excluded from protected patches by the loss of internal heterogeneity due to invasion of edge plant species; (2) it creates isolated populations that are susceptible to catastrophes and genetic drift; (3) it interferes with ecological relationships; and (4) fragmentation creates edge environments which typically increase predation. Fragmentation and insularization (the creation of disconnected, "island" like habitat patches) are known to cause higher extinction rates than those from reductions in area size alone (Wilcove, et al. 1986). Spatial scale is important in fragmentation effects such as dispersal (Doak, et al. 1992); however, the spatial arrangement of habitat patches does not mitigate against habitat loss in fragmentation processes (Fahrig 1997). Fragmentation and insularization are well advanced across the range of sage grouse (see discussion of the species range and the map compiled by Schroeder elsewhere in this review).

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

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

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

Fragmentation not only causes a decrease in effective area size, but also affects habitat heterogeneity (Wilcove, et al. 1986). In forested areas, forest-interior bird species are dependent upon large expanses of their preferred habitat (Wilcove, et al. 1986; Morrison, et al. 1992a). Several studies have shown that birds are habitat-specific (Lynch and Whigham 1984; Wilcove, et al. 1986; Morrison, et al. 1992a) and sage grouse are particularly habitat specific, being limited to sagebrush ecosystems. When an area is fragmented, individual fragments may not have all the habitat types that were initially found in the original block. Therefore, species that require specific habitats are vulnerable to local extinction (Wilcove, et al. 1986). If a fragment lacks a required habitat for a given species, then establishment of breeding populations in that fragment cannot occur (Wilcove, et al. 1986). Local abundances of individual bird species are influenced by the structural and floristic characteristics of the vegetation and these vegetation characteristics vary with area size (Lynch and Whigham 1984; Wilcove, et al. 1986). Many species, including sage grouse, require more than one habitat type for survival and reproduction. For example, within the overall sagebrush ecosystem type, sage grouse require low elevation, sparsely vegetated lek sites with sagebrush cover adjacent to the lek sites, nesting areas with abundant forb and grass cover, upland meadows that are rich in forbs, and low elevation wintering grounds, usually on south facing slopes. Habitat fragmentation isolates the various habitats needed by sage grouse from each other, preventing or reducing transit among required habitat types.

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

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

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

Metapopulation Effects

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

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

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

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

Model outcomes differ significantly between mainland-satellite metapopulation models (Fig. 3C in Poethke, et al. 1996, p. 86) and those with nearly equally distributed and sized isolates (Fig. 3A in Poethke, et al. 1996, p. 86). It is both intuitively obvious and easily shown mathematically that the latter situation carries higher risk of metapopulation extinction – local extinction rates must be smaller than colonization probabilities, else the entire metapopulation will become extinct (Hanski and Gilpin 1991; Poethke, et al. 1996, p. 87). This occurs because there is no large mainland source population which is so well buffered that it always serves as a source of immigration into patches. Instead, colonization probability is a function of the number of occupied patches. The number of linked patches is an important determinant of metapopulation extinction. For a finite number of linked isolates, metapopulation persistence depends on the number of interconnected local populations and the ratio of colonization probability to extinction rate must be 50% greater than with a very large number (near infinite) of isolates (Poethke, et al. 1996, p. 87).

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

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

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

Area Size

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

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

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

Minimum Dynamic Area

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

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

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

Habitat Connectivity and Permeability

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

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

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

Disjunct patches of sagebrush that were previously connected to other patches are likely to now be unsuitable source habitat for sage grouse because the birds require large home ranges. This need is especially strong for wintering flocks. Grouse select winter use sites based on snow depth and topography (Connelly 1982, Hupp 1987a, Robertson 1991) where sagebrush is accessible. Sagebrush heights of 25 to 30 cm (10 to 12 in) and canopy cover of 10 to 25 percent, regardless of snow cover, are important for winter use by sage grouse.

Habitat Vegetation Analysis

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

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

Population Assessments

Sage grouse populations have seriously declined throughout their entire range (Connelly and Braun 1997). Sage grouse are declining over both the long-term (last 100 years) and currently (last 20 years) (Hoffman and Stiver 2000). As Connelly (1997) put it, sage grouse are "currently undergoing range-wide population declines." The Service recognizes this and described these rapid and widespread declines as a "consistent decline in sage grouse in all states" like "an F-16 fighter going down" (Deibert 1999d). Sage grouse have been extirpated in 5 states and 1 Canadian province. In 3 other states and 2 provinces, breeding populations now number less than 2,000 birds, and effective population sizes are much lower. The "long-term existence" of sage grouse in at least 6 states and 1 province is uncertain (Gunnison Basin Sage Grouse Conservation Plan 1997, Preamble). Sage grouse have been uniformly extirpated from the entire periphery of the range, and "greatly reduced in distribution and abundance within their former core range" (Braun, et al. 1994). Sage grouse specialists have used various narrative terms to describe the degree of endangerment of sage grouse (Braun 2001l). Dr. Braun is concerned about the use of these terms, including the term "secure" and intends to publish a critique of the terms "secure," "persistent," "marginal," and "at risk" in the near future (Braun 2001l). The Service should exercise caution in evaluating population status based on information using these terms.

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

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

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

In early historical times, sage grouse were abundant (Bent 1932, Patterson 1952c). The WSSGTC estimate of 1.1 million birds noted above is likely an underestimate of populations before settlement, which probably numbered 2 million (Braun 2001c), or in the tens of millions. Their range included 16 states and 3 Canadian provinces, closely following the distribution of sagebrush, predominantly big sagebrush (*Artemisia tridentata*), and including other sagebrush species at the periphery of the range, such as *A. cana*, *A. filifolia*, *A. nova*, and *A. tripartita* (Braun 1998a). The range extended from southern Canada to northern New Mexico and Arizona (Bent 1932, Girard 1937, Huey 1939), and from the western edge of the sagebrush region along the Cascades and Sierra Nevada eastward up to the shortgrass prairie in the Dakotas. A disjunct population is known from the Oklahoma panhandle (Wood and Schnell 1984), but it may have been more extensive before it was first studied.

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

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

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

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

Within 15 years of the large scale introduction of livestock, vast areas were literally denuded of grass and forb vegetation by cattle grazing (Yensen 1981; Dobkin 1994; Paige and Ritter 1999, p. 7). Shortly thereafter, sage grouse began to decline, and by the early 1900s, sage grouse were found in 14 to 15 states and was the principal upland game bird in 9 states (Rasmussen and Griner 1938). By the 1930s, however, it was a major upland game species in only 4 states (Montana, Wyoming, Idaho, and Nevada), and only Montana maintained a regular open season (Johnsgard 1973). In the 1920's and 1930's sage grouse were believed to be declining throughout their range by all extant authorities (Bent 1932, Gabrielson and Jewett 1940, Rush 1942, Patterson 1952c, Rogers 1964). So steep were the early declines that some predicted extinction (Visher 1913, Hornaday 1916). Concomitant with the declines in sage grouse, and an apparent cause, was the destruction of habitat. The destruction of sage grouse habitat also decreased the capacity of the ecosystem to support livestock, and grazing capacity was estimated to have declined by 60% to 90% by the 1930s (Miller, et al. 1993, p. 119). Some of the most palatable species, such as giant wild ryegrass, as well as dense stands of bunchgrasses were devastated by 1880 (Miller, et al. 1993, p. 119).

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

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

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

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

Rich (1985a) found that sage grouse population numbers are cyclic. However, Braun (1998a) noted that these cycles take place within a pattern of overall decline, and as noted above, it is the lows in population size that are most important for extinction risk. "Cycles are not an adequate explanation of long-term sage grouse population declines" (Braun 1987b). If cycles exist, the cycles trend lower approximately every decade – the bird is thus cycling ever downward – stair-stepping towards extinction.

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

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

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

Methodology

Numbers of individuals are assessed here on a state by state basis, following Braun (1998a), because that is the manner in which the data have been gathered. Connelly and Braun

(1997) compared long-term (30 to 40 years) breeding numbers in each state with breeding numbers over a 10 year period after 1984. In the state by state discussion that follows, this compilation will be referred to as recent breeding numbers.

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

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

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

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

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

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

Population Densities

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

Extirpated State Populations

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

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

Reintroduction of sage grouse was attempted in 1993 but was ultimately unsuccessful – by 1989 the birds were again extirpated from the state (Drut 1994, p. 19).

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

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

Effects Occurring Throughout the Interior Columbia Basin

Habitat degradation has occurred over the entire range of the sage grouse. "By the mid-1800's, Euro-American settlers had begun to substantially alter the [Columbia] Basin's landscape and aquatic habitats". (Quigley and Arbelbide 1997a, p. 63). By 1860, over 200,000 cattle were settled in Oregon (USDA – Forest Service 1996b). Toward the end of the century, sheep were so numerous in eastern Oregon that reports and photographs suggested summer ranges so laden with sheep that they appeared to be snow drifts. Overgrazing damaged stream and riparian vegetation in many basins in eastern Oregon and Washington. Overgrazing also facilitated the spread of annual cheatgrass and reduced vegetation that had provided fuel for fires. In the early 1900's, declines in native vegetation abundance and condition in the Great Basin portion of the Interior Columbia Basin and in eastern Oregon and Washington became obvious. Excessive livestock grazing pressure was vividly apparent on Steens Mountain in southeastern Oregon (Quigley and Arbelbide 1997b, p. 764). The greatest historic declines in ecological integrity in the Interior Columbia Basin have occurred in native upland types, including native grasslands and shrublands (Marcot, et al. 1998). "Still-diminishing vegetation conditions [occur] principally in: rare plant communities, native grasslands, native shrublands and late seral forests" (Marcot, et al. 1998, p. 114). Of all the vegetative cover types in the basin, shrub-steppe habitats "have suffered the most drastic declines" (Saab and Rich 1997, p. 19; USDA – Forest Service, USDI – BLM 2000d). Wet meadows and riparian vegetation – cover types crucially important for brood-rearing by sage grouse – have declined substantially since historical times (Lee, et al., 1997; Quigley, et al. 1996). Moreover, these are "special habitat features" (Wisdom, et al. 1998, p. 2-147). "Rangeland integrity" is low in many areas within the range of sage grouse (Quigley and Bigler Cole 1997, p. 11). The majority of the range of sage grouse is highly susceptible to cheatgrass invasion and is also susceptible to spotted knapweed invasion (Quigley and Bigler Cole 1997, p. 15). Nearly all the range of sage grouse is susceptible to some form of exotic weed invasion (USDA – Forest Service 1996b). Indeed, GAP analysis conducted by the Institute shows that many areas have already been invaded by cheatgrass. As the Forest Service and BLM note, "noxious weeds are spreading rapidly, and in some cases exponentially" throughout the range of sage grouse, and in the Eastside areas of the Interior Columbia River Basin cheatgrass has "taken over" many dry shrublands (USDA – Forest Service, USDI – BLM 1997a, p. 89). There is "increased fragmentation" and "loss of connectivity" in habitats, "expecially in shrub steppe and riparian areas" (USDA – Forest Service, USDI – BLM 1997a, p. 89-90). Disjunct "patches of sagebrush that were previously connected to other patches may now be unsuitable" because sage grouse require large areas, e.g. for wintering (Wisdom, et al. 1998, p. 2-147). The agencies also expressed "special concern" regarding sage grouse, noting the "significantly reduced plant and insect forage, nesting cover, and hiding cover" for the species, as well as the "60 percent decline" since 1940 in sage grouse populations (USDA – Forest Service, USDI – BLM 1997a, p. 89, 100). These concerns are echoed – often in identical language – for the Upper Columbia River Basin (USDA – Forest Service, USDI – BLM 1997b, p. 23, 76).

Road creation and use has contributed to increased human disturbance in areas most important for sage grouse, and can be "especially harmful to sage grouse" during lekking and wintering seasons (Wisdom, et al. 1998, p. 2-149). Road densities (0.4 to 1.0 km per km^2 [0.7 to 1.7 mi per mi^2]) are typical in the Northern Great Basin, the Owyhee Uplands, and the Upper Snake River area. Roads and associated human disturbance can be especially harmful to sage grouse during the lekking and wintering periods. Proximity to roads thus causes habitat loss causes. Consequently, source habitats for sage grouse are projected to fall from about 140,000 $mile^2$ currently to less than 100,000 $mile^2$ under all management alternatives (Raphael, et al. 2000, p. TER 157). (The use of the term "source habitats" in ICBEMP documents apparently does not accord with standard use by population biologists, meaning an area producing a surplus of individuals that can then emigrate; instead, ICBEMP's use of the term appears to merely connote a habitat that is assumed to have only a stable population of the species in question (Wisdom, et al. 1998). Of course, there are no known stable populations of sage grouse, so the use of this term with respect to sage grouse is dubious at best.)

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

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

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

The results of the management changes envisioned by Wisdom, et al. (2000) are class C for environmental outcomes (meaning that suitable habitats are patchy or in "low abundance" causing population isolation) and only class D for population outcomes (near extinction throughout the basin: "frequently isolated" or in "very low abundance" with only some populations self-sustaining). Historically, sage grouse were in class A status throughout the basin ("continuous, well-distributed").

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

States with less than 2,000 Birds in 1998

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

North Dakota Population Assessment

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

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

South Dakota Population Assessment

Sage grouse were originally found in "many sections" of western South Dakota (Visher 1913). By 1907, they were extirpated from areas outside the badlands and the northwestern portion of the state, and by 1910 remained in only 2 counties, Harding and Butte (Visher 1913).

Visher noted that homesteading was eliminating sage grouse habitat, and he predicted the ultimate demise of the species in the state (Patterson 1952c, p. 20).

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

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

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

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

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

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

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

Utah Population Assessment

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

Settlement began in Utah during the 1840s, but much of the region did not experience settlement until the 1860s (Miller, et al. 1993, p. 117). Since settlement, sage grouse in Utah have declined by 50% or more (Drut 1994, p. 20; WSSGTC 1999, Utah section, p. 1). Utah Div. of Wildlife Resources personnel have noted that males per lek, and hunting harvest levels have declined since 1959 (Drut 1994, p. 20); however, these personnel maintain that production has been stable since 1959, something that is difficult to reconcile with decreases in harvest levels and males per lek. Males per lek have declined from about 50 in the 1960s to a low of about 10 in 1995, and then increased slightly to about 18 males/lek in 1998. Chicks per hen increased from the long term average of 2.07 to 4.2 in 1997. Recent breeding numbers have declined by 30% (Connelly and Braun 1997, Table 1). The largest remaining populations of sage grouse are found in Rich County, the Park Valley area of Box Elder County, on Diamond and Blue Mountains in Uintah County and on the Parker Mountains in Wayne County (Utah Draft Conservation Agreement 1998). Although Rich County contains some of the largest populations in the state, the county has been termed a "desperate situation" by state agency scientists working on the grouse there (Grandison and Welch 1987). Sage grouse harvest numbers fell from 3,000 birds in the early 1970s to only 320 birds by 1987 (Grandison and Welch 1987). This debacle was caused by "widespread sagebrush eradication" from BLM mis-management and by private parties (Grandison and Welch 1987). BLM again pursued sagebrush habitat destruction in the late 1980s and early 1990s (Grandison and Welch 1987).

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

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

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

Grazing has clearly had adverse impacts in Utah. Mitchell summarizes it as follows: "Excessive grazing has severely impacted the vegetative composition of sagebrush-steppe habitat on foothill and bench rangelands in Cache, Morgan, and Weber Counties. In many instances, annual grasses have replaced native bunch grasses and the canopy coverage of sagebrush is too dense. Excessive livestock grazing of riparian habitats in eastern Box Elder County has eliminated or reduced many bud-producing shrub species." On the other hand, not all areas have been affected in these ways. "Most of the sagebrush-steppe within dry-farm lands is in good ecological condition. This includes approximately 65 percent of the current distribution of sharp-tailed grouse, most of which is in eastern Box Elder County" (Mitchell 1999). These areas, too, may be threatened in the future, however. Mitchell continues "Although many tracts of sagebrush-steppe are partially fenced, most are not grazed or grazed lightly because of the lack of livestock water. Future livestock water developments could change existing conditions."

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

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

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

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

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

Colorado Population Assessment

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

In the early 1990s, Braun (1991) noted that sage grouse were then found in only 18 counties, and regarded only 6 counties as having secure populations. Dr. Braun is concerned about the use of the term "secure" and intends to publish a critique of the terms "secure," "persistent," "marginal," and "at risk" in the near future (Braun 2001l). As late as the mid-1990s, sage grouse in Colorado were thought to be stable (Drut 1994, p. 12). A few years later, Braun (1998a) noted recent declines in the number of active leks, and found that declines in the number of males ranged from 44% to 82% in two counties. These data indicate that no population studied was truly secure and that sage grouse can easily decline even when they are believed to be stable. Braun (2001h) expects that all sage grouse in Colorado will be extinct within 20 years, except for those in Jackson and Moffat counties and the small population of Gunnison sage grouse in the Gunnison Basin. However, Braun's predictions do not take into account the spread of juniper, pinyon, and cheatgrass – thus complete extirpation could occur within 20 years.

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

Moffat County has the largest amount of habitat and largest flock of sage grouse, but even this group has declined 80% since 1982 – including a 40% loss in North Park (Myers 1999 quoting Braun). Yet, according to Col. Div. of Wildlife personnel, North Park is the "best sage grouse area in the state" (Toolen 1999b). Moffett County has averaged only 943 males over the last 3 years (id., p. 6). In lower Moffat County, sage grouse leks are vanishing rapidly – from

1979 to 1996, known leks decreased from 62 to only 24 (Anonymous 1996, p. 7). The number of individuals is also rapidly declining: over the same time period the number of males counted has decreased from 3,166 to only 290 – more than an order of magnitude decrease (Anonymous 1996, p. 7).

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

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

Habitat has been heavily impacted throughout the range of the sage grouse. For example, the area north of US Highway 50 represents an unhealthy "vegetation complex" because of "soil loss, and reduction in the forb and grass component" caused by overgrazing (Braun 1999d). Defenders of the cattle industry had attempted to mischaracterize the unhealthy vegetation as resulting from "decadent," over-mature sagebrush. Instead, sagebrush is continually being renewed through seedling establishment, and regrowth of injured sagebrush (Braun 199d). Dr. Braun also pointed out that large "intervention to remove the sagebrush overstory" as had been proposed by livestock lovers would be "devastating for persistence of a viable population of sage grouse" (Braun 1999d).

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

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

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

It is not merely certain elements within the Service that are acting to harm sage grouse: Dr. Braun encountered significant opposition from the past Director of the Colorado Div. of Wildlife, John Mumma. Mr. Mumma's past history speaks volumes of his approach to wildlife. He now seeks to avoid public controversy no matter what befalls the Gunnison sage grouse, telling Dr. Braun "to keep his head down and do his job" and has "declined to support this project [the conservation plan]" (id., p. 5).

Nevada Population Assessment

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

Distribution in Nevada apparently changed little between that described by Gullion and Christensen (1957) and that described by Johnsgard (1983). However, both harvest levels and productivity declined over the past 25 years (Drut 1994, p. 19). During the mid-1990s populations were believed to be stable (Drut 1994, p. 12). The Nevada Dept. of Wildlife (NDW) has expressed concerns about decline in the northwestern populations (Klebenow, et al. 1990; Drut 1994, p. 19). Chicks/hen (estimated from brood surveys) and harvest levels were both more depressed in northwestern Nevada than in the northeastern part of the state (Drut 1994, p. 19). Despite this low productivity, males/lek increased during the same period, again indicating that males/lek is not the best metric for population assessments. Stiver suggested that low adult mortality and long lifespan may compensate for impaired productivity in the short term (letter from S. Stiver, Nevada Dept. Wildlife, cited in Drut 1994, p. 19). Such factors cannot, of course, compensate for low reproductive output over periods of even several years (the lifespan of adult birds). If birds are not added to the population, then it does not matter how long adults live – the population is doomed.

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

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

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

States with More than 20,000 Birds in 1998

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

Oregon Population Assessment

Both the Western and Eastern subspecies occur in Oregon (Aldrich 1946; Call and Maser 1985). Sage grouse were first reported from Oregon by J. K. Townsend in 1839 (Gabrielson and Jewett 1940, p. 218; Crawford 1982b). In the mid 1800s, areas such as the flat valley formed by the Silvies River were "carpeted with bunch grass, wild pea vines and red clover, interspersed with fields of camas" (Clark 1932, quoting topographic engineer Lt. Joseph Dixon). Western Juniper was found only in scattered stands, rather than the dense woodlands of today (Miller, et al. 1993, p. 116).

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

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

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

By the 1980s, sage grouse had been extirpated from 6 counties (Jefferson, Wasco, Sherman, Gillman, Marrow, and Umatilla counties), and their range was reduced in only other counties in which they were found (Klamath, Lake, Deschutes, Crook, Wheeler, Grant, Baker, and Union Counties) (Crawford and Lutz 1985; Crawford and Carver 2000). The number of sage grouse in Oregon "declined approximately 60% from the late 1950s to the early 1980s" (Crawford and McDowell 1999, p. 4; Crawford and Lutz 1985). ODFW (Oregon Dept. Fish and Wildlife) acknowledges that their "counts show sage grouse populations down 50 percent" (Denney 1980). Productivity also plummeted – both the ratio of chicks/adult and the proportion of adults with broods declined by nearly 80% over the same period (Crawford and McDowell 1999, p. 4; Crawford and Lutz 1985).

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

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

Birds occur on a mixture of private, BLM, USFS and some FWS national wildlife refuge (NWR) lands. On Malheur NWR, sage grouse have declined since the 1940s and are now rare to uncommon on the refuge (Littlefield 1990). On Hart Mountain NWR and elsewhere in Oregon, sage grouse populations are declining and these declines are likely to continue into the indefinite future (Crawford 2000a, 2000b). Demographic classes are skewed, indicating rapidly declining numbers. In the autumn population, the average is now only 1 chick/hen, portending serious population reductions. As an ODFW biologist put it: this is "a tremendous loss of reproductive potential" (Associated Press 2001). As with Idaho (see elsewhere in this review) and Canada (Aldridge and Brigham 2001), chick survival appears to be a major factor in declines.

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

Drut (1994) reviewed Oregon Dept. of Fish and Wildlife abundance estimates from 1941 to 1991. Both estimates (males/lek and grouse/16 km) declined from 1941 to 1983, and exhibited a slight upward trend from 1984 to 1991, then turned downward again (Drut 1994, p. 12). Drut (1994) thought the data also exhibited a cyclicity, but noted that subsequent peaks did not reach previous highs, and lows were lower for each cycle. This accords with the warnings of Braun (1987b). Harvest figures have also dropped precipitously from about 15,000 birds in the 1950's to less than 1,000 birds in the 1980's, necessitating the closing of hunting seasons four times (Drut 1994, p. 12, Table 3). By the 1990's, only a few hundred birds were harvested each year (Drut 1994, p. 12, Table 3). Males per lek have dropped substantially from about 90 in 1950 to about 30 in 1960 (WSSGTC 1999, Oregon section). Since 1960, declines have continued at a slower pace, and males/lek was about 12 from 1995 to the present (WSSGTC 1999, Oregon section). Total males counted have increased, but this is purely the result of the number of leks counted (WSSGTC 1999, Oregon section: compare graphs 1 and 3). The apparent increases in the total number of males reported are "the result of more intensive surveys" and probably not due to increased precipitation or better habitat, as males/lek did not increase (WSSGTC 1999).

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

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

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

In all of Deschutes County there are only 21 leks remaining, with only 225 male sage grouse counted (Prineville District, BLM; undated). BLM makes the same two females for every male assumption that was made in Colorado (see Webb 2000, which is incorporated here by reference), and lists the total number of birds as 675 (Prineville District, BLM; undated). However, BLM is aware that the actual sex ratio is only 60% females (which would yield a population of 562 birds), yet it still reports and cites the higher number (Prineville District, BLM; 1991). Even if the 2 for 1 assumption is accurate, this is far from a viable population. In Crook County, ODFW has only been able to find an additional 24 leks (for a total in both counties of 45 leks), thus the population in that county is at best only slightly larger than in Deschutes County, and similarly endangered (Prineville District, BLM; undated).

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

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

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

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

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

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

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

Wyoming Population Assessment

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

As late as the early 1900s, vast areas of Wyoming shrub-steppe held huge numbers of sage grouse. Birds were found in every county as late as the 1950s (Patterson 1952c, p. 28). In

Jackson Hole, flocks were so numerous that they were reported to form thick "clouds," but the birds were "nearly all gone" by 1916 (Hornaday 1916, p. 198). This extirpation coincided with increased cattle grazing in the area. Only about 100 cattle were known in Jackson Hole in 1883 (Daugherty 1999, p. 147), but numbers escalated rapidly to at least 1,339 cattle by 1899 (Daugherty 1999, p. 149). Conversion of native ecosystems to pastures also progressed rapidly, and pronghorn became extirpated from the valley by 1906 (Daugherty 1999, p. 161). With the reduction and then extermination of wolves, elk numbers would have rapidly increased, also causing damage to sage grouse food plants and cover. Fremont had seen large numbers of birds on the upper waters of the Green River in 1845 (Patterson 1952c, p. 19). In 1897, Huntington considered that sage grouse were most abundant in near Fort Bridger and southward through the Green River Basin all the way to the Uinta Mountains in Utah (Patterson 1952c, p. 19). Carpenter described the birds as numerous near Fort Bridger and in 1905 Burnett described the birds as most abundant in the counties of Albany, Converse, Natrona, and Carbon (Bent 1932, p. 303, 308). The birds were so numerous in these areas that a hunter could kill hundreds in a single day, even without a dog (Bent 1932, p. 308). As late as the early 1940s, Eden Valley in Sweetwater County "was one of the areas of heaviest concentration" of sage grouse, containing so many birds that they interfered with farming operations nearby (Allred 1946b, 1949). Before agricultural development and ranching were widespread in Goshen Co., birds were present in such "great multitudes" that people gathered their eggs for table use (McDowell 1956). McDowell (1956) listed dam building, agriculture, ranching, overgrazing, and highways as threats to the bird – again, these threats have been recognized for many decades. Some of the earliest studies of sage grouse were undertaken in Wyoming. Girard worked in Sublette County, and Patterson's study areas were in northern Sweetwater Co., southeastern Sublette Co., and southwestern Fremont Co. – one site in the Eden Valley irrigation district and other was between Pacific Creek and Dry Sandy Creek (Patterson 1952c, p. 22, 39).

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

(WSSGTC 1999). Overall, Wyoming state biologists have termed the declines in the last 20 years as "alarming" (Christiansen 2000, p. 14).

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

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

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

Although Wyoming has the largest areas of sagebrush in North America (Sundstrom, et al. 1973), virtually all of that area has been degraded. Grazing and development are major threats in Wyoming (Drut 1994, p. 20). These serious declines in what was once thought to be a stronghold of the sage grouse indicate that the species is headed for a range-wide extinction.

Idaho Population Assessment

At one time, Idaho was a stronghold for sage grouse and contained numerous large populations. At least 6 expeditions entered what is now Idaho in the 1800s and published their reports. Lewis and Clark passed north of the range of sage grouse in Idaho, following the Clearwater River (Moulten 1983a, 1983b; Merriam 1891, p. 4). In 1834, Townsend crossed the Snake River plains and noted the large numbers of grouse there (Merriam 1891, p. 4). Later, various railroad surveys entered the area, but made few natural history reports, and the next survey of biological resources in southern Idaho was made in 1872 by the 16 year old Merriam who accompanied the Hayden expedition as a naturalist (Merriam 1891, p. 4-5). Robert Ridgeway (often spelled "Ridgway") made the next foray into the City of Rocks area when he accompanied Clarence King (Ridgeway 1877). Bendire entered the area next, during his explorations of southeastern Oregon (Bendire 1877). Merriam re-entered the area in 1890 on a biological reconnaissance and published his report in the North American Fauna series (Merriam 1891). Merriam found "large flocks" of sage grouse (Merriam 1891, p. 13) and noted that the birds were "abundant" and normally seen in flocks of a "dozen or more" (Merriam 1891, p. 93). Sage grouse were common in the Teton Basin, along the Henry Fork of the Snake River, and at Henry Lake (Merriam 1891, p. 93). Merriam also noted that other species – which are now greatly reduced, such as Brewer's Sparrows and Sage Sparrows – were abundant or common in the area (Merriam 1891, p. 103).

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

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

Status Review: Eastern Sage Grouse

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

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

Sagebrush has been reduced by more than 60% in Idaho (Campbell 2000b). Remaining sage grouse habitat in southern Idaho is "clearly inferior" to that in the higher elevations of Idaho and Colorado because it has less annual precipitation and a depauperate herbaceous flora (Rich 1985a). Along major highways, such as Interstates 84 and 86, and US 30, huge areas of sagebrush have been converted into agricultural fields (personal obs. by author). Unfortunately, this region was formerly the least fragmented of all sagebrush areas in the state. North of the town of Arco, sagebrush habitat is fragmented into long fingers by forest intrusion (Tisdale, et al. 1969, Fig. 4). West of the city of Pocatello, sagebrush habitat is fragmented by forest and juniper woodland intrusion (Tisdale, et al. 1969, Fig. 4). Idaho riparian habitats are "under increased pressure from livestock grazing, logging, water management and recreation", and note that more than 90 percent of the original riparian habitat in the West has been eliminated by flood control and irrigation projects" (Saab and Groves 1992). Catastrophic floods in 1983, damaged large amounts of riparian areas. These floods were exacerbated by roading and grazing of large areas which reduced stream bank stability and increased runoff by removing vegetation and compacting soil (Hiatt 2000).

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

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

Hunting harvests are down 39% from the 5 year mean Idaho Upland Game - Summary of Estimated Statewide Harvest, Table 1 (http://www.state.id.us/fishgame/ugrharv.htm).

Sage grouse face major threats in Idaho, and these threats are ongoing. Habitat conversion is a severe and ongoing problem in Idaho. Boise is the largest city in Idaho, and is the second fastest growing city in the entire United States with about as many housing starts per year as the entire San Francisco Bay Area. Boise is also one of the worst cities in the US in terms of sprawl. Much of this sprawl impacts the remaining sage grouse habitat that was not already converted to agriculture (these agricultural lands themselves are also impacted by urban sprawl). In 1998 alone, "over 3 million acres of sage grouse habitat [were] converted to agriculture" (US Fish and Wildlife Service 1998, p. 2 of Attachment). The acreage converted to other uses is "among the most productive and best habitat, thus magnifying the impact" (Owyhee County Local Sage Grouse Working Group 1998). Owyhee County is now home to the largest cattle feedlot in the nation, and the largest hog farm in the nation is planned for that county. The hog farm, a major industrial operation, will require over 140 miles of new roads. Additionally, USAF is vastly expanding the bombing range in the most remote areas of sage grouse habitat in the county. Fires have caused massive damage to sage grouse habitat in Idaho. Surprisingly, 5 times as much acreage of sagebrush is being destroyed in prescribed burns as opposed to wildfires (Owyhee County Local Sage Grouse Working Group 1998). In the 1990s, and average of 6,000 acres were burned each year; and during the 1980s, about 57,000 acres were burned (Owyhee County Local Sage Grouse Working Group 1998). Fire is rapidly converting sagebrush habitat to exotic annual grasslands in southwest Idaho (Knick and Rotenberry 1999b). The US Air Force has plans to conduct bombing exercises on sage grouse habitat in Owyhee County in southern Idaho (Commons 2000b). The Air Force proposes to build a number of sites ranging in size from ¼ acre to 5 acres, with an extensive road network, construction of buildings and installation of barbed wire fences (Commons 2000b).

Montana Population Assessment

At one time, Montana was a haven for huge flocks of sage grouse. Sage grouse were widespread in the state, and were recorded by numerous early explorers. Members of the Lewis and Clark Expedition observed sage grouse along the Marias river north of present day Great Falls (Cutright 1969), and early explorers killed the bird along the Milk River (Coues 1874). Knowles (undated) presents an annotated bibliography of the published accounts from these early expeditions. In the 1920s, sage grouse were so plentiful that they "darkened the sky" (Eustace 1995). Even as late as 1964 hunters were able to take nearly 100,000 birds annually; but, by 1999 only 4,000 males could be counted in the entire state, even though the state wildlife agency greatly increased its attempts to find leks in an attempt to ward off a listing (Auchly 2000, p. 9-10). Large numbers of sage grouse were found locally as late as the 1970s and 1980s. Cade (1999) recalled that he often saw thousands of birds per day in 1984 at the foot of the

Beaverhead Mountains in Clark County, but saw none by 1999, even when employing multiple dogs.

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

By 1975, over 10% of all habitat in Montana had been converted into useless range areas (Johnsgard 1983, Wallestad 1975a). In some areas, such as Meagher County, nearly 50% of habitat had been destroyed by conversion to cropland (Johnsgard 1983). Habitat conversion is a severe problem throughout Montana. In just the 5 counties that contain most of the sage grouse habitat north of the Missouri River, nearly a million acres of rangeland were converted to cropland between 1954 and 1987" (Eustace 1995, p. 24 citing Montana Fish, Wildlife and Parks biologist Ray Mule).

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

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

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

SE-MT

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

In 1992 and 1993, the BLM and FWP inventoried 78,240 acres (31,662 ha) of land in Rosebud and Fallon counties, but were abie to find only 7 sage grouse leks in this entire area (Tribby 1994, p. 2). Moreover, only an average of 9.3 males/lek were observed, and no lek had more than 12 males. Thus, only about 9.3 * 7 = 65 males were found, representing a density of 8.3 males per 10,000 acres (or about 0.5 males/mile^2). The density of leks was less than 0.06 leks/mile^2. BLM and the Montana FWP also inventoried 321,320 acres in Rosebud and Custer counties in 1992 but found only 327 males on 20 leks, 15 of which were on private land and thus unprotected by law (Tribby 1992, Table 1). This gives a density of 0.65 males/mile^2, and 0.04 leks/mile^2. The agencies also inventoried 167,201 acres in Garfield County, yet found only 4 leks with 47 males on them (Tribby 1992, Table 3). This gives densities of 0.18 males/mile^2 and of 0.01 leks/mile^2 – both are even worse than the other areas in southeast Montana.

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

SW-MT

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

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

The reason for the decline in sage grouse in Beaverhead County is not hard to discover: the survey area suffers from "over browsing by [domestic] sheep and vegetation manipulation," causing parts of the "sage grouse habitat to be in very poor condition" (Schmidt 1998). Other portions of the survey area had "over-mature and decadent" sagebrush, caused by "excessive grazing by sheep" and "small and isolated" stands of sagebrush (Schmidt 1998). Development is a serious problem: "numerous fences intersect the surveyed sage flats" and "probably contribute to a significant percentage" of sage grouse mortality (Schmidt 1998). Even without systematic fence surveys, an "incidental check of a fence line" revealed 5 fatal fence strikes by grouse, and 2 others that were not immediately fatal (Schmidt 1998). The researchers felt the number of grouse found to be only a small fraction of those dying from fence collisions, because grouse remains often landed 40 to 70 feet away from a fence (too far to be seen from near the fence), and because wounded grouse walk away to die elsewhere. Agricultural development has apparently created "an artificially high concentration of eagles attracted to calving operations" and this probably "adds considerably" to sage grouse mortality (Schmidt 1998). Sage grouse in southwest Montana are also threatened by subdivision and the placement of houses or trailers in sage flats (Schmidt 1998). Besides the avoidance of buildings, this also exposes birds to "marauding dogs, cats, and children" (Schmidt 1998). This is a particularly strong threat in parts of the "picture-postcard" west, such as southwest Montana.

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

South-central Montana

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

North-central Montana

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

Threat Analysis

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

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

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

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

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

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

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

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

Dr. Braun, perhaps the foremost expert on sage grouse, believes that habitat conversion, habitat fragmentation and habitat degradation are the major threat categories to sage grouse (Braun 1999a, p. 1). Predation and other threats act because of the widespread effects of these three threat categories (Braun 1999a, p. 1).

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

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

Effects on Sage Grouse Habitat and Range

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

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

Various studies have attempted to assess the condition of the shrub and grassland ecosystem types in the western United States and none has been of much scientific validity (Noss and Cooperrider 1994, Donahue 1999). The Environmental Protection Agency is currently attempting to develop an Environmental Monitoring and Assessment Program for these arid lands as well as other ecosystem types. What is clear however, is that sage grouse are almost literally evaporating from a vast landscape like water in a very large, but shallow container.

Grazing

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

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

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

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

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

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

Livestock grazing in the arid West brought about sudden and immediate change to native ecosystems. In the American West, grazing by livestock began in the 1840s – some Texans drove cattle to California by way of Wyoming, Utah, and Nevada to fill the beef market created by the 1849 gold rush (Brown 1994, p. 43). In December of 1866, Nelson Story ended a long trail drive from Ft. Worth near Livingston on the Yellowstone River, thus starting the cattle industry in Montana (Brown 1994, p. 313). A range herd was established near Ft. Laramie in 1868, and large numbers of cattle were driven from the northwest into Wyoming at least as early as 1876 (Brown 1994, p. 313). By 1878, thousands of cattle occupied central Wyoming, and Johnson County was organized. Grazing increased rapidly throughout the West in the 1870s, and peaked around 1890 (Young and Sparks 1985; Saab, et al. 1995). By that time, native perennials grasses "were, for all practical purposes, no longer present on southern Idaho ranges," native forbs began to disappear, and topsoil loss was significant (Quinney 2000, p. 93). In the Interior Columbia Basin, grazing has caused "extensive soil losses from upland habitats" (Quigley and Arbelbide 1997b, p. 460). By 1900, much rangeland had been altered by the combination of high intensity livestock grazing and extreme drought (Yensen 1981, Saab, et al. 1995). By 1870, cattle had so reduced native plant communities that hunter-gatherer Native Americans could no longer obtain adequate food from wild lands (Steward 1938, Basin-Plateau Aboriginal Socio-political groups).

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

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

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

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

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

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

The scientific literature is replete with studies showing the serious ecological costs of grazing domestic livestock in arid ecosystems (Fleischner 1994; Robbins and Wolf 1994; Brown and McDonald 1995; Paine, et al. 1996; Brown and McDonald 1997; Clements and Young 1997; Dudley 1997; Bork, et al. 1998; Dobkin, et al. 1998; Belsky, et al. 1999). Grazed sites may have only one-third the species richness of ungrazed sites (Reynolds and Trost 1979, 1980; Rummell 1951). Removal of livestock can double grass densities, but an area may take 110 years to recover (Gardner 1950). Webb and Stielstra (1979) found that grazing caused the aboveground biomass of annuals to decrease by 60% and decreased the above ground biomass of perennial shrubs by 16% to 29%. Grazing is known to deleteriously affect bird species (Mosconi and Hutto 1982), in part due to indirect effects on habitat structure (Fleischner 1994).

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

However, cattle grazing allocations – measured as AUMs – have actually increased in states with sage grouse (Rich 2001). The "**total number of cattle AUMs on public land in**

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

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

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

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

Hens with broods avoid meadows where grazing has caused steep, eroded stream banks, dense shrub cover, and low forb availability (Klebenow 1985). Patterson (1952c) noted the decline in sage grouse use of excessively grazed areas. Many grazed areas need active restoration to be adequate for sage grouse (Autenrieth, et al. 1982; Klebenow 1985). Sage grouse sometimes feed in meadows that are maintained for grazing (Evans 1986), and this has lead some incautious observers to claim that grazing therefore benefits sage grouse. Grazed meadows are usually located in the most productive locales and would thus be chosen by sage grouse whether they wren grazed or not. Evans (1986) apparently did not control for this factor in his thesis. Moreover, sage grouse have few other places to feed since the uplands have been heavily degraded by decades of livestock use.

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

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

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

In localized areas, such as some southerly portions of the Greater Yellowstone ecosystem, grazing and browsing by native ungulates can negatively alter sage grouse habitat (Singer and Renkin 1995, Singer and Harter 1996, Singer, et al. 1998a, Singer, et al. 1998a, Wambolt 1998). Reintroduction of native predators, such as wolves, rapidly restores sage grouse habitat by suppressing ungulate foraging and movements. Wolf reintroduction has also shown great potential for coyote control, a predator of sage grouse, and may also serve to directly reduce domestic livestock numbers. However, it is unlikely that wolves will be able to exert sufficient controls on domestic livestock to restore sage grouse habitat in the near term.

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

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

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

Direct Trampling Effects

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

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

Trampling of Vegetation

Livestock trample both sagebrush and grasses and forbs that sage grouse need for both food and shelter. Trampling by livestock is especially damaging to juvenile sagebrush plants (Owens and Norton 1990). Trampling of vegetation by grazing livestock is detrimental to most upland wildlife (Fleischner 1994, Belsky and Blumenthal 1997). Cattle generally trample riparian areas first, moving into the uplands after they have depleted the valley bottoms and areas near water sources (Stoddard, et al. 1975). However, removal of cattle from near streams to protect fish would force cattle to make greater use of uplands. Uplands are sage grouse habitat in general, and upland meadows containing mesic sites such as streams, wet meadows, and springs provide critical summer and fall habitat for sage grouse, especially in arid areas (Savage 1969b, Oakleaf 1971, Autenrieth, et al. 1982). Nonetheless, USFS intends to "attract cattle away from the streams" in order to protect "sensitive riparian areas" (Duncan 1999, p. 2). USFS does not explain why it does not simply reduce or eliminate cattle grazing to protect all the public's lands and wildlife.

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

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

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

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

Removal of Food Plants

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

Competition from cattle for native grasses is a threat to the desert tortoise, which has very low metabolic needs compared to an endotherm such as the sage grouse (Holing 1986). Thus, livestock competition with sage grouse may cause greater effects on the bird. Another important factor is that grazing alters the competitive balances of shrubs, grasses, and forbs in shrub-steppe ecosystems. Grazing allows shrubs to out-compete grasses and forbs, and allows canopy closure of shrubs (Klebenow 1969), preventing re-establishment of the forb and grass understory, even after grazers have been removed from the area. Livestock are known to convert herbaceous plant communities to woody plants and remove native bunchgrasses (Archer 1994; Fleischner 1994; Ohmart 1996; Belsky, et al. 1999; Belsky and Gelbard 2000).

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

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

Removal of Cover Plants

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

Alteration of Ecosystem Processes

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

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

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

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

Invasion of Exotics

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

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

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

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

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

Degradation of Soil Quality

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

Fences

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

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

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

Some have suggested that grazing could be used as a management "tool to enhance sage grouse habitat," suggesting that grazing could be used in fenced meadows to reduce old vegetation" (Beck and Mitchell 2000). Besides the fallacy of assuming that "old vegetation" needs to be removed by an exotic import that never existed on this continent during the times of highest sage grouse abundance, Beck and Mitchell's suggested use requires the use of fences which are prominently displayed in a photograph on page 999 of their article. Fences act both as raptor perches and as barriers that kill or maim flying sage grouse. The suggested "cure" is worse than the problem. Cattle and sheep grazing "are tools that do more harm than good" Strassmann (1987, p. 42), and this applies even more strongly to the infrastructure of industrial agriculture needed to support livestock management. This is a significant threat because over 31,000 miles of fencing has been constructed on BLM lands in states with sage grouse habitat (Wilkinson 2001a, p. 1). Moreover, many additional miles of fence have been constructed to keep livestock out of the millions of acres of sagebrush that have burned since 1997 (Wilkinson 2001a, p. 1).

Conversion of Habitat

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

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

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

Vast areas of natural communities have been converted to anthropocentric land uses, especially for agriculture. In 1989, USDA Soil Conservation Service analyses showed that cropland accounted for 421 million acres, and pastureland for 132 million acres (Langner and Flather 1994, p. 14). Although much of that conversion took place in the East and Midwest, native grasslands are known to have suffered much higher conversion rates than have forests (Langner and Flather 1994, p. 14). Much agriculture does not produce food for human consumption, but instead merely feeds cattle. Approximately 37% of the Columbia Basin has been converted from native vegetation to agricultural use (Quigley and Arbelbide 1997b, p. 459). "Agricultural and urban development, livestock herbivory, the introduction of exotic plants, and changes in disturbance regimes have resulted in unprecedented changes." (Quigley and Arbelbide 1997b, p. 765). Habitat conversion is probably the major cause of sage grouse declines in Washington and some parts of Colorado, exceeding even grazing and livestock operations in those areas. About 2 million acres of sagebrush habitat on federal lands have been sprayed, chained or otherwise damaged in an attempt to convert them to livestock pastures, and the amount of habitat in private ownership that has been damaged or destroyed in this manner is even greater (Vale 1974). Between 1952 and 1977 alone, 2.5 million ha of sagebrush habitat were destroyed by conversion to livestock range (Ellis 1985).

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

At a more abstract level, habitat conversion will often be more damaging to sage grouse populations than mild or moderate habitat degradation. If the legal or economic environment changes to favor suburbanzation of ranch lands, then impacts to sage grouse could become more severe than if ranchers grazed livestock on those areas. Such changes in land use occur with no warning or notice to management agencies or to the public at large.

Habitat Conversion to Agriculture

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

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

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

Throughout the Columbia River Basin and Snake River Plains, dryland farming, made economically viable by subsidized irrigation water delivery from dams, has resulted in the destruction of immense expanses of sage grouse habitat. Ironically, this has occurred concurrently with the destruction of salmon runs by the same dams. Today, these once extensive shrub-steppe ecosystems exist only as tattered remnants of fragmented landscape in a sea of development, grazing lands, and agricultural fields.

Development and Habitat Conversion to Suburbs and Ranchettes

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

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

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

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

Sage grouse avoid areas within 0.5 mile of occupied dwellings (DCCP 1998, p. 20). Other studies have also noted declines in sage grouse use of an area after residential development. Hupp (1987b) found that leks in hay meadows were abandoned after nearby development. Given this proximity effect, it is relatively easy to delete these habitat areas from GIS based maps.

Mining as Habitat Conversion

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

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

Spatial Analysis of Habitat Conversion

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

Landscape data on habitat types and land uses will be important for recovery planning. Such datasets are available from a number of sources. Most USFS data are collected for forestry, such as Timber Survey maps based on aerial photointerpretation, and more recent GIS products. However, Dr. Bruce Welch at the Shrub Sciences Laboratory USFS Rocky Mountain Research Station in Provo, Utah is working on a monograph of big sagebrush to be published as a General Technical Report. Several chapters are in draft form (see Welch, draft manuscripts) but a chapter on the extent and condition of sagebrush is not yet completed (Welch 1999). Pipeline and utility companies often have maps of their facilities in GIS form. BLM has variable coverage of habitat and vegetation maps, and has not yet gathered comprehensive GIS information, but a project is underway (T. Rich, personal communication). Similarly, USGS-BRD (Biological Resources Div., US Geological Survey) has land use and land cover maps, and has a GIS project underway (S. Knick, personal communication). The EPA compiles ecoregion maps and the Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS) has soil type maps, although agricultural use mapping is not comprehensive.

NRCS has also compiled a National Resources Inventory, which contains information on land uses. State natural heritage programs also have various data, often in GIS form. These and other sources are described by Scott, et al. (1993, p. 15-16) and in more recent sources. Many states have completed or are near completion of GAP analysis, and various GIS layers will be useful for sage grouse habitat analysis and protection. In Idaho, GAP analysis shows that protecting sage grouse would also protect large numbers of other vertebrates that are currently unprotected (Kiester, et al. 1996). The same is likely to be true in other states. GAP analysis is not a panacea however. Two major limitations on the use of GAP analysis are that location data for species typically lack specificity and that data layers on species distributions are typically mere estimates of habitat affinities (Schwartz 1999, p. 98).

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

Rangeland "Improvements"

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

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

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

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

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

Invasive Species

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

Sagebrush habitats and other plant communities in the Great Basin are "highly susceptible to invasion" because annuals in these areas did not evolve to tolerate "intensive grazing" (J. A. Young, et al. 1972, p. 194), that is now rampant in the West. Invasion of alien plant species "is a major threat to remaining sagebrush habitats and in some areas overshadows all other concerns" (Paige and Ritter 1999). Invasive species have "taken over" more than 25 million acres of public land in the Great Basin alone (BLM 2000a), are spreading through grass and shrublands at rapid rates, and these rates are increasing in many areas (Quigley and Arbelbide 1997c). Infestations of noxious weeds alone are increasing by at least 14% annually (R. Johnson, et al. 1999, p. 13). This invasion of arid and semi-arid lands is "unprecedented" and "threatens native ecosystems" while "reduc[ing] the success of restoration" (Allen 1995). Over 860 exotic plant species have invaded the Pacific Northwest (Rice 1994 in Quigley and Arbelbide 1997c). Invasive plant species have a large effect on sage grouse in many areas, including the Gunnison Basin (GBCP 1997, p. 41). Invasion of exotics continues at epidemic rates, estimated as 2,200 ha/day on federal lands alone, and control strategies have been ineffective (BLM 1996a). "Noxious (exotic) weed spread is expected to accelerate dramatically" (Quigley and Cole 1997) and these noxious weeds are changing rangelands, leaving less habitat for wildlife. There are "at least 46 species" of "weeds" capable of entering and thriving in sagebrush ecosystems – 20 of these are classified as "highly invasive" and "competitive" (Pyke 2000, p. 43). Not all invasive alien species appear on state or federal noxious weeds lists – in some cases, control is so difficult or economically burdensome that regulatory powers have simply given up on control (Pyke 2000, p. 45). This abdication of responsibility – though the frustration is perhaps understandable – constitutes an inadequate regulatory mechanism.

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

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

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

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

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

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

Cheatgrass Invasion

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

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

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

Cheatgrass was apparently introduced into North America from Eurasia sometime during the mid-1800s, and was first noted in the Great Basin in the late 1800s (Miller, et al. 1993, p. 122). Cheatgrass invaded and spread with the degradation of arid ecosystems by livestock grazing (D'Antonio and Vitousek 1992, p. 65, 74). Grazing apparently facilitated the invasion of many other exotics, including medusahead wildrye (*Taeniatherum asperum*) and red brome

(*Bromus rubens*). Cheatgrass spread so rapidly as to escape recording (Leopold 1941), now dominates more than 41 million ha (100 million acres) in the Intermountain West, and forms virtual monocultures in former sage grouse habitat in many parts of Oregon, Idaho, Utah, Nevada, and Wyoming (Billings 1990). Cheatgrass threatens the entire sagebrush ecosystem, and thereby endangers sage grouse throughout its entire range (Billings 1990). Although its most significant effect is the alteration of natural fire regimes and consequent destruction of sagebrush, cheatgrass also alters pools and flows of both energy and nutrients (Christian and Wilson 1999). Moreover, cheatgrass may be favored by increased atmospheric CO_2 levels (Billings 1990). Yet even cheatgrass stands can be invaded by other exotic annual species – medusahead wildrye (*Taeniatherum asperum*) can outcompete and invade cheatgrass and is even less desirable because it is more flammable than cheatgrass (Hironaka 1994). One biologist stated that sage grouse will not dance (display) in medusahead wildrye (Fred Taylor, Oregon BLM cited in Anonymous 2001). The spread of medusahead is "adversely impacting sage grouse habitat" (Nevada State Office, BLM 2000a, p. 7).

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

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

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

A particularly chilling and immediate threat to sage grouse is that cheatgrass now appears to be invading higher elevation areas, even as high as the pinyon-juniper elevational belt (D'Antonio and Vitousek 1992, p. 75). Many scientists formerly believed that as cheatgrass invaded upwards from lower elevations and juniper and pinyon invaded downward from higher elevations, there would nevertheless be a middle elevation of sagebrush that would serve as a refuge for sage grouse, even though reduced in size. This is not a correct assumption. Billings (1990, p. 307) interprets the information provided by Young, et al. (1972) as showing the invasion of cheatgrass into "all sagebrush-grass vegetation types" in the northwestern Great Basin, "especially at the lower elevations." Cheatgrass has already invaded pine, hemlock, fir and other coniferous forests (Pierson and Mack 1990a, 1990b; Rice and Mack 1991c). It appears that the elevational ranges of cheatgrass and juniper already overlap (Billings 1990, p. 318-319), thus elimination of all sage grouse habitat appears certain without prompt remedial action – there are no elevational refugia.

Deliberate Plant Species Introductions

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

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

Juniper and Pinyon Pine Invasion

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

Juniper and pinyon trees can also dewater areas and destroy wet meadows and riparian areas needed for sage grouse especially during the critical brooding periods. Because sage grouse avoid areas with trees, areas invaded by juniper – even those with sagebrush and forb cover – are not habitat; and may serve as dispersal barriers, limiting gene flow. Pinyon-juniper forests (woodlands) cover 50 million acres in the West (Meeuwig 1983).

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

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

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

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

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

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

Reservoirs and Water Developments

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

Reservoirs greater than 100 acres in size are known to negatively impact the birds (SMBCP 1998, p. 24). Large reservoirs can directly kill sage grouse. Sage grouse are incapable of lengthy sustained flight, and birds have drowned in large reservoirs because of their inability to fly over them (Braun 1998a). Even small dams can harm sage grouse by changing needed wetlands and riparian areas into open water. There are "thousands of small dams in the [Interior Columbia] Basin" alone (Quigley and Arbelbide 1997a, p. 63) and tens of thousands across the range of sage grouse.

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

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

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

Logging

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

Predation

Most predation on sage grouse takes place as nest predation or on chicks (Braun 1975, Autenrieth 1986, Bergerud 1988b). However, predation of females about to breed may be most important, because the reproductive adult is destroyed together with all offspring that would have otherwise been produced. Sage grouse are particularly susceptible to predation because of their ground nesting and lekking habit (Hartzler 1974, Bergerud 1988b). Hens are more likely to encounter predators during the lekking period, perhaps because daily movements are increased (Gibson and Bachman 1992). This threat will be exacerbated when leks are spaced far from each other on the landscape, or when raptor perches such as powerlines, trees, or fence posts are common. One study found a mortality rate of 39% (n = 7 mortalities) on leks during the spring raptor migration (Jones and Braun 1994). Moreover, the sagebrush shrub-steppe contains a wide variety of both aerial and ground hunting predators and little in the way of concealing vegetative structure. Hartzler (1974) found that ground predators were observed less often than aerial predators, but killed more grouse.

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

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

Studies that examine only effects on reduction of food sources from decreased forb cover will under-predict population effects. Low recruitment has been noted in sage grouse populations, and predation of juvenile sage grouse has been cited as a major factor in sage grouse population declines. Ground squirrels and badgers can destroy up to half of yearly nest and egg production (DCCP 1998, p. 25). Grazing favors various ground squirrel species (Fagerstone and Ramey 1996; Sampson 1952). In one Colorado study, grazing severely altered the vegetation after a drought, and nest predation by Richardson's ground squirrels was the greatest cause of nest loss (Giesen 1995). A decline in preferred prey may also result in increased predation on sage grouse. Kindschy (1986) suggested that in southeastern Oregon, a decline in black-tailed jackrabbit (*Lepus californicus*) numbers may have caused predators to switch to sage grouse as their primary prey. In the Gunnison Basin, predation may be the primary cause of low recruitment on the remaining habitat in the area (GBCP 1997, p. 49).

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

(Robbins 1983) drove calcium specific nutritional hungers and hence egg predation (Holloran 1999, p. 112).

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

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

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

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

Anthropogenic effects greatly exacerbate predation on sage grouse by [1] altering habitat to prevent concealment, [2] reducing forbs and thereby increasing foraging time and hence exposure to predators, [3] artificially enhancing predator populations by providing alternate food sources such as road kill and garbage dumps, [4] providing perches for aerial predators, and [5] removing top carnivores such as wolves and coyotes, which allows the proliferation of meso-predators such as fox and ground squirrels. For example, ravens and raptors are more abundant along roads and powerlines (Knight and Kawashima 1993). Agricultural development creates artificially high concentrations of eagles and other predators that are attracted to calving operations (Schmidt 1998). This probably adds considerably to sage grouse mortality in winter and perhaps spring (Schmidt 1998). Schmidt felt such artificially elevated eagle predation to be the largest single winter mortality factor in southwest Montana. Agricultural developments, such as winter calving operations, also attract other predators. Schmidt (1998) found an "abnormally large fox population" in agriculturally dominated riparian bottoms. The situation in Strawberry Valley, Utah shows that indirect effects can be very important. Construction of a reservoir at Strawberry Valley and fish stocking provided an alternate food source for red fox, a non-native predator. The fox also prey on nesting sage grouse and have caused "almost complete reproductive failure" of sage grouse (Bambrough, et al. 2000a). The fox also feed on road kill (caused by the construction of roads to the reservoir and high use by recreationists), and on trash and fish entrails discarded by fishermen. Coyotes, a natural predator of fox, have been removed to favor sheep growers and other livestock interests. Artificial sources of food, such as livestock feeding operations, landfills, and garbage dumps have greatly increased the number of predators, as have various landscape changes allowing predators greater access to interior habitat (Andelt and Knowlton 1987, Toweill and Anthony 1988, Stiehl and Trautwein 1991b). A concise illustration of ways human activities have concentrated and increased predator numbers, and altered habitat to reduce grouse defenses and enhance predator effectiveness is presented by Bergerud (1988c).

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

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

Competition

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

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

In the extreme eastern portion of their range, sage grouse compete somewhat with prairie dogs. Two species, the Black-tailed Prairie Dog (*Cynomys ludovicianus*), and the White-tailed Prairie Dog (*Cynomys leucurus*), overlap with sage grouse. There may also be some overlap of Gunnison Sage Grouse with the Gunnison Prairie Dog (*Cynomys gunnisoni*) or the Utah Prairie Dog (*Cynomys parvidens*). Prairie dogs actively remove sagebrush plants and other vegetation in the vicinity of their towns (colonies). This creates local areas of unusable habitat for sage grouse. Also, sciurids are known as notorious nest predators. However, these areas are quite small and cause little problem for sage grouse relative to other threats. Moreover, sage grouse and prairie dogs coexisted in huge numbers before the agro-industrialization of the West.

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

Noise, Acoustic Interference, and Disturbance

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

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

There are numerous noise and disturbance sources affecting sage grouse. Traffic on roadways, off-road vehicle (ORV) and snowmobile use, oil and gas wells, and concentrations of livestock can all interfere with acoustic signals by sage grouse (GBCP 1997, p. 22; White and Thurow 1985). These activities are also likely to disturb the birds in a more active behavioral sense – birds will flush, become nervous, or abandon areas where these activities occur if they can hear or see the activities. Mining activities completely eliminated all sign of raptors from an area (Anderson undated). Numerous studies of various birds species show that recreational activity and the presence of humans reduces nest success (Anderson undated).

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

Frequency effects are likely important for sage grouse. Schroeder, et al. (1999a, p. 6) present sonogram plots for both species, showing that significant acoustical output is present