to stock public lands grazing allotments at 70 percent of normal levels.[37] In other parts of the country stricken by drought, the federal government re-opened lands for "emergency" livestock use" that taxpayers had paid to retire under the Conservation Reserve Program, thus forfeiting the (albeit minimal) conservation value provided from those lands.[38]

E. New Publications, Peer-Reviewed Science

Following are annotated references for the Service to consider (in addition to the enclosed bibliography) when evaluating this species for listing.

Beck, J. L., D. L. Mitchell, B. D. Maxfield. 2003. Changes in the distribution and status of sage grouse in Utah. West. N. Amer. Nat. 63(2): 203-214. [*Life history of sage grouse in Utah*].

Connelly, J. W., K. P. Reese, E. O. Garton, M. L. Commons-Kemner. 2003. Response of greater sage grouse *Centrocercus urophasianus* populations to different levels of exploitation in Idaho, USA. Wildl. Biol. 9(4): 255-261. [*Impacts of hunting on sage grouse populations, reporting "(l)imited or moderate rates of exploitation apparently slowed population recovery for sage grouse*].

[35] Utah Division of Wildlife Resources. "Biologists Concerned with Sagebrush Die-off in Northeastern Utah" (press release) (Aug. 7, 2003).
[36] BLM biologist (name withheld), pers. comm. (Sept. 22, 2003).
[37] Knowles, S. *State's sagebrush situation is dire.* The Salt Lake Tribune (May 23, 2003).
[38] Johnston, J. USDA approves CRP extension in four states. AgWeb.com. (Nov. 27, 2003).

Crawford, J. A., R. A. Olsen, N. E. West, et al. (in press). Ecology and management of sage-grouse and sage-grouse habitat. (J. Range Manage.). [*A major review (9 authors) of sage grouse ecology and management.*]

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F. Future of Sage Grouse

Considering the information provided here, the future of sage grouse appears tenuous at best. The plight of the Jackson Hole, Wyoming, population of sage grouse is illustrative of the

challenges confronting this species across its range. Sage grouse in Jackson Hole declined by 50 percent between 1957-2000. The total number of sage grouse in this population may be less than 300 birds. The Wyoming Department of Game and Fish, likely under pressure from sporting interests and seeking to increase its budget from hunting licenses and permits, has burned substantial areas of sage grouse habitat in the area to improve habitat for elk. The U.S. Fish and Wildlife Service has participated in these actions, and the National Park Service has prioritized additional projects to benefit bison in the area (at the expense of sage grouse). Additional areas have been burned by wildfires (possibly carried through the sagebrush by invasive weeds such as cheatgrass). Other habitats were lost on National Park Service lands with the recent expansion of the runway for the Jackson Hole Airport. A new golf course has also negatively affected surrounding habitat. Grazing occurs on both private and public lands in the area. Chances for sage grouse in Idaho to move into and from Jackson Hole are increasingly remote as development on public and private lands degrades the habitat that links the Idaho and Jackson Hole birds. The only reason this population still exists is probably due to emigration and immigration of birds through the upper North Fork of the Gros Ventre River. The Wyoming Department of Fish and Game closed Jackson Hole to sage grouse hunting. However, the Department, BLM and other agencies have recently burned the last major winter range known to be used by sage grouse in the area, which will probably lead to their extirpation from the area in the next decade.[39]

[39] Braun, C. E-mail to Mark Salvo, re: "Jackson Hole, Wyoming Sage Grouse." (Nov. 11, 2003); Wyoming Game and Fish Commission. Chapter 11: Sage Grouse Hunting Seasons/Emergency Rule. Sept. 11, 2003.