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Conservation of Greater Sage-Grouse on Public Lands in the Western U.S.: Implications of Recovery and Management Policies

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The mission of the Policy Analysis Center for Western Public Lands is to help rural communities, policy makers, resource managers and users, and others understand, analyze and engage effectively in the public land policy process. The Center will provide relevant, science-based information and analysis of ongoing and proposed public land management policies.

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1. Introduction

1.1. The Center's Role and Objective

The role of the Policy Analysis Center for Western Public Lands is to provide integrated social, economic and ecological analyses of public land policies that affect communities in the West. Its mission is to help rural communities, policy makers, resource managers, resource users and others understand, analyze and engage effectively in the public-land policy process.

Our general objective is to identify a set of short-run (three to five years) policy alternatives that are based on a synthesis of empirical research into the needs of the greater sage-grouse (*Centrocercus urophasianus*) and its relationship to the sagebrush system. In other words, based on what we know from research, we try to identify the best set of policy alternatives for maintaining and increasing sage-grouse populations on public lands that policy makers could implement and expect some results within a three- to five-year time frame.

1.2. Why a Policy Study at This Time

Detailed discussions of sage-grouse decline, recovery and biology are available (Connelly et al. 2000c, Nevada Sage-grouse Project 2001). Almost all discussions of the greater sage-grouse recognize that its wide distribution across most western states links its status, and the status of the extensive sagebrush ecosystem in which it lives, to the ecological, economic and social futures of communities in those states. Because of its almost total dependence on sagebrush habitats (Connelly et al. 2000c, Patterson 1952, Schroeder et al. 1999), sage-grouse may serve as an indicator species for the overall condition of the sagebrush ecosystem. A decline in populations likely indicates that the sagebrush ecosystem is also in decline. Because other species of wildlife and plants are also dependent upon the condition of the ecosystem, most analysts see the decline of the sagebrush ecosystem at the landscape scale as a major policy issue.

Given the amount and quality of the information available, why is a policy study needed at this time? We think a policy study is needed for two reasons. First, we see a need for a set of alternatives that could be pursued within a short policy time frame of three to five years that provide the foundation for longer-term recovery plans. These alternatives would rely almost solely on what current empirical research can tell us and focus on the greatest impact for the effort. Our analysis focuses on what we can do immediately that we think will create a positive effect as soon as possible. Hence, we use a three- to five-year policy window.

The second reason for this study is the institutional context within which the Endangered Species Act (ESA) is implemented. An ESA listing reduces options available to managers and increases the likelihood and extent of possible adverse social and economic effects on individuals and communities. In many states, the Bureau of Land Management lists the sage-grouse as a "sensitive species;" the U.S. Forest Service lists it as a "management indicator species." This status opens the land management policy process to actions intended to support sage-grouse that are tantamount to species recovery actions. Recent submission of range-wide petitions to list sage-grouse on the Endangered Species list is accelerating this policy process. Some of the impetus for this study stems from evidence that some agencies, organizations and individuals are or may soon be taking broad and potentially disruptive management actions related to sage-grouse recovery. Some of these actions may or may not be justified either by population conditions or by an adequate knowledge of the habitat requirements needed to maintain or recover populations.

For example, "Guidelines to Manage Sage-grouse Populations and Their Habitats," recently published in the *Wildlife Society Bulletin* (Connelly et al. 2000c), is an extensive revision of sage-grouse management guidelines originally published in 1977 (Braun et al. 1977). The Western Association of Fish and Wildlife Agencies (WAFWA) requested the revision to summarize current knowledge and assist their membership in designing conservation programs for sage-grouse. Reliable population estimates are needed for managers to make appropriate decisions and understand the effects of actions on a particular site. In many areas, these data are lacking for specific local populations. In addition, scientific and professional literature pertaining to sage-grouse contains some scientific uncertainties (Connelly et al. 2000c, Schroeder et al.1999). There is a lack of understanding of how sage-grouse use some important components of their habitats at the landscape level. Without this landscape-level of understanding, management actions can have unintended consequences. Finally, the WAFWA "Guidelines" are just that – guidelines. Attempts to derive standards or to rationalize management decisions in the face of uncertain ecological information are not a responsible use of this information. We provide a short list of policy alternatives that maximize positive impacts on sage-grouse, are based on empirical research and, hopefully, do not create unintended consequences, economic, social or otherwise.

1.3. Our Policy Question and Organization of this Analysis

Our policy question is this: "What actions can be taken on public lands to maintain and enhance sage-grouse populations where they currently exist and to restore populations on rangelands where they formerly existed?"

We begin our systematic evaluation by presenting two criteria for evaluating current and future policy decisions: a detailed description of sage-grouse population characteristics, and a description of sage-grouse habitat needs across seasons. This information is derived from a synthesis of the available research literature and includes an assessment of current issues.

We then present general policy variables, or "alternatives," which we consider as realistic actions that can be taken under current circumstances to stabilize grouse populations. Each alternative is described in terms of how its scientific foundations relate to the needs of the grouse and the sagebrush system. When we say that there is little or no research to support a policy, or that available evidence does not point to a certain conclusion, we mean that and only that. The question remains open and adequate research is yet to be conducted. A policy alternative that lacks research support is not right or wrong and justification for it must then be made on other grounds. We discuss some implications for policy alternatives and grouse recovery that might stem from an Endangered Species Act listing for sage-grouse. We apply the insights from this analysis to present a brief road map of suggestions for pursuing sage-grouse recovery outside of the Endangered Species Act.

2. Relevant Criteria: Populations

2.1. Population Characteristics

Most upland game bird species are characterized by relatively short lives and high reproductive rates. Until recently, wildlife managers assumed sage-grouse had the same characteristics. With improved radio telemetry equipment and long-term field studies, biologists learned that most sage-grouse have relatively long lives (annual survival rates for adult and yearling females range from 55 to 85%, while annual survival of males ranges from 38 to 54%), but generally lower reproduction than other upland game bird species (Connelly et al. 1994, Connelly et al. 2000c, Schroeder et al. 1999, Zablan 1993). Moreover, many sage-grouse populations are migratory and may occupy areas that exceed 800 miles^2 (1,300 km^2) on an annual basis. Although Schroeder (1997) reported that virtually all female sage-grouse nested in Washington, a lower frequency of nesting occurs in other parts of the birds' range (Connelly et al. 1993, Gregg 1991, Lyon 2000). Nest success varies from 12 to 86% (Schroeder et al. 1999), but, in most areas, average nest success exceeds 40% and is often much higher (Schroeder et al. 1999).

2.2. Historic Status and Distribution

Sage-grouse originally occurred in 16 states and three provinces (Aldrich 1963, Johnsgard 1973), and their distribution closely approximated that of sagebrush. Forests, deserts, rivers and mountain ranges fragmented the birds' original distribution naturally (Braun 1998). However, sage-grouse evolved to use large expanses of shrub steppe habitat (Connelly et al. 2000c). Early estimates of sage-grouse abundance were largely anecdotal, but suggested this species was abundant in many parts of its range (Braun 1998). Western settlers reported seeing the skies darkened by large flocks of sage-grouse. Pioneers described filling wagons with sage-grouse to provide food for their communities as well as for miners and other working groups (Rogers 1964). Both Colonel John Fremont (1845) and Elliot Coues (1874) reported that sage-grouse were abundant throughout much of Wyoming in the early to mid-1800s. Prior to 1870 in Montana and 1900 in Idaho, little or no protection was afforded these birds (Autenrieth 1981, Wallestad 1975). In Colorado, Rogers (1964) indicated that thousands of sage-grouse were killed each year to feed participants in the annual "Sage-hen Days" in the town of Craig.

Concerns over population declines date from the early 1900s (Girard 1937, Hornaday 1916) until Rusch (1942) reported that, because of the bird's scarcity, there were not many localities where they could be legally killed by the late 1930s and early 1940s. In his book on wildlife conservation, Wing (1951) listed sage-grouse as a rare and threatened species in North America, perhaps foreshadowing current efforts to list sage-grouse as threatened or endangered under the Endangered Species Act.

2.3. Current Status and Distribution

Sage-grouse have been extirpated from five states and one province, all at the periphery of the species' original distribution (Braun 1998). Connelly and Braun (1997) and Braun (1998) recently documented these losses. Connelly and Braun (1997) provided evidence that both breeding populations and reproductive rates were declining over the long term. Most population data comes from observations at leks, communal display sites used by grouse during the breeding season. Based on lek count data, losses in breeding populations over the long term ranged from a 17% decline in Wyoming to 47% decline in Washington, with a range-wide average of 33% (Connelly and Braun 1997). Similarly, sage-grouse production (number of juveniles per female in the fall) declined from 10 to 51% with a range-wide average of 25% (Connelly and Braun 1997).

By the late 1990s, Braun (1998) estimated the range-wide breeding population to be less than 150,000 birds, with no sustained increases in sage-grouse population levels within any portion of the species' range (Braun 1998). Braun (1998) estimated that only three states had breeding populations exceeding 20,000 birds, while six states and two provinces had breeding populations of less than 15,000 grouse. From these estimates, Braun (1998) concluded that the overall distribution of sage-grouse has declined by 50% since European settlement, while the apparent breeding population has decreased by 45 to 80% since the early 1950s.

The Western Association of Fish and Wildlife Agencies (WAFWA) compile population numbers from states and provinces with sage grouse. The WAFWA held a sage grouse population analysis workshop in Tucson early in 2002 to work on improving collection methods, sampling, reducing shortcomings of data sets, and to explore methods of improving data quality. The quality, extent and accuracy of current population estimates for the sage-grouse often vary greatly both within states and between states and are not always consistent across years. The total breeding population in the region may be about 150,000 birds, or possibly higher or lower depending on the quality of data used to estimate this overall population. As also noted, better inventory and monitoring is needed in order to construct the most accurate possible count of the total population. Accurate counts of the total population of grouse determine, in a sense, how much time is available to develop and implement management actions to help the bird recover. In addition, the ability of sage-grouse experts to explain their population methods and the reliability of their data for decision making is key to an adequate public discourse on acceptable and defensible management actions for sage-grouse (Renn et al. 1995; Sexton et al. 1999). [For additional issues concerning sage-grouse population estimates, see Section 6.3.1: Social Issues Related to Sage-Grouse Recovery.]

3. Relevant Criteria: Habitat Needs by Season

Habitat needs serve as policy criteria because grouse are an obligate species to sagebrush ecosystems, depending on the extent and characteristics of sagebrush systems for their survival. We set out these criteria by season and by grouse needs for various landscape habitats within each season. The seasonal habitat needs discussed in this section are summarized in Table 1. The relationship of sage-grouse to their seasonal habitats is generally well understood, especially with regard to sagebrush characteristics necessary to support sage-grouse populations.

Prior to settlement, the sagebrush biome generally provided optimal grouse habitat in space and time, but large portions were also probably less than optimal to marginal. Researchers and managers should recognize the dynamic nature of the sagebrush biome and realize that sites may vary widely in biological potential (R. Miller, personal communication). Thus, there is and always has been much spatial and temporal variability across the very large region generally characterized by a sagebrush overstory (Miller and Eddleman 2001, R. Miller, personal communication, Schroeder et al. 1999). The variability in characteristics of sagebrush stands used by sage-grouse reflects the species' ability, at least to some degree, to adapt to differing amounts of sagebrush cover. There also appears to be some variability associated with understory characteristics of sage-grouse habitat (Connelly et al. 2000c), but more information is needed on these characteristics and their ability to support a healthy sage-grouse population. Regardless, much sagebrush rangeland has been permanently lost or altered (Braun et al. 1976, Braun 1998, Vale 1974). Thus, conservation and restoration of existing habitats is now even more critical to the continued existence of sage-grouse.

3.1. Spring

During spring, sage-grouse use sagebrush habitats for breeding, feeding, roosting, nesting and rearing young (Connelly et al. 2000c, Patterson 1952, Schroeder et al. 1999, Wallestad and Pyrah 1974, Wallestad and Schladweiler 1974). Leks occur in openings within sagebrush stands (Connelly et al. 1981, Gill 1965, Patterson 1952). Sagebrush, herbaceous cover and insects are the major components of spring habitat (Connelly et al. 2000c).

Sagebrush: A great deal of scientific data exists documenting sage-grouse dependence on sagebrush during spring (Connelly et al. 2000c, Patterson 1952, Schroeder et al. 1999, Wallestad and Pyrah 1974). Large, relatively continuous sagebrush stands, often exceeding 50 miles^2 (80 km^2), are needed to provide all habitat components used by sage-grouse during spring (Hulet 1983, Leonard et al. 2000). Most sage-grouse nests occur under or adjacent to sagebrush (Gill 1965, Gray

Table 1. Sage-grouse habitat needs by season.

		Season			
		Winter	Spring	Summer	Fall
Habitat need		December - Early March	March - Early June	June - September	September - December
Sagebrush	Forage	Almost 100% of diet	50% - 70% of diet; insects (ants, beetles) are very important on breeding range until summer	Males and adult females without chicks	All age classes are consuming - can be up to 90% of diet
	Cover	Canopy provides cover relative to height of snow; cover and feed behavior changes based on snow; will forage by sagebrush type [site dependent]	Very important; nesting cover; protective cover; need certain height, understory mix; leks	Canopy cover is important; chicks move into sage at 4-6 weeks	Canopy cover is very important
Herbaceous cover	Forage		Need mix of grasses and forbs; forbs a little more important; data is mixed; variables are not standardized	Forbs are important to hens and chicks; need a composite of species; grass becomes less important in late summer; can become too thick for good cover	Forbs are decreasing in dietary importance
	Cover		Important		
Location		Normally lower elevations; aspect matters, south- or west-facing slopes make difference; may be 10% of total habitat needs, but is open ended	Larger than winter/summer; a very messy issue because habitat size is quite variable	Hens with chicks go to mesic areas (meadows, farm fields, etc.); longer, narrower areas better; water control to retain mesic areas can be an issue	Most mobile time of year; dispersed out of uplands; moving back into winter ranges
Importance		Very critical [some believe most critical]	Many believe most critical time; 70 - 80% of chick mortality occurs in first 3 weeks; no consensus on best mix of cover	Generally not limiting habitat	Juveniles are foraging as adults; birds pretty secure this time of year

1967, Patterson 1952, Wallestad and Pyrah 1974), but grouse will sometimes nest under other shrubs or in clumps of grass (Connelly et al. 1991, Gregg 1991, Klebenow 1969, Sveum et al. 1998). However, Connelly et al. (1991) indicated that when grouse select non-sagebrush nest sites, nest success is markedly lower (22%) than sagebrush nest sites (53%). The average height of sagebrush most commonly used by nesting grouse ranges from 11 to 32 inches (28 to 81 cm) (Connelly et al. 2000c), and nests tend to be under the tallest sagebrush in the stand (Apa 1998, Keister and Willis 1986, Wakkinen 1990). Sage-grouse nests are usually placed under shrubs with larger canopies and more ground and lateral cover in stands with more shrub canopy cover than at random sites (Fischer 1994, Heath et al. 1997, Holloran 1999, Sveum et al. 1998, Wakkinen 1990). Areas with 15 to 25% sagebrush canopy cover provide optimal nesting and early brood habitat for sage-grouse, although grouse may use areas with somewhat lower or higher amounts of sagebrush (Autenrieth 1981, Klebenow 1969, Holloran 1999, Klott et al. 1993, Lyon 2000, Wakkinen 1990, Wallestad and Pyrah 1974). Sagebrush is important in the spring diet of adults (Leach and Hensley 1954, Patterson 1952, Schroeder et al. 1999), and chicks will feed and roost in these habitats until they are 4 weeks of age or older (Holloran 1999, Lyon 2000, Schroeder et al. 1999).

Herbaceous Cover: Although sage-grouse are strongly dependent on grasses and forbs in the understory, less is known about this component of the bird's habitat. Grass associated with nesting areas was taller and denser than grass at random sites (Gregg 1991, Sveum et al. 1998, Wakkinen 1990). In Oregon, grass cover was greater at successful nests than at unsuccessful nests, and grass >7 inches (18 cm) in height in stands of sagebrush 16 to 32 inches (41 to 82 cm) tall resulted in lower nest predation than in stands with shorter grass heights (Gregg 1991, Gregg et al. 1994). Herbaceous cover at nest sites may provide scent, visual and physical barriers to predators (DeLong et al. 1995). Average heights and canopy coverage for herbaceous cover associated with sage-grouse nests have been reported from Idaho, Oregon, Washington and Wyoming. Values for average grass heights range from 6 to 13 inches (15 to 33 cm), and average grass cover ranges from 3 to 51% (Apa 1998, Connelly et al. 2000c, Gregg 1991, Schroeder 1995, Wakkinen 1990). Current empirical information indicates that productive sage-grouse breeding habitats have herbaceous cover averaging at least 7 inches (18 cm) in height and canopy cover of 15% or more (Connelly et al. 2000c).

Females need succulent forbs in their early spring diet for successful reproduction, and a healthy understory containing numerous forbs also enhances nest concealment and results in relatively high nest success (Barnett and Crawford 1994). Forbs are also a critical source of food for young chicks. During spring, important forb species include common dandelion (*Taraxacum officinale*), yellow salsify (*Tragpopogon dubius*), prairie pepperweed (*Lepidium desiflorum*), clover (*Trifolium* spp.), knotweed (*Polygonum* spp.), alfalfa (*Medicago sativa*), yarrow (*Achillea* spp.), sweet clover (*Melilotus* spp.), vetch (*Vicia* spp.), milk vetch (*Astragulus* spp.), and prickly lettuce (*Lactuca serriola*) (Schroeder et al. 1999).

Insects: The dependence of chicks on insects has been well documented (Fischer et al. 1996, Johnson and Boyce 1990, Klebenow and Gray 1968, Patterson 1952). An abundant supply of insects, usually ants and beetles, is necessary for sage-grouse chick survival (Johnson and Braun 1999). In Oregon, 41 families of invertebrates were documented in the diets of sage-grouse chicks (Drut et al. 1994). Ants (*Hymenoptera*) and beetles (*Coleoptera*) are important components of early brood rearing habitats (Drut et al. 1994, Fischer et al. 1996). Both ants and beetles occurred more frequently at brood activity centers than at non-brood sites (Fischer et al. 1996). Normally, habitats with healthy stands of sagebrush and herbaceous cover will provide an adequate supply of insects, but ants declined after a prescribed burn in a Wyoming sagebrush (*Artemisia tridentata spp. wyomingensis*) habitat (Fischer et al. 1996).

3.2. Summer

From late June through July, as food plants in sagebrush uplands desiccate (dry out), sage-grouse hens with broods move to areas that support succulent vegetation (Connelly et al. 1988, Fischer et al. 1996, Klebenow 1969). Hens without broods and adult males sometimes forage in moist areas used by broods, but they also may occupy uplands where understory vegetation has matured. In years of high precipitation, succulent forbs may persist in sagebrush uplands and change bird movements. Though not the usual situation, where habitat is in good ecological condition and grouse find succulent forbs on dryer upland sites all summer, birds may remain in these areas rather than move to moister sites (Savage 1969).

In very dry years, sage-grouse may use summer habitat until November (Connelly 1982, Hanf et al. 1994). Summer habitats may be lower elevation native or irrigated meadows, or farmland in a matrix of sagebrush uplands (Connelly and Markham 1983, Gates 1983, Savage 1969). Grouse may also move to higher elevations containing moist sites (Gill 1965, Klebenow 1969, Oakleaf 1971, Savage 1969, Wallestad 1971). These areas include stringer meadows in drainages, riparian zones and irrigated hay fields. All summer habitats must provide two key elements: an abundance of moist forbs for food and sagebrush for roosting and escape cover (Apa 1998, Drut et al. 1994, Dunn and Braun 1986, Klott and Lindzey 1990).

Because of the wide variety and abundance of habitats that sage-grouse occupy during summer, these habitats generally have not been reported as limiting grouse populations. However, degraded meadows may have a negative impact on sage-grouse (Savage 1969), and fires in sagebrush habitats may decrease insects used by grouse as food (Fischer et al. 1996, Nelle et al. 2000). In southeastern Oregon, Drut et al. (1994) indicated that, in an area of low grouse productivity, forbs were less abundant and sagebrush was a major part of the chick's diet. Sage-grouse using agricultural lands may be exposed to harmful insecticides that cause direct mortality of these birds (Blus et al. 1989). Grouse using farmlands face additional hazards and are sometimes killed by mowing machinery and from flying into obstacles such as power lines (J. W. Connelly, unpublished data).

Forbs: Apa (1998) reported that sites used by grouse broods had twice as much forb cover compared to independent random sites that he measured. Important foods during summer include hawksbeard (*Crepis* sp.), milk vetch (*Astragalus* sp.), common dandelion, western yarrow, prickly lettuce and others. Many forbs eaten by grouse are members of the Asteraceae family that contain milky juice (Drut et al. 1994).

In some areas, meadows are important summer habitat for sage-grouse because they provide an abundance of succulent forbs. These areas are especially important during drier summers (Klebenow 1985). Livestock grazing on these meadows may improve habitat for sage-grouse, and birds will often select grazed rather than non-grazed meadows for foraging (Evans 1985, Klebenow 1985, Neel 1980). In northwestern Nevada, sage-grouse foraged where vegetation height ranged from 3 to 6 inches (8 to 25 cm), compared to 4- to 10-inch (10 to 25 cm) heights in surrounding areas. Given a choice, grouse apparently selected areas where herbaceous cover was about 4 inches (10 cm) tall (Klebenow 1985). Grazing may further benefit summer forage areas by improving the quality of food plants for sage-grouse. Re-growth of grazed food plants resulted in greater moisture and nutrient content than in ungrazed plants (Evans 1985).

Sagebrush: Although sagebrush is less important to sage-grouse during summer than it is during the remainder of the year, it still provides secure roosting sites and necessary cover to allow escape from predators. Moist areas interspersed among relatively open sagebrush stands with 10 to 25% canopy cover usually characterize productive sage-grouse summer habitat. Birds are most likely found where shrub cover is less than 30% (Klebenow 1969, Klebenow 1985, Wallestad 1971). Sagebrush in these stands averages 16 to 32 inches (41 to 81 cm) in height (Connelly et al. 2000c).

3.3. Fall

Fall is a transition period for sage-grouse. Desiccation and frost kill forbs in summer foraging areas. Sage-grouse form flocks as broods break up in early fall (Browers and Flake 1985), and birds begin to move towards winter range. These movements are slow and meandering, and occur from late August to December (Connelly et al. 1988). At this time, grouse are largely found in sagebrush habitats and sagebrush consumption increases, forming the major part of the birds' diet by mid-fall (Gill 1965, Leach and Hensley 1954, Patterson 1952, Rasmussen and Griner 1938, Wallestad et al. 1975).

3.4. Winter

Unlike other seasonal habitats that have two or more components important to sage-grouse, the only critical habitat component important during winter is sagebrush. Sage-grouse are totally dependent upon sagebrush habitats for food and cover throughout the winter period (Beck 1977, Eng and Schladweiler 1972, Hupp and Braun 1989b, Patterson 1952, Wallestad 1975). Observations of sage-grouse in other habitats during winter normally occur only when birds are in transit between sagebrush-dominated areas.

In Montana, most observations of radio-marked sage-grouse occurred in sagebrush habitats with more than 20% canopy cover (Eng and Schladweiler 1972). However, in Idaho, grouse used sagebrush habitats that had an average canopy cover of 15%, and used areas with greater canopy cover of Wyoming big sagebrush in stands containing taller shrubs compared to random sites (Robertson 1991). Beck (1977) indicated that sage-grouse might be restricted to less than 10% of the sagebrush habitat in Colorado during winter because of variation in topography and snow depth. However, winter habitat may not be restricted in all portions of the species' range. For example, in southeastern Idaho, severe winter weather did not result in the grouse population greatly reducing its seasonal range (Robertson 1991). Sagebrush canopy cover and height are also extremely important in winter, as documented throughout the range of the species (Autenreith 1981, Beck 1977, Connelly 1982, Eng and Schladweiler 1972, Hanf et al. 1994, Hupp 1987, Ihli et al. 1973, Robertson 1991, Schoenberg 1982, Wallestad 1975). Sage-grouse prefer taller, more robust, exposed sagebrush for both foraging and cover in winter (Connelly et al. 2000c). However, low sagebrush (*A. arbuscula*) and black sagebrush (*A. nova*) also provide important winter habitats when snow depth allows grouse access to these relatively low-growing shrubs (Connelly 1982, Schroeder et al. 1999). Sagebrush canopy cover in sage-grouse winter habitats ranges from 12 to 43%, and sagebrush height above snow ranges from 8 to 22 inches (20 to 56 cm) throughout the species' range (Connelly et al. 2000c). This dependency on sagebrush occurs from late November through early March. On a landscape scale, sage-grouse winter habitats should allow grouse access to sagebrush under all snow conditions (Connelly et al. 2000c).

During winter, sage-grouse feed almost exclusively on sagebrush leaves. The dependence of sage-grouse upon sagebrush for food in winter is well documented (Hupp 1987; Patterson 1952; Remington and Braun 1985; Wallestad et al. 1975; Welch et al. 1988, 1991). Big sagebrush dominates the winter diet in most portions of the species' range (Patterson 1952, Remington and Braun 1985, Wallestad et al. 1975, Welch et al. 1988). However, low sagebrush, black sagebrush, fringed sagebrush and silver sagebrush are consumed in many parts of the species' range, depending on availability (Connelly 1982, Schroeder et al. 1999). There is little, if any, evidence that severe winter weather affects sage-grouse populations unless sagebrush cover has been eliminated or significantly reduced (Beck 1977, Robertson 1991, Wallestad 1975). However, without adequate sagebrush leaves available for winter forage, body mass may decrease and spring breeding displays may be reduced (Hupp and Braun 1989a).

4. Policy Variables

We consider actions available to federal and state land management agencies to be policy variables, or policies that can be realistically chosen to meet the needs of sage-grouse and help their recovery. Other variables that play a part in sage-grouse population trends, such as drought, are not policy variables, but other policies need to be adjusted when variables like drought occur. In that sense, we discuss issues like drought or harsh winters in the context of other policies over which agencies have control.

4.1. What About Livestock Grazing?

Livestock grazing is possibly the most contentious, polarizing, politically charged and complex issue facing those who make and implement public-land policy. Advocates for removing livestock argue that their "evidence" of ecological damage is incontrovertible, and their opponents argue that grazing can be managed in a sustainable and ecologically friendly manner (Clifford 2002). Attempts to integrate empirical results have not quelled the argument that "the science is out there" to bolster the argument of any of the various interests in this contentious debate (Vavra et al. 1994). In the middle are land managers, mostly from federal agencies. On one hand, anti-grazing interests accuse land managers of not making the difficult decisions necessary to get livestock off of public land. At the same time, grazing interests accuse land managers of making decisions based on weak or nonexistent science and/or data.

The key policy issue before us is this: to restore grouse populations, sagebrush systems will have to be managed for the benefit of the bird. How this affects livestock grazing is a complex question. Overall, most of the research on sage-grouse habitat needs took place, and continues to take place, on habitats that are grazed. We can see from the range of data that grouse and grazing coexist in many, if not most, areas so we know with reasonable certainty that grouse and livestock are not mutually exclusive.

There are few scientific, peer-reviewed articles that address the grazing and sage-grouse issue — none that are designed experiments, and none with replicates. Most of what is available reflects conclusions or thoughts without empirical data, or it represents gray literature. Our general opinion is that any argument that livestock grazing presently is the primary cause of sage-grouse population decline cannot be supported by available research. Conversely, the alternative hypothesis, that grazing has had no effect on sage-grouse populations cannot be supported either. Our conclusion does not dismiss the reality that grazing history is often linked to the spread of invasive species that in turn increased fire frequencies, resulting in further habitat loss, fragmentation and degradation.

We have a great deal of research data on the habitat characteristics associated with sage-grouse seasonal ranges. These data can help us to understand and manage for characteristics needed for healthy sage-grouse populations. Again, virtually all of these data were gathered from sage-grouse habitats that are grazed. Relatively healthy populations of sage-grouse occur where domestic livestock graze sage-grouse habitats, and grazing management in these areas results in habitat characteristics that support sage-grouse populations. However, low density or declining sage-grouse populations also occur in some areas characterized by depleted herbaceous understories that may be the result of past or present grazing practices. Changes in grazing management may be necessary to increase these sage-grouse populations, but experimental data are lacking to guide these management decisions.

The empirical data we have on sage-grouse habitat includes some uncertainties. Nonetheless, we have good data on the vegetative characteristics necessary for sage-grouse success, regardless of land use. We can manage grazed areas for those characteristics if we choose to do so.

In the final analysis, grazing considerations will always be important to maintain habitat quality, but, do not appear as important in the next three to five years for the recovery of sage-grouse as are fire, habitat loss, invasive species and the other alternatives that we discuss in other sections. In the long run, ranchers and the communities in which they live need to make some difficult and complex decisions about how to achieve the mix of vegetative characteristics that best support sage-grouse population growth.

4.2. Fire

In recent years, the size and frequency of wildfires have increased significantly in many areas that provided important breeding and winter habitats for sage-grouse (Crowley and Connelly 1996, Knick and Rotenberry 1997). In 1999 alone, wildfires burned 1.7 million acres in Idaho's Great Basin (USDI Bureau of Land Management, 1999). At least in some areas, the frequency of prescribed burning has also increased.

Although prescribed burning is routinely used by some agencies to manage sagebrush habitats (Byrne 2002), numerous studies have recently documented the negative effects of fire on sage-grouse populations and habitat (Byrne 2002; Connelly et al. 2000b, c; Fischer et al. 1996; Nelle et al. 2000; Peterson 1995). To our knowledge, there is no empirical evidence supporting the notion that fire has positive effects on sage-grouse over the short or long term. Fire removes large sagebrush plants that provide thermal and security cover and food, and reduces important insect populations vital to sage-grouse diets. Fire tends to burn the most productive and best grouse habitats within an area — where grasses and forb cover are greatest — leaving unburned, less productive sites of inferior habitat value (Connelly et al. 2000c). Benson et al. (1991) reported that sage-grouse use only the remaining sagebrush stands in burned habitat and Byrne (2002) documented avoidance of burned areas less than 20 years old by radio-marked female sage-grouse. Fischer et al. (1996), working in Wyoming big sagebrush, found that a prescribed fire did not enhance sage-grouse brood-rearing habitat, and actually reduced the abundance of ants (*Hymenoptera)* that are important food items for sage-grouse. Nelle et al. (2000) reported similar observations for a mountain big sagebrush (*Artemisia tridentata vaseyana*) site supporting sage-grouse nesting and brood-rearing habitats. They argued that burned areas did not become adequate nesting or brood-rearing habitat for more than 20 years.

Fire and Forb Production: Forbs are a vital component of sage-grouse diets. During late spring and early summer, phosphorus and protein content is greater in forbs than in sagebrush (Welch 1989). No scientific data identifies the pounds per acre of forbs that sage-grouse require, and no scientific study concludes that forbs limit sage-grouse production. Pyle and Crawford (1996) argue that reducing sagebrush canopy cover increases forb production and thereby improves sage-grouse habitats. However, Pyle and Crawford (1996) did not provide any data demonstrating that sage-grouse increased their use of burned areas as a result of increased forb production.

The relationship between forb production and sagebrush canopy cover has also been evaluated. Blaisdell (1953) found forb production on sites with 35 to 40% sagebrush canopy cover ranged from 104 to 127 pounds per acre. Goodrich and Huber (2001) reported forb production to be 179 pounds per acre on sites with a shrub canopy cover greater than 20%. Thus, some available evidence suggests that adequate production of forbs can occur in areas with relatively high canopy coverage of sagebrush.

Following fire, increased forb production may be influenced by factors other than sagebrush canopy cover. Passey et al. (1982) clearly show that soil type and precipitation plays major roles in forb production. Their data were collected on a site that had never been grazed by domestic livestock. Forb production varied from 138 to 296 pounds per acre (10-year mean) across six soil groups. Across soil types, forb production varied between 99 and 245 pounds per acre over the 10 years. Differences in annual precipitation may account for this, but no direct relationship was documented between sagebrush production and forb production. Available evidence does not support the use of fire to specifically increase forb production.

Fire Frequency: Fire intervals are important to sage-grouse management policies because their interpretation has direct consequences for how fire is used and/or managed by agencies and landowners. Sagebrush may require 40 to >100 years after fire to provide habitat capable of supporting sage-grouse (Houston 1973, Whisenant 1990, Wright and Bailey 1982). Natural fire frequency in the sagebrush ecosystem has been estimated to range from 10 to 110 years depending on species, subspecies and habitat (Britton 1979, Houston 1973, Whisenant 1990, Winward 1991, Wright and Bailey 1982, Young and Evans 1978). It is logical that considerable variation in fire frequency exists due to the continuum of environments found in sagebrush communities. The relationship of fire frequency to grazing history and invasive species is considered in other sections of this paper.

Much of the research on fire in big sagebrush ecosystems has focused on members of the big sagebrush complex, mountain and Wyoming big sagebrush. Winward (1991) suggests a fire interval of 10 to 40 years. Arno and Gruell (1983) found that the fire interval prior to 1910 at ecotones between mountain big sagebrush ecosystems and forest ecosystems ranged from 35 to 40 years (Gruell 1983). Wambolt et al. (2001) collected data on 13 mountain and Wyoming big sagebrush burn sites. Big sagebrush at the 13 sites, burned as much as 32 years earlier, had not recovered to the levels growing in unburned portions of each study site. Also, the long-term decrease in sagebrush from burning did not result in the generally anticipated increase of herbaceous species. Hanson (1929) noted that grasses were dominant over big sagebrush 5 to 10 years after a fire. Pechanec and Stewart (1944) noted that little sagebrush had returned 11 years after fire. Blaisdell (1950), studying what was probably a mountain big sagebrush stand, noted some reestablishment 15 years after a fire. Blaisdell (1953) found little reestablishment of what was probably a Wyoming big sagebrush stand 12 years after a fire. Harniss and Murray (1973) noted that full recovery of big sagebrush had not occurred after 30 years. Bunting et al. (1987) set mountain big sagebrush recovery at 15 to 20 years, and further argued that Wyoming big sagebrush takes even longer to recover than other taxa. Eichhorn and Watts (1984) stated that Wyoming big sagebrush was removed from the site by burning and had not reinvaded after 14 years. Wambolt and Payne (1986) reported that, 18 years after a fire, Wyoming big sagebrush canopy cover was only 16% of the control area. Fraas et al. (1992) found little recovery of mountain big sagebrush on an 8-year-old burn, where the burned portion of the site had only 1% canopy cover of sagebrush compared to 12% where unburned. Wambolt et al. (1999) reported that, for three subspecies of big sagebrush 19 years after a fire on the northern Yellowstone winter range, recoveries of burned compared to unburned Wyoming, mountain and basin (*Artemisia tridentata tridentata*) big sagebrushes were 0.1, 1.4 and 11% for production of winter forage, respectively. They also studied seven other burn sites of mountain big sagebrush on the northern Yellowstone winter range and found no significant recovery 10 and 14 years after prescribed burning. On these seven sites, sagebrush canopy on unburned portions averaged 12 times that of burned portions, and sagebrush densities were 15 times greater on unburned portions. Humphrey (1984) found a pronounced delay of some 18 to 32 years in the establishment of big sagebrush after fire in big sagebrush habitat. He attributed this delay to big sagebrush dependency on the dispersal of its propagules, achenes or seeds. Big sagebrush seed dispersal could take from 105 to 211 years to spread 1 mile (Noste and Bushey 1987).

A 31-year study of a mature big sagebrush stand in the Gravelly Mountains in Montana demonstrated that a big sagebrush ecosystem could maintain itself without the occurrence of fire (Lommasson 1948). Houston (1973) estimated the fire interval in what he termed "bunchgrass steppes" of northern Yellowstone National Park winter range to be 53 to 96 years. Arguing that suppression policies have affected the fire interval, he adjusted the interval by subtracting 80 years from the ages of living trees and came up with an adjusted fire interval of 32 to 70 years in the big sagebrush steppes of northern Yellowstone National Park, an area dominated by mountain big sagebrush. Wright and Bailey (1982) suggested fire intervals of 50 years because gray horsebrush (*Tetradymia canescens*) responds vigorously to fire and can require more than 30 years to decline following fire. They further argued that a fire frequency of 20 to 25 years could result in sagebrush being dominated by gray horsebrush and rabbitbrush (*Chrysothamnus* spp.) in eastern Idaho. For Wyoming big sagebrush ecosystems, they suggested a fire interval as long as 100 years.

Under some conditions, mountain big sagebrush can have a burn cycle of 20 to 30 years (Miller et al. 1999b). This is based on higher vegetative productivity of the mountain big sagebrush sites producing higher fine fuel accumulation, and higher frequency of lightning strikes, which some believe result in a shorter fire cycle compared to basin and Wyoming sites with less fine fuels and fewer lightning strikes. However, the greater accumulation of biomass and higher number of lightning strikes on mountain big sagebrush sites may be offset somewhat by lower temperature and higher humidity that occur on these sites. Monsen and McArthur (1985) and Goodrich et al. (1999) reported average annual precipitation of 17 inches for mountain big sagebrush stands, 14 for basin big sagebrush and 11 for Wyoming big sagebrush. Tisdale and Hironaka (1981) noted that stands dominated by Wyoming big sagebrush were the first to become water deficient, by mid-July. Basin big sagebrush stands were second, in late July to early August, and mountain stands were last to become water deficient, in September. Shorter fire-free intervals in mountain big sagebrush communities are often argued based on proximity to fire-scarred trees. However, some tree ring analysis experts see no credible evidence to directly (and automatically) relate sagebrush burning to fire scars on nearby conifers (L. Graumlich, personal communication 2002). Although there are undoubtedly sites where sagebrush did burn when conifers were fire-scarred, there are many sites known where sagebrush was not burned when conifers were scarred. The survival of fire-scarred conifers indicate none of the scarring events were intense enough to destroy the conifer and, therefore, would require a leap of faith in most instances to assume that the surrounding vegetation was all burned.

Although some research indicates an estimated fire interval of 20 to 30 years for mountain big sagebrush communities, other evidence suggests that this estimated fire interval may be too short and a natural or normal interval could be much longer. It also ignores the fact that an optimum growing season for germination and establishment of sagebrush may not occur for many years after a fire, which can greatly increase the interval required for reoccupation of the site by sagebrush (Wambolt and Hoffman 2001). Often overlooked in discussions of fire frequency is the impact of fire size and intensity. Sagebrush recovers so slowly that large fires compound the consequences to sage-dependent organisms. Where sagebrush seed sources are destroyed over large areas, the recovery is greatly prolonged (Wambolt et al. 1989). With this in mind, fire suppression should be the highest priority for land management agencies and prescribed use of fire in existing sage-grouse habitat must be carefully and thoroughly evaluated for each site (Connelly et al. 2000c). Further, prescribed fire should not be used in sage-grouse breeding and winter range.

Sage-grouse also occupy habitats dominated by silver sagebrush (*A. cana)* (Aldridge 2000). Fire may play a more important role in maintaining quality nesting and brood-rearing habitats in areas dominated by silver sagebrush compared to habitats dominated by big sagebrush or low sagebrush. However, virtually no information is available on the response of sage-grouse to fire in silver sagebrush dominated habitats.

4.3. Maintaining and Protecting Habitat

Early explorers and pioneers described the trip from Fort Laramie, Wyoming, to the Blue Mountains of Oregon by way of the Snake River Plains of Southern Idaho as an 800-mile trek through a sea of sagebrush; mostly big sagebrush, *Artemisia tridentata* (Fremont 1845, Johnson 1986, Knick 1999, McArthur and Plummer 1978, Settle 1940, Stansbury 1852, Townsend 1834, Vale 1975, Wislizenus 1839). Since that time, at least 50% of pre-settlement sagebrush rangeland has given way to agriculture, cites and towns, reservoirs, roads and highways, and other human developments (Knick 1999).

Extensive sagebrush stands have been removed or thinned, as a matter of public policy, for the express purpose of altering the plant communities in those systems. A frequent assumption underlying treatments of sagebrush communities is that canopy cover is too high and should be subject to control measures. However, documented sagebrush canopy cover values in sage-grouse breeding habitats range from 15 to 38% (Connelly et al. 2000c). Big sagebrush canopy cover measured on undisturbed relicts and never-grazed kipukas (areas surrounded by lava and inaccessible to almost all grazing animals) can be used to evaluate variation in big sagebrush canopy cover. Daubenmire (1970) reported that big sagebrush canopy cover varied from 5 to 35% on pristine or near-pristine study sites. Recent measurements using line intercept (Canfield 1941) taken in four ungrazed kipukas indicated big sagebrush canopy cover ranged from 14 to 34% (Bruce Welch, unpublished data). Others have found ranges from 4 to 25% (R. Miller, personal communication).

A number of articles argue that big sagebrush canopy cover has increased above natural levels due to overgrazing (Blaisdell 1949, Blaisdell et al. 1982, Christensen and Johnson 1964, Clark 1981, Cooper 1953, Daubenmire 1970, Hanson and Stoddart 1940, Laycock 1978, Pickford 1932, Robertson 1947, Stoddart 1941, Tisdale et al. 1965, Winward 1991, Wright and Wright 1948, Young 1943, Young et al. 1976). Few of these papers present conclusions based on original field data. Other investigations refute the contention that grazing causes big sagebrush cover to increase beyond what is considered normal. Holechek and Stephenson (1983) found that big sagebrush canopy cover was higher inside the exclosure on their upland site, and higher on the outside of their exclosure on their lowland site. Eckert and Spencer (1986) also reported inconsistencies concerning big sagebrush canopy response to grazing. Peterson (1995) noted greater big sagebrush canopy cover inside an exclosure than outside due to heavy ungulate grazing. Wambolt and Sherwood (1999) found an average of three times as much big sagebrush cover inside exclosures at 19 sites across the northern Yellowstone winter range. These four studies cast doubt on the argument that grazing automatically increases big sagebrush canopy cover above natural levels. Overall, research indicates that thinning of sagebrush to reduce canopy cover may remove too much cover as sage-grouse breeding habitats range from 15 to 38% cover (Connelly et al. 2000c).

In addition to the over-thinning of sagebrush canopies, millions of acres of historical sagebrush habitats have been lost to cultivation, urban development and other habitat conversions (Dobkin 1995, Patterson 1952, Schneegas 1967, Swenson et al. 1987, Yocom 1956). The remaining acres of sagebrush have become critically important to the sage-grouse. Existing sagebrush habitats should be viewed as currently or potentially useable by sage-grouse, and, therefore, the retention of sagebrush habitats should be a high priority for all management agencies. Conversion of existing sagebrush stands to agricultural lands, energy developments, power line right-of-ways, roadways, fences, housing developments and other structures, and other range "developments" should be discouraged to retain as much sagebrush as possible. In general, activities that remove sagebrush or fragment sagebrush habitats into smaller pieces should be avoided to the extent possible.

4.4. Invasive Plant Species

Invasive (exotic or introduced) plants are a negative influence on long-term productivity of otherwise native ecosystems (Vail 1994). This is largely because they alter the natural composition of habitats, which in turn negatively affect organisms, such as sage-grouse, that rely on the native plants that were replaced by the invasive species. The first impacts are found in plant composition, but animals, both invertebrate and vertebrate, are soon also affected. The spread of secondary weeds has been estimated to occur at the rate of 2,300 acres per day on USDI Bureau of Land Management lands and 4,600 acres per day on all public lands (USDI Bureau of Land Management 1996). Consequently, it is essential that both landscape and local inventories made across lands of all ownerships be kept current to facilitate intelligent decision-making and to permit monitoring over time. Since settlement days, (Pickford 1932) such influences have come primarily from the introduction of exotic plant materials (Stutz 1994, Vail 1994), improper grazing practices (Billings 1994, Young 1994), and the interactions of natural and prescribed fire (Whisenant 1990).

A long list of invasive plants occurring in sagebrush ecosystems could be compiled. There are a number of extremely important invasive perennial species that are distributed throughout the sagebrush region that severely reduce the productivity for both native fauna and livestock. In the Great Basin and portions of the Columbia Plateau, within the heart of the sagebrush region, a number of exotic annual species are climatically suited for long-term occupation when native systems are altered. However, one introduced annual species best illustrates the magnitude of problems encountered with invasive plants as they relate to the long-term welfare of sage-grouse.

Fire has been identified as the most important negative influence on sage-grouse in an earlier portion of this paper. Thus, among all the negative impacts of invasive species, it is the interaction of the exotic annual, cheatgrass (*Bromus tectorum*), with fire that merits special consideration. Fire and other disturbances in the western range of sage-grouse often lead to the domination of large areas that were formerly sagebrush by annual exotic plants such as cheatgrass (Dobkin 1995, Knick and Rotenberry 1997). Habitats dominated by annual grasses and other exotic species result in an increasing fire frequency, size and intensity and, thereby, do not support sage-grouse or other sagebrush obligates (Beck and Mitchell 2000, Connelly et al. 2000c, Leopold 1949, Pellant 1990, Peterson 1995, Young et al. 1979). Cheatgrass has an enormous influence on shortening the fire interval in many sagebrush ecosystems. Billings (1994) noted the drastic ecosystem changes resulting from cheatgrass in areas where it provides abundant fuel for extensive and disastrous fires. It was approximately 1909 when cheatgrass was noticed in Elko County, Nevada (Billings 1994). By 1952, Robertson (1954) noted extensive burn scars in the same areas that were dominated by cheatgrass. Unfortunately, the trends discovered five decades ago by Robertson (1954) have accelerated to the present. Extensive portions of the Great Basin (Young 1994) and the Columbia Plateau (Whisenant 1990) are now dominated by cheatgrass with no likelihood of returning to the native condition required by many taxa, including sage-grouse. Prior to settlement, fire-return on the Snake River Plains was between 60 and 110 years compared with intervals of less than five years following extensive cheatgrass invasion (Whisenant 1990).

Cheatgrass is generally dry enough to create a very flammable fuel by late spring or early summer. Thus, the fire season is greatly extended by the presence of cheatgrass. When combined with the surrounding habitat, cheatgrass forms a continuous fuel bed, and the result is a decrease in fire intervals with large-scale burns that have resulted in the loss of extensive sage-grouse habitats. This has been described as a cyclic phenomenon accelerating in a concentric spiral, ultimately terminating in conversion of native habitats to annual grassland (West 1978, Young and Evans 1978).

Associated with the trend to annual grassland is a continuing simplification of the ecosystem to fewer species, largely just cheatgrass and other introduced annuals (Whisenant 1990). Theoretically, sagebrush can reestablish following fire. But, the fact that seeds are short-lived makes the impact of frequent fires especially harmful to sagebrush taxa and may lead to extinction of sagebrush in such localities (Whisenant 1990). What remains may be subject to further fragmentation by range management practices (e.g., fences, roads), or expansion of conifers such as piñyon/juniper (*Pinus* spp./ *Juniperus* spp.) (Chambers 2001, Knick 1999, Miller et al. 1999a, Patten 1969, Schultz et al. 1996, Tausch 1999, Walker et al. 1996, Whisenant 1990, Winward 1991).

The shrub-steppe of Washington illustrates the magnitude of sagebrush decline and invasion by exotics. In Washington, Dobler (1994) estimated that 41% of the original shrub-steppe remains, with 59% converted to agriculture, housing developments and water storage. Much of the remaining acreage has been converted to annual grasses and weeds, such as cheatgrass, or to exotic monocultures, such as crested wheatgrass. The most productive big sagebrush sites, those with deep and highly fertile soils, were developed for agricultural use, leaving big sagebrush growing on less fertile and shallower soils, steep unusable hillsides and some sites not yet developed. The largest remaining big sagebrush stands in Washington are on the Hanford Reservation. This area is infested with cheatgrass and burned in 2000.

Protecting sagebrush communities from invasive species is ultimately much easier than restoring communities already degraded by cheatgrass or other invasive plant species. Thus, suppression of invasive species in or near sage-grouse habitat is vital to their survival and is tied directly to fire management and habitat loss.

During the past 130 years, juniper and piñyon have increased as much as 10 fold in the Intermountain Region and presently occupy far less land than they are capable of under current climatic conditions (Miller et al. 1999a). A large percentage of this expansion has occurred in the more productive sagebrush cover type, particularly in mountain big sagebrush. In areas where cultivation has had minimal impact, large increases in annual exotics at the lower elevations and conversion of shrub-steppe habitat to woodlands at the upper elevations has had a major impact on sage-grouse populations. In the long term conifer expansion can play a significant role in reducing sage-grouse habitats in some regions, but this change requires decades to realize and is not of the urgency of factors such as fire (Grove 1998).

4.5. Physical Changes to Habitat

Energy developments, including associated roads, power lines and fences, have increased considerably throughout the range of sage-grouse (Braun 1987, Braun 1998, Lyon 2000). Although some data suggests that there is some recovery of sage-grouse populations following the negative effects of initial development (Braun 1987), Braun (1998) suggests that energy developments cause both short-term and long-term habitat loss for sage-grouse. Sage-grouse are injured or killed by colliding with power lines (M. Lucia, unpublished information), and power lines provide perches for raptors (Ellis 1984, Ellis et al. 1989) that subsequently may prey on sage-grouse causing abandonment of historic use areas. Many other physical barriers to sage-grouse use of historic habitats have also been reported including reservoirs, roads (especially high-speed paved and gravel), urban/ suburban developments, fences, pipelines, active mining and oil/gas developments (Braun 1987, Braun 1998). These perturbations not only fragment habitats and reduce habitat patch size, but also some (i.e., power lines, roads, reservoirs, fences) are known sources of direct and indirect mortality. Both direct and indirect mortality have serious long-term negative impacts on sage-grouse populations. Many physical barriers to sage-grouse also have had significant ecological consequences (i.e., reservoirs, roads, urban/suburban developments). Most ecological consequences are not reversible as society is not willing to do without transportation and power-delivery systems. Local mitigation of negative impacts to sage-grouse is possible on a case-by-case basis (e.g., closure of some roads, underground installation or movement of power lines).

Despite the proliferation of physical barriers in sage-grouse habitats over the last 40 years, little work has been done to evaluate their long-term impacts or assess possible mitigation measures. Lyon (2000) studied the potential effects of natural gas development on a sage-grouse population in Wyoming. Results from this study indicated that sage-grouse hens associated with leks near disturbed sites had lower nest initiation rates, and traveled twice as far from leks to nest sites compared to hens associated with leks in relatively undisturbed areas. More work appears necessary to further understand short- and long-term impacts of physical barriers on sage-grouse populations and habitat, as well as to develop appropriate programs to mitigate negative impacts.

4.6. Predation

Sage-grouse are prey for a host of predators (Patterson 1952, Schroeder and Baydack 2001). In most portions of the birds' range, coyotes, badgers, red fox, bobcats and several species of raptors are common predators of adult and juvenile sage-grouse (Schroeder et al. 1999, Schroeder and Baydack 2001). Coyotes, badgers, ravens and ground squirrels are common nest predators (Patterson 1952, Schroeder et al. 1999). Some predators such as red fox (Fichter and Williams 1967) and raccoon may have increased in sagebrush habitats because of human disturbance, while others have decreased (i.e., gray wolves, grizzly bears).

Many argue that reducing predator populations in sage-grouse habitat will boost grouse populations. The ecological implications of removing and/or controlling numbers of predators that prey on sage-grouse have not been studied in sagebrush habitats. Removing coyotes could increase red fox numbers (Sargeant et al. 1987, Sovada et al. 2000). Moreover, because sage-grouse comprise only a small part of the predators' diets, it is likely that populations of other prey species commonly found in diets of sage-grouse predators would increase if those predators were removed or significantly limited (Terborgh et al. 2001). This could have significant ecological impacts as rodents (mice and ground squirrels) and lagomorphs (hares and rabbits) could alter vegetation (primarily grasses and forbs) structure, height and density (Terborgh et al. 2001). Habitat quality and quantity greatly affect the impacts predators have on prey (Schroeder and Baydack 2001).

Numerous researchers have used radio-telemetry to document sage-grouse survival and nest success (Connelly et al. 1993, Gregg 1991, Gregg et al. 1994, Holloran 1999, Lyon 2000, Robertson 1991, Schroeder 1997, Wallestad 1975). Only two studies (Gregg 1991, Gregg et al. 1994) indicated that predation was limiting sage-grouse populations by decreasing nest success, but both studies indicated that low nest success due to predation was related to poor nesting habitat. Two early studies (Autenrieth 1981, Batterson and Morse 1948) suggested that high raven populations may decrease sage-grouse nest success, but rigorous field studies using radio-telemetry have not supported these findings. Most reported nest success rates are >40%, suggesting that nest predation is not a problem (Connelly et al. 2000c). Similarly, high survival of adult and older juvenile grouse (Connelly et al. 1994, M. Lucia personal communication, Zablan 1993) indicates that population declines are generally not caused by high predation rates.

Recently, work in Utah's Strawberry Valley indicated that red fox are taking a high proportion of the sage-grouse population (Flinders 1999). Work in other states also has documented an increased rate of predation by red fox (Nathan Burkepile personal communication, Holloran 1999, Lyon 2000). This may become a major issue if red fox become well established throughout the sage-grouse range.

There is little published information supporting the notion that predation is a widespread limiting factor on sage-grouse populations (Connelly and Braun 1997, Connelly et al. 2000ca, Schroeder and Baydack 2001). That which is available largely suggests that high predation rates result from poor habitat and/or non-native predators (Flinders 1999, Gregg 1991, Gregg et al. 1994). Despite a lack of evidence suggesting predation is a serious threat to sage-grouse populations, Bodenchuk et al. (2002) strongly inferred that sage-grouse are negatively impacted by predation and that predation management to protect this species, including lethal removal of predators, has a high benefit/cost ratio. Unfortunately, their assessment was based simply on the previously mentioned work in the Strawberry Valley (Flinders 1999), a personal communication on raven predation of sage-grouse nests in Utah, and a pilot study conducted in southern Idaho (Collinge and Maycock 2000, Maycock 2000). Bodenchuk et al. (2002) did not use any peer-reviewed publications or even graduate student theses to support their claims. Moreover, they only provided part of the information acquired during the pilot project in Idaho. This project indicated that 28% of artificial nests placed in a predator control area were destroyed compared to 98% in an area without control. If predator removal efforts resulted in decreased nest loss, then predators and nest loss rates should have declined within the removal area but remained unchanged in the non-removal area. Instead, raven numbers increased five-fold in the area without predator control and total number of nests lost to avian predators in this area increased by 97% following predator removal efforts (Maycock 2000). The number of ravens in the predator control area decreased markedly following removal, but the proportion of nests destroyed by avian predators remained the same (Maycock 2000). Thus, these data may also suggest that predator removal efforts increased losses in the non-removal area by shifting foraging areas of predators that survived removal efforts. Interpretation of results was further confounded because only a highway separated the predator removal and non-removal areas. Moreover, no effort was made to relate artificial nest loss to loss of actual sage-grouse nests. Sage-grouse lek count data did not indicate an increase in breeding populations in the predator control area following removal efforts, but rather a decline of more than 30% from the previous year (Idaho Department of Fish and Game 2001).

There is a great deal of evidence indicating that predation may limit populations of some prey species, and that predator removal is a legitimate and sometimes necessary management tool (Gazda et al. 2002, Greenwood et al. 1995, Schroeder and Baydack 2001, Terborg 1989). However, predator control is often controversial (Bodenchuk et al. 2002) and its inappropriate use or poorly planned application may result in strong public opposition. This opposition, in turn, could jeopardize management programs needed to protect rare or declining species. Therefore, proposals to apply predator control programs should be based on sound science and objective evaluation. With regards to sage-grouse, predator management programs may be justified if nest success rates or annual survival of adult hens are relatively low (Connelly et al. 2000c), or if other data (e.g., lek counts combined with data on predator abundance and species composition) suggest sage-grouse population declines are likely related to changes in predator abundance or species composition. However, predation losses are often caused by raptors (Patterson 1952, Schroeder et al. 1999, Schroeder and Baydack 2001), especially golden eagles (*Aquila chrysaetos*). These species are protected and usually cannot be included in a predator control program. Thus, any predator management program developed for sage-grouse can only address a portion of the predator species that may affect grouse numbers. Future research should address the response of sage-grouse populations to predator removal programs in both high-quality and degraded habitats. This would provide a sound foundation for developing predator management programs that are appropriate for sage-grouse populations under a variety of habitat conditions.

4.7. Hunting

A well-regulated harvest from a wildlife population in high-quality habitat is sustainable over time (Campbell et al. 1973, Hoffman 1985, Hudson and Dobson 2001, Kokko 2001, Kubisiak 1984, Potts 1986, Small et al. 1991, Willebrand and Hornell 2001, Williams and Nichols 2001). However, a harvest of too many birds in fall can reduce the size of the spring breeding population and reduce the population size (Anderson and Burnham 1976). Determining the appropriate harvest rate for a fall population is a continuing effort for many populations of upland game birds (Guttierrez 1994).

Sage-grouse are hunted in 10 western states; only Washington and two Canadian provinces prohibit harvest. If sage-grouse populations are declining, why not eliminate fall harvest by hunters? What is the impact of hunter harvest on sage-grouse? Historically, sage-grouse populations were exploited heavily in the late 1800s and early 1900s until most states prohibited harvest (Patterson 1952). By the 1950s, populations rebounded and limited hunting seasons were instituted (Autenrieth 1981, Patterson 1952). Hunting currently occurs with widely varying season lengths and bag/possession limits (Table 2). Many states have, in response to declining sage-grouse populations, eliminated hunting of sage-grouse in specific areas, and/or have restricted season lengths and bag limits.

Decades-old research on upland game birds suggested that up to 50% of the annual mortality could be removed by hunters without impacting population trend (Hickey 1955). Harvest that does not reduce breeding population trend is usually considered “compensatory.” This means that other forms of mortality that would naturally occur, such as from predators, starvation diseases, or exposure, are reduced in their impacts so that the total mortality of the birds over the winter does not produce fewer breeding birds in the subsequent spring (Anderson and Burnham 1976). In contrast to compensatory mortality, harvest mortality may be “additive,” i.e., each bird killed by hunters is an additional death that adds to the natural mortality such that total mortality of the population is larger than if hunting did not occur (Anderson and Burnham 1976).

Over the past 40 years, research has continued to suggest that it is possible for hunters to over-exploit upland game birds during the fall (Bergerud 1985, Bergerud 1988, Dixon et al. 1997, Ellison 1991, Gregg 1990,). Wildlife management agencies attempt to prevent this through harvest regulations. Sage-grouse may be more susceptible to over-harvest than other upland game bird species because they differ in their life history traits. Many species of upland game birds have short life spans (1 to 2 years), high natural rates of mortality over winter (40 to 70%), and produce many offspring through large clutch sizes of 10 to 17 eggs (Christensen 1996, Giudice and Ratti 2001, Gullion 1984, Petersen et al. 1988, Potts 1986). Harvest of these species removes many birds that likely would die over the course of their first or second winter.

Table 2. Calendar year 2001 hunting seasons for sage-grouse.

State	Opening date for state or specific areas	Number of days	Bag and possession limit
Montana	1-Sep	62	3 / 6
Idaho (1)	15-Sep	23	2 / 4
Idaho (2)	15-Sep	7	1 / 2
Wyoming	1-Sep	16	3 / 6
Nevada (1)	13-Oct	9	2 / 4
Nevada (2)	15-Sep	4	3 / 6 w/150 permits
Nevada (3)	22-Sep	2	3 / 6 w/75 permits
Utah	15-Sep	9	1 / 2
Colorado	8-Sep	7	2 / 4
North Dakota	10-Sep	3	1 / 1
South Dakota	8-Sep	2	1 / 2
Oregon	8-Sep	5	2 / 2 season limit 1,265 permits, 12 areas
California (1)	8-Sep	2	2 / 2 season limit 275 permits
California (2)	-	-	1 / 1 season limit 50 permits

Sage-grouse, in contrast, are long-lived (3 to 6 years), have low rates of over-winter mortality (2 to 20%), and produce relatively few young with average clutch size of 6 to 9 eggs (Schroeder et al. 1999).

What is the appropriate harvest rate for sage-grouse? In Idaho, Autenrieth (1981) stated that a harvest rate of up to 30% of the fall population was allowable, but that this high harvest rate was never reached in any area. He also emphasized that harvest should be more conservative in xeric areas closer to urban centers. In mesic portions of grouse range, forbs are available throughout the summer and early fall habitats, and the birds remain dispersed and less vulnerable to hunters. However, in xeric ranges, birds often congregate in August and September at moist sites. In these locales, they are more vulnerable, especially if near cities, and harvest could be additive (Autenrieth 1981).

Crawford (1982) analyzed 20 years of data from Oregon, including harvest figures, hunter numbers, hunting season regulations and population trend data (lek counts, summer transect counts and numbers of chicks/adult), and concluded, "the mortality from harvest may have been compensatory." Crawford and Lutz (1985) suggested that hunting may have short-term effects on sage-grouse population by lowering the survival rate, but concluded that hunting was not responsible for the long-term decline in Oregon's sage-grouse population. Braun and Beck (1985) used banded birds, harvest figures and lek counts to report that 7 to 11% of the fall population of sage-grouse was harvested in an area of Colorado. They reported no measurable effect of hunting on sage-grouse densities - in the spring, and that "20 to 25% of the fall population could be removed without hunting mortality becoming additive" (Braun and Beck 1985).

More recently, Johnson and Braun (1999) conducted a population viability analysis (PVA) of sage-grouse in North Park, Colorado. A PVA, in part, assesses the risk of a species population going extinct based on the production and survival values of the population (Boyce 1992). Johnson and Braun used 23 years of lek count and hunter harvest data from 1973 to 1995. Their analysis revealed that, up to some threshold level, hunting mortality was compensatory, but, at or beyond that level, exploitation of sage-grouse may be additive. The harvest rate level that became additive was not specified.

In Idaho, Connelly et al. (2000b) examined mortality patterns of radio-equipped adult sage-grouse spanning 1978 to 1998. Of known causes of the birds' deaths, hunting was responsible for 15% of male and 42% of female mortality. Females were more likely to die from harvest than were males. Forty-two percent of all documented male mortalities and 43% of female mortalities occurred from March through June. Twenty-eight percent of all documented male mortalities occurred during July and August, while 10% of female mortalities occurred during this period. In September and October, 28% of documented mortalities again occurred for males but 46% of female mortalities occurred during these months. Nearly half the total annual mortality of adult female sage-grouse occurred in September and October, during the hunting season. After the hunting season, during November, December, January and February, only 2% of the deaths of both males and females were attributed to hunting. These low mortality figures over the winter support earlier statements that sage-grouse do not find winter a difficult period, that juvenile birds continue to grow over winter and that adults gain weight over winter (Beck and Braun

1978, Remington and Braun 1988, Sherfy 1992).

Because sage-grouse suffer very little mortality over winter (as low as 2% of annual mortality), hunting mortality in September and October cannot be compensated to a very large degree. Connelly et al. (2000b) reported the harvest rate of adult female sage-grouse averaged 6% over 15 years in Idaho, and that, in six of those years, the rate was higher than 10%. They stated that "hunting losses are likely additive to winter mortality and may result in lower breeding populations" (Connelly et al. 2000b). This result applies only to adult hens; to date similar data are not available on juvenile hens in their first fall and winter. However, current research being conducted in Idaho will soon provide information on harvest rates and survival over winter of juvenile sage-grouse (M. Lucia, personal communication).

While most wildlife agencies have reduced sage-grouse harvest rates, a recommended harvest level has not been universally accepted, and may not be appropriate for all sage-grouse populations. The Oregon Department of Fish and Wildlife (ODFW) explicitly states that Oregon's season is designed to limit harvest to no more than 5% of the fall sage-grouse population (ODFW 2001). This level of exploitation ensures that production data can be collected from wings of harvested birds, but likely does not reduce spring breeding population size.

Hunting seasons for sage-grouse should be established with caution (Schroeder et al. 1999), and harvest rates should be low (Connelly et al. 2000b). There are no available data to suggest that harvest of sage-grouse is a major cause of declining populations, but caution is warranted given the status of most populations. Connelly et al. (2000c) recommended that harvest be prohibited when a defined population contains ≤ 100 males on leks or when the entire breeding population is ≤ 300 birds. Many wildlife agencies would hopefully stop harvest of a sage-grouse population prior to these low numbers. Harvest in Washington has been prohibited since 1988 when the total statewide population was estimated at 1,500 birds (Schroeder et al. 2000). By the year 2000, the population had not rebounded, but was estimated at 1,100 birds (Schroeder et al. 2000). Habitat management issues, not exploitation, caused and are preventing the recovery of sage-grouse populations in Washington (Schroeder et al. 2000).

Some late winter and spring hunting of sage-grouse occurs (Connelly et al. 1994), and it is likely that the vast majority of these birds would have survived to enter the spring breeding population. Connelly et al. (2000c) recommend that spring hunting be discouraged or confined to males-only during the early part of the breeding season.

There are minimal ecological implications of a low harvest rate for sage-grouse unless harvest was sufficiently large (i.e. over harvest) to reduce spring population sizes. In most states, this is not likely to occur (Table 2), nor would it be tolerated for long by the management authorities. There is a consequence of not harvesting the birds, to a limited extent. Considerable population data can be determined from the wings of harvested birds including age and sex ratios, percentage of successful and unsuccessful hens, and average production per hen. These data serve as the basis for understanding the population dynamics of the birds, and could not be acquired in other ways except through expensive, population-specific studies using radio-equipped birds.

4.8. Inventory and Monitoring

Uniform application and careful interpretation of inventory and monitoring methodology are required to (1) measure the quality, quantity and configuration of seasonal and annual habitat for sage-grouse populations across the landscape, (2) select and implement appropriate management practices to maintain or improve sage-grouse habitat and prevent or reduce fragmentation, (3) predict future habitat conditions and variability based on existing or projected environmental conditions and ongoing or proposed management objectives and practices, and (4) formulate decisions to institute specific passive and active restoration measures and to evaluate the implementation, effectiveness and validity of such measures (Connelly et al. 2000c, Miller and Eddleman 2001, Wisdom et al., in preparation). Inventories are conducted to describe the status of selected physical or biological resources or ecosystem functions (e.g. the hydrologic cycle, nutrient cycling, energy flow) to answer specific questions. In contrast, monitoring measures change in resources or functions over time (Natural Resources Council 1994).

Adequate assessments of sage-grouse habitat require that inventories be conducted at multiple scales. To meet seasonal needs, sage-grouse populations require extensive tracts of sagebrush-dominated vegetation, as much as 1,700 miles^2 (2,700 km^2) for migratory populations (Hulet 1983, Leonard et al. 2000). Remote-sensing techniques are used to ascertain the spatial distribution and characteristics of sagebrush-dominated areas across ownerships, and to monitor landscape fragmentation within these broad areas over time. Ground-based local inventories at appropriate scales are also needed because of the general requirement of sage-grouse for healthy sagebrush communities, characterized by high levels of sagebrush cover and a healthy native grass and forb understory, their fidelity to seasonal ranges, and specific requirements for breeding, nesting, rearing and wintering habitat (Berry and Eng 1985, Connelly and Markham 1983, Connelly et al. 2000c, Fischer et al. 1993, Klebenow 1969).

Maintenance of healthy sagebrush-dominated communities and landscapes centers upon management to protect or improve their physical and biotic resources and functions. Inventory and monitoring considerations for these areas include landscape analyses and evaluation of site condition and potential (Society for Range Management 1999). Thus, inventory and monitoring, and resulting management efforts for sage-grouse are, or should be, to a great extent consistent with efforts to sustain the integrity of sagebrush systems if specific seasonal habitat requirements of sage-grouse are also considered (e.g. minimal patch sizes, absence of transportation corridors) (Miller and Eddleman 2001). Because of their requirement for healthy sagebrush communities and their extensive home ranges, sage-grouse may be considered an umbrella species (Caro 2000, Launer and Murphy 1994) for managing the sagebrush steppe (Rich and Altman 2001). Habitat loss or long-term population declines have placed more than 300 organisms associated with sagebrush-dominated landscapes at risk (Paige and Ritter 1999, Saab and Rich 1997, Suring, personal communication, Wisdom et al. 2000). Thus, protection of sage-grouse should also conserve the habitats of these and other more poorly known species. Understanding of sagebrush-dominated areas at an even broader scale, however, may be required to manage wide-ranging species and to make decisions regarding human uses of rangelands.

Formidable problems complicate the inventory and monitoring issue. Because of their extensive ranges that normally include lands of varied ownerships, inventory data for a single sage-grouse population may be gathered by a combination of state and federal agencies with overlapping boundaries and jurisdictions. Objectives, methodologies and terminology used in conducting inventories and monitoring vary within and among agencies and have evolved over time (Natural Resources Council 1994). The original mandates for inventory of USDA Forest Service, and later USDI Bureau of Land Management, lands emphasized measurements of carrying capacity for livestock, as did early national surveys of federal rangelands (Box 1990, Chapline and Campbell 1944, Rowley 1985, U.S. Congress, Senate, 1936). The USDA Forest Service currently uses a line intercept technique that over-estimates sagebrush canopy cover by including openings in crowns of individual shrubs as crown cover (U.S. Department of Agriculture 1993). This leads to control justification at significantly lower canopy cover values than if more precise techniques considered appropriate for research were used. USDA Soil Conservation Service inventories were designed to measure soil erosion and the status of natural resources to aid in ranch management (Helms 1990). Inventory systems developed by these agencies were based upon the successional status of the observed plant community relative to the historic climax plant community (Dyksterhuis 1949) or to a desired plant community. The systems differed in their classification of sites, evaluation of site status or condition, estimation of site potentials, determination of trend or the direction of change in vegetation (see Natural Resources Council 1994 for a detailed discussion of these differences).

The Society for Range Management Committee on Rangeland Inventory has developed a standardized terminology for use by range management professionals (Society for Range Management 1983, 1999; Task Group on Unity in Concepts and Terminology 1995). The Society also has attempted to use available inventory data to compile a national assessment of rangelands and provided guidelines for standardizing inventory procedures for making management decisions in order that data might be interpreted across agencies (Society for Range Management 1989). However, analysis of inventory data collected by different agencies to assess and manage sage-grouse habitat is often difficult or impossible due to the problems described above. In addition, some community attributes important to sage-grouse generally are not evaluated, or they are measured in manners that cannot be interpreted in terms of their value to sage-grouse (see, for example, the discussion of canopy cover measurements above; Floyd and Anderson 1987, Goodrich and Huber 2001). Further, data may not be available or current for all portions of the areas under consideration.

Increasing concern for rangeland condition and environmental legislation from the 1960s to the present contributed to ongoing efforts to develop inventory systems evaluating indicators of rangeland health to determine the degree to which the "integrity of the soil and ecological processes of rangeland ecosystems are maintained" (Natural Resources Council 1994). Such inventories would focus on "the sustainability of ecological processes and indicate the capacity of rangelands to produce commodities and to satisfy human values on a sustainable basis" (Natural Resources Council 1994). Rangeland health assessments aim to evaluate ecological processes (the hydrologic cycle, energy flow and nutrient cycling) to estimate the integrity of soil, vegetation, water and air for land areas based on comparison to ecological site descriptions or ecological reference areas. Evaluations use current successional theory including the concepts of states, transitions and thresholds (National Resource Council 1994, Pellant et al. 2000, Pimm 1984). Assessments are completed using combinations of site-specific indicators. Further research is required to describe ecological sites, refine rangeland health assessments and interpret findings.

At present, inventory systems and their applications continue to vary both within and among agencies, complicating assessment of rangeland resources at both local and landscape scales. Available data is often outdated. To address this issue, the 2002 Appropriations Bill for the Department of Interior included funding for a coordinated 10-year interagency effort to standardize soil surveys and ecological classification on all rangelands for use at local management levels, as well as a plan for standardized monitoring and assessment methodologies for carrying out a periodic National Cooperative Rangeland Survey (Office of Management and Budget 2001).

Additional factors affecting inventory and monitoring of sage-grouse habitat include spatial and temporal considerations. Sage-grouse occupy an area of varied topography, geology, climate and sagebrush communities (Miller and Eddleman 2001). Climatic conditions within this area have fluctuated dramatically over the long-term, and short-term fluctuations in precipitation and temperature are common. Other natural and generally more localized disturbances such as wildfires and disease outbreaks contribute to spatial and temporal variability across landscapes. Since European settlement, human-caused disturbances have created drastic landscape-scale alterations in vegetation. Annual habitat losses result from activities including urbanization, agricultural development, recreation, construction of transportation and utility corridors, mineral extraction, expansion of piñyon-juniper woodlands, wildfires, and the associated spread of annual and, more recently, perennial or secondary weeds (D'Antonio and Vitouskek 1992).

Increasing concerns over the condition of sagebrush rangelands and populations of sage-grouse and associated species led to signing of a Memorandum of Understanding between the Western Association of Fish and Wildlife Agencies, the USDA Forest Service, the USDI Bureau of Land Management, and the USDI Fish and Wildlife Service in 2000 (McCarthy, unpublished report). This memorandum provided for establishment of a team of representatives (Framework Team) from these three federal agencies and four states (Nevada, Idaho, Montana and Wyoming) to coordinate state and federal efforts to conserve sagebrush and sage-grouse. A 3-year position to oversee this effort has been established and funded. Western states are completing sage-grouse conservation plans that will be implemented in local plans at the county level. Representatives of the federal agencies are involved in the state-level efforts.

An interagency Sagebrush Habitat Steering Committee, formed at about the same time as the Framework Team, has the objectives of coordinating the planning of broad-scale assessments for sagebrush ecosystems, including species at risk within these systems, and to coordinate the addition of ecosystem and conservation planning information into federal land management plans (McCarthy, unpublished report). This committee assembled five teams to address pertinent issues: 1) Mapping - Prepare hierarchy for mapping vegetation communities; 2) Planning - Integrate data into land proposals for mapping at broad- and mid-scales and develop sagebrush classification use and forest plan revisions; 3) Conservation/Restoration - Develop conservation and restoration priorities at broad-scale levels; 4) Inventory/Monitoring - Increase consistency in inventory, monitoring and classification in sagebrush ecosystems; and 5) Communication Team - Disperse committee products to agencies. A number of parallel inventory, monitoring, conservation and restoration efforts are ongoing within federal and state agencies, particularly in the area of mapping. The mapping team will attempt to coordinate these efforts to minimize redundancy. USDA Forest Service Regions 1 and 4 are developing classification systems for nonforested ecosystems to address inventory and monitoring needs.

5. Policy Alternatives

What are the most important policy alternatives that can be derived from the above criteria and their related issues? Focusing on the needs of the grouse, we have identified two major categories of policy alternatives: population data needs and maintaining and protecting habitat. Population data needs include applying more consistent inventory and monitoring efforts, minimizing effects of non-native or abnormally high predator populations, and establishing appropriate hunting seasons. Maintaining and protecting habitat includes suppressing fire, minimizing effects of invasive species, improving inventory and monitoring of habitats, and mitigating effects of physical barriers.

A myriad of policy alternatives could be selected under each of the above topics. However, those described below appear to have the greatest likelihood of stabilizing, and perhaps ultimately increasing, sage-grouse populations. In most cases, they will only require relatively minor changes in current programs by state and federal agencies and should not require large sums of new funding.

5.1. Population Alternatives

Although most sage-grouse population declines appear to be related to habitat (Braun 1998, Connelly and Braun 1997, Patterson 1952), some of the greatest controversies surrounding sage-grouse conservation appear to be centered on other population-related issues. There is some disagreement over current size of populations and the effect of predators and hunting on these populations. Current information clearly demonstrates a need for standardized monitoring across the species' range. Additionally, the most current published information suggests minimum impacts of predators or hunting on sage-grouse populations, with a few isolated exceptions (e.g., Strawberry Valley, Utah).

5.1.1. Inventory and Monitoring

A range of alternatives is available, from no population monitoring to intensive radio telemetry. The most reasonable appears to be routine monitoring of populations throughout the species' range. Rigorous and systematic monitoring should be a priority within state natural resource agencies and is necessary to assess the effects of other policy alternatives. Current databases should be thoroughly analyzed and monitoring programs should be developed or modified with the help of statisticians. This approach will allow implementation of adaptive management programs (Gratson et al. 1993) that incorporate current information into management decisions.

All states and provinces with sage-grouse populations expend some effort monitoring these populations. Some agencies place a high priority on these activities while others spend a minimal amount of time tracking populations. In any case, there is a large amount of range-wide data available for assessing the status and distribution of sage-grouse. Most states and provinces monitor breeding populations. Some assess production, harvest and winter populations. Unfortunately, monitoring techniques differ among agencies, complicating attempts to understand population trends.

Because sage-grouse gather on traditional display areas (leks) each spring, wildlife biologists are afforded relatively easy methods for tracking breeding populations. These methods include lek censuses (annually counting the number of male sage-grouse attending leks in a given area), lek routes (annually counting the number of male sage-grouse on a group of leks that are relatively close and represent part or all of a single breeding population), and lek surveys (annually counting the number of active leks in a given area). All monitoring procedures are conducted during early morning (1/2 hour before to 1 hour after sunrise), with reasonably good weather (light or no wind, partly cloudy to clear) from early March to early May.

Lek censuses are a relatively common means of monitoring sage-grouse populations. In a lek census, male grouse in some, or perhaps most, of the leks in a given area are counted using accepted techniques (Jenni and Hartzler 1978). However, leks may be widely separated and no assumption is made that the census samples a single breeding population. Because some sage-grouse may use several leks in a given breeding season (Dalke et al. 1963), changes in lek attendance observed during a census may be due to birds shifting to other leks rather than actual changes in the grouse population. Unless all leks are counted during a census, there would be no way to assess observed changes.

Although lek censuses are widely used, concern over their usefulness has been expressed (Beck and Braun 1980). However, techniques for correctly conducting lek censuses have been described (Emmons and Braun 1984, Jenni and Hartzler 1978), and problems generally seem to be related to disregarding accepted techniques. A recent review of raw data recorded while conducting lek route counts in Idaho indicated that leks were sometimes counted when conditions were windy, ceiling was overcast and rainstorms were occurring; in some cases, counts were not begun until after 7:30 a.m. (M.C. Kemner, unpublished data).

Lek routes have some of the same problems as lek censuses (Beck and Braun 1980), and problems are usually related to disregarding accepted techniques (Emmons and Braun 1984, Jenni and Hartzler 1978). Whenever possible, leks should be counted along routes to facilitate repetition by other observers, increase the likelihood of recording satellite leks and account for lek shifts in breeding birds, if they occur. Lek routes should be established so that all leks along the route can be counted within 1.5 hours. Currently, some states use lek censuses while others use lek routes, and little attention appears to be paid to how these data are collected. Before establishing lek routes in a given area, some thought should be given to personnel available for conducting route counts. It is much better to have a few routes with high-quality data than many routes with virtually useless data.

Brood observations or brood routes, and wing surveys have been used to assess sage-grouse production (Autenrieth et al. 1982). Brood observations, sometimes called random brood routes, are simply records of all sage-grouse broods observed in a given area by any field personnel that find themselves in that area. This information provides some idea of the juvenile-to-adult ratio and percent of hens observed with broods. Thus, it is somewhat better than anecdotal data. However, it is not easily replicated and comparisons among years can be difficult to interpret.

A sage-grouse wing collected in September and sometimes early October can be used to determine age, gender, and, for females, reproductive status. For hunted populations, wing surveys are the most useful technique for assessing sage-grouse production. However, sample sizes should exceed 150 wings; a much larger sample size is usually preferable (Autenrieth et al. 1982).

Wing analyses and brood routes allow assessments of trends in production and comparisons of production among areas (Autenrieth 1981). However, these data may not reflect population trends. For example, a portion of a population's winter habitat may be lost, but the breeding range could remain intact. Production (juvenile-to-adult ratio) may be stable, but the overall population may decline because of increased mortality on winter range. Thus, it is best to use this information in conjunction with data on breeding populations to make inferences on population trends. Unlike breeding populations and production, there are no widely accepted methods for assessing winter populations. In part, this is because birds may be spread out over large areas during mild winters, but clumped in less than 10% of the available habitat in severe winters (Beck 1977).

5.1.2. Predation

With the exception of a few isolated areas (Flinders 1999), there appears to be little evidence that predation is causing significant declines in sage-grouse populations. Based on the current data, widespread predator control does not appear to be a necessary or reasonable management approach. Instead, the establishment of exotic predators (e.g., red fox, house cats) should be discouraged in sage-grouse habitats. In some cases, control of these predators may be warranted and, in many areas, the presence of coyotes will discourage red fox populations (Sargeant et al. 1987, Sovada et al. 2000). Guidelines presented in Connelly et al. (2000c) for implementing predator control programs should be followed.

5.1.3. Hunting

As with predation, hunting does not appear to be a major cause of population declines for sage-grouse. However, given sage-grouse reproductive characteristics, it may be possible in some instances for relatively high harvest rates to slow population recovery or stabilize populations at lower-than-desirable levels. Thus, states should base hunting seasons on population size and trends. They should not assume that hunting is a totally compensatory form of mortality, nor should they base seasons on the general idea that small game seasons and bag limits can be very liberal because of high annual turnover (Allen 1954).

5.1.4. Translocation

Numerous attempts have been made to translocate sage-grouse into former range or into habitats that have relatively few grouse (Patterson 1952, Reese and Connelly 1997). Over 7,200 sage-grouse have been translocated in at least 56 different efforts (Reese and Connelly 1997). Only three of these efforts appear successful and populations within these areas remained relatively small (Reese and Connelly 1997). Given the apparent difficulty of translocating sage-grouse, this activity should be considered experimental and cannot presently be viewed as a viable strategy to restore extirpated populations.

5.2. Habitat Alternatives

Overall, it is clear that policies to control sagebrush when its canopy cover exceeds 5 to 20% in order to benefit sage-grouse are not supported by ecological evidence. Sage-grouse and other sagebrush obligates exist and thrive in habitats with about 15 to 30% canopy cover of sagebrush. A healthy understory of grasses and forbs is also necessary to support breeding populations of sage-grouse. Both components must be considered in conservation and management programs.

5.2.1. Fire

Fire is by far the most important policy issue with respect to sage-grouse. How fire affects the different sagebrush types determines what effects fire will have on obligate species such as sage-grouse. Sagebrush taxa carry fire differently, and respond differently after burning. A general approach to systematically and routinely burning sagebrush rangelands is counterproductive to stabilizing and increasing sage-grouse populations. Instead, all prescribed burning in habitats occupied by sage-grouse should generally be discouraged. If prescribed burning is judged to be the only appropriate tool for improving sage-grouse habitat (Connelly et al. 2000c), it should be applied with utmost caution. All wildfires in sage-grouse habitat should be vigorously suppressed and this approach should be made a very high priority within both the USDI Bureau of Land Management and USDA Forest Service. Given the documented negative effects of fire on sage-grouse populations and habitat, the future of this species may likely rest on the ability of these agencies to implement meaningful management programs including fire suppression and control of invasive plant species that frequently follow fire.

5.2.2. Physical Barriers

Clearly there is a major need for more information on the impacts of various physical disturbances to sage-grouse populations and habitats. Natural resource agencies and private businesses, especially energy and utility companies, should work together to seek sound and effective methods to mitigate for habitat loss due to energy development. Moreover, it is unlikely that current disturbances such as roads, active transmission/power lines, reservoirs, urban/suburban developments, active mines, and oil and gas wells would or could be significantly altered to benefit sage-grouse. Thus, where possible, impacts should be minimized by discouraging raptor use of power poles in sage-grouse breeding habitats, marking fences and other obstacles that present a danger to flying grouse, conducting exploration and drilling activities outside the sage-grouse breeding season, and so on. A handbook of mitigation techniques should be developed and implemented. It should also be updated as new information becomes available.

5.2.3. Inventory and Monitoring

As suggested for populations, standardized methods of habitat inventory and monitoring are necessary to track changes in sage-grouse habitats and assess the success of habitat management programs. These techniques should be based on the scientific literature and should be directly comparable (if not the same techniques) to those used by scientists currently studying sage-grouse habitats. Except in a very general sense, no habitat management decisions should be based on "ocular assessments" of either shrub overstory or herbaceous understory.

6. Endangered Species Act Implications

A successful petition to list the greater sage-grouse as a threatened or endangered species has implications for all the policy alternatives discussed here. In addition, most of the social and economic impacts that are occurring or could occur stem from management decisions based on the potential ESA status of the bird. In this section, we present a brief discussion of the potential effects an ESA listing might have for each policy alternative. We then provide a brief social assessment of current sage-grouse policies, and offer a discussion of possible economic impacts from an ESA listing stemming from likely reductions in spring grazing on federal lands containing grouse breeding, nesting and brooding habitats.

6.1. Populations

6.1.1. Inventory and Monitoring

Reliable data on populations is necessary to realistically deal with efforts to list sage-grouse under the Endangered Species Act. If the species is listed, responsibility for this activity may move from the states to the U.S. Fish and Wildlife Service with unforeseen consequences. Reliable data may help prevent a listing by demonstrating that populations are being closely monitored and appropriate and effective management programs are in place.

6.1.2. Predation

The implications of listing sage-grouse under the Endangered Species Act could have local effects on predator populations, provided that attempts were made to control sage-grouse predators. No long-term effects on predator populations would be expected from local control efforts. If management efforts were directed at improving the quality and quantity of habitat for sage-grouse in an attempt to reduce apparent predation rates, other uses of these lands could be affected both for short- and long-term periods. However, public attitudes towards active predator control would likely make most control efforts problematic (Messmer et al. 1999).

6.1.3. Hunting

Endangered Species Act listing of sage-grouse could result in further restrictions to, or elimination of, hunting and falconry across the species' range. As demonstrated previously, closure of sport hunting of sage-grouse in Washington over the past 12 years has not produced an increase in sage-grouse numbers nor stopped the decline in population size (Schroeder et al. 2000). Social and economic implications of the closure in Washington are unknown. The social and economic impacts of a range-wide hunting closure are also unknown. Sage-grouse management has been a responsibility of state wildlife agencies, and federal intrusion into sage-grouse management may have unforeseen implications. In addition, costs of acquiring data on population productivity and age and sex structure will increase if wings of harvested birds are no longer available.

6.2. Habitat

To arrive at a zero net loss of sagebrush habitats, managers must prioritize areas to be protected and retained. An inventory of distribution, quality and abundance of all sagebrush habitats is needed and is currently being developed (SAGEMAP 2001). Large stands of high-quality sagebrush used by sage-grouse could receive the highest priority for protection and retention. All use areas with known migration corridors or seasonal ranges might be managed for protection and retention at a second level of priority. Cooperating management agencies and interested groups could further develop prioritization categories for specific sagebrush areas incorporating geography, climate, knowledge of sage-grouse use, ownership, extent of threats to each area and land uses. Considerations of size of area, degree of fragmentation, types of surrounding habitats, degree of isolation from other sagebrush habitats, duration and timing of seasonal range use, current and future land-use patterns, and sage-grouse abundance would be necessary for such planning.

Similar prioritization is needed for sagebrush habitats needing enhancement to be more suitable to sage-grouse. Several criteria for priority are possible. Large sagebrush stands in less-than-desired condition for sage-grouse should receive higher priority for restoration efforts than small stands, and stands closer to high-quality habitats may be of higher priority than stands far from such habitats (see references in Schroeder et al. 1999). Management actions that enhance conditions in a single seasonal range may be a higher priority than actions necessary if birds exist in an area with poor conditions on several seasonal ranges. Populations of birds threatened with extirpation should receive higher priority for action than secure populations. In all cases, the extent and intensity of the problem in each habitat, the probability of success of an action to enhance each habitat, and the cost of actions must be included in the planning process.

As discussed above, sage-grouse depend on sagebrush throughout the year. All seasonal habitats are important and need to be identified and maintained for continued existence of each grouse population (Leonard et al. 2000, Schroeder et al. 1999). In addition to sagebrush habitats, sage-grouse during summer may use irrigated hay fields, croplands and meadows, riparian zones, and natural wet meadows (Blus et al. 1989, Gates 1983, Gill 1965, Oakleaf 1971, Savage 1969, Wallestad 1971). In many years, these may be critical to successful production of chicks to independence (Drut et al. 1994, Dunn and Braun 1986). Identification and maintenance of these brood-rearing habitats is needed to ensure adequate availability to sage-grouse populations nesting in the surrounding or adjacent sagebrush habitats. Failure to provide continuing moist habitats with abundant forbs and invertebrates would negatively impact sage-grouse population persistence through reduced chick survival (Johnson and Boyce 1990, 1991; Savage 1969).

6.2.1. Fire

Failure to eliminate or vigorously suppress wildfires in key sage-grouse habitats will result in further long-term loss of critical habitat and, thus increase the likelihood that this species will be listed as threatened or endangered. Conversely, vigorous wildfire suppression will likely decrease the chance the species will be listed and should help stabilize and perhaps ultimately increase populations. The widespread use of prescribed fire in sage-grouse breeding and winter habitat is also likely to increase the likelihood of this species being listed as threatened or endangered. Fire may be a useful tool to enhance sage-grouse habitat by eliminating invading conifers, but its use should be carefully planned and monitored. Conifer encroachment effects on sagebrush decline require decades while the impact of fire is immediate and more severe (Grove 1998).

6.2.2. Maintain Habitat

Maintaining existing, and preventing further loss of, sagebrush habitats, along with improving conditions for sage-grouse on poor condition sites, would contribute positively towards the sage-grouse remaining off the Endangered Species list. Obvious, immediate threats to the species' habitats would be minimized. Expansion of sagebrush acres by restoration of juniper- and cheatgrass-dominated habitats and crested wheatgrass areas to sagebrush habitats, or the seeding of sagebrush into Conservation Reserve Program (CRP) fields, would also reduce the urgent threats of habitat loss to sage-grouse. Neither Endangered Species Act protection nor the lack of ESA protection of sage-grouse prohibits agencies or interested groups from initiating many of the above-discussed actions unilaterally or cooperatively.

Producing an adequate number of young animals is of utmost importance in maintaining population stability or growth. Maintenance of non-sagebrush, but critically important, brood-rearing habitats would help to ensure that sage-grouse are not listed as an endangered species based on habitat criteria.

Listing of sage-grouse would have far-reaching consequences on how federal agencies manage sagebrush ecosystems. It would require an emphasis on sagebrush ecosystem conservation where the removal of sagebrush would be an act of "last resort." Prescribed fires, for the most part, would be sharply curtailed and the often-unofficial policy of letting wildfires burn in sagebrush would be greatly modified.

6.2.3. Physical Barriers

If sage-grouse were listed under the Endangered Species Act, it is logical to expect that placement of all new perturbations into occupied sage-grouse habitats would be closely examined. For example, power line placement would most likely be outside of sage-grouse use areas or in designated corridors. Alteration of fences to reduce direct mortality from collisions and to reduce the number of raptor perches could also be expected. Provided critical habitat was designated, many new or planned uses of habitats presently occupied by sage-grouse would not be permitted unless population goals were met. However, it is not likely that current disturbances such as roads, active transmission/power lines, reservoirs, urban/suburban developments, active mines, and oil and gas wells would be significantly altered.

6.2.4. Inventory and Monitoring

Listing of sage-grouse would necessitate completion or updating of inventories at multiple scales over entire annual ranges of affected populations, states or the limits of the species' range, depending upon the nature of the listing, to permit development of recovery plans and revision of land-use and forest plans. Thus, decisions regarding land use, management and restoration would also be dependent upon completion of these inventories. Additional inventories might be required to assess specific uses, such as livestock grazing, and provide a basis for long-term monitoring of use. Such efforts could restrict most uses of affected public lands for considerable time periods.

6.3. Social Issues Related to Sage-grouse Recovery

The social issues or impacts that result from sage-grouse management activities are primarily a function of how different interest groups perceive and interpret the effects of such activities. Different people and social groups "define the situation" according to their own personal values, economic interests, attitudes, life experiences and the "facts of the situation" as they create and recreate those facts (Cohen 1991). Little empirical research has been done to date on social effects of sage-grouse management activities. But it is possible to describe and understand how many groups do, and will, "define the situation" from knowledge of other natural resource conflicts.

In the following section we describe how major interest groups may be defining the situation or social impacts for each of the potential management alternatives described earlier in this report. The potential perceptions and reactions of each of seven interest groups are described for each alternative. The groups are ranchers, farmers, hunters, environmentalists, energy and utility providers, real estate developers and small towns or rural communities. The data used are from prior studies of natural resource conflicts, newspaper and magazine accounts, personal interviews, personal conversations and prior knowledge and observations from the authors of this report (Bogdan and Taylor 1975). We have not tried to cite sources since to do so would have rendered the report unreadable. Readers and reviewers will each assign their own level of credibility to the analysis.

There is considerable value to the descriptions supplied here which we call a "social mapping" of the "definitions of the situation" held by members of the major interest groups. If our descriptions are reasonably accurate, the various parties to the issue will gain better understanding and appreciation of how and why other groups are taking the positions that they are. Such understanding can produce empathy for other's values and situations, and can possibly increase the willingness of many to seek compromises that can result in win-win actions that lead to solutions to the larger problem, the stabilization and increase of sage-grouse populations.

6.3.1. Population Estimates

Some individuals and/or interest groups may not support attempts to obtain relatively accurate estimates of sage-grouse populations because such data may interfere with attaining their goals. Absent better data, they can claim there are more or fewer birds whichever serves their purposes. We believe such an approach is akin to trying to put toothpaste back into the tube: The population decline has become part of the scientific and social discussion of grouse management. The sage-grouse issue has definitely become far too prominent to be affected by such claims.

There appears to be agreement, however, among all interest groups that there has been a serious decline in grouse populations from the late 1970s to the present. The exact rate at which the population is declining cannot currently be known for most areas. Even with significant qualifications concerning available population data, an overall decline in sage-grouse population is evident. Most people agree that population is still declining overall at an alarming rate and this decline needs to be reversed as quickly as possible.

Most interest groups are negatively affected by a continued decline in the grouse population and want to see populations increase substantially. Some groups are experiencing, or can experience, negative economic impacts due to management actions to protect the bird. At this time these impacts appear to be falling mostly on public land ranchers, and therefore the communities in which they live. So it appears to be in the interest of all parties to have improved inventory and monitoring efforts for the population throughout the region. Decisions made in the absence of good data only increase the likelihood and magnitude of adverse social and economic impacts. This is especially true in those specific areas where populations seem most threatened.

6.3.2. Fire

Natural or prescribed burning of sagebush is seldom good for sage-grouse. This assessment recommends that fires within sage-grouse habitat be avoided in most cases, and should be allowed only after careful study of each local situation. The evidence also indicates that habitat loss due to fire may well be the most serious of all the factors contributing to the decline of the grouse. Given the significance of this finding, most interest groups will likely support management actions aimed at reducing sagebrush fires.

Many in the livestock industry believe that burning sagebrush increases grass and forb production for grazing. However, if such burning continues under most circumstances, the economic value derived from any increase in forage values will be lost when grazing on burned allotments is restricted because grouse populations declined following the burn. It appears, therefore, that most grazing interests should be willing to comply with restrictions on burning.

Interestingly, differences over the value of curtailing fires in sagebrush may occur more between federal agencies that have different mandates and goals. Other disagreements may emerge between natural resource managers and scientists within wildlife management units in both state and federal agencies. There appears to be important differences of opinion between wildlife experts within these agencies in some states as to the value of fire. Presumably, studies such as this one will bring these disagreements to the fore and bring pressure to reach agreement on fire policies.

6.3.3. Physical Changes

Physical changes to sage-grouse habitat can include a wide variety of activities. The most studied are changes due to roads, power lines, pipelines, energy developments and agricultural development. These activities alter the habitat by presenting barriers to grouse movement, removing habitat entirely, or more subtle changes such as providing sanctuary and perch for predators. The primary policy alternatives discussed in this analysis address the conclusion that grouse will avoid habitat if the physical disruption is sufficient. All disruptions are not created equal, and different groups are likely to experience direct consequences from grouse recovery differently.

Real estate developers, local municipalities and energy companies are most likely to have their development activities curtailed. Even without an ESA listing, these groups are likely to experience significant opposition to planned developments. For example, grouse seem to be negatively impacted by energy development. The economic consequences of curtailing these activities are likely to be high, and born by a larger portion of the local economy than those coming from other sectors such as range cattle. This is due, particularly with oil and gas development, to their having more employees. Environmentalists are likely to see such consequences as the price of doing business on public lands. Local governments have a complex role to play in this as well. They will be caught up in roads, bridges, property tax and right of way issues related to energy development that are all entangled in sage-grouse habitat needs as it relates to public land permitting of energy development. An ESA listing could essentially stop energy development on or near sage-grouse habitat.

Other physical barriers such as power lines and pipelines disrupt grouse habitats. Many of these are already in place, but others are planned. The same groups are likely to experience the economic downside of moving these projects away from grouse. Local government impacts due to property tax losses are an example. Alternatives such as burying lines might mitigate this impact. However, other groups such as environmentalists and ranchers may well see these costs as being born by deep pockets and, therefore, find such policies preferable to other possible policy changes.

6.3.4. Predation and Drought

The role that predation and drought played in the rapid decline of sage-grouse since the late 1970s is the basis of many concerns expressed by numerous groups. Both of these issues affect grouse, but how those affects come into play are complex and not easily understood. Because many groups believe these factors may have a pronounced effect, it is important to try to be explicit as to what effect each may, or may not, be having.

Predation: Many people, including some ranchers, farmers, range ecologists and hunters believe that the reduction in predator controls that began in the 1970s has had a major effect on sage-grouse populations. Their logic is that, prior to predator control restrictions from the early 1900s to the 1970s, there was a "surplus" in the grouse population that persisted because predators were being artificially controlled. These people usually agree that prey and predator populations have evolved together, so normally predators will not cause a permanent decline in a prey population. However, they argue that any natural balance between the grouse and its major predators was disrupted early in the last century. They further argue that the grouse has been declining for most of the century, but that the decline would have been even greater except that many predators were being reduced with extensive control. When these control methods were severely restricted in the 1970s, they observed the resultant increase in certain predators and associated the increase with the sharp decline in sage-grouse over the last 20 years.

Groups who take this view of the role of predators feel that it is naïve to ignore the effect of these predators given the current status of the grouse. They argue that, at a minimum, pilot programs and experimental studies are needed to better determine the impact of predator removal on grouse populations.

Environmentalists, conservationists and others are very resistant to this line of reasoning. It took them decades to get predator controls restricted. They point to the fact that the more objectionable predator control mechanisms kill wildlife other than targeted predators. The original reasons for banning these mechanisms still apply. They see the killing of predators, particularly using currently banned techniques, such as M-44, as stepping backward in time. If the grouse habitat, including grasses, forbs and sagebrush, are of sufficient quality, the grouse will come into balance with predators. Further, some of the natural predators of coyotes and foxes, such as the wolf and the mountain lion, are being reintroduced and/or are expanding naturally. Given time, these natural controls will restore balance with the grouse population.

All sides in the predator debate have some legitimate interpretations of the facts. Some on both sides of the issue are trying to use their interpretations in a "strategic" manner. Some ranchers might see the chance to use grouse predation to regain some currently banned predator control techniques. Some environmentalists do not want a close examination of the predator issue because it may challenge accepted beliefs about natural balance and reduce pressure to restrict grazing by domestic livestock on public lands. But beyond these more extreme views, many actors in these interest groups appear to agree that there are legitimate points of contention over the role of predators. Any resolution of this issue is hampered by the absence of useful research on the effect predator removal has on sage-grouse populations.

The case of exotic predators, such as red fox, presents a special aspect to the general predator issue. Most ecologists, wildlife managers and environmentalists appear to agree that introduced and exotic species are not good for any ecosystem. But, again, the issue becomes how to remove such introduced species. Most ranchers and farmers would like to see these species removed. However, they are notably concerned that the negative effects of such species on the grouse will be ignored simply because it is politically easier to advocate for the removal of livestock from public lands than to design a politically acceptable, species-specific predator control method. Ranchers are more likely to believe that the mandate of multiple-use on public lands requires that the predator issue in general, and the exotic issue specifically, be addressed directly, rather than as a conflict between domestic livestock and sage-grouse.

Drought: Concerns about the effects of drought on the grouse are much the same as predator concerns. Ranchers, farmers and range ecologists agree that the grouse has evolved with drought. But much of the grouse region, though not all of the area, has been experiencing an extended drought during the 1980s and 1990s when the grouse appear to have been experiencing an increasingly rapid decline. They argue that the drought has had some effect and that as the drought ends, as it always does, grouse numbers will recover somewhat. Therefore, management strategies should focus on how to jointly manage for livestock and grouse during this period without making permanent changes in grazing regimes. When drought is severe on most allotments, grazing regimes are already, or should be, altered to comply with the agency standards and guidelines. Public grazing lessees often feel that grouse advocates are singling them out unfairly. They feel that many factors affect the grouse and, until other factors are addressed as well, grazing should not be further restricted beyond what is required to meet standards and guidelines.

Grouse advocates and most environmentalists counter by pointing out that if grouse habitats were "optimal" then the grouse population should be able to withstand drought periods without such serious declines. They seem to feel that the standards and guidelines simply do not account for the needs of many species such as the grouse. They appear to agree that the science related to habitat needs is incomplete. They demand management actions that go beyond agency standards and guidelines and are focused directly on needs of the grouse.

6.3.5. Habitat Needs and Domestic Livestock Grazing

As stated previously, no available research links livestock grazing directly to reductions in sage-grouse populations. Available indirect evidence does indicate that livestock compete with sage-grouse for forage and habitat. Significant disagreement among experts about the exact nature of this competition and whether properly managed grazing always has a detrimental effect on the grouse precludes a clear consensus on this matter.

Current scientific literature on grouse habitat needs, such as height of grass characteristics, quantity and type of forbs needed and when, and optimal sage canopy is available. As with grazing, the results reflect such ranges of values that conclusive, quantitative answers are, at best, indefinite. Experts in these areas can explain the variety of habitat characteristics needed, as reflected in current guidelines from the Western Association of Fish and Wildlife Agencies (Connelly et al. 2000c). However, the variation of specific habitat characteristics and measures is reflected in the fact that the WAFWA wrote guidelines, not standards. Guidelines reflect the scientific consensus on specific habitat needs for certain areas, but they are generally applicable across the sage-grouse range. However, considerable additional research is required before such guidelines for sage-grouse management can evolve into standards. Given these uncertainties, many ranchers and range experts will resist major changes in grazing regimes until the quantitative relationships between specific sage-grouse habitat needs and livestock grazing are clearly measured.

Therefore, public land grazing lessees and others contend that current grazing regimes should not be seriously altered until several other things happen. First, other activities that clearly have a negative effect on the grouse should be addressed. These include fire in the sagebrush ecosystem; landscape fragmentation from energy development, subdivisions and utility corridors; and outright removal of sagebrush for farming and other uses. Many grazing lessees are adamant that the negative impacts from these other activities are better understood and should be considered before grazing plans are seriously altered. Second, research on the specific relationships between grazing and grouse needs should be conducted to explicitly understand how to best change grazing patterns to benefit grouse. Changes to grazing would then be based on locally specific research.

Social impacts arise from the sage-grouse management issues because significant reductions in grazing AUMs on public lands can have identifiable negative economic effects on individual producers and rural communities. The economic impacts section of this study confirms that negative economic effects can result from large reductions in public land grazing. Public land grazers also point out that alternative management actions, such as reducing fire in the sage ecosystem or requiring habitat mitigation for sagebrush fragmentation, do not have the same negative economic consequences for individuals and local communities. The economic impacts of such actions are usually exported from the region and spread over many consumers nationwide.

Some environmental groups and advocates for the grouse believe that livestock grazing definitely does create a negative impact on the grouse. Ranchers and rural communities often see this view as anti-grazing rather than pro-grouse because the accumulated scientific research to back up such claims does not appear to be compelling at this time. Some environmental groups, hunters and others are willing to take a more gradual approach to managing grazing regimes. A few environmental groups have begun to take the position that rushing to put ranchers out of business might encourage alternatives such as subdividing that may be even worse for the grouse.

6.3.6. Cumulative Impacts

The primary outcome of this limited exercise is to see that the nature and extent of social impacts are determined, to a great extent, by those to whom you are talking. In our opinion, impacts are most likely to fall on those whose lives are intertwined most closely with public lands policies on a daily basis: public land ranchers. Secondary impacts will flow to the communities in which they live. Other groups have legitimate interests, but are less likely to experience tangible impacts in the very short term. The second group is likely to be rural communities in general. Not only do they feel the impacts through ranchers, but also hunters and localized fiscal impacts on other economic activities like energy development, road building, etc. The cumulative effects on local communities more or less account for most of the local impacts. Environmentalists, developers, energy companies and others will escape the local impacts, but experience their own, maybe positive, impacts elsewhere. None of the management policies for protecting the sage-grouse suggested in this report appear to have serious negative social impacts for local rural communities. However, social conflict can increase in these communities, reducing cohesion among groups in the communities, thus making it more difficult for communities to act together and achieve their desired objectives (Fisher et al. 1991, Wondolleck and Yaffee 2000).

6.4. Economics of Livestock Grazing and the ESA

As discussions about listing the greater sage-grouse under the Endangered Species Act intensify, it can be expected that anti-grazing groups will demand the removal of cattle from public lands in the name of sage-grouse recovery. Even if such a ban does not occur, altered public land grazing regulations based on the current understanding of sage-grouse habitat needs might be expected. Moreover, some policy changes could be required prior to an official listing since the Bureau of Land Management lists the sage-grouse as a "sensitive species," and U.S. Forest Service lists it as a "management indicator species." These designations require land agencies to manage for and meet the needs of the species.

While the condition of spring habitat is critical for the survival of sage-grouse, this spring period is critical for rangeland production and livestock production as well. In our associated paper (Torell et al. 2002), we estimate the value of spring grazing for livestock production. We also estimate the economic consequences of eliminating spring grazing and reducing overall grazing capacity on public lands.[1] The projected economic consequences of the two policy changes would be applicable for numerous other endangered species and land-use issues where similar policy changes have been suggested.

The policy impact economic models used in this analysis are structured for western livestock ranches that rely on both deeded and public lands for grazing capacity. The models developed were dynamic, multi-period, linear programming models designed to use land, livestock and financial resources so as to maximize discounted net ranch income over a 40-year planning horizon. For this analysis, the models are applied to three specific ranching areas in Idaho, Oregon and Nevada that will potentially be impacted by policy changes related to sage-grouse recovery. The analysis focuses on the impacts to net ranch income and optimal (profit-maximizing) livestock production with the removal of one month of spring forage use and the phased-in removal of public land forage from the representative ranch operations. Eliminating BLM grazing to improve habitat for sage-grouse would have a significant impact on the economic viability of affected western ranches. Early spring grazing is valuable because few alternative forage sources are available at that time. In most cases, the only feasible forage alternative would be to feed hay.

Rowe and Bartlett (2001:64) concluded that once hay was needed to compensate for public forage losses, reducing herd size would be the most cost-effective adjustment. Our results generally support this conclusion. Making alterative grazing resources available during the spring always minimized losses relative to feeding hay or reducing herd size. If complete flexibility of other deeded forages were possible, the economic loss of restricting the early use of BLM lands was minimal.

The economic value of the BLM forage during the spring period was found to be 5 to 10 times the value in other seasons later in the year for both the Idaho and Nevada models. In this case, the elimination of spring grazing was equivalent to a permanent cut because the BLM forage could not economically be used at a later date. This was not the case for the Oregon model, with the major difference being the differences in assumed hay resources. The Lake County, Oregon model was defined to have substantial hay land resources that made feeding hay a feasible alternative for the spring period.

The economic impacts of reducing BLM grazing in any season were found to vary widely depending on several key factors. First, various ranches will be able to substitute alternative forages to varying degrees as federal AUMs are eliminated. Substituting forages always minimized economic losses relative to the option of feeding hay and reducing brood cow herd size. Those ranches with restricted seasons of forage availability will have less ability to substitute alternative forages if BLM grazing is removed.

Economic losses from removing federal forage ranged from $2.50/AUM for the Jordan Valley, Idaho model, $5.50/AUM for the Northeastern Nevada model, to nearly $20/AUM for the Lake County, Oregon model. This is a wide range in economic value, but other similar studies in the literature report even wider ranges. The contributory value of public land grazing permits for livestock production varies widely depending on the seasonal complement of forage and pasture resources, and the level of dependency on federal lands.

[1] More detail on model assumptions, background and economic results is provided in the PACWPL report "Ranch-Level Impacts of Changing Grazing Policies on BLM Land to Protect the Greater Sage-grouse: Evidence from Idaho, Nevada and Oregon."

7. Conclusions

Stabilizing sage-grouse populations across the West will involve setting priorities in the short and long run. Our conclusions are based on an evaluation of the available scientific literature on both the organism and its habitat. From this evaluation, actions that can be part of public policy were outlined. In addition, some represent higher priority policies than others. Here we suggest actions that we think will give land management agencies the most impact in the shortest time. In general, the suggested actions should be employed throughout the sage-grouse range. These actions should not substantially increase demand for funding or manpower currently supporting sage-grouse conservation efforts. They also should have minimal impact on current rangeland programs. However, their application should provide a firm foundation for sage-grouse conservation.

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