Status Review and Petition to List the Gunnison Sage Grouse (*Centrocercus minimus*)

Prepared by:

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I. Introduction

The Gunnison sage grouse formerly occupied large parts of Colorado and was found in Utah, Arizona, New Mexico, Oklahoma and probably Kansas. Today, the bird has been extirpated from all but two states, and only remnant populations exist. Existing populations are highly fragmented, and population trends are downward even among the largest populations. All remaining habitat has been degraded. The Gunnison sage grouse is nearing extinction and no regulatory mechanisms exist to halt its rapid decline.

Petitioners request the Secretary of the Interior (the Secretary) and the United States Fish and Wildlife Service (the Service, or FWS) to list the Gunnison sage grouse under the Endangered Species Act (ESA) 16 U.S.C. § 1531-et seq. (as amended). Please contact Dr. Webb or Mr. Salvo (in Portland) should any questions arise regarding this petition.

II. Taxonomy

The two species of sage grouse, the Gunnison sage grouse, with the proposed binomial *Centrocercus minimus*, and the Northern sage grouse, *Centrocercus urophasianus* (Bonaparte), are referred to the family Phasianidae (formerly to the family Tetraonidae), in the order Galliformes (AOU 1998, p. 118-119). Grouse have sometimes been referred to the subfamily Tetraoninae.

A. Common Names

The standardized common names are Gunnison sage grouse and Northern sage grouse but the species have also been referred to variously as sage hen, sage cock, spiny-tailed pheasant, spine-tail grouse, fool hen, cock of the plains, tétras des armoises (French), Beifusshuhn (German) or sage chicken (Coues 1893, Girard 1937, Patterson 1952, Jewett, et al. 1953, Johnsgard 1973, p.155; Johnsgard 1983, p.109). Lewis and Clark used the term "Cock of the Plains" (Terres 1980). Male sage grouse have been called toms, master-of-the-plains, old toms, bustards, prairie turkeys, heath cocks, sage fowls, turkey gobblers, and turkey buzzards, while females have been called brush hens, battle hens, and heath hens (Girard 1937). The standard AOU (American Ornithologists' Union) code was CEUR, and no AOU code has yet been assigned to the Gunnison species.

B. Affinities of Higher Taxa

Sage grouse are taxonomically distinctive and *Centrocercus* is a designated subgenus (AOU 1998). Bonaparte (1827) first described a single species as *Tetrao urophasianus*, and the genus was revised to *Centrocercus* in 1831 (Patterson 1952). Hudson, et al. (1964) proposed that sage grouse were most closely related to species of forest grouse, rather than to sharp-tailed grouse or other prairie dwelling birds. Johnsgard (1973) followed Holman (1964) in suggesting that speciation in these taxa followed increasing aridity, and that *Centrocercus* is most closely related to a genus of forest dwelling grouse, *Dendragapus*. This scheme differs somewhat from that of Short (1967) who proposed that sage grouse are most closely related to *Dendragapus* *obscurus*, the Blue Grouse. Lumsden (1968) supported this view based on behavioral similarities, and Johnsgard (1973) supported it based on adult and downy plumage characteristics. The taxonomic affinities assigned by these studies parallel those of Sibley and Monroe (1990, 1993).

The oldest fossils of the Galliformes date from the middle Eocene (Kuz'mina 1992). The Phasianids are the largest family in the order and are predominately found in tropical and sub-tropical areas (Kuz'mina 1992). Tetraoninae are endemic to the Holarctic with 18-21 widely distributed species (Kuz'mina 1992). Mayr (1946) and Short (1967) ascribed the origin of the Tetraoninae to North America.

Sage grouse hybridize rarely with sharp-tailed grouse (*Tympanuchus phasianellus*) and blue grouse (*Dendragapus obscurus*) (Johnsgard 1983).

C. The Gunnison Sage Grouse

The Gunnison sage grouse, consisting of isolated populations in the Gunnison Basin of Colorado, represents a distinct, but as yet unnamed species (AOU 1998, Hupp and Braun 1991, Young 1994, Young, et al. 1994, Braun and Young 1995). Importantly, both nuclear and mitochondrial DNA studies show a barrier to gene flow between the two species, and support a species rank for the Gunnison sage grouse (Kahn, et al. 1999; Dr. T. Quinn, Univ. Denver, personal communication). Making all the assumptions implicit in molecular clock hypotheses of evolutionary divergence, and the additional assumption that divergence rates of grouse equal those of geese, these species have been separate since the Pleistocene (Kahn, et al. 1999, p. 821). Dr. Clait Braun, the recognized expert on the Gunnison sage grouse has written an article regarding the taxonomy of the Gunnison sage grouse and proposing it as a new species (Braun, personal communication). This article has been reviewed by the AOU and a notation regarding the species is forthcoming. If Dr. Braun's article is published before the July issue of the AOU's journal, THE AUK, goes to press, then the Gunnison sage grouse will be formally listed as a new species, pursuant to action by the AOU's Committee on Classification and Nomenclature. The Committee has already noted that the Gunnison sage grouse represents a "distinct unnamed species" (AOU 1998, p. 119).

The mating behavior of the Gunnison sage grouse "differs markedly" from that of the Northern sage grouse, and they are smaller than the Northern species (SMBCP, p. 4). Gunnison sage grouse perform strut displays at a slower rate than do Northern sage grouse males, and Gunnison sage grouse displays contain unique visual and acoustical characteristics not found in the Northern sage grouse (Young, et al. 1994). Gunnison males have whiter retrices (outer tail feathers), thicker filoplumes (which they use more conspicuously by tossing them above their heads during the strut), more frequently compress their air sacs, reduce the amount of wing movement, and end the strut display with a tail wag – all these features differ strongly from the Northern sage grouse (Young, et al. 1994). Gunnison sage grouse also differ from Northern sage grouse when culmen length and tarsus length are arrayed in a scatter plot, as well as in body mass (Hupp and Braun 1991). Male Gunnison sage grouse have a "black pony tail" of plumes down the back of the neck that are seen during mating displays. Gunnison sage grouse has more distinct barring on its tail, and sharply pointed tail feathers that are longer than are those of the Northern sage grouse.

Petition to List the Gunnison Sage Grouse

Because most of the divergent traits of the Gunnison sage grouse are either secondary sexual characteristics or are sexually dimorphic, divergence caused by sexual selection is implicated (Young, et al. 1994, Wiley 1973). Sexual selection has the potential to cause very rapid inter-population divergence in male traits and female preferences, thus quickly leading to speciation (Fisher 1958, Lande 1981, Lande and Kirkpatrick 1988). This is apparently what has occurred between the Gunnison and Northern sage grouse.

The Service has previously recognized the Gunnison sage grouse as a distinct species. For example, in its Cooperative Agreement with the State of Colorado signed in 1997, the Service adopted the statement that the "Gunnison sage grouse (*Centrocercus minimus*) is a declining species which is neither federally listed nor a candidate species." (Cooperative Agreement 1997). Thus, the Service should recognize the Gunnison sage grouse as a separate species for purposes of this petition. The Service is aware that the AOU will soon designate the Gunnison sage grouse as a separate species (Long 1999). Alternatively, the Service should recognize the Gunnison sage grouse as a distinct population segment of the Northern sage grouse.

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

III. Description

Sage grouse are large, robust birds, characterized by considerable sexual dimorphism. In the Northern sage grouse, the body mass of females ranges from 1 to 2 kg, with lengths from 48 to 58 cm, while the body mass of males ranges from 2 to 3 kg, with lengths from 66 to 76 cm (Crunden 1963, Beck and Braun 1978). In the smaller Gunnison sage grouse, the body mass of females ranges from 2 to 3 pounds [1.8 kg to 1.36 kg] and the body mass of males ranges from 3.3 to 4 pounds [1.5 kg to 1.82 kg] (Gunnison Basin Sage Grouse Conservation Plan (GBCP), p. 3). Gunnison sage grouse are also morphologically distinguished from the Northern species by their longer, more distinct white barring of the tail feathers, and by bill shape and size (GBCP, p. 3). Gunnison sage grouse are also characterized by a single genetic haplotype (GBCP p. 5). Both sexes have narrow, pointed tails, feathering to the base of the toes, and grayish brown, buffy, and black variegated pattern on the upper body parts, with paler flanks, and diffuse black abdominal pattern (Johnsgard 1983).

A. *Sexual Dimorphism*

During the breeding season, considerable color dimorphism exists between the sexes in both species (Johnsgard 1983, Braun 1991b, Patterson 1952). Males have blackish brown throats which are separated from a dark "V" shaped pattern on the neck by a narrow white band. Males have expansive white breast feathers which conceal two large, frontally directed gular sacks of olive green skin, which the male inflates and deflates during sexual display (Dunn, et al. 1987). Short white feathers with stiffened shafts are located on the margins of the gular sacks and grade into softer and longer white feathers, and finally into a number of long black filoplumes. These hair like structures are erected during sexual display. Females lack these display features, have buffy throats with black markings, and have blackish brown barring on their lower throats and breasts. Additional accounts of sexual dimorphism are given by Honess and Allred (1942), Clarke, et al. (1942), Crunden (1963), and Beck and Braun (1978). General descriptions can be found in standard guides such as Udvardy (1977), National Geographic Society (1987) and Harrison (1978), and in Dunn, et al. (1987), Girard (1937), Jewett, et al. (1953), Johnsgard (1973), among others.

B. *Description of Life History Stages*

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

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

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

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

C. *Distinctiveness*

Sage grouse are the only species of Phasianid living in desert shrub (Johnsgard 1983, p.6). Sage grouse are uniquely adapted to the sagebrush shrub-steppe. The relationship to sagebrush is obligate and sage grouse require sagebrush for food. Sage grouse possess unique physiological and biochemical adaptations for the digestion and detoxification of sagebrush (Wambolt, et al. 1987, Welch, et al. 1989). These detoxification mechanisms make sage grouse of considerable importance for biomedical and genetic engineering research. Sage grouse are extremely habitat specific, and one report states that "no other bird is so habitat specific to one particular plant type [sagebrush] in meeting annual life requirements" (Gunnison Basin Sage Grouse Conservation Plan (GBCP) 1997, p. 38). The size of sagebrush habitat and lack of fragmentation of that habitat is crucial to the species because sage grouse species move seasonally to different areas within the sagebrush shrub-steppe (GBCP, p. 38). Sage grouse are unable to adjust to patterns of land use that eliminate or adversely affect large tracts of sagebrush (GBCP, p. 39).

Sage grouse provide a great deal of aesthetic enjoyment to bird watchers, recreationists, and hunters, and were relied on as a food source by many Native American tribes, who incorporated various rituals, including dances, relating to the bird into their culture. The birds' lekking behavior has occasioned a great deal of interest by behaviorists and evolutionary theorists, and the spectacular aural and visual displays of mating males have provided endless wonderment and amusement to the general public.

D. Locomotion

Sage grouse are weak flyers and often prefer to walk to reach useable habitats except when snow cover increases their conspicuousness (GBCP, p. 48, SMBCP, p. 22). Sage grouse are slow, low, and laborious in flight. Sage grouse spring into the air with some difficulty, particularly for the heavier bodied males (Johnsgard 1983). Less than half a minute is typically spent airborne – after 5 to 8 wing beats, sage grouse glide for 23 to 32 m, and then repeat this cycle (Girard 1937). The average distance covered during a flight bout is 575 m for males and 221 m for females (Girard 1937). Sage grouse are incapable of lengthy sustained flight – birds have been found dead in large reservoirs because of their inability to fly over them (Braun 1998a). Birds usually fly at heights of 14 m (females) and 23 m (males) (Girard 1937). This physiological performance explains the propensity for walking, and emphasizes the threat of habitat fragmentation to the bird.

E. Dietary Specialization

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

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

Nutrition affects the productivity of all grouse and ptarmigans, and can be particularly important during the breeding season (Moss, et al. 1975). Females with better nutrition put more nutrients into eggs (Jenkins, et al. 1963), have larger clutch sizes and better chick survival

(Jenkins, et al. 1963, Eastman and Jenkins 1970). Nutrient deficiency is known to reduce egg and chick production in birds generally by reducing eggshell thickness (Gutowska and Parkhurst 1942, Taylor, et al. 1962, Ellis and Labisky 1966). More general reviews of the effects of nutrition of hens on offspring are given by Robbins (1983), King (1972), and the various publications by the Romanoffs – Romanoff (1934, 1960, 1967, 1972) and Romanoff and Romanoff (1949). Nutritive issues are of extreme import to sage grouse declines because widespread habitat degradation severely affects nutrition, and hence productivity, throughout the species range.

1. Sagebrush

Numerous studies have documented the year-round use of sagebrush by sage grouse (Beck 1975, Call 1979, Call and Maser 1985, Klebenow 1973, Patterson 1952, Schneegas 1967, Sime 1991, Wallestad 1975a, Wallestad, et al. 1975). A Montana study, based on 299 crop samples, showed that 62 percent of total food volume over the year was sagebrush (Wallestad 1975a). Between December and February sage brush was the only food item found in all crops. Only between June and September did sagebrush constitute less than 60 percent of the sage grouse diet (Wallestad 1975a). Sage grouse are incapable of digesting most seeds or other hard foods as they lack a muscular gizzard (Johnsgard 1983).

Sage grouse differentially choose certain sagebrush species. Sage grouse generally prefer big sagebrush to other species (Eberhardt and Hoffman 1991, Tirhi 1995). However, sage grouse in Antelope Valley, California, browsed black sagebrush more frequently than the more common big sagebrush (Schneegas 1967). Among the big sagebrush subspecies, basin big sagebrush is less nutritious and higher in terpenes than either mountain or Wyoming big sagebrush. Sage grouse prefer the other two subspecies to basin big sagebrush (Autenrieth, et al. 1982). Welch, et al. (1991) found that sage grouse preferred mountain big sagebrush, Wyoming big sagebrush, and basin big sagebrush, in order from most preferred to least preferred. Remington and Braun (1985) found that Wyoming big sagebrush was preferred over mountain big sagebrush; however, their sagebrush samples were from different areas. Sage grouse will also eat other sagebrush species to a lesser extent than big sagebrush, including Alkali sagebrush (*A. longiloba*), black sagebrush (*A. nova*), low sagebrush (*A. arbuscula*), and half shrub fringed sagebrush (*A. frigida*) (Barnett and Crawford 1994, Patterson 1952, Remington and Braun 1985, Rogers 1964, Wallestad, et al. 1975).

During winter, sage grouse have been observed selecting plants with high protein levels (Remington and Braun 1985). Vegetation high in nitrogen is known to be preferred by sage grouse (Roberson 1984, Myers 1992). Sage grouse require high quality foods in winter (Roberson 1984, Welch, et al. 1988).

2. Forbs

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

(*Trifolium* and *Astragalus*) contributed more than 90 percent of the sage grouse diet. Forbs are critical for egg productivity and nutritional status of hens during the pre-laying period (Barnett 1993, Barnett and Crawford 1993).

Sagebrush is a negligible constituent (1%) of the diet for young sage grouse (Peterson 1970, Pyrah 1971). Instead, forbs constitute more than 50% of juvenile diets up to 11 weeks of age (Klebenow and Gray 1968, Peterson 1970).

3. Insects

Overall, insects are a minor diet item for adult sage grouse but are nonetheless a necessary and extremely important dietary component depending upon seasonality and life history stage. Martin, Zim, and Nelson (1951) reported that insects comprised 2 percent of the adult sage grouse diet in spring and fall and 9 percent in summer. Sagebrush made up 71 percent of the year-round diet. Females are known to consume cicadas (Sime 1991, p. 27). It is likely that gravid females have increased nutrient demands (Robbins 1983), and may require increased amounts of micro-nutrients, protein, and lipids. Gates (1983, p. 63) found that hens used forbs most both before and after incubation. Also, high density foods such as insects have a disproportionate amount of nutrients relative to their proportion of dietary composition.

Insects are a necessary food item for sage grouse chicks. In their first week of life, sage grouse chicks consume primarily insects, especially ants and beetles (Patterson 1952). Insects can constitute up to 75% of the diet of juvenile sage grouse (Patterson 1952). Survival and growth rates of chicks decrease proportionately with decreased insect material in the diet, even when diets contained abundant preferred plant material (Johnson and Boyce 1990).

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

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

F. Water Requirements

Sage grouse apparently do not require open water for day to day survival if succulent vegetation is available. They will use free water if it is available, however. Sage grouse distribution may be seasonally limited by water in certain areas. In summer, sage grouse in true desert regions occur only near streams, springs, and water holes (Howard 1996). However, this may be due to dependence on succulent vegetation rather than on any need for free water. Physiological studies of water conserving ability and osmoregulatory function have apparently not been conducted.

In winter in Eden Valley, Wyoming, sage grouse have been observed regularly visiting partially frozen streams to drink from holes in the ice (Call 1979). Sage grouse have been observed frequenting wet meadows and riparian areas in some studies (Pederson 1992, Willis, et al. 1993) but not in others (Cadwell, et al. 1994). Water has been considered a key component of summer and fall habitat by some (Carr 1967a, 1967b; Savage 1969; Call and Maser 1985) but this may be merely an epiphenomenon of more succulent vegetation occurring near water, as others have not found that sage grouse prefer sites close to open water (Wallestad 1975, Autenreith 1981, Caldwell, et al. 1994). Without samples of vegetation water content, this issue is unlikely to be resolved – moreover, spatial analysis of habitat degradation and conversion is a substantially higher research priority. It is important to exclude cattle from wet meadow areas (Jones and Braun 1994).

Because there were far more sage grouse before the period of European settlement of the West than are extant currently, there is no reason to suppose that water developments associated with livestock operations provide any net benefit to sage grouse. 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.

IV. Demographics and Life History Events

Sage grouse may live up to 10 years in the wild (Dalke, et al. 1963, Wallestad 1975a, Tirhi 1995, citing Braun, personal communication), but a more common lifespan is probably 2 to 3 years (Wallestad 1975a). Elman (1974) found average lifespans of only 1 to 1.5 years, while Drut (1993) indicated that a typical lifespan was 2 to 4 years. Returns of marked birds returning to the strutting grounds one year later ranged from 5% to 21% over a 3 year study (Dalke, et al. 1963). Annual mortality rates have been reported as 50% to 60% in two studies (Braun 1975, Tirhi 1995, citing Connelly, personal communication). However, Schroeder (1994) reported annual mortality rates of 29%. In Colorado and Wyoming, populations were composed of 51% and 58% juvenile birds, respectively (Patterson 1952, Rogers 1964). Sex ratios in both states were about 40% males.

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

Different stressors act at different seasons on different age classes and sexes. Breeding and nesting periods are energetically demanding: sage grouse experience a negative energy balance at these times and lose weight (Beck and Braun 1978, Roberson 1984).

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

A. Lekking

Leks are traditionally used sexual display grounds where males concentrate and females can observe large numbers of male displays, and exercise mate choice. Leks can range in area from 0.04 to 40 hectares and from several males to about 50 males; however, leks may have contained much larger numbers of males historically (Scott 1942, Call 1979, Call and Maser 1985). There appears to be a minimum viable number of males for a lek – there are numerous reports of leks being abandoned and apparently coalescing into a smaller number of larger leks. This is consistent with contemporary theories of female choice and supra-stimuli displays for mating (see the numerous papers by Gibson and Wiley in the Bibliography), but also points up the danger of assuming that lek use will continue as population level decline. Males seek lekking areas with high quality habitat, and with large numbers of males and females present (Bradbury, et al. 1989a). Thus, as the number of individuals at a lek becomes smaller, it will eventually be abandoned at some threshold size. Such effects will contribute to Allee effects in sage grouse.

Males gather on the lek in late February to April, as soon as the lek area is relatively free of snow. Yearling males arrive somewhat later (Eng 1963, Rothenmaier 1979). Sage grouse are highly conservative in moving to new leks, and in retaining use of traditional leks. Only a few dominant males, often only two, breed. Females typically gather on the lek beginning in mid-March, although this varies with weather conditions. Sage grouse mating behaviors, which are complex, are summarized by Johnsgard (1973). Older males establish lek territories earlier than younger males and exclude the latter; males with territories near the center of a lek have higher mating success (Davis 1978). Thus, younger males have significantly reduced mating success. Males employ vocalizations and visual displays which attract females and either repel or antagonize other males (Hjorth 1970, Hartzler and Jenni 1988). Auditory elements of the display are generated by the rapid inflation and especially deflation of the ventral air sacs, and possibly by wing movements. Dr. Clait Braun noted that the auditory display of the Gunnison sage grouse "sounds like the bubbling of a tea-kettle" as opposed to the "poik, poik" vocalization of the Northern sage grouse display. This auditory difference is apparently the result of 9 pops of the air sacs in the Gunnison sage grouse as opposed to 2 pops in the Northern species (Young, et al. 1994). Braun also notes that each species flees the calls of the others. Males employ 16 or more elements in the strutting sequence (Welch, et al. 1995). Displays typically occur at dawn and dusk (Dalke, et al. 1963, Johnsgard 1973, Wallestad and Schladweiler 1974); however, on cloudy days, displays continue through the middle of the day. Thus, exclusion of humans from lek areas only at dawn and dusk will not offer adequate protection of the lek area.

Males deplete lipid reserves during courtship, indicating that lekking activities are energetically demanding for males (Hupp and Braun 1989a). The holding of center territories entails even more energetic demand (Beck and Braun 1978). Moreover, lipid reserves are influenced by winter snowfall and air temperature (Hupp and Braun 1989a), showing that exposure caused by inadequate winter habitat cover or winter food could affect breeding activities, and hence fitness and population persistence, even if the effect was too small to affect individual survival.

Of particular importance for the analysis of population viability is that a very small proportion of males obtain nearly all matings -- typically, only 1 or 2 males per lek (Young 1994, p. 33). Thus, effective population sizes (N_e) are significantly smaller than actual population sizes, and consequently, the stochastic effects of genetic drift and demographic stochasticity are highly magnified in these birds. Older, established males are known to repel subadults from leks (Thorvilson 1969, p. 2).

B. Pre-Laying Period

During the period before a hen lays her clutch (and possibly including much of the lekking period), protein balance is critical for successful reproduction by hens. Hens require a diet with at least 18% crude protein (J. Craig, personal communication). However, sagebrush provides only 14-16% crude protein, so a diet rich in forbs is crucial (Barnett and Crawford 1994, J. Craig, personal communication). Lack of forbs in the diet will cause reductions in the number of eggs and fledglings (Barnett and Crawford 1994).

Egg formation and nesting are known to be energetically demanding periods for female sage grouse (Beck and Braun 1978, Roberson 1984). The same is true for many, and perhaps most, other species of birds (King 1972, 1974; Robbins 1983). Thus, females must accumulate fat stores during winter and the lekking season to last throughout the breeding season. If they are unable to do so, or if they must squander these energetic resources in long distance movements, breeding will fail.

C. Nesting

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

Laying occurs 7 to 10 days after mating (Peterson 1980, Autenrieth 1981). Yearling females lay later than do adults (Peterson 1980). Hens typically lay 1 egg per 1 to 2 days (Peterson 1980, Johnsgard 1983). Hornaday listed the clutch size as 13 to 17 (Hornaday 1916, p. 193). Modern accounts give clutch sizes averaging 7 to 8 eggs (range: 6 to 13 eggs) (Nelson 1955, Autenrieth 1981, Johnsgard 1983). This suggests that sage grouse may be experiencing reduced clutch sizes, probably due to poor nutrition of females caused by habitat degradation.

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

Males do not participate in nesting, incubation, or brooding (Wallestad 1975b, Autenrieth 1981). Consequently, the female must leave the nest unattended to forage. Nelson (1955) and Girard (1937 reported that excursions off the nest last about 15 to 25 minutes, about twice a day during incubation. Girard (1937) reported that excursions from the nest were bimodal, occurring from about 9:30 to 11:30 am, and from 2:00 to 3:00 pm. Such excursions are consistent with biophysical analyses indicating that shading of the eggs from radiative exposure during the middle of the day is necessary (Webb 1993a, 1993b). The timing of nest absences to late morning and early afternoon is consistent with temporal periods of hypothermic environments early and late in the day, as found by Webb and King (1983) for other species. Reduced forb and grass cover near the nest negatively impacts the nest microclimate (Autenrieth 1981, Call and Maser 1985, Webb 1993b). The amount of grass cover over 18 cm. in height near the nest differentiates successful from unsuccessful nests (Gregg 1992, Gregg, et al. 1994). Call (1979) developed management recommendations for sage grouse habitat.

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

Renesting is low in sage grouse (Connelly, et al. 1993, p. 1042) and may be inhibited by moisture and vegetation conditions (GBCP, p. 3). Subsequent nests, if attempted at all, have few eggs. Clutch sizes of second nestings are reported to be only 4 to 7 eggs (GBCP, p. 3). These findings point out the importance of preventing disturbance to nesting sage grouse.

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

Bergerud (1988b) also reviewed two studies on renesting rates in sage grouse, finding it to average 42%. Other studies have found renesting rates to be about 10% (Patterson 1952, Autenrieth 1981). Finally, Bergerud (1988b, p. 606, Fig. 15.13) found that higher density of males was related to lower juveniles per adult in sage grouse. This effect has conservation implications: as birds are crowded into smaller and smaller habitat fragments, population productivity can be expected to decline.

D. Brooding

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

Chicks fly by 2 weeks of age, although their movements are limited until they are 2 to 3 weeks old (Wallestad 1975a). They can sustain flight by 5 to 6 weeks of age. Juveniles are relatively independent by the time they have completed their first molt at 10 to 12 weeks of age

(Girard 1937, Patterson 1952, Johnsgard 1983). The hen and her chicks mix with other sage grouse on the summer ranges (Patterson 1952).

Most juvenile mortality takes place in the first 2 weeks after hatching, before the chicks are able to fly (Patterson 1952, Autenrieth 1981). During the pre-flight period, chicks respond to predators by freezing – their cryptic coloration provides good pattern matching, so long as adequate vegetation is available for cover (Paterson 1952). The major predators on chicks are corvids, raptors, and coyotes (Autenreith 1981). Ready availability of food and cover is crucial to juvenile survival (Klebenow 1972, 1985). Hickey (1955) reported early brood mortality ranging from 32% to 54% in three studies. Bergerud (1988b, p. 618, Table 15.6) reviewed mortality rates for various grouse species and found that nest mortality rates for sage grouse were 59%, and chick mortality rates were 29%, with mortality rates of adult females being 37%. Other reports of chick mortality rates range from 40% to over 60% (Wallestad 1975a, Braun 1975). These are very low survival rates. Ricklefs (1969) has analyzed the significance of high egg and juvenile mortality in a population and evolutionary context.

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

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

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

Mortality of chicks caused by wet weather during the brood-rearing period is not sufficient to account for population size during the following year (Jenkins, et al. 167, Bergerud 1970, Bendell 1972a, Myrberget 1972, Watson and Moss 1979 in Rich 1985).

E. Summer & Autumn

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

Males and hens without broods, which typically form small gender-based flocks in the spring, move to summer ranges in the following order: males, broodless hens, and last, hens with broods (Schoenberg 1982, Connelly, et al. 1988). Young males typically flock with females which are segregated from male flocks (Patterson 1952, Dalke, et al. 1960, Beck 1970, Dunn and Braun 1986). Movements to wintering areas are initiated by decreases in temperature and reductions in forb availability (Patterson 1952, Dalke, et al. 1963). Female habitat selection and movement patterns are directly linked to forb cover (Gregg, et al. 1993) which in turn is determined by livestock grazing, recovery from strip mining, and other threats.

F. Over-wintering

Sage grouse form unisexual winter flocks (with immature males associating with females). In the past, these flocks sometimes ranged upwards of 1,000 birds during severe weather, while in more moderate weather flocks typically ranged from 50 to 300 birds (Dalke, et al. 1963). In winter, birds do not migrate long distances, and survival over winter depends on adequate cover and food. Sagebrush is consumed almost exclusively during winter, and also provides cover for the birds from the very high wind speeds common in their winter range. Of particular concern, is that the birds must not only survive the winter but also need to emerge from the winter season with sufficient lipid stores for male mating displays (Hupp and Braun 1989a; King 1972) and perhaps for female egg production (King 1972, Robbins 1983). Bergerud (1988a) suggested that the reason that not all sage grouse females ovulate and nest was because of yearling females in the population. This is consistent with physiological limits from overwintering stress, but could also result from inexperience, or delayed maturation.

Sage grouse show some site fidelity to wintering areas. Berry and Eng (1985) observed hens in Montana moving to known wintering areas before the onset of heavy snowfall, suggesting fidelity to specific wintering areas. Thus, sage grouse will be particularly susceptible to destruction or degradation of traditional wintering areas. Access to winter habitat is critical (Young 2000). Winters also fluctuate in severity. For example, Dr. Braun has stated that a severe winter will occur at 7 to 10 year intervals in central Colorado (Summary of North Park Working Group Meeting 1999, p. 5). Even with operation of the proposed conservation plans, such winters would "certainly [cause] decreases in population" (id., p. 6). During 1984, only 7% of the observation points for Gunnison sage grouse were above the surface of the snow (Hupp and Braun 1989).

G. Seasonal Movements

Sage grouse occupying low elevation areas often do not migrate (Wallestad 1975). Of the populations that do migrate, movements are typically on the order of a few dozen kilometers or less. Longer movements have been reported, but there is no doubt a bias to report such extremal events, as neither journals nor individual scientists consider typical movements of much note. Movements are often greater than 16 km (Roberson 1984 citing Baker 1978, Barry and Eng 1985). Longer distance movements, ranging from 80 to 160 km have also been reported anecdotally (Pyrah 1954, Connelly and Markham 1983, Barry and Eng 1985). Much shorter distance movements are more common (Bradbury, et al. 1989a).

Fall movements to wintering areas are driven by weather conditions and usually occur gradually. After late winter or spring lekking activity, sage grouse may move to higher elevations or down to irrigated valleys for nesting and feeding. Most broods moved only a few km from nesting areas to summer ranges, but a few moved up to 13.4 km (Gates 1983). In contrast, movements from summering areas to wintering areas may often be 50 km in Colorado, Wyoming, Idaho and Montana (Dalke, et al. 160, Martin 1976, Beck 1977, Connelly, et al. 1988). Sage grouse may move only short distances, not at all, or distances in excess of 75 km between wintering, breeding, and summer ranges (Dalke, et al. 1963, Braun, et al. 1977, Connelly, et al. 1988). These long distance movements may well be a response to habitat fragmentation in modern times.

A closer examination of these disparate movement distances is required. Schlatterer (1960) reported that in southern Idaho, brooding grounds were 13 to 27 miles (21-43 km) from the nesting grounds. Anecdotal evidence suggests that males may be capable of moving long distances over the seasons. During winter in Wyoming, Patterson (1952) recovered a male sage grouse 75 air miles (120 km) from where he had banded it the previous summer. However, it is not known if the captured male moved purposefully, or was merely blown off course by the very strong winds common in Wyoming winters. Yearling males are much more likely to move long distances than are adult males, and some of the movements reported in the literature are the result of destruction of sagebrush by chemical sprays (Wallestad and Schladweiler 1974, Wallestad 1975b, Martin 1976). The Gunnison Basin Sage Grouse Conservation Plan reported movements by both sexes exceeding 20 miles to locate foraging and roosting areas (GBCP p. 5). No data support such long distance movements by adults outside of the winter season. Moreover, the movements that did occur by Gunnison sage grouse are likely extremal responses to the very low availability of habitat in those areas. Radio telemetry data indicate that males typically stay within 1.5 km of leks, although a few males were located up to 9 km away (Gates 1983). Movements from wintering areas to leks in the Gunnison Basin generally followed river valleys, and did not exceed 35 km even after a severe winter (Hupp 1987b, p. 62). After the breeding season, males in the Gunnison Basin remained within a few km of leks, and females remained within a few km of their nest sites throughout the summer (Hupp 1987b, p. 67).

Although limited, the best available scientific data indicate that birds typically move relatively short distances unless forced to move greater distances due to habitat limitations. Typical movements are only a few km, substantially shorter than the few anecdotal reports of long distance movements, and the latter may have been made by young birds. It is likely that mortality risk increases substantially as movement distances increase.

It is important to distinguish seasonal movements by flocks of birds from movements between demes by individuals, and to distinguish both those movement patterns from movements between feeding, breeding, and roosting areas within the home range (Wallestad 1971). In analyzing movement data, what is important is not whether birds <u>can</u> move long distances, but whether birds <u>do</u> move long distances and breed sufficiently frequently for gene flow to overcome drift and other deleterious genetic and demographic aspects of small population size.

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

H. Summary of Life History and Habitat Needs

Young (1994, p. 44) suggested that two habitats and life history periods critically limited Gunnison sage grouse: the density and height of sagebrush in winter, and the abundance of forbs and grasses in the summer early or late brooding periods.

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

V. Population Mechanisms & Vulnerability

Sage grouse possess certain physiological, anatomical, behavioral and population characteristics that render them more vulnerable to various environmental effects in terms of extinction risk. A variety of studies have identified increased vulnerability to extinction due to the following factors: small population size, low population density, isolation of sub-populations (demes), ineffectiveness of dispersal, large body size, large home range size, concentration of individuals (e.g. lekking), non-random mating system, and low fecundity, among others (Ehrenfeld 1970, Terborgh 1974, Pimm, et al. 1988, Primack 1993).

One such characteristic is large body size. Sage grouse are the largest grouse in North America, and large body size increases metabolic rate and food requirements. Space needs, such as foraging area, are increased as a consequence. Sage grouse are diet and habitat specialists, and this high dependence on particular habitat and food types increases the likelihood of extinction should those habitats become degraded. Sage grouse have low fecundity, low adult survivorship, and very low productivity. Their recovery time when threats are removed is slow, as is that of their habitat.

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

Small population size is itself a threat to a species, even if no trend towards even lower numbers is seen. In the Population Assessments section, below, we discuss examples where sage grouse became extirpated without downward trends in population size. Small populations are at high risk of extinction for several reasons, including loss of genetic variation through inbreeding or genetic drift, demographic fluctuations (such as variation in births, deaths, or age classes), and environmental fluctuations (such as variations in predation rate, disease or parasitism rates, climate, episodic weather events, competition, food supply and a host of other abiotic or biotic factors). The most recent analyses require a minimum of 5,000 individuals for population viability (Lande 1995). This is particularly true for populations that have been gradually reduced in size over time, such as sage grouse (Lande 1995, p. 786). Another factor which interacts with genetic phenomena is environmental fluctuations -- such changes in the environment are likely to have fitness consequences, resulting in a high degree of variance in selection coefficients, which in turn "drastically decreases the mean time to extinction" (Lande 1995, p. 787), and such extinction risks are comparable to those from environmental stochasticity even for merely reasonable levels of variance of selection coefficients " (Lande 1995, p. 788). Population sizes of 10,000 or more may be needed to maintain single-locus traits, such as disease resistance, which has been suggested as an important mating system effect in sage grouse (Lande 1995, p. 789; Boyce 1990). Moreover, synergistic interactions among risk factors must be considered to understand population viability, and such interactions likely require minimum population sizes greater than 10,000. The Service has agreed that even more birds are needed for viability. Mr. Terry Ireland (a FWS employee in Grand Junction, Colo.) stated that "10,000 individual birds are necessary to maintain a population for 100 years." (Summary of North Park Working Group Meeting 1999, p. 6). However, 10,000 would probably not assure a persistence time of 100 years for Gunnison sage grouse, because of the threats the species faces.

Corbin (1977) found that "marginal populations may be less variable than central populations," thus increasing the likelihood of extinction in such peripheral isolates. Peripheral populations may also lie in less favorable habitat, further increasing their risk of extinction (Wilson 1975, p. 113).

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

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

These factors, and others, are discussed further below under each topical heading.

A. Loss of Genetic Variation

Small populations face increased susceptibility to chance environmental and demographic effects, and also typically lose genetic variation due to drift, inbreeding or other population phenomena (Lande 1988, Caro and Laurenson 1994). Loss of genetic variation reduces mean population fitness and decreases the ability of the population to respond to environmental stressors (Westemeier, et al. 1998). Drift, founder effect, inbreeding and other factors causing reduced genetic variation increase as population size decreases and ultimately reduce fitness and survivorship (Allendorf and Leary 1986; Roelke, et. al. 1993; Lacy 1987).

Rare alleles are lost as is the proportion of heterozygous genes per individual and in the entire population (Avise 1994, Gyllensten). Westemeier, et al. (1998) report a study on a species related to sage grouse, the greater prairie-chicken (*Tympanuchus cupido*), which also leks. Populations of greater prairie chickens may have become trapped in an "extinction vortex" (*sensu* Gilpin and Soule 1986) where loss of genetic variation interacts synergistically with demographic and environmental stochastic effects to drive populations to extinction. Populations of the greater prairie chicken, like those of sage grouse, exist in a series of isolated relicts with little habitat connections and only sporadic gene flow to restore genetic variation. The breeding population remained smaller than 500 individuals for 35 years. Prairie chicken population size, productivity, genetic heterogeneity, and fitness decreased even though both habitat quality and quantity increased, and predation and nest parasites were controlled (Westemeier, et al. 1998, p. 1697). Thus, both current and planned methodology to enhance sage grouse populations may prove ineffective.

B. Demographic Stochasticity

In small populations, *r* fluctuates due to demographic effects, even in a constant environment. Small populations thus suffer erratic swings in size due to demographic stochasticity, and at the same time, such small numbers provide no buffer against declines in numbers resulting in extinction. Because sage grouse exist in small demes (sub-populations) they are particularly susceptible to such effects.

The recovery time of populations subject to demographic stochasticity strongly affects extinction risk. Extinction risk also increases sharply as carrying capacity (K) decreases (MacArthur and Wilson 1967), and is strongly affected by r_m (Lande 1993).

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

Gunnison sage grouse are at extreme risk from demographic stochasticity, as detailed elsewhere in this petition. These threats are ongoing in nature and interact with other threats.

C. Environmental Stochasticity

Contemporary models of metapopulation dynamics often assume that persistence depends on the balance of extinction and colonization in a static environment (Hanski 1996). Environments are not static, however, particularly the grass and shrub lands that constitute the habitat of sage grouse. Besides extreme climatic variation, these habitats are being reduced in size, degraded in quality and fragmented at rapid rates. Large and unpredictable fluctuations in climatic and other environmental factors are known to occur frequently across the entire range of the species. These are thus anticipated risk factors that must be considered by the Service – no one can claim that these fluctuations are unanticipated natural events.

Environmental stochasticity can be fully examined only if the factors of predictability and amplitude of effect, as well as the periodicity and contingency of environmental variation are considered (Colwell 1974, Stearns 1981). Climate and its short-term analog, weather, are particularly variable and unpredictable in sagebrush ecosystems. Drought is perhaps the major climatic variable affecting sage grouse productivity and viability (Klebenow and Gray 1968; Peterson 1970; Drut, et al. 1994a, 1994b; Gregg, et al. 1994). Declines in sage grouse populations during the 1930s are strongly related to the drought in the continental interior at that time (Patterson 1952). And populations recovered in most states in the 1950s (see Population Assessments sections) immediately after the period of abundant rainfall in the west during the World War II years (Malone and Etulain 1989, p. 111-112). Drought from the mid-1980s to the mid-1990s has also been suggested as a cause of sage grouse declines in Oregon and Idaho (Fischer 1994, Hanf, et al. 1994, Connelly and Braun 1997). Drought strongly affects the food supply of both gravid females and maturing young sage grouse, and probably affects cover providing concealment and radiative and wind buffering (Autenrieth 1981, Hanf, et al. 1994, Fischer, et al. 1996). Periods of low temperature and rain, snow or sleet can also cause nest failures (Patterson 1952).

Sage grouse are highly susceptible to variation in precipitation. Rich (1985) found that about 65% of the variation in juvenile/adult ratios was explained by the amount of precipitation in July and August. Moreover, 8 of 9 monthly weather variables that were significantly correlated with lek counts in Idaho were precipitation measures (Rich 1985). At higher elevations, temperature may be more important (Rich 1985, p. 12). Drought and grazing pressure interact to exacerbate negative effects on sage grouse productivity (Blake 1970). During low precipitation years (less than 15 cm), meadows are critical habitats for sage grouse; unfortunately, they are heavily used by grazing cattle (Oakleaf 1971; Klebenow 1982, 1985; Evans 1986).

Gunnison sage grouse populations are at extreme risk from environmental stochasticity, including weather related factors such as a drought year, a hard and snowy winter, or insufficient spring precipitation. Such events may occur in the next few months, i.e. this winter, spring, or summer, and would affect the entire range of the Gunnison sage grouse. Any of these weather events could be very severe, and cause complete extinction of the Gunnison sage grouse. Even if a lessor severity or magnitude were to occur, a significant proportion of the population would be extirpated. These threats are ongoing in nature and interact with other threats.

D. Effective Population Sizes

Effective population size (N_e) is a term used to incorporate various environmental, demographic, and genetic effects on population dynamics. N_e has been calculated in various ways, and can incorporate the effects of drift, inbreeding, and loss of alleles at segregating loci (Burgman, et al. 1993, p. 238). The population dynamics of small populations cannot be accurately estimated without consideration of effective population size.

Schroeder (1998b) applied the N_e concept to sage grouse but only incorporated a subset of the effects. Thus, N_e will be lower than those calculated using the formula given by Schroeder (1998b). However, if used cautiously, Schroeder's formulation is a useful metric until population viability models are established for the species.

E. Allee Effects

The term Allee effect refers to the negative effects on population processes of low population size or density (Allee 1938, 1951; Drickamer and Vessey 1992), sometimes also termed "undercrowding." Sage grouse are likely to show significant Allee effects because of the lekking habit – if the number of males declines sufficiently, the joint signaling function of having many males undergoing simultaneous sexual display and the advantage to females of gathering information regarding multiple males will both decline. Thus, as lek size decreases, the advantage of lekking collapses, at some threshold value. This is borne out by the numerous reports of lek abandonment below a threshold size. Other types of Allee effects are also likely to occur in sage grouse. Allee effects are not limited to mating behavior: Allee noted that groups of fish survived toxic conditions better than single fish, as did groups of flatworms.

Because of Allee effects, decreases in population size are unlikely to be linear; instead, as population size decreases to some threshold value, rapid declines and extirpation are likely. Such declines may be so rapid as to be undetectable before they actually occur, or if detected, extirpation may not be preventable by that point. Certain aspects of the environment combine with Allee effects to greatly increase the likelihood of extinction for sage grouse. First, Dennis (1989) has shown that environmental stochasticity amplifies Allee effects. As explained elsewhere in this report, sage grouse populations fluctuate greatly and sage grouse habitat are subject to great amplitudes of environmental stochasticity as well as unpredictability of these fluctuations. Second, "harvesting also amplifies those [Allee] effects" (Dennis 1989, p. 481). Thus, hunting of sage grouse can greatly increase extinction risk, and this risk will not be accounted for in conventional models of population harvest. Petitioners request that the Service consider all such non-linear effects of population declines in evaluating the status of sage grouse species.

F. Cultural Inheritance

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

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

G. Population Cycling

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

Hamerstrom and Hamerstrom (1961) noted that sage grouse were subject to dramatic changes in abundance. Importantly, it is not known if sage grouse are even adapted to fluctuations in population size. No studies were undertaken of the birds before cattle and sheep grazing degraded the shrubsteppe. It is known that population fluctuations are greater in marginal habitat (Rich 1985, Linden and Rajala 1981, Jenkins, et al. 1967, Hilden 1965, Rowan 1948). Furthermore, even if the birds are adapted to cyclicity, it is not clear that they are adapted to the degree of cyclicity that they now face, because a given variation in a climatic factor, such as precipitation, may have profoundly greater effects in degraded and fragmented habitat than it would in intact habitat.

H. Re-introductions

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

Johnsgard (1983, p. 99) noted that there were few instances of successful propagation of grouse, thus complicating the recovery of populations that fall to very low levels and the introduction of sage grouse to their historic range (Batterson and Morse 1948; Pyrah 1963, 1964). Re-introduction was tried in Montana with 242 sage grouse at 8 sites, but was unsuccessful (Martin and Pyrah 1971, p. 135).

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

I. Importance of Peripheral Populations

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

Peripheral populations often differ genetically from more centrally located populations, thus adding genetic diversity to the species and providing genetic backgrounds where natural selection can more easily increase the gene frequency of novel alleles or combinations. Peripheral populations are also often located at the ecological limits of the species, thus exposing these novel genetic combinations to environmental circumstances that may later become prevalent in central populations. Such testing of the periphery can act to stabilize the entire species in the face of environmental change.

Rapid evolution is likely when a peripheral population is isolated from gene flow, allowing a local deme to evolve to a local ecological optimum (Garcia-Ramos and Kirkpatrick 1997). Such evolution can be the first step to speciation, independent of genetic drift ("genetic revolutions," sensu Mayr 1963, 1982) or founder event mechanisms (Carson and Templeton 1984).

Peripheral isolates are also of great importance to recovery of species where re-introduction is difficult, such as sage grouse.

VI. Geographical Distribution

A. Historic Range of Gunnison Sage Grouse

Formerly, Gunnison sage grouse ranged through much of Colorado, and in Utah, New Mexico, Oklahoma, Arizona, and probably Kansas (Young, et al. 1994, p. 1360 citing Braun, unpublished data; Anonymous, undated document 2). Attempts to reconstruct the extent of the range prior to European settlement are difficult because this widespread habitat destruction occurred before scientific study took place, except for a few surveys. In Colorado, the Gunnison sage grouse was found in 21 or 22 southwestern counties: Mesa, Pitkin, Lake, Delta, Gunnison, Chaffee, Montrose, Ouray, San Miguel, Saguache, Dolores, San Jaun, Hinsdale, Mineral, Rio Grande, Alamosa, Montezuma, La Plata, Archuleta, Conejos, Costilla and possibly Fremont.

The historic range of Gunnison sage grouse extended from east of Sargents (Marshall Creek, upper Tomichi Creek), west to Blue Creek (further west to Colorado Hwy. 347 or further), north to at least Brush Creek and Taylor Park, and south to the Hinsdale-Gunnison County boundary and to Cochetopa Park in Saguache County (GBCP p. 5). Summer use may have occurred up to an elevation of 9,500 feet in sagebrush areas, and seasonal distribution was probably generally below 9,000 to 9,500 feet (GBCP p. 5). Generally, the historic range of the Gunnison sage grouse included many areas in Colorado and the southwestern states that are now heavily degraded sagebrush habitat or have been converted from sagebrush to agricultural or other land uses. Their historic status in Kansas and Arizona is unclear (GBCP p. 5).

B. Present Range of Gunnison Sage Grouse

Of the 6 states in which it formerly occurred, the Gunnison sage grouse now exists in relict populations found only in southwestern Colorado and southeastern Utah (San Miguel Basin Conservation Plan, p. 2, 5). The bulk of what remains of this species range is shown as a disjunct area in the WSSGTC (1999, Colorado section). Gunnison sage grouse no longer have any intact geographic range. Instead, the species is "known to occur in nine highly fragmented populations" (Pinon Mesa Conservation Plan, PMCP, p. 2). Even worse, these populations are not in close geographic proximity to each other, but are "in scattered localities in southwest Colorado and southeast Utah" (PMCP, p. 2).

Fragmentation has produced isolation within this range, and sage grouse within the above delineated area cannot be assumed to form a single population. Nor can all the sage grouse within any county be assumed to form a single population. Even within their existing range, numbers have declined dramatically and these declines are ongoing (Braun 1998a, Connelly and Braun 1997, Wisdom, et al. 1998). Populations are now disjunct, sporadic in occurrence, and thinly distributed across the landscape. Braun (1993) considered birds remaining in both Colorado and Utah to be "marginal" or "greatly reduced."

Today, Gunnison sage grouse are distributed south of the Colorado and Eagle rivers in Colorado, extending east to the Arkansas river and San Luis valley. Gunnison sage grouse also occur east of the Colorado river in extreme southeastern Utah (GBCP p. 5), where they apparently exist in two small disjunct populations (one of these populations may now be extinct). Gunnison sage grouse are now uncommon east of Sargents, in Cochetopa Park, the Waunita Hot Springs area, north of Almont, and are absent in Taylor Park (GBCP p. 5). The range has thus shrunk substantially along its periphery as well as its core. The species has been extirpated from over 75% of its former range. Continued local extinctions are imminent, and the range will continue to contract.

No viable populations exist. Instead, Gunnison sage grouse exist in scattered groups ranging from 10 birds to 100 or more (Anonymous, undated document 2, p. 2). Even the largest groups of Gunnison sage grouse have at most, only 200-300 birds (in the Crawford Area) (Anonymous, undated document 2) and will go extinct if habitat manipulation is neglected (Braun 1995g). Indeed, the top expert on sage grouse in Colorado, Dr. Clait Braun, stated that "I don't believe this population can be sustained for 10 years, let alone 20 years unless immediate steps are taken" (Braun 1994). Very few persistent leks were found in 1994 in the Crawford area, and mortality of males was "high" (Braun 1994). The populations in the other, smaller groups are "decreasing markedly" and "most populations have decreased by one-half within the last 3 years" (Anonymous, undated document 2). "This trend is expected to continue unless proactive management is implemented in the near future" (Anonymous, undated document 2). Thus extinction of this entire species is imminent and could occur even before it is officially designated as a new species.

C. Population Isolation

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

Many authors have found that hens are more likely to move between leks, while males are very site specific. Wallestad and Schladweiler (1974) observed complexes of leks and found that daytime movements were restricted to 0.8 to 1.1 miles from the strutting grounds. Of these movements, 82% exceeded 0.2 miles. Carr (1967b) found a similar pattern, observing that birds did not venture beyond 0.9 miles from the lek. Dominant males rarely move between leks (Johnsgard 1973, p.164), and Dalke, et al. (1963) reported that in a two year study of 78 banded males and 107 banded females, only 6% of females and 18% of males were even observed present on lekking grounds other than where they were first banded. In the 2 year study, Dalke (1963) found that sage grouse showed great fidelity from the first year to the second year to the lek complex, but not to the lek itself. This suggests that unless lek complexes are adjacent to each other, the maximum size of sage grouse populations will be determined by the extent of the lek complex. Even this may overstate population sizes: in a previous study, Dalke, et al. (1960) found that banded birds rarely changed from one strutting ground to another, even over a several year period. Johnsgard (1973) concurred, noting that movements between leks were rare. Sage grouse are unlikely to cross more than 6 to 8 miles of unsuitable habitat (NWEA 1991, p. 26; citing Braun, personal communication, and Connelly, personal communication).

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

Matings, and production of viable offspring would likely be much lower than these movement rates. Such movements, even if accompanied by matings, would not constitute effective levels of gene flow unless impregnated females were able to raise viable offspring who could prevail during all life history stages and raise viable young themselves.

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

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

VII. Habitat

Sage grouse are completely dependent on sagebrush-dominated habitats (Benson, et al. 1991). Sagebrush is a crucial component of their diet year-round (Johnsgard 1983). When selecting cover, sage grouse rely on sagebrush almost exclusively (Johnsgard 1983, Howard 1996). Declines in the abundance and range of sage grouse "relate to habitat loss, habitat degradation, and habitat fragmentation" (MOU 1995). Sage grouse habitat and cover requirements are inseparably tied to sagebrush, but sage grouse also require abundant forb cover. Sagebrush with more than about 30% canopy cover may cause reduction in forb cover due to competition (GBCP, p. 40). This may be of particular concern in the Gunnison Basin because grasses and forbs are under-represented in a large proportion of the sagebrush areas of the Gunnison Basin (GBCP, p. 39). Call (1979) developed management recommendations for sage grouse habitat, and management recommendations for habitat for the Gunnison sage grouse are presented in the Gunnison Basin Sage Grouse Conservation Plan (GBCP, Appendix E). Today, there are no known areas of habitat that have not been degraded or destroyed by conversion to other uses, livestock operations, or "rangeland treatments" (Braun 1998a). Reduction or elimination of grasses, cryptogamic crusts, and forb cover by livestock has led to increased densities of sagebrush and juniper invasion (Tisdale and Hironaka 1981).

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

Historically, shrubs dominated the Intermountain West below tree line, and true grasslands were limited to moist valley bottoms, riverine areas, and some hillsides (Vale 1975). Sagebrush shrubsteppe is a structurally simple habitat (Dasmann 1964, Bendell 1972). And, at least before the era of European settlement, habitat occurred in large blocks (Rich 1985, Fig. 1; Leopold 1933). This habitat has now been severely fragmented. Loss of habitat by conversion to agriculture, and habitat degradation has been "severe" and "the future for remaining sagebrush steppe in particular is bleak" (Paige and Ritter 1999). Welch (manuscript, Ch. II, pp. 12-14) reviews the degradation and destruction of habitat by land managers under the aegis of "vegetation control," comments on the problems, and summarizes consultation recommendations. Grazing of livestock has severely degraded most of the remaining sagebrush habitat: 30% is "moderately" grazed (moderate means that only "remnants of native herbs" remain), and another 30% has been so heavily grazed that "the native understory [is] replaced by introduced annuals (Paige and Ritter 1999, p. 7; West 1988, 1996).

Some habitat types appear to be used at all seasons of the year, and for all life history stages. For example, relatively dense, tall stands of sagebrush are used by all age classes for roosting (Drut 1994). Also, substantial forb and grass cover is required at all life history stages. This point was recently emphasized by Crawford (1997).

Additional habitat needs are analyzed by life history stage, below. In these analyses, it is important to realize that the optima or the requirements found for sage grouse habitat represent joint probabilities. If optimal sagebrush canopy cover is found on a steep slope then habitat will not be optimal and may be unusable.

O'Connor (1986) has cautioned that it is unsafe to predict bird densities on simple linear, or even monotonic habitat functions. Moreover, the mere observation that populations are abundant in an area cannot be used to justify an argument that habitat is adequate in that area (Van Horne 1983).

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

Degradation of habitat is a significant risk factor throughout the range of the species (Braun 1999a, p. 1). For the Gunnison sage grouse, inadequate quantity of habitat is a significant risk factor in all areas with the possible exception of the Gunnison Basin (Braun 1999a, p. 1).

A. Plant Associations

Sage grouse are obligate residents of the sagebrush (*Artemisia spp.*) ecosystem, usually inhabiting sagebrush-grassland communities (Crawford 1999). Sage grouse are rarely found far from sagebrush (Drut 1993). Much of what is termed sagebrush-steppe consists of areas where bunch grasses are co-dominant with sagebrush (West 1996). In Utah, southern Colorado, and northern New Mexico and Arizona (Paige and Ritter 1999, p. 3, map), sagebrush is often the sole dominant (West 1996). Rhizomatous grasses occur further east in sage grouse habitat in the Great Plains. The aforementioned dominance refers to potential natural vegetation - livestock grazing and "vegetation control" have removed most grasses and forbs from huge expanses of landscape. Meadows surrounded by sagebrush may be used as feeding grounds (Johnsgard 1973). All sage grouse are habitat specialists on sagebrush. The habitats inhabited by the Gunnison sage grouse are a little-loved landscape, and consequently, little protection has been established for this eco-region.

Sage grouse are associated with the following physiographic regions and plant cover types (Howard 1996):

BLM PHYSIOGRAPHIC REGIONS :

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

KUCHLER PLANT ASSOCIATIONS :

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

SRM (RANGELAND) COVER TYPES :

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

408 Other sagebrush types
612 Sagebrush-grass

SRM 107 and Kuchler type K024 will not be suitable sage grouse habitat because juniper trees serve as raptor perches. They are included above as potential natural vegetation classifications.

Sage grouse formerly occurred throughout the range of big sagebrush (*A. tridentata*), except on the periphery of big sagebrush distribution or in areas where it has been eliminated (Call and Maser 1985). Sage grouse prefer mountain big sagebrush (*A. t. ssp. vaseyana*) and Wyoming big sagebrush (*A. t. ssp. wyomingensis*) communities to basin big sagebrush (A. *t. spp. tridentata*) communities.

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

Estimates of the historical range of sagebrush vary. Beetle (1960) estimated the original extent of big sagebrush as 79.3 million hectares (196 million acres), and the range of all sagebrush species as 109 million hectares (268.5 million acres). Campbell and Harris (1977) estimated that big sagebrush (*Artemisia tridentata*) originally dominated over 36.4 million hectares, and Miller, et al. (1986) estimated that it currently (in the 1980s) dominated 36.5 million hectares. Some authors have suggested that sagebrush has expanded, but those who have examined this assertion closely disagree, believing instead that sagebrush range has contracted (Welch 1999). McArthur and Ott (1996) favored Kuchler's classification over Bailey's because the Kuchler approach defines vegetation types on a finer scale. The amount of land in the two sagebrush dominated Kuchler associations was quantified by McArthur and Ott (1996).

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

B. Winter Habitat

Winter habitat is typically the most limited seasonal habitat needed by sage grouse (Patterson 1952, Eng and Schladweiler 1972, Beck 1977). The best winter habitat is below snowline, on flat or gently sloping south or west facing areas, where sagebrush is available all winter (Edminster 1954, Rogers 1964, Schneegas 1967, Jarvis 1974, Beck 1977, Autenreith 1981, Martin 1976, Hupp and Braun 1989). However, these are precisely the areas threatened by habitat conversion.

Birds exist exclusively on sagebrush during the winter, and it is relatively nutritious (Edminster 1954, Welch manuscript). Birds typically forage in the tallest sagebrush (over 25 cm high) with the greatest canopy cover (more than 15%) (Wallestad and Schladweiler 1974, Beck 1977, Autenreith 1981, Schoenberg 1982). Dalke, et al. (1963) reported that wintering grounds of sage grouse in Idaho were usually located where snow accumulation was less than 6 inches (15 cm). Deep snow restricts the use of various areas and sage grouse winter where sagebrush has grown above the snow level (Dalke, et al. 1963, Autenrieth, et al. 1982, Hupp and Braun 1989). As snow begins to accumulate, sage grouse are restricted to areas that support taller, denser sagebrush stands, such as south facing slopes. Damage or removal of sagebrush in such areas could severely impact all sage grouse populations because other areas may be buried by snow. These concerns apply to all sage grouse and have been raised in particular for Gunnison sage grouse in the Gunnison Basin (GBCP, p. 40). Adequate winter habitat is also unavailable for Gunnison sage grouse in parts of the San Miguel Basin (SMBCP, p. 4).

Snow cover that exceeds one foot in depth tends to force sage grouse into areas with taller sagebrush (> 16 inches) in valleys and lower elevation flat areas, and roost in shorter sagebrush along ridge tops (GBCP, p. 4). In periods of extreme cold and deep snow, sage grouse often spend the night and portions of the day burrowed into snow drifts (GBCP p. 4-5).

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

In winter and throughout the year, sage grouse select areas of little or no slope. Autenreith (1986) found that birds selected areas of less than 15% slope. In a Colorado study of an area of 500 square miles (1,252 km^2) of sagebrush, nearly 80 percent of sage grouse winter use was on less than 35 square miles (87 km^2): on flat areas where sagebrush projected above the snow, or on south- or west-facing sites of less than 5 percent slope, where sagebrush was sometimes quite short but still accessible (Johnsgard 1983, Howard 1996). In Montana, during a winter with light snow cover, wintering areas were large flat expanses of dense sagebrush (Eng, et al. 1972). One study found that sage grouse selected wintering areas with slopes greater than 5°, probably because of the severe winter with greater than average snow depths occurring in that study (Hupp 1987b).

Winter home ranges of 5 females in Montana varied from 2,615 to 7,760 acres (1,050-3,100 ha) during two different years (Eng, et al. 1972). Robertson (1991) found winter home ranges exceeding 140 km^2 (53 mi^2).

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

Braun 1989b). In years with heavier snow cover, most feeding activity occurs in drainages, or on south or west facing slopes (Hupp and Braun 1989b).

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

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

Thus, breeding activities could be affected by winter habitat degradation, even if the reduction in lipid reserves was too small to affect individual survival. Because of the lekking habit and extreme degree of mate selection, this could have potent consequences for extinction risk of affected populations. Because the timing of lipid reserves, and not merely their size, is believed to be under strong selection, temporary disruption to winter foraging could affect populations, even if those lipid reserves were normal at other times (Hupp and Braun 1989a; King 1972).

Area effects can be especially important in winter, where episodic temporal events, seasonal events and spatial limitations combine. Hupp and Braun (1989b) reported that during the severe winter of 1984, only 7% of the 1,600 km^2 of sagebrush vegetation was available to sage grouse, primarily located in drainages. This reduction in foraging area significantly affected reproductive condition (Hupp and Braun 1989b). Unfortunately, much sagebrush removal effort is concentrated in these same drainages (Hupp and Braun 1989b). Such sagebrush removal can easily endanger the bird, even though no effects would be seen in normal winters. Beside the total amount of area available to wintering birds, fragmentation of winter habitat can cause wind penetration into those fragments (Geiger 1965), and would be an especially severe problem for wintering birds by causing hypothermia or forcing them to raise their metabolic rate for thermogenesis (Sherfy and Pekins 1995).

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

C. Lek Habitat

Open areas such as swales, irrigated fields, meadows, burns, and roadsides and barren areas or areas with low, sparse sagebrush cover are used as leks (Klebenow 1973, Ellis, et al. 1989, Klott and Lindzey 1989). Visibility on the lek itself is important for observation of male display, and visibility surrounding the lek is important for predator evasion (Gill 1965, Wiley 1973). Sage grouse have tremendous site fidelity to lekking grounds and have been reported to use gravel pits, bare openings in sagebrush, wheat stubble, salt licks, remote air strips, bare exposed ridges, paved roads, knolls, dry lake beds, and the Jackson, Wyoming airport runway as leks (Connelly, et al. 1981, Roberson 1986, Welch, et al. 1990). Of 45 leks, Patterson (1952) reported that 11 were on windswept ridges or exposed knolls, 10 were in flat sagebrush, 7 were in bare openings, and the remaining 17 were on various other site types. In the Gunnison Basin, leks were located near river valleys Hupp (1987b, p. 56). Leks are often located near water, although water is not necessary on the lek (Call 1979). Leks are usually located on flat or gently sloping sites (Eberhardt and Hoffman 1991, Caldwell 1994).

Leks are usually surrounded by areas with 20 to 50 percent sagebrush cover, with sagebrush no more than 1 foot (30 cm) tall (Klebenow 1973, Ellis, et al. 1989, Klott and Lindzey 1989). Nearby sagebrush for escape cover is of particular importance for leks (Welch manuscript, Ch. II, p. 12). If forced to do so sage grouse will use lek areas that lack surrounding cover. Apparently, no comparisons of losses to predators on such leks have been made to leks with predator escape cover. In parts of the San Miguel Basin, known leks for the Gunnison sage grouse are no longer active, apparently because of the lack of nearby sagebrush habitat (SMBCP, p.4). Gunnison sage grouse need relatively tall (> 12") sagebrush near the leks (within 200 m) for cover. Such nearby shrub areas are used by males for foraging, shelter, and loafing and are usually within 1 km of the lek (Rothenmaier 1979, Emmons and Braun 1984, Autenreith 1981). Areas near the lek with good forb and grass cover, shrub heights from 18 to 38 cm tall, and canopy cover of 20% to 50% are selected by males (Call and Maser 1985, Rothenmaier 1979).

When not on the lek, sage grouse disperse to the surrounding areas (Wallestad 1975a). Some females may travel between leks. In Mono County, California, the home range of marked females during 1 month of the breeding season was 750 to 875 acres (300 to 350 ha), enough area to include several active leks (Bradbury, et al. 1989a).

D. Nesting Habitat

Sage grouse prefer relatively tall sagebrush with an open canopy for nesting. In Utah, 33 percent of 161 nests were under silver sagebrush (*Artemisia cana*) that was 14 to 25 inches (36-63.5 cm) tall, while big sagebrush of the same height accounted for 24 percent of nests (Rasmussen, et al. 1938). Sagebrush plants are preferred for nesting, and nests placed under sagebrush plants are more successful than nest placed under other bushes (Connelly, et al. 1991). In a three-tip sagebrush (*A. tripartata*) habitat averaging 8 inches (20 cm) in height, hens selected the tallest plants for nesting cover. No nests occurred where three-tip sagebrush cover exceeded 35 percent. Similarly, Patterson (1952) reported that in Wyoming, 92% of sage grouse nests in Wyoming big sagebrush were in areas where vegetation was 10 to 20 inches (25-51 cm) tall and cover did not exceed 50 percent. In Idaho no hens nested in areas with less than 10 percent sagebrush cover or where sagebrush cover was greater than 25 percent (Klebenow 1973). Hens also select nest sites with taller grass cover – over 18 cm in height (Connelly, et al. 1991, Gregg, et al. 1994).

Klebenow (1981) found that sage grouse inhabited meadow sites with effective cover heights ranging from 7-16 cm, dependant on what was available. Dense grassy meadows that were grazed lightly or moderately were attractive to sage grouse. They avoided heavily grazed meadows in poor condition, with few grasses or forbs and dense, shrubby vegetation (Klebenow 1981). In areas where both three-tip sagebrush and big sagebrush were available, nests were typically associated with three-tip sagebrush (Klebenow 1969).

Autenrieth (1985) stated that the quality of nesting habitat surrounding the lek is the single most important factor in population success. Where a 35% sagebrush canopy and 60 cm height are combined with residual grass cover, the probability of predation is significantly reduced. The percentage of successfully nesting hens and the juvenile to adult females ratios are significantly higher in areas with robust shrub-grass production and where forbs are a common component of the spring range (Autenrieth 1985). Wallestad (1974, p. 632) found that successful nest sites had "significantly greater sagebrush cover within 24 inches (60 cm) of the nest."

Hayden-Wing and Costain (1986) found that live vegetation cover at the nest sites was high for both years (66.3% in 1982 and 75.7% in 1983). Crown diameter of big sagebrush on the nest sites averaged 17.9 inches and 13.8 inches. Crown diameters and heights of nest bushes averaged 31-87% wider and 48-67% higher than adjacent bushes. In general, nests were located in mature stands of relatively dense big sagebrush with a healthy understory of grass cover. Both components are important: shrub cover provides shading from the hot rays of the sun at midday and obscures the view of aerial, visually hunting predators such as corvids and raptors (Webb 1993b), while grass cover prevents wind penetration into the nest environment (Webb 1993b) during cold periods and obscures the view of visually hunting ground predators such as coyotes (Webb 1993b; Tirhi 1995 citing Schroeder, personal communication). The sensory ecology of olfaction is poorly understood, but grass cover probably prevents any odors from the nest from wafting downwind, retaining them in the boundary layer.

The amount of grass cover surrounding a nest and the height of that cover (more than 18 cm) are crucial in determining predation rates (Crawford, et al. 1992). On Hart Mountain National Antelope Refuge, Crawford and Delong (1993) found nest depredation rates of 73%, and nesting success rates of only 20%. Several studies show that shrub height and grass cover surrounding the nest significantly reduce predation: Crawford and Delong (1993) found that nests placed in grass taller than 15 cm and shrubs ranging in height from 40 to 80 cm had the lowest predation rates, and Gregg, et al. (1994) confirmed these results in an independent study, finding that greater grass canopy cover (18% vs. 5%) and greater shrub cover (41% vs. 29%) were correlated with lower nest depredation rates.

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

Edelmann, et al. (1998) reviewed the literature and summarized plant characteristics for optimal nesting habitat as: 25-35% sagebrush canopy cover, 40-50 cm sagebrush height, 25-35% residual herbaceous cover, and 0-5% slope. The probability of a successful nest drops sharply outside these optima (Edelmann, et al. 1998, Fig. 3). Summer home ranges may range from 3 to 7 km^2 (Connelly and Markham 1983, Gates 1983).

The amount and distribution of nesting habitat appears to be a limiting factor for sage grouse in the Gunnison Basin (GBCP, p. 39). Nest sites in the Gunnison Basin are in taller (> 20 inches), more dense (> 25% canopy cover) areas of sagebrush than average, and have an abundance of forbs and grasses (GBCP, p. 3). Residual forbs and grasses remaining from the previous season are important because females nest in mid to late April, before most herbaceous plants in the Gunnison Basin begin growing (GBCP, p. 3). Sage grouse are particularly susceptible to loss of nesting habitat because they show very strong nest site fidelity (Fischer, et al. 1993).

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

1. Aspect and Slope

Most nests (8 of 10) exhibited some degree of eastern aspect and most (7 of 10) were located on gentle slopes of less than 8%. None were located higher than the upper one-third of the slope (Hayden-Wing and Costain 1986). Musil (1989) found that sage grouse chose sites for nesting that had flatter slopes than nearby sites.

2. Nesting Distance from Lek

Hens often nest near the lekking grounds (Schlatterer 1960), but some hens have been noted to fly as far as 12 to 20 miles (19-32 km) to favorable nesting sites (Gill 1966, Rogers 1964). Wallestad (1974) reported that the hens traveled on average, 1.5 to 1.7 miles from the strutting grounds to their chosen nesting site. Hayden-Wing and Costain (1986) found that birds nested up to 3 miles away from leks, while Wallestad and Pyrah (1974) found that 68% of all nests occurred within 1.5 mile of the lek (mean = 1.5 mi for adults, 1.7 mi for yearlings). Only one nest was within 1 km of the lek. Most hens moved into a relatively small area and stayed fairly sedentary until nesting. In general, it will not be possible to adequately protect sage grouse nesting habitat by simply restoring habitat within a 2-3 mile radius of a lek site; instead, habitat within 20-30 miles of a lek site must be restored – and perhaps more, as radio telemetry studies cannot yet locate birds at great distances from the receiver.

Oddly, a number of Environmental Impact Statements (EISs) and Environmental Assessments (EAs), have analyzed impacts on sage grouse solely in terms of nesting and lekking habitat. This is completely inappropriate. Sage grouse need habitat to carry out all of their life-history stages.

3. Nesting Distance to Other Habitat Components

All nests studied by Hayden-Wing and Costain (1986) were relatively close to mesic or wet vegetation types. However, Autenrieth (1986) found no relationship to proximity of water, meadows, or a brood food source such as anthills.

4. Feeding and Roosting Habitat in the Nesting Season

During the nesting season, cocks and hens without nests use relatively open areas for feeding, and roost in dense patches of sagebrush (Klebenow 1969, 1973).

5. Edge Effects

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

E. Brooding Habitat

Brooding habitat requires relatively open canopy cover and abundant insect prey and forbs in close proximity to denser sagebrush stands for predator escape. Juvenile sage grouse stay mostly in open sagebrush with a forb component through June (Gill 1965, Savage 1969). As the season progresses, they move to riparian areas and other areas still containing green vegetation, such as meadows and areas associated with permanent and intermittent streams, springs, and seeps. By August, they are often clustered near permanently wet meadows and other such sites (Gill 1965, Savage 1969, Klebenow 1969). High levels of food and shelter provided by forbs, grasses and low sagebrush are key requirements for chick survival (Klebenow 1972, 1985). Broods often make use of open meadows (Bean 1941, Carhart 1941, Eng 1952, Rogers 1964, Klebenow 1969). For this reason, any effect which causes stream channelization, and reduces the belt of wet forbs and other vegetation which occur at considerable distances from streams, will harm populations at this critical stage. Livestock grazing is a notable cause of stream channelization.

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

Early brood rearing habitat has a relatively open canopy of sagebrush and a fairly low height of sagebrush. Canopy cover was less than 25% in Montana (Wallestad 1975a, Martin 1976), and less than 31% in Idaho (Klebenow 1981), and these sites were primarily associated with feeding. Also in Montana, Peterson (1970) found canopy cover to be 6% and shrub heights to range from 15 to 30 cm in June, and that by August canopy cover was 12% and shrub heights ranged from 30 to 45 cm. Pyrah (1971) found canopy cover was 14% in June and increased to 21% by September. Drut (1993) also found that birds in Oregon used low sagebrush for the first 6 weeks post-hatch, and moved into taller sagebrush stands as they matured.

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

Broods require forbs, insects and cover for growth, concealment and shade (Autenrieth 1985; Patterson 1952). Where these requirements are met at or near the nest site, Autenrieth (1985) found that the brood moves less, reducing exposure to predation and conserving energy. Birds also use denser areas of sagebrush in late summer when the forbs on preferred habitat are desiccated (Wallestad 1970, p. 25). On dry ranges, however, broods are forced to move to the nearest meadow for attaining their needs. Broods follow moisture gradients to higher elevations (Oakleaf 1971) or move to bottom lands and fields where forbs are more available (Klebenow 1969; Peterson 1970; Wallestad 1975a; Call and Maser 1985; Connelly, et al. 1988; Crawford, et al. 1989; Sveum 1998b). Such movements expose the young birds to predators and desiccation, and can deplete their energy reserves. When the birds move to farmed fields, they may become exposed to high levels of pesticides and herbicides, as well as enhanced predation or attacks by domestic dogs and cats. Hens remain near the nest site with their broods until forced to move by desiccation of the vegetation (Gregg, et al. 1993, Connelly, et al. 1988). In wetter years, movements away from the nesting area is delayed (Klebenow 1969, 1985; Wallestad 1975, Autenreith 1981). Thus, any activities that cause drying of nesting area vegetation, such as stream channelization by cattle or ground water pumping for livestock "guzzlers," will increase the threats to the birds by forcing the hen to prematurely move her young brood into or through areas with high predation risk.

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

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

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

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

The amount and distribution of early brooding habitat appears to be a limiting factor for sage grouse in the Gunnison Basin (GBCP, p.39).

F. Non-brooding Birds During Summer

During summer, females without broods and males select big sagebrush stands with canopy cover ranging from 20% to 35% (Patterson 1952, Martin 1970, Wallestad and Schladweiler 1974, Wallestad 1975a, Braun, et al. 1977, Roberson 1986, Ellis, et al. 1989). During summer and early fall, male sage grouse remain segregated from brood and hen flocks, typically remaining within 2 to 3 miles (3.2 - 4.8 km) of the lek (Wallestad 1975a). Hens without broods and male flocks are less dependent on wet meadows and riparian areas than are hens with broods; however, some dependence is still present, and these birds follow the same habitat use patterns as do hens with broods (GBCP, p. 4).

G. Fall Habitat

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

H. Habitat Degradation

Sagebrush removal will not benefit sage grouse unless increased forb production occurs, and only if the density of sagebrush does not become too low (Autenrieth 1985). Sagebrush has been removed with herbicides, intense fire, and by chaining or bulldozing in most of the range of the sage grouse. Consequently, populations have plummeted.

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

In one study, Webb (1993b) was unable to find even small portions of undegraded habitat in Wyoming outside of a National Park. This accords with the findings of Connelly and Braun (1997), Braun (1998a, 1999a), and Paige and Ritter (1999). The scope of habitat degradation and the various threats causing degradation are discussed throughout this report.

I. Home Range

Home range size varies with season, being smallest in summer, but are generally large than those of other grouse (Bergerud 1988). Annual home ranges may be as large as 1,500 km^2 (577 mi^2) (Paige and Ritter 1999, p. 33, citing unpublished data of Connelly. Home range sizes will be much larger in grouse that travel some distance among different habitat components than is those birds who have all the habitat types they need adjacent to each other. Home ranges will also be small in birds that simply cannot find their needed habitat except in a small remnant land area. Habitat degradation or fragmentation is likely to result in larger home ranges as birds must travel further and further to find needed resources.

J. Habitat Fragmentation

Habitat fragmentation is one mechanism that has been proposed to explain declines in a number of species, and has perhaps been most extensively studied in forest dwelling birds, particularly neotropical migrants (Wilcove, et al. 1986, Finch 1991, Faaborg, et al. 1992, Morrison, et al. 1992, Sherry and Holmes 1992). Fragmentation effects are by no means restricted to forest landscapes, however, and have been demonstrated in flat, or two-dimensional landscapes such as sagebrush shrub-steppe (Johnson and Temple 1986, Burger, et al. 1994, Herkert 1994, Knick and Rotenberry 1995, Welch draft manuscript) and specifically, in sage grouse populations (Kerley 1994, Commons, et al. 1997, Schroeder 1994, 1997b).

Habitat fragmentation occurs when a large tract of habitat is dissected into smaller patches isolated by other habitats or vegetation types different from the original (Wilcove, et al.

1986, Morrison, et al. 1992, Faaborg, et al. 1992). These patches (also referred to as fragments, islands, or isolates) are redistributed into variable sizes, shapes, and locations from the original area (Diamond 1975a, Wilcove, et al. 1986, Morrison, et al. 1992, Faaborg, et al. 1992). Forman and Gordon (1981) offer a readable introduction to patch dynamics and a variety of textbooks offer simple introductions to fragmentation concepts (Primack 1993, Meffe and Carroll 1994). Wilcove (1987) identified four ways that fragmentation can cause extinction: (1) a species can be excluded from protected patches by the loss of internal heterogeneity due to invasion of edge plant species; (2) it creates isolated populations that are susceptible to catastrophes and genetic drift; (3) it interferes with ecological relationships; and (4) fragmentation creates edge environments which typically increase predation.

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. 1992). 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.

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. 1992). 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. 1992). Several studies have shown that birds are habitat-specific (Lynch and Whigham 1984, Wilcove, et al. 1986, Morrison, et al. 1992) 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. 1992). 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. 1992). 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. 1992).

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 and 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.

Sage grouse are "especially sensitive to fragmentation because of their fidelity to lek, nest, winter, and brood-rearing sites" (GBCP, p. 41). Although this statement was made in the context of Gunnison sage grouse, it applies to all sage grouse. Fragmentation has nearly caused the extinction of the greater prairie-chicken, a close relative of the sage grouse (Westmeier, et al. 1998, Bouzat, et al. 1998).

1. Metapopulations

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).

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. 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.

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). Instead, some of the features of Gill's model seem to fit sage grouse. Because of severe habitat degradation, there are no large source populations left and few or no source patches exist. Source patches become sink patches as time and habitat destruction or degradation progress. However, as with various other species declining in abundance because of habitat loss and fragmentation, it is not likely that many sink patches will become source patches, thus extinction processes will predominate over immigration processes. 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."

2. 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 recolonisation rates will be low or nonexistent. This is particularly true for sage grouse because vast expanses of habitat have been degraded, and because re-introductions 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 the disturbance processes generating patches of suitable habitat, and the frequency and longevity of those patches. 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.

The minimum dynamic area must also include internal recolonisation sources (or "hot spots" <u>sensu</u> 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 report. 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 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). Sage grouse are known to use a yearly range of 30 to 60 square miles (Anonymous undated document 4).

K. Habitat Vegetation Analysis

Most of the range of sage grouse was assigned to the Great Basin (11) and Rocky Mountain (19) biogeographic provinces by Udvardy (1975).

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). Ellison (1960) summarized this development. More recent understandings of community development, incorporating multiple cliseres and disturbance mediated shifts among these multiple stable states, have been proposed by Westoby, et al. (1989) and discussed by Laycock (1991) and Friedel (1991). At its simplest, community development theory encompasses successional changes from priseres to cliseres (cliseres are often dubbed "old growth" or "ancient forests" for various forest ecosystems). A large body of theory on community development, together with numerous experimental tests and extended field data, exist for forest ecosystems. 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 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. 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.

VIII. Population Assessments

Gunnison sage grouse numbers have declined strikingly. 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. Species can become endangered even if populations are not declining. Flather, et al. (1994) note that 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. Nonetheless, the declines in sage grouse numbers are troubling, and increase the likelihood of extinction.

In early historical times, sage grouse were abundant (Brent 1938, Patterson 1952), and their range closely followed 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). 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 European 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 1952, 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.

Domestic cattle and sheep were completely unregulated in the 1800's and until the early 1930's (Edminster 1954; Drut 1994, p. 20; Foss 1969). Degradation of sage grouse habitat from grazing caused severe declines in populations (Edminster 1954, Autenreith, et al. 1982, Klebenow 1982, 1985) and rendered much sage grouse habitat unsuitable, perhaps permanently (Autenreith 1981).

Large numbers of domestic livestock were introduced to the west in the late 1800s. By the late 1880s, overgrazing and overstocking of livestock led to the disaster of 1887 (Schlebecker 1963, Limerick 1987). Notably, a conjunction of factors coalesced to cause massive die-offs of cattle: cattle were weakened by drought and overgrazing followed by a severe winter. 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 1984, 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 were 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 (Brent 1938, Gabrielson and Jewett 1940, Rush 1942, Patterson 1952, Rogers 1964). So steep were the early declines that some predicted extinction (Visher 1913, Hornaday 1916).

Most states limited the number of birds any hunter could take (bag limits) and reduced the length of the hunting season (Patterson 1952). Notably, the Taylor Grazing Act (1934) limited the worst 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 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, when some states re-opened hunting seasons. 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). Braun (1998a) estimated that the remaining range of the bird is declining by an average 33%, and that in 1998 a total of about 142,000 birds remained throughout its range. The rebounds in sage grouse populations in the 1930s in Colo. and some other states are not comparable to potential rebounds in the future – habitat is more degraded, populations are more fragmented, and the magnitude and severity of other threats have increased. Perhaps, most importantly, an apparent rebound in such small populations as the Gunnison sage grouse now occurs in, does not remove threats to the bird from small population size. Even if a population could be increased to a large size, the past history of genetic bottlenecks would strongly decrease viability.

Rich (1985) 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. If cycles exist, the cycles trend lower approximately every decade – the bird is thus cycling towards extinction

A. 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 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). As one example, younger birds are more susceptible to hunting harvest, thus population estimates derived from harvest data are likely to overestimate the actual size of reproductive sage grouse populations (Drut 1994, p. 13).

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. Jenni and Hartzler (1978) also found that evening lek counts are unreliable predictors of numbers using morning leks. 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.

B. Population Densities

Patterson (1952) estimated the density of strutting grounds to be 1 per 5.7 square miles, and the density of males to be 12.5/mi^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/mi^2, or from 13 to 21 acres per bird. Rogers (1964) found that only certain counties in Colorado supported densities of 10 to 30 birds/mi^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/mi^2. 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).

C. Extirpated State Populations

Sage grouse have been completely extirpated from the states of Arizona, New Mexico, Kansas, and Oklahoma (Braun 1998a). Sage grouse were extirpated from New Mexico early in the 1900's. There are no Oklahoma records since 1920 (Sutton 1967). 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). The main cause of the declines has been blamed on overharvest; however, the massive numbers of livestock introduced in the late 1800s cannot be discounted as a major cause of the extirpation. Re-introduction 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).

Today, Gunnison sage grouse remain only in Utah and Colorado. 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 report also endanger the birds throughout their range.

D. Utah Population Assessment

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). Sagebrush was once found in large islands scattered across the entire state (Foster 1968). Pioneer journals indicate that sage grouse were abundant in Utah in the early 1800s (Utah Draft Conservation Agreement 1998).

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). 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.

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). Habitat for the Gunnison sage grouse is in particularly bad shape. Landsat 30 m resolution data has been obtained from 1984 and 1993, and subjected to some analysis using geographic information systems (GIS). The analysis showed striking declines in sagebrush habitat with open canopies (Utah Draft Conservation Agreement 1998). Some lands were 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.

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.

In the Monticello area, Gunnison sage grouse face "obvious problems" from "fences, powerlines, gas lines" and other detritus of development which create problems that "cannot be easily solved" (Braun 1996c). The La Sal area is small and has "substantial pinon/juniper invasion," as well "recent chemical treatments of sagebrush, overgrazing," and habitat conversion to irrigated crops (Braun 1996c). Powerlines and roads also occur in sage grouse habitat in the La Sal area, and there is little habitat left that "hasn't been massively altered" (Braun 1996c). Brood habitat and escape cover are "serious problems" (Braun 1996c).

A pipeline is proposed to be constructed through some of the most sensitive Gunnison sage grouse habitat in both Utah and Colorado (Mid-America Biological Survey 1998, Map 1). The pipeline will be put through the heart of nesting and brooding habitat in this area and within 2 to 5 miles of known leks; moreover, impacts to wintering habitat are nearly certain (Mid-America Environmental Assessment 1998, p. 4-33). Some mitigation measures were proposed but they are inadequate, and the EA fails to analyze important environmental effects, such as habitat fragmentation, creation of predator movement corridors, the time to restore sagebrush, cheatgrass invasion, and others (Mid-America Environmental Assessment 1998). Reseeding with sagebrush is not required and will occur only where "feasible" (Mid-America Biological Assessment 1998, p. 1-8). The pipeline is proposed even though habitat in this area is already endangered by agricultural fields, which are the "predominant land cover," leaving only a few "relict stands of sagebrush" to serve as "important winter cover, forage, and movement corridors for sage grouse" (Mid-America Biological Survey 1998).

The Colorado BLM has proposed oil and gas leasing throughout Gunnison sage grouse habitat with stipulations that are clearly inadequate to protect the species (District Manager 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, Gunnison sage grouse occur in only 1 county (WSSGTC 1999, Utah section, p. 1). Gunnison sage grouse are presently restricted to the area east of the Colorado river in extreme southeastern Utah (San Juan Draft Concept Plan 1997). "Nearly all birds found south and east of the Colorado River are thought to belong to" the Gunnison sage grouse (Beck, et al. 1999). The state is attempting to set up a core conservation area of 65,000 acres of habitat, but 99% of this area is private land, primarily devoted to agriculture, and is managed by 30-35 different landowners (Mitchell 1999). Only an estimated 192 Gunnison sage grouse exist and they are only found in Utah in San Juan County (WSSGTC 1999, Utah section, p. 1). For the same reasons detailed in the Utah and Colorado sections of this report, this estimate is probably too high. Indeed, there are "probably actually less than 100 birds" in Utah, they are "down to 1 lek," and knowledge of the population is "very limited" (Olterman 1972, p. 2). In 1996, only 3 leks were found, and the number of males was far below the long term average (San Juan Draft Concept Plan 1997). In 1998, only 32 birds were counted. Even if the higher estimate is accurate, such small populations are not viable, and the Gunnison sage grouse will soon be extinct in Utah.

E. 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. 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 re-opened 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. 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.

Gunnison sage grouse numbers have been, and are, declining (SMBCP, p. 6). Overall, the "total number of Gunnison sage grouse has declined <u>at least</u> by 80-90% since 1950" (Braun 1999a, p. 1) (emphasis added). This represents Dr. Braun's latest and best professional judgment. Even in the Gunnison Basin, sage grouse numbers "have decreased at least by 50-

60% since the early 1950's" and only 706 males are known to exist based on actual counts (Braun 1999a, p. 1, 3). Declines in range and population numbers from published and peer reviewed accounts are also presented in this report. However, such accounts may understate the danger to the Gunnison sage grouse, because the publication and peer review processes themselves require a year or more to complete. So quickly is this species being lost that the Service must give considerable weight to communications from recognized experts such as Dr. Braun.

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). 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). A map showing range reductions is presented in the Appendix.

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). As of 1997, only 2 populations of Gunnison sage grouse were thought to be stable and 1 of those (Crawford) had so few birds as to be imminently imperiled (from the document: "Gunnison Sage Grouse Breeding Populations"). Furthermore, 4 other populations had negative trends, and 2 populations were unknown. Dr. Braun estimated that even the largest Gunnison sage grouse population (in the Gunnison Basin) would likely persist for no more than 20 more years (Minutes of Fruitland Mesa/Crawford Sage Grouse Meeting of March 30, 1995). Despite its dismal characterization of extinction risk, this is probably an overly optimistic estimate, because of Allee effects and other problems of small populations. The effective population size for the Gunnison Basin is quite small, and is no larger than 500 birds (Young 2000) and is probably much lower when variance in female reproductive success and lack of genetic diversity are considered (Young 2000).

Yet this is the "'healthiest' population of Gunnison sage grouse" in existence (Braun 1999a, p. 1). Dr. Braun used quotation marks around the word healthiest because he does not believe that any group of Gunnison sage grouse is viable for very long (Braun 1999a, p. 1), and that all Gunnison sage grouse could become extinct if there were a "string of very dry springs/summers followed by a severe winter" (Braun 1999a, p. 1). Unfortunately, such climatic events are common within the range of the Gunnison sage grouse. The second best Gunnison sage grouse population is the one at Miramonte/Dry Creek, followed by the Crawford area, and Dove Creek. Only the above 4 areas have sage grouse that have even a reasonable chance of avoiding extinction, because Dr. Braun doesn't "have much hope for [the other populations] Sims Mesa, Poncha Pass, Cimarron, Monticello, and Pinon Mesa/Glade Park" (Braun 1999a, p. 1). Dr. Braun believes that those populations will only survive "if we (society) are very lucky" (Braun 1999a, p. 1). Following this "bleak" assessment, Dr. Braun immediately stated that there are "no guarantees" that any population – even the "healthiest" ones would survive climatic events (Braun 1999a, p. 1). When asked if he can "foresee a time when Gunnison sage grouse are extirpated from Colorado" (question 6), Dr. Braun replied: "Yes, for all populations except the Gunnison Basin" (Braun 1999a, p. 2). He then noted that complete extinction is foreseeable because disease or parasites could cause a "rapid loss of the entire population in a give area," noting that the Colo. Div. of Wildlife "allows releases of exotic/introduced species which are known to be carriers of parasites/diseases harmful to sage grouse into habitats where sage grouse live" (Braun 1999a, p. 1). Population trends alone, however, have caused Dr. Braun to predict extinction of the Gunnison Basin grouse within 20 years (Minutes of Fruitland Mesa/Crawford Sage Grouse Meeting of March 30, 1995), and he has stated that the Gunnison Basin grouse will not last "10 years let alone 20 years unless immediate steps are taken" (Braun 1994).

Unfortunately, petitioners believe that Dr. Braun's assessment of extinction risk – as "bleak" as it is (his words) – is, in fact, overly optimistic. The latest and most modern science in assessing population viability, coupled with the climatic extremes typically found in the range of the species, indicate that extinction risk is much higher. These factors are detailed in this report, and petitioners believe that the Gunnison sage grouse is likely to become extinct – in all its populations – imminently, perhaps even before it is officially designated a new species. Dr. Young has concurred with Dr. Braun in all respects, except that her assessment is even more bleak (Young 2000).

Habitat has been heavily impacted throughout the range of the Gunnison sage grouse. For example, even in the Gunnison Basin, "large regions" are not available "as breeding habitat because favorable summer foraging areas are not available" (Hupp 1987b, p. 86). In the limited area where breeding is still able to occur, "loss of nesting habitat or diurnal cover used by males during spring courtship could have a disproportionately severe impact" (Hupp 1987b, p. 86). Habitat loss between 1953 and 1993 averaged 20% and was as high as 50% in some areas (Braun 1999a, p. 2; Oyler-McCance 1999). The lowest amount of habitat loss was in the Gunnison Basin, and that area still had quite high rates of habitat loss, averaging 11% (Braun 1999a, p. 2; Oyler-McCance 1999). The average loss was over 5,030 hectares of habitat destroyed each year (Braun 1999a, p. 2; Oyler-McCance 1999). 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 in the Gunnison Basin have been degraded or lost altogether, impacting some the most important habitat for sage grouse.

Of particular concern is that fewer than 4,000 breeding individuals remain in the entire Gunnison Sage Grouse species (San Miguel Basin Conservation Plan (SMBCP), p. 2). Moreover, this species is isolated into 8 or 9 "highly fragmented populations scattered in 6 counties" (SMBCP, p. 2; CACP, p. iii). Most of the remaining birds are in Gunnison and Saquache counties (NPS 1999b). The Gunnison Basin has the largest population (although only 706 males are known to exist (Braun 1999a, p. 3) and the largest area of contiguous distribution (PMCP, p. 2). The San Miguel Basin group itself has had its range "greatly reduced in size and [habitat] quality" with less than half the range remaining (SMBCP, p. 29), the range is fragmented into 6 separate isolates, and the intervening land is in private ownership (SMBCP, map facing p. 6). Private land also makes up substantial proportions of the range of the San Miguel group, and these ranges are further subdivided by Colorado highway 141 (CO-141) and other highways (SMBCP, map facing p. 6). The range of the largest sub-group in the San

Miguel Basin is in the form of a long narrow band, only about 3 miles across at its widest point. But this narrow width of habitat is not the worst landscape factor for this sub-group: the entire range is further sub-divided all along its length by the road that runs from the town of Basin to Highway 90 (SMBCP, map facing p. 6). Thus, the habitat is likely only 1.5 miles in width on either side of the road. As bad as this state of affairs is for the Gunnison sage grouse, however, the San Miguel range map probably overestimates the conservation status of the bird. The range map legend notes that the range is "derived from vegetation data" (SMBCP, map facing p. 6). The hazards of inferring distribution, much less viability, from vegetation data are well known and are discussed elsewhere in this review. The legend also notes that the map was reviewed by L. Bennet in 1997; however, the details of that review are not presented. Thus, the "range map" may actually represent the potential range, not the actual range. Furthermore, if either population or habitat conditions have deteriorated since 1997 – as is likely given the trends in both (SMBCP, p. 6) – then the status of the San Miguel grouse is perilous indeed.

Although the SMBCP refers to each isolate as a "population" that is almost certainly inaccurate. Each of these groups is, in turn, almost certainly fragmented into multiple populations, thus this report will avoid using the term "population" for these fragmented isolates. For example, the San Miguel Basin group is fragmented by two major highways, Highway 90 and CO-141 (SMBCP, map facing p. 4). Both are modern high-speed highways with high traffic flows which serve as dispersal barriers to sage grouse. Moreover, big sagebrush – the preferred habitat type – is itself broken into four separate fragments, each of which is isolated by at least 2 miles (SMBCP, map facing p. 4).

In the Dove Creek area of Dolores county, the habitat is fragmented by two major high-speed highways, US-666 and CO-141 as well as numerous county roads (Dove Creek Conservation Plan (DCCP), p. 4, 7). Homes, ranchettes, and other suburban or exurban developments have also fragmented habitat (DCCP, p. 22). Rocky canyons and invading pinyon-juniper woodland also cause a high degree of habitat fragmentation (DCCP, p. 7, 21). Sage grouse in the Dove Creek area are reduced to lekking in agricultural fields, and the quantity and quality of sagebrush dominated habitat at these sites are reduced (DCCP, p. 5). Not surprisingly, the number of males on lek sites is "greatly reduced" (DCCP, p. 5). Indeed, only 4 lek sites remain, and the population is declining (DCCP, p. 7). Winter habitat also appears to be a limiting factor in the Dove Creek area (DCCP, p. 5) as is nesting and brooding habitat (DCCP, p. 20). "Pinon/juniper invasion is a major problem" and the "grass/forb understory needs major improvement" (Braun 1996a).

Only 27 birds are known to exist in the Dove Creek area (DCCP, p. 8). The DCCP assumes an optimistic 2:1 sex ratio to generate total population estimates of 81 to 135 birds (DCCP, p. 8). Even if these liberal and optimistic estimates were correct, this is far below the minimum number of animals needed to sustain a viable population – no population viability specialist has maintained that such small vertebrate populations can persist. Besides counting birds that are not known to exist, the Dove Creek plan sets goals that are too low: it contemplates only a total of 480 birds – and this is based on spring population numbers which will be higher than at other times of the year such as winter. Population goals should be set to avoid winter bottlenecks. Moreover, the birds in the Dove Creek area are almost certainly fragmented into smaller isolates because their habitat is fragmented into smaller patches (see above). Not surprisingly, the number of birds in the Dove Creek area has declined sharply since 1994 (DCCP, p. 9).

Despite these dire circumstances, the Dove Creek plan itself reveals that no on the ground conservation actions have yet been implemented (DCCP, p. 12-15). Instead the Plan itself notes that "plan accomplishment will require a lengthy period to complete" (DCCP, p. 16). The US FWS has signed an agreement to cooperate with the state Div. of Wildlife and has provided $60,000 to pay off farmers and landowners in the area (Cooperative Agreement 1997). Although laudatory, it would be less expensive and more effective to have simply purchased the lands in question or to have purchased permanent conservation easements on those lands. Instead the funds will be disbursed pursuant to the CRP which is discussed elsewhere in this report. Some funds will also be used to buy seed for native vegetation and provide technical assistance. The agreement is thus in no way a regulatory mechanism, and is of dubious efficacy and efficiency.

The Crawford Area Conservation Plan (CACP) also uses an unusual standard for population viability. It refers to the Sims Mesa group of less than 10 birds as no longer viable, but suggests that other populations, ranging in size from 75 to 225 birds, are viable. Independent scientists initially hypothesized that the short-term threshold of viability was close to 500 individuals. Later work showed that this estimate was too liberal, and that minimum viable population sizes range from 5,000 to 10,000 individuals (Lande 1995). No peer reviewed science shows that very small populations such as the CACP uses are viable. Population viability is discussed elsewhere in this report.

No conservation plans exist yet for the Pinon Mesa (now in draft form, see PMCP) or Glade Park areas; nonetheless, employees of the Service have already begun discussing 4(d) rules and incidental take permits with interested citizens (Agenda, Pinon Mesa 1999). This appears to put the cart before the horse, and points up the politically charged nature of the Service's listing decisions. Significant habitat conversion has occurred in this area. For example, the "Thompson Reservoirs area continues to see development for private homes and no activity by sage grouse has been observed in this area" (Graham 1999). The reservoirs themselves probably removed some of the best wet meadow habitat in the area; now, suburban and exurban sprawl is eating up the rest, and sage grouse have been extirpated form the area. Likewise, sage grouse have been extirpated from the historic Jefferson Canyon lek sites: no viable population remains, and only a "lone bird" was seen there and that observation was not verified (Graham 1999). Similarly, no birds have been observed using the Fish Park lek (although a bird may have investigated the area, as judged by the presence of a single pile of fecal droppings) (Graham 1999) and these birds "have declined to very low levels" such that no viable population exists (even using the very liberal definition of viability in the Colorado conservation plans) (PMCP, p. 10).

Only 75-100 birds are estimated to remain in the Pinon Mesa area, and again, these estimates vastly overstate the number of birds actually counted. Indeed theses estimates have been inflated not once but 3 separate times: (1) the PMCP assumes that males exist that were not counted, that leks exist that were not counted and that 2 females exist for every male (PMCP, p. 8-9). Such over-optimism is not consistent with conservation of a vanishing species – instead, any errors made should be conservative ones so that the bird is not rendered extinct by errors in estimation.

Petition to List the Gunnison Sage Grouse

The Pinon Mesa Conservation Plan shares the deficiencies of the other conservation plans – participation, much less actions provided under the plan, is "strictly optional" and is on "a volunteer basis" (PMCP, p. 2). The birds' range is contracting and only the most favorable habitats are still in use (PMCP, p. 3). The largest remaining use area for sage grouse is west and northwest of the Grand Mesa National Forest lands (PMCP, p. 11). No sage grouse have been sighted in over 10 years from the Glade Park store area of Pinon Mesa (PMCP, p. 3) and the Colorado Div. of Wildlife believes that sage grouse no longer exist in eastern Glade Park (PMCP, p. 10). Sage grouse are no longer found near lower Bieser Creek and the lek at Renegade Point has been abandoned (PMCP, p. 11). Similarly, sage grouse appear to have vanished from historic lek sites near the Thompson Reservoirs (PMCP, p. 3). Only 23 males have been counted and only 4 active leks remain (PMCP, p. 8), a decrease of 46% since 1959 (PMCP, p. 9). The primary causes of the decline appear to be extensive urbanization and alteration of vegetation (PMCP, p. 3) as well as pinyon and juniper invasion, lack of grasses and forbs in the sagebrush understory (a typical result of overgrazing), a shortage of wet meadows and riparian areas (no doubt caused by construction of numerous reservoirs and tanks in the area) (PMCP, p. 9-10). The core of this area is private land with an outer periphery in the north and west of BLM land. Many of the remaining leks are on private land (PMCP, p. 11) and thus lack the protection of any federal laws. An isolated portion of the Pinon Mesa National Forest lies in the middle of private land, and the Colorado National Monument lies in the northern part of the area, just south of I-70. Numerous roads dissect the area and several powerlines are found in the area as well. Only in the extreme northern and southern parts of the area can even a square mile be found without roads. There are a few Gunnison sage grouse in Utah near Fish Park along the west boundary of the area.

Other areas have such small numbers of birds that, sadly, they merit little conservation attention. The birds in these areas probably can never be recovered and triage efforts should be focused on other areas. Sims Mesa has only 10 birds, Poncha Pass is the site of a transplant attempt, and Cimarron has only about 50 birds. Birds in these areas may be extirpated even before the Service completes an emergency review.

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 also stated that conservation plans could provide some "relief or relaxation from [an 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 has encountered significant opposition from the 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).

The other threats discussed elsewhere in this report also indicate that the Gunnison sage grouse is not secure anywhere within its range. For example, the Gunnison Basin Sage Grouse Conservation Plan admits that the Gunnison sage grouse is secure in only a single county, Gunnison County (GBCP p. 5). However, the plan uses overly optimistic criteria for assessing the security of populations, as explained below. Indeed, the plan itself recognizes that Gunnison sage grouse populations cannot be considered secure. On the very next page (GBCP p. 6) after it declared the bird secure in Gunnison County, the plan notes that a population of 500 birds (its criterion for security) cannot protect against inbreeding depression, and cites to the best and most recent study on this issue, that of Lande (1995). The Gunnison sage grouse is not secure anywhere.

Mining, grazing, and development in the Gunnison Basin are of particular importance for the Gunnison sage grouse. Hupp (1987b) presents a map of sagebrush dominated areas in the Gunnison Basin which shows that sagebrush no longer occurs in the most mesic areas near rivers. Continued habitat loss, grazing, and habitat fragmentation are of particular concern throughout Colorado (Drut 1994, p. 19). The grouse in the Crawford Area have declined because their habitat has been removed by mining, suburbanization, and water developments or degraded by grazing, fire suppression and fragmentation (CACP, p. 4). The "primary use of all land" in the Crawford area "is grazing (Jones and Braun 1994, p. 2). Because of this grazing, pinyon/juniper invasion, and fragmentation "habitat in the Crawford area is marginal at best" (Jones and Braun 1994, p. 8). In the Green Mountain portion of the Crawford area, "current grazing practices ... are unacceptable if the sage grouse population is to be maintained" (Jones and Braun 1994, p. 8). The Gunnison Basin Sage Grouse Conservation Plan particularly cautions against the superficial appearance of improved conditions on the shrub-steppe, and states that "in reality these areas are smaller, more fragmented, and subject to more intensive use" today than prior to settlement (GBCP, p. 8). "Reduction of sagebrush habitat" caused by "ever increasing housing developments, croplands, reservoirs, etc." is a key threat to the survival of the Gunnison sage grouse (NPS 1999b).

The Gunnison sage grouse is presently restricted to the area south of the Colorado and Eagle rivers and east to the Arkansas river and San Luis Valley (SMBCP, p. 5). The range of the Gunnison sage grouse in the Crawford Area has been reduced by 50% (CACP, p. 27). Fragmentation is severe in the Crawford Area as well. Map 2 of the CACP shows that the small present range in the Crawford Area has an unfavorable shape ratio (long and narrow) and is dissected by several areas having less than 10% sagebrush. The largest piece of intact habitat is only 4 miles long (CACP, p. 5). The nests in this area are all within 1/4 mile of the Black Canyon road (CACP, p. 5), a source of considerable danger for nesting hens, their eggs and chicks. Besides the likelihood of disturbance by humans or their pets, many nest predators use roads, as detailed in the Threat Analysis sections of this report.

Movements of birds in the Crawford Area are believed to be "restricted due to loss of suitable habitat from ongoing land use conversion" (NPS 1999a). There are no data showing that birds are able to move between the central and western Gunnison Basin (NPS 1999a). Large numbers of roads fragment habitat in the Gunnison Basin. For example, high speed highways such as state highways 92, 135, and 149, U.S. 50, and the paved road along Ohio Creek fragment the area, as do numerous lower standard roads. Blue Mesa reservoir has destroyed large amounts of habitat, and developments have spread outward from the reservoir.

Sage grouse populations in the Gunnison Basin are rapidly declining. In 1953-54, about 100 males displayed per lek, but by 1994-95 the number of males per lek was only about 22 to 26, a decrease of about 75% in only 43 years (the Gunnison Basin Sage Grouse Conservation Plan (GBCP) 1997, p. 29). The plan suggests a population of 2,200 birds (GBCP p. 6), but on the same page notes that "sage grouse habitat in the Gunnison Basin tends to be linear" and then proceeds to divide the habitat into "discrete areas" (GBCP p. 6). These linear strings of habitat, of course, are already fragmented and are highly susceptible to further fragmentation. For the other reasons explained below in the "Management in Colorado" section, this estimate is virtually certain to be overly optimistic.

In the Crawford Area, Gunnison sage grouse have almost certainly "declined substantially" (CACP, p. 1) and have ranged from about 10 to 50 males on leks since 1978 with a peak in 1996 (CACP, p. 4). At present, populations appear to be static or slightly declining (CACP, p. 5). Even using the most optimistic assumptions, only about 129 to 228 Gunnison sage grouse remain in the Crawford Area. The actual number counted is only 43 males. Assuming a 1:1 sex ratio – as the Crawford Plan admits is common in unhunted populations (CACP, p. 4) – there would be only 86 birds remaining in the entire Crawford Area. This also assumes that there are no "unknown, hidden" leks which have an average number of birds, but have somehow not been found and counted. The Crawford Area plan, however, estimates the upper boundary of the number of grouse in the area by assuming that an additional, "unknown" lek exists (CACP, p. 3). This is an extraordinarily optimistic assumption and is presented without any estimate of the search effort undertaken or needed to find active leks. The lower boundary for the number of grouse in the area does not contain a correspondingly conservative estimate – instead, a "lower" limit is calculated by assuming the optimistic 1:2 sex ratio (CACP, p. 3). It is odd that the population estimates use optimistic assumptions for both lower and upper estimates. This makes no sense, and suggests a political motive rather than an attempt to conduct verifiable science.

The Crawford Area Plan appears to overestimate the present range, and hence the conservation status of the bird. The plan estimates the present range of Gunnison sage grouse in the Crawford Area based, in part, on the "present potential of remaining sagebrush-dominated habitats" (CACP, p. 3). But, one cannot assume, of course, that birds live everywhere that habitat exists. Perhaps, the plan only used the above statement with reference to the historic range of the species, but that is not explicit in the text.

In the Dry Creek Basin/Miramonte area of the San Miguel Basin no more than 165 to 276 birds remain (SMBCP, p. 6). This estimate uses the 1:2 sex ratio assumption of the SMBCP and is similarly dubious. Only 55 birds have actually been counted (Anonymous, undated document 3, p. 1). These birds are spread over 4 leks (SMBCP, p. 6). The group of birds in the Miramonte area cannot survive without the Dry Creek area and its birds, and the same is true for the Dry Creek area (Braun 1995f). These two areas thus have an obligatory linkage. Moreover, private land in the Miramonte area is "crucial for maintenance of this [group] of sage grouse" (Braun 1995f). Only protection under the ESA will ensure proper management of these lands. For example, grouse in the Iron Springs mesa area have already been extirpated apparently due to development on private lands (Brigham 1995b). Sage grouse in the Dry Creek Basin/Miramonte area lack adequate winter habitat; moreover, habitat near leks is poor, and has apparently caused the abandonment of several leks (Anonymous, undated document 1, p. 1). Indeed, breeding, nesting, and brood-rearing habitat are limited (Braun 1997, p. 2). Moreover, the "grass/forb understory needs major improvement" in this area (Braun 1996a). Livestock grazing dominates other land uses in the basin (DCB-CRMP, p. 6) and other threats include uranium mining, ORV use, hunting, various potential disturbances such as wildlife viewing and photography (DCB-CRMP, p. 6), as well as oil and gas fields, a large number of unpatented mining claims (DCB-CRMP, p. 28), and a coal mine (DCB-CRMP, p. 38). Livestock grazing is the greatest threat in this area, as it "occurs on nearly all of the watershed at various times of the year" (DCB-CRMP, p. 28). This small, arid area is allocated over 8,500 AUMs (DCB-CRMP, p. 69). Virtually none of the range is in "excellent" condition, and much of it falls into the second lowest status condition (termed "good" by BLM but widely regarded as not good by others) (DCB-CRMP, p. 55).

Gunnison sage grouse in the Dry Creek Basin/Miramonte area have experienced astounding declines: from 1992-94 to 1997 the number of birds counted decreased by 46%. Populations in this area may already be unrecoverable, and could become extinct any year. Despite the severe risk of extinction for these birds, no enforceable management plan exists for their protection. The Dry Creek Basin Coordinated Resource Management Plan (DCB-CRMP), signed by various federal and state agencies in 1993, provides no regulatory mechanism to protect sage grouse. Instead it is purely voluntary (DCB-CRMP, p. 15). The CRMP matches the other Colo. conservation plans in its insufficiency – for example, it does little to define specific land management practices, and instead contents itself with "establish[ing] a process and put[ting] in place a framework" (DCB-CRMP, p. 4). Moreover, the CRMP fails to recognize the importance of habitats and time periods for wintering, nesting, and brood-rearing as it states that only the December to March period is "crucial habitat' [sic] (DCB-CRMP, p. 67). The Gunnison sage grouse need protection and habitat improvement, for all critical life history periods, not processes and frameworks.

An estimate of the effective population size can be made by using simplistic textbook equations (e.g. Meffe, et al. 1997, p. 173) for N_e based on the monopolization of breedings by a few males. For a liberal estimate of N_e, assume that all birds are in a single population, and that the population size is 276, the largest of the estimates. There are 92 males and 184 females. Make the further liberal assumption that all of the females breed successfully. If 2 males garner all matings at a lek as is often the case in sage grouse, then 8 males have mated with the 184 females. The effective population size for sex ratio effects is given by:

$$N_e = \frac{4 * N_m * N_f}{[N_m + N_f]} = \frac{4 * 8 * 184}{[8 + 184]} = 30,$$ where N_m = the number of males breeding in the population, and N_f = the number of females breeding in the population, and fractional results are truncated. This simple analysis using optimistic, not conservative assumptions, shows that no Gunnison sage grouse population is secure – even in the short term. N_e will be further reduced by variation in family size among females, and that effect can be calculated as:

$$N_e = \frac{4 * N_c}{\sigma^2 + 2}$$, where N_c = size of the census population , and σ^2 = the variance in family size.

I predict that the next major drought will cause the extinction of all Gunnison Sage Grouse outside of the Gunnison Basin. If the drought is severe, then the entire species will become extinct.

In general, all of these conservation plans read as though they were concocted to advocate for minimal effects on established interest groups, and to paint the rosiest possible picture of the Gunnison sage grouse. The conservation plans do not present a sober assessment of the population status of the grouse, nor do they propose effective measures to arrest its alarming decline.

Taken together, or considered separately, the conservation plans for the Gunnison sage grouse are inadequate to conserve the species; because of their lack of enforceability and emphasis on protecting vested interests rather than protecting the grouse, they represent extinction plans for the Gunnison sage grouse. Even worse, even if each conservation plan were completely effective, the extinction risk for the Gunnison sage grouse would still be high. None of the conservation plans would provide connections among the isolated populations that are the subject of each individual plan. Thus, at best, the Gunnison sage grouse would eventually consist of several isolated and non-viable populations, each of which would then become extinct. As Storch (1997) noted in a study of several grouse species closely related to sage grouse: "attempts to stabilize a population below minimum viable population size will fail unless dispersal from neighboring populations occurs." Unfortunately, "travel corridors for sage grouse throughout their range are becoming restricted" thus preventing gene flow among these scattered isolates (Braun 1999a, p. 3).

A few years ago, Braun (1995) suggested that "the long-term fate of sage grouse in Colorado [was] uncertain." Dr. Braun now has a "rather bleak" outlook, and believes that there are "no guarantees" preventing the extinction of the Gunnison sage grouse, and doesn't have much hope" for over half the remaining populations of the species (Braun 1999a). Today, the fate of sage grouse in Colorado will be certain extinction unless the enforceable conservation measures designed by Congress in the Endangered Species Act are implemented to protect the birds.

IX. Threat Analysis

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, Hoffman 1991, Hayes, et al. 1998, Livingston 1998, Schroeder 1998, Braun 1999, Young 2000). Sage grouse populations began declining from 1900 to 1915, when livestock utilization of sagebrush shrub-steppe was heavy (Patterson 1952). 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, Young 2000). 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). 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 conversation, and disruption of natural fire ecology. Flather, et al. (1994) reported that regions showing high species endangerment in the western United States were 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).

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, et al. 1997, p. 152-154). 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, which can both damage habitat directly by destroying sagebrush, and by enhancing the invasion of cheatgrass. 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 report, 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.

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 Secretary may not consider actual or "possible economic or other impacts" in the listing decision. 50 C.F.R. § 424.11(b). Petitioners incorporate all parts of this petition, 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.

Dr. Braun, perhaps the foremost expert on sage grouse and the recognized expert on the Gunnison sage grouse, believes that habitat conversion, habitat fragmentation and habitat degradation are the major threat categories to sage grouse (Braun 1999a, p. 1). Dr. Young, another expert on this species, concurs (Young 2000). Predation and other threats act because of the widespread effects of these three threat categories (Braun 1999a, p. 1).

A. *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. Small area size is particularly pernicious: 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).

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.

1. Grazing

Grazing of domestic livestock has affected the entire range of the sage grouse, and grazing with its associated livestock operations is probably the number one threat to the continued existence of the species. The impacts and extent of grazing on sage grouse are widely documented (e.g. Yocom 1956, Dobkin 1995, Autenrieth, et al. 1977, Klebenow 1981). No sage grouse habitat is known to have escaped degradation by livestock grazing (Braun 1998a).

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. Ungrazed sagebrush steppe in the Intermountain West has declined by 98% or more since European settlement (Noss and Peters 1995, table 1; Noss, LaRoe and Scott 1995). 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).

Even 35% of all wilderness areas have active livestock grazing allotments (Reed, et al. 1989). The 35% figure represents an average over the entire U.S., so the figure for the west is probably substantially higher. Effects on wildlife are severe: Smith (1977) termed grazing "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 1952; 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. First, much of the range of sage grouse did not overlap with that of bison (Bison bison) (Reynolds, et al. 1982). 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, are found on gentle slopes near water (Van Vuren 1982) -- these are precisely the areas needed by sage grouse for critical life history stages, such as nesting (Hayden-Wing and Costain 1986) and brooding (Gill 1965, Savage 1969, Klebenow 1969). Third, grazing by domestic livestock is repetitive, with annual or biennial grazing periods of varying timing and length (Braun 1998a). Fourth, most native ungulates browse rather than graze and often do so in the dormant season (CACP, 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 1991, Norland 1984, Wuerthner 1998, p. 374-375).

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 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, p. 43). This factor alone is a 35% to 59% increase. Moreover, the calves are also larger, and mature more rapidly (GBCP, 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.

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. Belsky and Blumenthal (1997) recently reviewed this literature.

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 (1952) 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).

In the Gunnison Basin, 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, p. 42). These life history stages have been identified as of critical importance to the Gunnison sage grouse (GBCP).

Riparian areas, which are critical for brood- rearing, are heavily grazed in the Gunnison Basin (GBCP, p. 43). These critical riparian areas have been impacted by livestock grazing (GBCP, 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, p. 42). Gully formation has also led to loss of surface moisture and vegetation (GBCP, p. 42). In the Gunnison Basin, gully formation is common and has caused the loss of surface water, the lowering of water tables, a reduction or elimination of riparian vegetation and the encroachment of upland vegetation on riparian areas (GBCP, p. 46).

Horses were extirpated from their center of origin, North America, at the end of the Pleistocene. Grass and shrubland ecosystems evolved without horses (or 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 1730. Reintroduced horses are believed to have intensively grazed some areas of the West at that time (Harris and Chaney 1984). Grazing by feral horses continues but has been reduced in most areas by trapping programs.

In this section, we discuss the effects of grazing *per se*. However, it is important to realize that livestock operations have many more negative effects besides those due to grazing, and such losses of sage grouse have been documented (SMBCP, 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. These effects are discussed in other sections below.

a) Direct Trampling Effects

Trampling of nests has been a concern since the early part of this century (Hornaday 1916, p. 188). Trampling of chicks is also a concern, although trampling of adults is unlikely Livestock also produce soil compaction (Adams, et al. 1982) particularly near water developments, which in turn are usually located on the best soils.

b) Trampling of Vegetation

Livestock also trample both sagebrush and grasses and forbs that sage grouse need for both food and shelter. 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. Upland meadows containing mesic sites such as streams, wet meadows, and springs provide important summer and fall habitat for sage grouse, especially in arid areas (Savage 1969, Oakleaf 1971, Autenreith, et al. 1982).

Livestock trample and damage cryptogamic soil crusts (variously known as microbiotic, microphytic, or cryptobiotic crusts). Crusts have been so reduced that it is now difficult to determine their exact range and role in sagebrush communities (Mack and Thompson 1982, St. Clair, et al. 1993).

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 1981, 1985; Autenreith, et al. 1982; Winward 1991). 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 Gunnison sage grouse.

c) *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 of sage grouse chicks during their early developmental period.

Competition from cattle for native grasses is considered 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, Gelbard and Belsky 1999). 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.

d) *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). 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).

e) *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 and 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). 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 provide 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, and on promoting equable soil temperature regimes (Belnap 1993, 1994; St. Clair and Johansen 1993; Kaltenecker 1997).

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*) (Hoffman 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, Gelbard and Belsky 1999). 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 Gelbard and Belsky 1999). Besides promoting the invasion of noxious species, cattle create an environment that is susceptible to invasion (review by Gelbard and Belsky 1999).

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, et al. 1993, Kaltenecker 1997).

2. 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, p. 39). Wind erosion can be a particularly strong erosive effect within the range of the Gunnison sage grouse. 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, p. 39).

3. 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 (Braun 1998a, DCCP, 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.

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, p. 22; DCCP, p. 23). Sage grouse are known to avoid fences in Colorado (Braun 1998); thus fences serve to fragment habitat.

4. 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 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 (Hays, et al. 1998, Schroeder 1998b). 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 heading 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). Habitat conversion is probably the major cause of sage grouse declines in some parts of Colorado, exceeding even grazing and livestock operations in those areas.

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 suburbanization 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.

a) 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 1984). Of the habitat required by sage grouse, 98% or more has been degraded since European 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 losses due to farming have been problems since the early part of the century (Hornaday 1916, p. 188).

Croplands can not 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.

b) Development and Habitat Conversion to Suburbs and Ranchettes

Suburbanization (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 buildings on working ranches 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 greater than 1%. 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 countý, Colorado (Brigham 1995b). Suburbanization also tends to occur near water, where higher quality soils are located, so its population impacts are also likely to be disproportionate to the amount of habitat affected.

Suburbanization rates are disproportionately greater than population growth. 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.

Suburbanization also unleashes large numbers of domestic pets, which can predate 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, p. 47).

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

c) 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 years, but only if migration corridors from population source areas are available (see Braun 1998a). 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, p.47).

d) *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). A habitat quality model suitable for remote sensing (thematic mapper) and GIS applications has already been developed (Edelmann 1998). For example, the Interior Columbia Basin Ecosystem Management Plan (ICBMP) 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.

5. 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 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. 1954). Often, sagebrush is removed to allow for the growing of crested wheatgrass (*Agropyron cristatum*) for livestock forage (Drut 1994, p. 21). There are a large number of studies on the effects of such treatments and all studies have shown that effects on sage grouse are detrimental (Rogers 1964; Klebenow 1970; Martin 1970; Pyrah 1970a, 1971; Wallestad 1971, 1975a, 1975b, Braun, et al. 1977). 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. 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).

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 its 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 1987).

6. Invasive Species

Invasive species are a major cause of species extinction, second only to habitat loss (Flather, et al. 1994; Wilcove, et al. 1998). 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 are spreading through grass and shrublands at rapid rates, and these rates are increasing in many areas (Quigley and Arbelbide 1997c). 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, 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). Alien species affect other threats to sage grouse, and in turn, are affected by other threats discussed in this report.

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 report.

Cheatgrass (*Bromus tectorum*) in particular can alter fire regimes, and outcompetes native grasses and forbs (Kauffman 1990). Eventually, cheatgrass creates a non-diverse uniform annual grassland which carries fire so frequently that shrubs and perennials cannot co-exist (Whisenant 1990). 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 knapweed are widespread in sage grouse habitat.

Cryptogamic crusts are affected by cheatgrass and other invasive plants (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).

Creation of microsites by grazing and other soil disturbing activities is a major factor in the invasion of alien plants into shrubsteppe ecosystems (Mack 1981). 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, as well as by damaging the soil. In the Gunnison Basin, invasion of cheatgrass is particularly evident along roads (GBCP, 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.

Attempts to control invasive species can expose the birds, and plants they need for food and cover, to herbicides, pesticides, and endocrine disrupters.

Today, cheatgrass threatens to dominate or completely convert 25 million hectares (62 million acres) – over half of the sagebrush eco-region in the West (Rich 1996). Other invasive exotics, such as medusahead (*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 1980, West 1996). Over 40 million hectares have been invaded (Mack 1989, Whisenant 1990).

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. Crested wheatgrass plantings damage sage grouse habitat by replacing plants used for food, shelter and concealment such as sagebrush and forbs (Beck 1975), and by altering the fire regime. Sage grouse have occasionally used areas planted to crested wheatgrass (*Agropyron cristatum*) as lekking grounds. The use of crested wheat grass 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).

7. 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). 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, 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).

Water developments can also concentrate water and soil moisture. Sage grouse do not require open water, but do require fobs. Water developments, by spatially concentrating water and soil moisture, replace a 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.

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. 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.

8. Logging

Logging could 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 trees that can serve as raptor perches and have recently invaded sagebrush areas may be required for sage grouse recovery in some areas.

9. Predation

Most predation on sage grouse takes place as nest predation or on chicks (Braun 1975, Autenreith1986, Bergerud 1988). However, predation of females about to breed is probably 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 1988). 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.

To the extent that predation merely substitutes for other factors reducing fitness, and takes place at the same stage of the life history, it is of little consequence to evolutionary metrics such as mean population fitness, or even to ecological phenomena such as population persistence. Unfortunately, most sage grouse now exist in very small populations, isolated from other populations by fragmentation, thus any impacts are important (Commons, et al. 1998). These impacts were demonstrated by predator removal experiments, which substantially increased hatching 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 predated. 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). Adult males are more often predated 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. Sage grouse may thus be an exception to the finding by Lande (1988) 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).

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 1998). 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 (DCCP, 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, p. 25). 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, p. 49).

Predators on adult and juvenile sage grouse include: coyote (*Canis latrans*) (Kindschy 1986), bobcat (*Lynx rufus*) (Bailey 1981, Kindschy 1986), badger (*Taxidea taxus*) (Kindschy 1986), falcons (Falconidae) (Pennycuick 1994), and hawks, kites, and eagles (Accipitriidae) (Beck 1975, Dunkle 1977, Kindschy 1986, Phillips 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 (CSCP, p. 47). Coyote predation is a concern for the Gunnison sage grouse (GBCP, 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. This is a particular problem in the Gunnison Basin (GBCP, p. 49). Crows and ravens (*Corvus spp.*) and magpies (*Pica spp.*) predate juvenile birds (Kindschy 1986) and are attracted by dump sites and livestock feeding operations (YTC CA 1994). Ground squirrels (*Spermophilus spp.*), coyotes, weasels (*Mustela spp.*) and badger 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). Yearlings have higher nest predation rates than adults (Peterson 1980). In the Gunnison Basin, ground squirrels and weasels have predated up to 50% of the yearly nest and egg production (GBCP, p. 49).

The Oregon Dept. of Fish and Wildlife proposed that predation was the limiting factor on sage grouse populations. 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 (Drut 1994, p. 22). This ignores 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) and there is no reason to believe it will help conserve sage grouse.

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, p. 24). 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 1991).

10. Competition

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

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

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

11. Noise and Acoustic Interference

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 1996, Gibson and Bradbury 1985), thus noise can have profound effects on population viability. Traffic on roadways, oil and gas wells, and concentrations of livestock can all interfere with acoustic signals by sage grouse (GBCP, p. 22). 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 1 km from a road. Contact enhancement between the hen and newly hatched chicks is mediated by acoustical signals (Girard 1937, Patterson 1952). Therefore, noise effects will be particularly important during the brooding period.

Frequency spectra of noise sources need to be compared to the detection ability of sage grouse at each frequency, but such data are lacking. The transmission of different sound frequencies through forest habitats types has been determined (Wiley and Richards 1978, Richards and Wiley 1980), but the attenuation of noise spectra over sagebrush areas has not been determined. However, it is highly likely that all frequencies of noise will travel much greater distances from the source over sagebrush than through forested areas, because sagebrush areas have no height of leaves and branches to attenuate noise spectra.

Low frequency (infrasonic) sound is easily detectable by at least some species of birds (Kreithen and Quine 1979, Dooling 1982) and forms a component of sage grouse mating displays. Low frequency sounds also propagate for great distances (Marten and Marler 1977, Morton 1975, Witkin 1977, Wiley and Richards 1978). Thus, such sources as artillery fire, seismic exploration explosions, mining, and drilling may be particularly disturbing to the birds.

There appear to have been no studies of the effects of noise conducted on sage grouse. Thus, the best available scientific data are obtained by analogy to other species. Most studies of noise effects on birds appear to have been conducted on raptors and the results of such studies have been variable. Studies on raptors and other predators may not be particularly relevant to prey species such as sage grouse. Prey must remain alert to predators, and are likely to have behavioral responses to abrupt sensory stimuli (startle responses) that disrupt feeding, courtship, or other important behaviors. Studies of other avian prey species appear to have centered on geese. There are no data on noise propagation, or on signal detection showing differences in the habitats between geese and sage grouse. Such studies appear to be appropriate guides to effects of noise on sage grouse because, like sage grouse, geese occupy open habitats, nest and forage on the ground (although the water and land mix is quite different), and face threats from both aerial and ground based predators. Helicopter disturbance can have serious effects on brant (Derksen, et al. 1992). Fixed site noises, such as those associated with geothermal or oil exploration, drilling, and pumping operations, or with mining can also cause problems for sage grouse.

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

12. Fire

Direct fire-related mortality of sage grouse has not been documented in the literature; however, fire has strong and complex effects on sage grouse habitat. Prior to settlement, wildfire was the major disturbance agent in shrub-steppe habitats (CH2M-Hill 1996), but fire return intervals may have been fairly lengthy in many or most sagebrush habitats (Winward 1985, Braun 1987). Most species of sagebrush are killed by fire (Winward 1985, Peterson 1995, Wright, et al. 1979). However, early explorers found sagebrush to be both widespread and abundant in the west (Townsend 1839; Fremont 1895; Thwaites 1959; Tisdale, et al. 1969; Gambel 1974a, 1974b, 1974c; Vale 1975; Evans 1997). These vast sage lands could not have existed if stand replacement fires had been frequent. Tisdale and Hironaka (1981) suggested that fires were uncommon in the drier sagebrush types, and more frequent in areas with higher fuel loads. Together with overgrazing, fires caused by settlers are implicated in the reduction of sagebrush and of native grass and forb understories (Tisdale and Hironaka 1981).

Depending on habitat quality before the fire and the type of fire, fire can be beneficial or harmful to sage grouse. Sage grouse use sagebrush of different age classes and stand structures as lekking, nesting, brooding, and wintering grounds. Neither expansive dense sagebrush nor expansive open areas constitute optimal sage grouse habitat: Klebenow (1973) reported that in three summers of sampling, no sage grouse were observed in large acreage, dense sagebrush in southern Idaho.

Fire that creates a mosaic of sagebrush of different ages and structures would benefit sage grouse (Klebenow (1973). Newly burned areas interspersed with patches of sagebrush offer increased forb production while providing nesting and brooding cover (Blaisdell 1953, Hargis, et al. 1986, Mangan and Autenrieth 1985, Martin 1990). The younger age classes of sagebrush that establish after fire offer more nutritious and palatable browse than do old sagebrush stands (Gates, et al. 1984). Additionally, burns can provide new lekking sites: sage grouse have established leks on burns in areas where open cover was lacking before fire. Sage grouse show lek fidelity, however, and may not use burns as lekking grounds if there is a sufficient number of old leks (Benson, et al. 1991).

Fire always removes a certain amount of sage grouse food and cover. Fire initially reduces insect populations (Fischer 1994) which are required by young chicks (Johnson and Boyce 1990). Griner (1939) noted that burning resulted in a decline in sage grouse in Utah. If the burn is small in relationship to the surrounding area, it will probably enhance sage grouse habitat. Fire that destroys large tracts of sagebrush, or destroys key winter habitat, can be harmful (Klebenow 1969, 1973). However, large-acreage fires do not always harm sage grouse. A 17,250-acre (6,900-ha) wildfire in mountain big sagebrush in southern Idaho burned in a mosaic pattern, leaving many unburned islands. The wildfire occurred at an ebb in the sage grouse population, so nesting sites were not limiting in the first postfire nesting season. Overall effect of the wildfire on the sage grouse population was apparently neutral: the sage grouse population increased after the fire, but this was part of a regional trend of sage grouse increase following several years of low reproduction. Martin (1990) suggested that had nesting habitat been limiting, the large-acreage fire probably would have adversely affected the sage grouse population.

Suppression of natural fires allows invasion of pinyon pine (*Pinus spp.*) and juniper (*Juniperus spp.*) into sagebrush areas (Miller and Wigand 1994, Miller and Rose 1995, Belsky 1995, Davenport, et al. 1998). Expansion of pinyon and juniper into sage grouse habitat reduces the use of these areas by the birds because of increased predation (Commons, et al. 1998).

Some sagebrush species (*A. cana*, *A. filifolia*) can resprout after burning, suggesting that they evolved with fire (Braun 1998a). Big sagebrush (*A. tridentata*) is killed after burning and cannot resprout (Wright, et al. 1979), suggesting that it did not evolve with fire (Braun 1998a).

Cheatgrass and other non-palatable species can invade after a fire (Pickford 1932, Stewart and Hull 1949). Once present, cheatgrass can alter fire regimes to the point that many sagebrush stands are eradicated (GBCP, p. 41). Once cheatgrass is established, it is extremely difficult to remove and can prevent sagebrush from recolonizing an area – the endpoint of community succession has been altered (see Invasive Species section). Land managers are partly to blame for habitat conversion: after a burn, areas are often seeded to crested wheatgrass instead of native vegetation and are thus eliminated as sage grouse habitat (Wallestad 1971, Martin 1976, Braun, et al. 1977).

Fire is much more likely when humans and their developments are present in sage grouse habitats. Roads, ORV use, oil and gas or coal developments, suburbanization, unattended campfires, agricultural operations, and other human activities can greatly increase fire risk. Fires in forests or woodlands can also spread into sagebrush areas.

a) Temporal Fire Regimes

Fire regimes can be roughly divided into three temporal periods. The earliest period would be wholly natural and occurs before aboriginal human populations reached North America. The middle period includes the time of Native Americans and may begin 15,000 to perhaps 50,000 years ago. Fire was probably somewhat more common during this period because of anthropogenic origin; however, fires may have been less intense because increased frequency reduced fuel loads. Sage grouse are known to have been extremely abundant at the close of the middle period, so Native American land management practices and hunting cannot have had especially severe effects on populations. Fire intervals are poorly known but probably did not exceed 30 to 50 years in most areas (Bunting, et al. 1987, Bunting 1994). In southern Idaho, fire return intervals are thought to have been 20 to 25 years in wetter regions, and 60 to 110 years in arid shrub-steppe (Tisdale and Hironaka 1981; Whisnant 1990). Fires were probably patchy and small in extent except in very dry years. In Nevada, fires may not have been important in determining vegetation type (Paige and Ritter 1999, p. 6 citing McQuivey).

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

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

Burning of grasslands at the sagebrush-pinyon-juniper interface probably prevented the spread of conifers into sagebrush areas (Bunting 1994, Evans and Workman 1994). Fire would not have burned uniformly and large areas went unburned for decades (Winward 1984, Braun 1987). Of particular importance is that natural fires in the past did not operate the same way as fires do at present. Today, fires burn much larger areas, and burned areas often have large numbers of confined livestock grazing soon after the fire passes (GBCP, p. 42). Another factor today is that cheatgrass invasions have likely altered fire return times for many areas. Finally, fire suppression has allowed invasion by western juniper (*Juniperus occidentalis*) and increased canopy cover by sagebrush (Kauffman 1990). These vegetative changes have reduced grass and forb cover, an essential habitat component for sage grouse (Winward 1991).

b) Use of Fire

Howard (1966) called for a diversity of sagebrush habitat, in terms of sage grouse food and cover, as a management objective. Klebenow (1973) recommends burning sagebrush on a rotational basis to create sage grouse habitat. Different patches should be burned each year or every few years, with as long as 20 years between burning each patch. Benson, et al. (1991) recommend burning in patches of less than 100 acres in size. Because livestock may concentrate in small burns, livestock should be excluded from the burns to optimize revegetation. Fire can enhance forb production (Cook, et al. 1994) and sage grouse may respond to this by foraging in burned areas (Pyle and Crawford 1996).

No general, overall benefits of fire to sage grouse have been documented, and some disagreement exists among the sage grouse experts in various state wildlife agencies and universities. This may well result from elevational and other edaphic differences in sage grouse habitat in the respective states, and the degree and imminence of threats from cheatgrass invasion. This disagreement needs to be resolved so that management plans for use or containment of fire to improve habitat and recover sage grouse can be developed. A large body of fire effects data has been developed for forests and some of those general concepts may be applicable to sagebrush shrub-steppe. It is safe to say that fire must be used in a very careful and well monitored fashion if it is to be encouraged at all (Benson, et al. 1991, Fischer, et al. 1996, Connelly and Braun 1997, Connelly, et al. 1998). Gains expected in multi-aged vegetative mosaics must be balanced with both potential loss of sagebrush *per se* and the risk of cheatgrass invasion. The total area burned by both wild fire and prescribed fire at 10 year intervals is unknown, but appears to be increasing (Connelly and Braun 1997). If used at all, fire must be used very carefully, and alternative methods of vegetation modification must be strongly considered.

(1) Fire on Leks and Nesting Grounds

Fire that occurs outside the mating season will probably not affect postfire sage grouse use of the grounds for mating. Fall wildfires on sage grouse leks in southern Idaho had no effect on sage grouse use of the leks the next breeding season (Martin 1990). Areas immediately surrounding leks, however, are heavily used as nesting grounds, and fire in areas surrounding leks may have a negative impact on consequent use of the surrounding areas by hens. Wallstad and Pyrah (1974) recommend that sagebrush within 1.9 miles (3.2 km) of a lek not be burned in order to protect nesting habitat. This recommendation may be most applicable to areas where nesting habitat is limited, however. Also, it is now established that nesting often takes place at substantially greater distances from the lek than was believed in 1974, at the time of the Wallstad and Pyrah study.

Gates and Eng (1984) noted that on their southern Idaho study site, which was surrounded by 120 square miles (300 km^2) of Wyoming big sagebrush, nesting habitat was plentiful. While their summer-fall prescribed fires did burn near several established leks, the fires also created an open area that sage grouse used as a lekking ground the next spring. The fire treatment apparently did not deter hens from using grounds adjacent to the burns for nesting and brooding. Most radio-collared sage grouse hens nested within 3 miles (5 km) of the lek on which they were captured the year before fire treatment. In the first summer postfire, 5 of 11 collared hens moved their brood into agricultural areas adjacent to the burn. Broods apparently made little use of the burns as foraging areas. Schlatterer (1960) and Dalke, et al. (1963) noted that following unintentional fire, sage grouse used small burned openings as leks. To create openings in homogeneous sagebrush, Klebenow (1973) recommended small fires, 1 to 10 acres (0.4-4 ha) in size.

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

(2) Brooding Areas

Fall spot fires burning several patches of a few acres can result in suitable brood rearing areas by increasing forb availability. Spot burns along edges of meadows where sagebrush is encroaching may also enhance brood rearing areas if adequate sagebrush-meadow ecotone is left to provide cover (Howard 1996, Autenrieth, et al. 1982). Martin (1990) noted that in southern Idaho, broods neither preferred nor avoided large burned areas ($P<0.05$).

(3) Wintering Areas

Klebenow (1973) does not recommend burning in winter habitat. Autenrieth, et al. (1982) recommend that fire in winter-use areas be applied cautiously: what may appear as an excess of sagebrush in summer may provide only minimal amounts of sagebrush in winter. They recommend that prior to burning, winter sage grouse distribution during peak snow conditions should be assessed so that key wintering grounds are not depleted by fire.

13. Roads

Roads eliminate habitat directly because the road surface itself and the band of altered vegetation on both sides of the road and its drainage structures do not support the needed habitat characteristics for sage grouse. Roads also induce noise effects from passing traffic that can disrupt lek activities, inhibiting mating. Braun (1998a) estimated that noise effects would be disruptive as far away 1 km from a road. Additionally, raptors may use road signs as perches. Roads also restrict movements of sage grouse and remove culturally transmitted knowledge of traditional movements from the population (SMBCP, p. 22, Cultural Inheritance section of this report). Roads are particularly pernicious in their fragmenting effects on populations because they constitute linear isolating elements in the landscape – there may be no way to transit a landscape without crossing a road. Many of the effects of roads are also present for railroad lines.

Traffic on roads, particularly paved roads or graveled through routes, causes direct sage grouse mortality by mechanical impact, or can disrupt energy budgets and behavioral activities when they must evade speeding traffic. Bean (1941) counted 11 sage grouse killed by automobiles and this mortality factor continues today (Hays, et al. 1998 citing Schroeder, personal communication). Sage grouse often prefer to walk to reach useable habitats except when snow cover increases their conspicuousness (GBCP, p. 48, SMBCP, p. 22). This form of locomotion greatly increases their danger from traffic. In the Gunnison and San Miguel Basins, all primary and many secondary roads reduce the size of sage grouse populations (GBCP, p. 47, SMBCP, p. 22). Sage grouse use roads to dust bathe which makes them particularly susceptible to vehicular collisions (Bean 1941). Sage grouse will also dust bathe along the margins of paved roads, so it is not only dirt or gravel roads that pose a hazard.

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

14. Off Road Vehicles

Clampitt (1993) reported that off-road vehicles (ORVs) caused alterations of grass and forb cover and reduction of plant species diversity. ORV operation is a well known cause of soil compaction, reduced water infiltration rates, and negative effects on vegetation (Adams, et al. 1982, Eckert, et al. 1979, Iverson, et al. 1981, Webb 1979). Many of the effects of ORVs are discussed in the section Military Operations.

Even light use of a truck on a shrub landscape can damage the shrubs (Vollmer, et al. 1976). Not surprisingly, ORV use causes decreased diversity, density and biomass of breeding birds, and ORVs have a negative effect on desert wildlife over large areas (Bury, et al. 1977).

Affected areas can take extremely long times to recover, or may not recover at all (Iverson, et al. 1981). In the Gunnison Basin, ORV use is "increasing and expanding into more and more sagebrush and riparian areas" (GBCP, p. 50). ORVs and other motorized vehicles tend to travel in valley bottoms, which are particularly critical to grouse because these areas are one of the most important feeding areas for young birds (GBCP, p. 50). Roads and trails formed by ORVs become corridors for predators and for invasive plant species (GBCP, p. 50).

ORV use also is a major cause of invasion of weed seeds and other pests into grass and shrub lands (Tyser and Worley 1992, Hobbs and Humphries 1995, BLM 1996a). Landscape scale is important in understanding the invasion of weeds, and ORVs and livestock are of primary importance in introducing weeds from roadsides into grass and shrub land areas away from roads (Gelbard and Belsky 1999).

Snowmobile use causes harm to wildlife, vegetation and soils. Because of their high noise levels and extreme speed, snowmobiles harass sage grouse and other wildlife, causing increased metabolic rates and stress responses. During the winter months, sage grouse are especially vulnerable to this harassment because they are already burdened by increased levels of stress due to low temperatures, inclement weather, and reduced food supply, and the need to gain weight for the energetically demanding breeding season. Snowmobile use can also cause disruption in movement patterns, making it more difficult to locate reliable food sources. These impacts are best understood and documented for ungulates (Cain, et al. in press, Greer 1979, Moen, et al. 1982, Parker, et al. 1984, Severinghaus and Tullar 1975); nevertheless, many other wildlife species suffer the same sorts of direct impacts from exposure to and harassment by snowmobiles. It is virtually certain that sage grouse within the range of snowmobile use will be harassed by noise and visual impacts. Accumulation of snowmobile exposures over the course of a winter or several seasons can result in significant long-term wildlife displacement and expanded home ranges, increasing winter stresses and energy expenditures. In many winter areas, sage grouse have very limited suitable habitat available. As a consequence, wildlife often suffer increased winter mortality in areas where snowmobiles are used, even in low intensities (Berwick 1968, Bury 1978, DeMarchi 1975, Dorrance, et al. 1975, Neumann and Merriam 1972).

In winter, snowmobile and other ORV use can cause significant damage to exposed and unexposed vegetation. Abrasion and breakage of seedlings, shrubs, and other exposed vegetation is common (Neumann and Merriam 1972, Rongstad 1980, Ryerson, et al. 1977). Similarly, shallow roots and rhizomes such as are found in sagebrush can be crushed or otherwise damaged. Especially on steeper slopes, and particularly when snow levels are low, snowmobile use can lead to considerable soil erosion. Increased sedimentation and turbidity, for instance, can occur both in the immediate area and throughout the watershed (Aasheim 1980). Repeated snowmobile use can lead to changes in plant density and species composition and set back seral stages (Aasheim 1980, Wanek and Schumacher 1975), and the associated loss of vegetative cover generally leads to increased soil erosion (Montana Fish, Wildlife and Parks 1993).

Snowmobile-induced snow compaction is implicated in numerous, often overlooked environmental impacts. For instance, snow compaction can cause considerable below-surface vegetation damage (Neumann and Merriam 1972). Significant reductions in soil temperatures may also result from snow compaction (Aasheim 1980, Rongstad 1980), retarding both soil microbial activity and seed germination (Keddy, et al. 1979), and these impacts may be exacerbated by compaction of the underlying soil layers. Snow compaction is also responsible for numerous and severe impacts to sage grouse because they depend on subnivean spaces (the spaces between the snowpack and the ground surface) for winter survival. Compaction lowers the temperatures in subnivean spaces, which in turn leads to increased metabolic rates, and thus, increased mortality or reduced energy stores. In some cases compaction restricts movement to the point of asphyxiation. When snow is compacted, grouse must work harder to dig for vegetation (Fancy and White 1985), increasing their energetic demand and increasing the amount of time they are exposed to harsh conditions and predators on the snow surface. Surface snow compaction by snowmobiles also increases the mobility of terrestrial predators such as coyotes, bobcat, and red fox (Neumann and Merriam 1972). Finally, because most of the snow compaction occurs on the first snowmobile pass, even minimal use of any area can cause considerable damage (Aasheim 1980; Gabrielson and Smith 1995; Keddy, et al. 1979). Snow compaction often retards melting of snow, altering vegetative phenology, besides leading to muddy trails and roads, which are then highly susceptible to significant damage and enlargement. For the same reason, snow compaction can lead to altered melting and discharge regimes, further increasing soil erosion (Montana Fish, Wildlife & Parks 1993). Smith (1996) recently summarized snowmobile impacts.

ORV use is accelerating and as BLM states, has shown a "dramatic increase" in just the last few years (ABC News 1999). Other federal lands are also experiencing rapid increases in ORV use (ABC News 1999).

15. Military Operations

Military operations include troop movements, cross-country operation of tracked and wheeled vehicles, military overflights (often very close to the ground), live firing exercises of small arms and artillery, the dropping of both live and dead (dummy) bombs, and stationing of mechanized and armored combat forces and construction of various temporary and permanent installations with their associated utility needs. The deleterious effects of ground based military operations are concentrated in the best sage grouse habitat, because both sage grouse and military trainers prefer areas with slopes of less than 10% which comprise a limited subset of lands in many areas of sage grouse habitat (Caldwell, et al. 1997, Livingston 1998). Generally speaking, the best soils, best vegetation, and most critical habitat are in valley bottoms with slopes of less than 10%.

Use of tracked vehicles ("tanks") can cause even greater damage than use of ORVs. Both operations in a straight line and turning or stopping of the vehicle (causing divots) are significant causes of erosion, sagebrush destruction and understory destruction (Watts 1998). Effects on cryptogamic crust are particularly severe (Watts 1998). Both vehicle and foot traffic are known to compact soils, increase erosion, reduce vegetative cover, facilitate the spread of alien plants, and increase fire frequency. Firing of tracer bullets and use of pyrotechnic devices are major sources of fire (YTC CA 1994, p. 4, section VI.H). Troop training also involves the excavation of soil for foxholes, latrines, and other uses, and the establishment of bivouacs, which damage vegetation.

Sage grouse are particularly vulnerable to human disturbance at nests and lek sites. Females are known to abandon nests and possibly their broods if disrupted by foot traffic such as troops, by vehicles, or by explosions and noise (Livingston 1998). Leks are likely to be abandoned if vehicles drive on the roads while sage grouse are displaying or mating. Sage grouse on military areas have a number of unusual behaviors, such as large home ranges, atypical and extensive movements, and the seeking of areas with low levels of human disturbance, that are likely related to disturbance by military training operations (Eberhardt and Hoffman 1991).

Military operations can also degrade habitat, and military operations areas often have low levels of sagebrush cover (Caldwell, et al. 1996, Sveum, et al. 1998a). Further loss of sagebrush is particularly endangering to the birds, yet is more likely than in other areas because of the likelihood that military operations will set off fires. Even a single training exercise can do tremendous damage to sage grouse habitat. In 1995, the Yakima Training Center (YTC) conducted an exercise termed Cascade Sage, which impacted approximately 14% of the big sagebrush in sage grouse primary habitat, and immediately killed 1.7% of all sagebrush plants in the area, and severely damaged 7.8% of all sagebrush plants in the area (Caldwell, et al. 1996). Damaged plants, of course, may die later on, and do not provide needed cover for sage grouse, which declined following the exercise (Caldwell, et al. 1996). These deleterious effects are not unusual: training by the Washington Army National Guard in 1996 caused similar levels of habitat destruction (Stephan 1996). Nor are these isolated instances: training exercises on the scale of Cascade Sage are planned to reoccur regularly in future years. Such negative impacts will have serious cumulative effects on sage grouse. Caldwell, et al. (1996) estimated that exercises of this scale will reduce sage grouse habitat by nearly 1% per year, a loss of 133 hectares every year. Additional losses of sagebrush are expected due to training related fires and natural mortality. Caldwell, et al. (1996) estimate that sagebrush cover would decline to merely 5.4% after 25 years of such biannual training, which is well below even the minimal level needed to support sage grouse. Stephan, et al. (1996) presented similar estimates of cumulative habitat loss from military training.

16. Oil and Gas Operations and Prospecting

Prospecting and operations for oil and gas, mining, and other such resource development typically involves the use of ground vehicles and road construction. Prospecting often involves setting off underground explosions which can interfere with the low frequency mating vocalizations of male sage grouse and otherwise disturb the birds. It is known that "sage grouse use decline[s] markedly" in areas with coal, oil and gas installations (BLM undated, p. 33).

The use of low-flying helicopters, in an attempt to avoid ground disturbing activities, can also enhance the dispersal of weed seeds, as well as create high noise levels that interfere with sage grouse activities. Aircraft over-flights are apt to be particularly disturbing to prey species such as sage grouse, as explained elsewhere in this report.

These resource development activities also require an infrastructure which is harmful to sage grouse. For example, oil and gas field facilities such as powerlines, treater stacks and storage tanks create raptor perches which greatly increase predation on sage grouse and produce sage grouse avoidance of large areas near each facility even in the absence of any predation. Moreover, human activity around facilities increases the incidence of poaching, road kill, and noise and movement effects producing avoidance behaviors in sage grouse.

17. Utility Corridors

Pipelines, electrical transmission lines, and the like cause degradation of natural vegetation, soil disturbance, and the hydrological regime (Artz 1989). Recovery times for vegetation on these areas are 30 to 100 years or even longer (Artz 1989). Pipeline construction can probably be managed so as not to permanently disrupt sage grouse activities. This will require narrow disturbance zones, reseeding or replanting of native vegetation, construction limited to seasons when sage grouse are not using the area, and effective closure of roads and trails nearby.

Utility poles also represent perches for aerial predators and can serve as a behavioral deterrent to migration. Electrical utility poles and their lines can permanently disrupt sage grouse populations (Graul 1980; Ellis 1984, 1987). Sage grouse are known to reduce their use of areas near power lines, even as far away as 600 m (Braun 1998a). Fragmentation effects and reductions in security of sage grouse are estimated to extend out for more than 1 km (Braun 1998a). In both Utah and Colorado, studies have documented the loss of all leks visible to perching raptors on powerline poles (GBCP, p. 47; DCCP, p. 23). Other data, including pellet counts and radio-tracking data, also support the magnitude of the effects on sage grouse. Sage grouse have also been observed to fly into powerlines (Hays, et al. 1998 citing Connelly, personal communication).

Powerlines also directly affect sage grouse in terms of collisions. Sage grouse have been seen to fly into powerlines (Hays, et al. 1998 citing Connelly, personal communication).

Much of the data on utility corridors have probably been compiled in spatial form, and the remote sensing and GIS techniques noted elsewhere in this document are easily applicable to this issue. The "effects of powerlines on sage grouse are severe" (GBCP, p.47, SMBCP, p. 21). Sage grouse "avoid powerlines when possible" (DCCP, p. 23). Paradoxically, utility companies have often tried to create raptor perch sites to enhance wildlife.

A design that eliminates perch sites for raptors may reduce the impact of power lines on sage grouse (Braun 1998a); however, if sage grouse respond negatively not to raptor silhouettes on powerlines, but to the powerlines themselves, the mitigation becomes much more costly and rerouting or burial will be required.

18. Weather

By weather, this report adopts the conventional view that weather encompasses relatively short-term changes in such variables as precipitation, temperature, wind, and solar insolation, while climate refers to longer term changes in these factors. Weather events have direct effects on adult birds (Walsberg 1978, 1983; Walsberg and King 1978b; Gessaman and Worthen 1982; Root 1988a, 1988b), their eggs (Walsberg and King 1978a; Webb and King 1983) and chicks (Webb and King 1984). For sage grouse, weather events can reduce breeding populations by 50% (letter from Montana Dept. of Fish, Wildlife and Parks, cited in Drut 1994, p. 19, p. 40). In combination with other factors, such as habitat fragmentation, grazing, and hunting, such episodic weather events as heavy rain, snowfall, or hail could easily cause multiple population extirpations within the range of the sage grouse.

19. Climate Change and Global Warming

Climate refers to long term changes in weather. The greenhouse effect is the term used to describe the trapping of heat in the atmosphere by various gases. Carbon dioxide (CO_2) is estimated to account for about 49% of the contribution to the greenhouse effect (Hansen 1988). Methane, nitrogen oxides (NO_x), and chloroflurocarbons (CFCs) are the main gases accounting for the remainder of the greenhouse effect (Hansen 1988). Interestingly, livestock are estimated to account for 15% of methane inputs to the atmosphere – each cow emits 400 litres of methane per day because it farts or belches every 90 seconds. When summed over the number of cattle on Earth, this is a very large amount of methane.

Regardless of the sources of the greenhouse effect or whether the greenhouse effect itself is a significant contributor to planetary warming, the warming trends are real and could have severe effects on sage grouse and their habitat. Prairie has been retreating westward in Recent times (T. Webb 1981), and this is likely occurring with sagebrush as well, reducing the habitat available of sage grouse.

Warming would push the entire range of sage grouse and their required habitat northward. Unfortunately, even if the birds could migrate quickly enough, their required plants could not. Second, even if sage grouse were able to establish new ranges on new habitat, most of that habitat would then be in Canada, not in the U.S., and the birds' status in the U.S. – the *sine qua non* of the Endangered Species Act – would be in even greater jeopardy.

20. Ozone Layer Depletion

Thinning of the layer of ozone in the Earth's atmosphere removes the primary barrier to the transmission of ultraviolet rays (UV). Increases in high energy UV radiation can damage plant tissues, thereby inhibiting plant growth and vigor and affecting photosynthesis, can cause thinning of avian eggshells, and can affect insect production (GBCP, p. 45). Thus ozone depletion can affect sage grouse directly, as well as by reducing their food supply. Effects on eggs and young chicks will be particularly strong in areas where livestock grazing has removed radiative cover from nesting areas (Webb 1993b).

21. Natural Factors and Environmental Variation

Environmental variation in climate, food sources, and predators is high in the areas used by sage grouse. This contributes to significant environmental stochasticity making it even more likely that small populations of these birds will become extirpated.

Sage grouse ranges are generally xeric with high evapotranspiration rates except in northern latitudes, and low rainfall, ranging from 15 to 32 cm per year. Available moisture for plant growth is highly variable, and drought is common both seasonally and for periods lasting for several years (Palmer 1965, Braun 1998a). Drought periods seem to often exacerbate declines in sage grouse populations (Patterson 1952, p. 68-69; Connelly and Braun 1997). Drought is believed to reduce grass and forb cover, much as grazing does, causing increased detection by predators, and decreased food availability both of forbs directly and of insects which eat and make use of the forb cover (Klebenow and Gray 1968; Peterson 1970; Drut, et al. 1994a, 1994b; Gregg, et al. 1994; Fischer, et al. 1996). Factors affecting populations interact, and if a major drought occurs at a time when habitat has been severely degraded by grazing and other effects, the effects on sage grouse populations could be catastrophic. Drought is known to reduce forb cover at brooding sites and cause low production of young (Young 1994, p. 45). One prediction from global warming models is increased drought in continental interiors, such as the range of the sage grouse.

Drought impacts both plants and insect populations that sage grouse depend upon for food and cover. In the Gunnison Basin, both nesting success of females and brood survival decline severely during years with low soil moisture (GBCP, p. 45). This effect is compounded if land management practices remain unchanged during years with low soil moisture (GBCP, p. 45).

22. Effects of Chemical Agents

Use of herbicides, pesticides, and other chemical agents is known to have damaged sage grouse populations, even though it has been little studied. Effects on sage grouse are surely larger than have been reported, and limitations on the use of various chemical agents will be required to recover the bird.

Both herbicides and insecticides are consumed by, and will often be bioaccumulated in insects, which are an important food source for both chicks and pre-laying hens. Thus, the most susceptible life-history stages of the bird are exposed to chemical agents.

Besides the effects on habitat, water sources can be contaminated by spraying of nearby fields which drain into the water source. Breakdown of chemicals in dry soils may be particularly slow, due to lack of microbial activity in low moisture environments.

a) Effects of Herbicides

A variety of chemical herbicides have been used to remove sagebrush and other shrubs in sage grouse areas. Besides any direct effects on the birds, such chemicals are used to target habitat which the birds need. Herbicides are also used for weed control. Common herbicides used have been 2, 4-D, 2, 4, 5-T, and Tebuthiuron, often labeled as Spike 20 or Grasslan (Braun 1998b). Use of 2, 4-D was curtailed in the late 1970s but is now increasing again, as is that of Tebuthiuron (Braun 1998b). Despite the deep affection for Tebuthiuron by BLM and some other land management agencies, Braun (1998b) noted that no study has ever "demonstrate[d] any positive responses by sage grouse to any tebuthiuron treatment anywhere in sage grouse range."

Moreover, Braun examined several tebuthiuron treated areas and found all of them to be harmful to sage grouse, at least over the short time frame of the studies conducted (Braun 1998b). Consequently, he recommended that his state agency (Colo. Div. Wildlife) not support its use at all and prohibit its use on state lands (Braun 1998b). Treatment of large patches (200 or more ha in size) is particularly deleterious to sage grouse (Braun and Beck 1996). Tebuthiuron is particularly damaging to sagebrush and forbs, both critical habitat components for sage grouse (Braun 1998c, p. 3).

Despite the lack of data showing benefits to wildlife, millions of acres have been sprayed with these herbicides since the early 1960's, and Braun (1998a) estimates that more than 25% of all sagebrush areas has been affected. About 91,000 km^2 of rangelands were sprayed between 1985 and 1990 for grasshopper control alone (Johnson and Boyce 1990). Martin and Pyrah (1971, p. 137) and Martin (1965) describe the effects of treatment of a 1,700 acre area with herbicide. Over a 3 year study after the spraying, a total of 15 sage grouse were found in sprayed areas, while 400 sage grouse were found in unsprayed areas (Martin 1965, Table III). Sprayed areas constituted 90% of the total area, but yielded only 4% of the observations of sage grouse. The difference was related to alterations in the vegetative cover of the sprayed areas. Over 90% of the sage grouse that were in the sprayed strips were within 30 m. of an unsprayed area (Martin 1965).

Higby (1969) reported the extirpation of an entire wintering population of 1,000 birds from spraying in Wyoming. Moreover, the area was not repopulated for 5 years. After sagebrush was sprayed in the late 1950s in the Gunnison Basin, lek counts declined to about one-third of their former numbers near the treated area but did not decline in other areas (Hupp 1987b, p. 87, Fig. 13; Rogers 1964).

Wallestad (1975a) and Blus, et al. (1989) have noted the detrimental effects on sage grouse populations from contamination by spraying of herbicides and pesticides. Both authors discuss die-offs of birds using agricultural lands for foraging caused by chemical spraying. Besides their acute effects, many herbicides have chronic effects, and may act as endocrine disrupters. It is clear from the studies above that herbicide spraying completely destroys habitat for sage grouse. Habitat may not recover for decades after spraying.

b) Effects of Animal Pesticides

Pesticides have been used to kill various insects occurring in sage grouse habitat areas, including Mormon crickets, mosquitoes, and grasshoppers. Pesticides harm sage grouse populations by depleting their food supply, by acute poisoning, by chronic poisoning, and – at exceedingly low concentrations – may disrupt neuronal and endocrinological systems affecting immune function, development and behavior. Sage grouse chicks die of malnutrition if deprived of sufficient numbers of insects, and spraying of pesticides has been implicated in declines of other Galliformes (Johnson and Boyce 1990). The amount of sage grouse habitat exposed to pesticide contamination is unknown as is the magnitude of pesticide spraying; however, Johnson and Boyce (1990) estimated that over 5 million acres were sprayed between 1980 and 1985 to control just one insect species, the grasshopper. Blus, et al. (1989) documented the direct mortality of sage grouse from organophosphate insecticides used on cultivated crops. Carbamate pesticides are known to harm sage grouse (Blus, et al. 1989). Malathion and dieldrin are known to be toxic to a closely related species, the sharp-tailed grouse (McEwen and Brown 1966).

Sage grouse kills from organophosphate insecticides have also been noted in southeastern Idaho (Blus, et al. 1989). Sage grouse that fed on sprayed alfalfa fields were especially susceptible; however, even use of the sprayed alfalfa fields for roosting or loafing caused severe effects (Wallestad 1975, Blus, et al. 1989). Mere occupation of sprayed potato fields also caused death or severely adverse effects (Blus, et al. 1989).

Pesticides render habitat unsuitable for sage grouse by destroying the insect food supply needed for critical life history stages. Additionally, many pesticides have chronic effects, and can act as endocrine disruptors.

c) Effects of Endocrine Disrupters

A number of chemical compounds, some otherwise thought to be benign, have been implicated as causing subtle, but long-lasting effects, including behavioral alterations, and disruption of development. The term Endocrine Disrupters has been applied to many such compounds. Importantly, these effects are hypothesized to occur at concentrations several orders of magnitude below those at which either acute or chronic effects are known from conventional chemical agents. A second important concern is that effects are believed to have occurred at concentrations below detectability limits, even using modern analytical techniques, such as HPLC (high performance liquid chromatography) or mass spectrometry.

Sage grouse in areas that have been treated with Tebuthiuron (Spike) have been observed engaging in atypical behaviors. For example, during a period when most males were flocking, "one male [was] consistently alone in an area where sagebrush has been treated with Spike" (Brigham 1995a). Further, a male was observed sitting out "in the open" in "the heat of the day" even though a big sagebrush bush provided shade only 50 meters away (Brigham 1995a). Although anecdotal, such observations may reflect contaminant mediated behavioral alterations.

23. Acid Precipitation

Acid precipitation – often termed acid rain – can occur as rain, snow, or particulate fallout carried by any type of precipitation. It occurs when nitrogen or sulfur oxides are released into the atmosphere. Vehicle emissions are the major source of nitrogen oxides and industrial plants are the major source of sulfur oxides.

The susceptibility of certain lifeforms such as lichens to acid precipitation is quite high The susceptibility of plants such as sagebrush, forbs and grasses used by sage grouse is not clear. What is important in analyzing acid precipitation is not whether the absolute amounts generated in the west are comparable to the amounts generated in the mid-western and eastern U.S. Instead, it is whether the susceptibility of sagebrush, forbs and other plants needed by sage grouse is within the range of acid precipitation reaching them. Concentrations of automobiles and trucks in Los Angeles, the San Francisco Bay Area, Denver, Salt Lake City and other cities as well as smelters and power plants such as those located in the Four Corners area and in Colorado may be generating acid precipitation in quantities sufficient to harm sagebrush, grasses or forbs needed by sage grouse.

24. Fragmentation

Fragmentation is discussed extensively elsewhere in this report, and is also known to affect social behavior in vertebrates (D. R. Webb 1981). Webb postulated that the increase in agonistic behavior, and the decrease in amicable behavior seen in fragmented areas was caused by the difficulty of juvenile dispersal to new areas, and was unrelated to such factors as elevation, foraging time, and other non-landscape factors. Habitat fragmentation could cause similar behavioral alteration in sage grouse. For example, if juvenile sage grouse experience difficulty in dispersing to new habitat patches because of fragmentation, then the number of males at a given lek may increase. Researchers would see more males per lek, and assume that beneficial effects were taking place in that population. However, increased male density could instead lead to increased fights among birds, or such large displays that females would make incorrect choices of potential mates. Although data are lacking on the issue of crowding, it is one that must be considered for listing decisions, designation of critical habitat, and the crafting of recovery plans.

25. Habitat Recovery Time

As previously discussed, sage grouse habitat may not be able to recover from certain events such as cheatgrass invasion which can cause the complete eradication of sagebrush in an area. Other past effects include the extremely heavy grazing of the west which took place between the late 1800s and World War II, ORV use and military exercises. Depletion of vegetation and loss of soil by erosion are grazing effects that may prevent full recovery of the ecosystem. Unfortunately, heavy grazing continues today. Much sagebrush habitat has been treated with herbicides such as 2, 4-D which leads to establishment of rabbitbrush (*Chrysothamnus* spp.) rather than regrowth of sagebrush. Overgrazing and other events may have already irreversibly altered sagebrush habitat (Patterson 1952, Yocom 1956, Autenrieth, et al. 1977, Autenreith 1981). The most recent research on recovery times in arid areas indicates that full ecosystem recovery may not occur for literally thousands of years (Lovich and Bainbridge 1999). In the Gunnison Basin, the "long-term health of the ecosystem may have been altered, possibly irreversibly, affecting [] carrying capacity" (GBCP, p. 43). Thus, significant amounts of sage grouse habitat may have been lost for ever. "Even under themes [management scenarios] where aggressive restoration activities are planned ... it is thought that the deterioration and loss of sagebrush habitat will outpace restoration success" (Saab and Rich 1997, p. 16).

Even if livestock are removed from an area, the presence of invasive weeds, overly dense stands of sagebrush, or heavy browsing by rodents and rabbits can inhibit recovery of grasses and forbs (Tisdale and Hironaka 1981). For native grasses, recovery times can also be very long – bluebunch wheatgrass will not recover from even a single season of heavy grazing for 8 years, even under the best management practices (Anderson 1991).

After fire, many sagebrush species do not resprout and must re-establish by seed set. This process is very slow (Britton and Clark 1985) and 30 years or more may be required to regain pre-burn sagebrush densities (Harniss and Muray 1973, Tisdale and Hironaka 1981). This time interval may be even greater in areas with lower precipitation or higher potential evaotranspiration (Griner 1939, Pyrah 1963, Call and Maser 1985, Drut 1994).

Even if sagebrush shrubsteppe areas can recover and reestablish themselves as good sage grouse habitat, the time this may take can be so long – 100 years or more – that sage grouse populations will not be able to persist long enough for habitat recovery to occur. The lag in sage grouse recovery may also add to the lag in habitat recovery – even if sage grouse populations are able to maintain some viability in a degraded area, the local population is unlikely to be capable of serving as a source population in a landscape sense for many decades.

B. Over Utilization of the Species

A species must be listed if it "is endangered or threatened" because of "over utilization for commercial, recreational, scientific, or educational purposes." 50 C.F.R § 424.11(c)(2); 16 U.S.C. § 1533(a)(1)(B). The Secretary must conduct a "review of the species' status." 50 C.F.R.§§ 424.11(c). The determination to list the species must be made "solely on the basis of the best scientific and commercial data." 16 U.S.C. § 1533(b)(1)(A); 50 C.F.R.§ 424.11(b). The Secretary may not consider actual or "possible economic or other impacts" in the listing decision. 50 C.F.R.§ 424.11 (b).

1. Hunting

Sage grouse are a popular game bird. Sage grouse hunting is regulated in those states where it is allowed, and has not generally cited as a factor in recent sage grouse declines (Autenrieth, et al. 1982, Blaisdell, et al. 1982, Johnsgard 1973, 1983). However, at least one former advocate of sage grouse hunting and a recognized expert on sage grouse, Dr. Clait Braun, now feels that hunting policy for this bird may have "negatively impacted" the species (Braun 1995d, p. 2).

Excessive hunting was likely a major factor causing early declines in sage grouse populations (Girard 1937, Batterson and Morse 1948). In historic times, sage grouse were considered a primary game species and hunting was so heavy that wagon loads of birds were carried out (Girard 1937, Rasmussen and Griner 1938, Patterson 1952). However, analyses of habitat degradation by grazing had not been undertaken at that time. Indeed, the importance of habitat quality on wildlife populations was not widely appreciated until the efforts of Leopold (1933).

Unfortunately, the states where hunting is allowed have powerful motivations to maintain hunting, not only in terms of direct financial benefit to their Game Programs, but also in terms of general economic benefit and prestige. It is possible that some states would fail to properly regulate hunting or other effects on the birds and their habitat. The very low population recruitment of these birds and the extraordinarily slow recovery of upland desert and shrub-steppe habitat areas also bode ill for population recovery. Even if all threats to the birds were immediately halted, many populations would likely go extinct, and others would not recover for decades, perhaps centuries.

Hunting may reduce sage grouse population size (Zunino 1987). However, low levels of hunting, particularly when restricted to birds that are not likely to breed, is probably not an important factor in reducing population sizes (Braun and Beck 1985, 1996). The problem is that the levels of harvest permitted are not proven to involve the take of merely "surplus" birds or replacive mortality. Crawford and Lutz (1985) and Klebenow, et al. (1990) have particularly cautioned against heavy hunting harvest, and against harvest in years of poor productivity.

Of particular importance to the effects of hunting on sage grouse population viability is whether hunting truly replaces other mortality factors that would operate before the particular individual would have bred. The notion that hunting merely compensates for other mortality factors dates back at least to the time of Allen (1954, p. 131). Bergerud (1988c, section 16.3) suggested otherwise, particularly with respect to overwinter mortality. However, data for sage grouse are lacking. Crawford (1982) noted that the notion that hunting constituted merely replacive mortality was based on studies of other game birds which are less susceptible to the effects of hunting than are sage grouse. For example, sage grouse congregate in wet areas and at water holes, and are easier to hunt than other upland game birds (Crawford 1982). Hunting is known to constitute additive mortality for ptarmigan, a close relative of sage grouse (Braun 1995d, p. 3).

If the sage grouse population subjected to hunting is large and hunting effort is low, then hunting mortality may lie below a threshold where it is largely compensatory for other mortality factors (Crawford 1982, p. 376). The fact that populations increased after hunting seasons were closed in Colorado and other states (discussed in the "Population Assessment" section), strongly argues against the notion that hunting merely substitutes for other forms of mortality. More recent studies have also implicated hunting as a significant threat to sage grouse. In a long term study in Nevada, Klebenow, et al. (1990) found that during a time of population increase, grouse populations on unhunted areas increased by about 7 times the amount on hunted areas (Drut 1994, p. 19). Johnson and Braun (1999) used matrix projection models to incorporate age structure in assessing the impacts of hunting on sage grouse populations. Although not a full viability analysis, their results did show that hunting should be allowed only if juvenile and adult survivorship are sufficiently high that survival rates do not limit population increase, because hunting mortality is probably additive only above some threshold level (Johnson and Braun 1999).

The Service will need to be extremely cautious in evaluating which areas of sage grouse range can be opened to hunting after the bird is listed. Hunting is known to exacerbate Allee effects and increase extinction risk (see Allee Effects section, and Dennis 1989).

Surprisingly, nearly all states allow hunting of sage grouse, even those where populations are declining rapidly and have reached very low levels (e.g. Utah). This suggests mis-management of the wildlife resource because of political pressure within the states. If true, then the states have violated the public trust and the wildlife trust.

Poaching is the intentional taking of birds out of season or the intentional taking of more birds than are allowed by hunting regulations. Importantly, poaching levels are not measured by the techniques used by state wildlife agencies to monitor hunting levels. Thus, few reliable estimates of the loss of birds to poaching are available. However, in Colorado, poaching has occurred in all months of the year, and is greatest during winter and during big game season (Oct. and Nov) when more hunters are afield and the birds are concentrated (GBCP, p. 48; DCCP, p. 27). Roads and the use of ORVs greatly increase the level of poaching.

Inadvertent killing of sage grouse by hunters looking for other birds can be a significant problem for small populations. Open seasons for other upland game birds such as chukar, pheasant, quail, and other grouse species will expose sage grouse to mortality when the open hunting areas are within the range of sage grouse. Sage grouse may also be misidentified and shot by hunters of other birds such as chukar and other partridges, pheasant, and quail (YTC CA 1994). Hunting of other birds in an area inhabited by sage grouse may also disturb sage grouse even if they are not shot. Moreover, open seasons for other birds may afford an alibi for poachers or otherwise operate to conceal or obscure their operations.

2. Falconry

Sage grouse are a preferred prey species for many types of falconry. However, the extent of take by falconers is not known.

3. Bird Watching and Recreational Use

The only recreational use of sage grouse at present is viewing, particularly of lekking birds. Nonconsumptive uses, such as bird watching, are not always benign. Humans could disrupt lekking activities and hence mating if they -- or their domestic pets – approach leks too closely. The same disruptions can occur near nest sites, but the implications could be worse, as hens have already invested considerable nutrient stores into egg production, and inadequate time for locating another nest site and relaying may exist in that season. Disturbance at a lek can reduce mating opportunities and cause decreased production (Call 1979) or even abandonment of the lek. If humans approach a lek on foot, birds may avoid the lek for the rest of the day (Call 1979). Quiet observation from enclosed vehicles does not appear to disrupt lekking activities. However, tourists often leave their vehicles to get a closer look at the birds. State wildlife agencies appear to follow an informal policy of having a "sacrifice" lek near an all weather road to which the inquiring public is directed for viewing. Other lek locations are generally not revealed to the public. Tourists at viewing areas may need to be monitored and controlled to avoid disruption. Sedatives administered by dart guns, as have often been used for wildlife capture, are likely to be highly effective in tourist control. Disruption of nesting or lekking activities are most likely near suburban areas, areas populated by ranchettes, and popular recreation areas. For example, disturbance in the Gunnison Basin is a concern (GBCP, p. 49-50).

4. Agricultural Operations

Mowing, beating, or plowing can directly kill sage grouse, especially young birds (DCCP, p. 28). "Sagebrush beating throughout entire pastures has eliminated sage grouse use in those pastures in the short term" (Braun 1997). These practices also alter habitats and make them unsuitable for the birds.

5. Road Kill

Road kill of sage grouse has not been estimated; however, death of other animals from motor vehicle collisions is an important mortality factor. There is no reason to suppose that this is not important in sage grouse, especially when the number of roads fragmenting sage grouse habitat and the preference of the birds to walk is considered. Roads are a major threat both directly and in terms of habitat fragmentation and are discussed elsewhere in this report.

6. Scientific and Educational Purposes

Concerns have been expressed regarding the effects of scientific study on the birds, particularly with respect to lekking activities and nesting (SMBCP, p. 24). Study of the birds often involves capture and marking of the birds, and may involve fitting the birds with radio transmitters. Radio transmitters are known to increase the energetic burden on passerines (Caccamise and Hedin 1985), and likely do so to a lesser extent for sage grouse. Capture techniques include spotlighting, hand capture, use of long handled nets, and walk-in traps. All techniques involve some stress to the birds, and repeated disturbance of lekking birds causes them to become more wary and flush more easily (GBCP, p.50). Because sage grouse have extremely strong site tenacity, especially for lekking areas, the fact that they return to a lek after capture and marking (SMBCP, p. 24) does not mean that they have not been severely stressed. It may be possible to examine blood corticosteroid levels to determine the degree of stress from capture and marking operations. Certainly, such methods will be needed to recover populations.

C. Disease and Parasitism

A species must be listed if it "is endangered or threatened" because of "disease or predation." 50 C.F.R.§ 424.11(c)(3); 16 U.S.C. § 1533(a)(1)(C). The Secretary must conduct a "review of the species' status." 50 C.F.R.§ 424.11(c). The determination to list the species must be made "solely on the basis of the best scientific and commercial data." 16 U.S.C. § 1533(b)(1)(A); 50 C.F.R.§ 424.11(b). The Secretary may not consider actual or "possible economic or other impacts" in the listing decision. 50 C.F.R.§ 424.11 (b).

Girard (1939) and Batterson and Morse (1948) suggested that disease caused local declines in sage grouse populations. Stoddard and Kay ascribed a marked drop in 1932 in populations of birds in Utah to parasites (Lords 1951). Disease outbreaks are commonly associated with drying water holes causing high bird densities (Wallestad 1975a). Death was generally caused by coccidiosis, which is the most prevalent disease affecting sage grouse (Simon 1940, Thorne 1969). Coccidiosis is episodic, not continuously epidemic in sage grouse (Honess 1947). Coccidiosis is transmitted by the protists *Eimera angusta* and *E. centrocerci* in contaminated water, and is more prevalent near drying water holes where the birds are concentrated (Simon 1940). Maggots and beetles, which feed on sage grouse droppings and are then consumed by sage grouse, are common disease vectors (Grover 1944). *Plasmodium* and several other hematozoa are known to occur in sage grouse, including those in Colorado (Stabler, et al. 1966, 1974, 1977, 1981). Parasites reduce male mating success (Deibert 1995).

Crowding of birds will also likely result from loss of habitat and from fragmentation. Such crowding will further expose birds to transmission of disease vectors, increasing the risk (YTC CA 1994). Furthermore, birds in a weakened physiological state or under behavioral stress are more susceptible to diseases and parasites. Gabrielson and Jewett (1940, p. 218) suggested that the near extirpation of the Oregon population on Hart Mountain was because of disease.

Coccidiosis epidemics occurred in Montana during July and August when water was limited (Wallestad 1975) and during drought in Wyoming (Scott 1942). Symptoms of coccidiosis include weakness, inability to fly, emaciation, and diarrhea leading to death (Autenreith 1986).

Other diseases affecting sage grouse include salmonellosis, botulism or limberneck, aspergillosis, avian tuburculosis and pasturellosis (Thorne 1969). Malaria outbreaks can affect reproduction because male sage grouse infected with malaria may not attend leks during the mating season (Boyce 1990). As sage grouse populations become smaller and more isolated, disease threat will increase. Numerous parasites are identified with sage grouse and include tapeworms *(Raillietina spp.),* protozoans (such as *Eimeria spp.),* and ticks *(Haemaphyalis spp.).*

Exotic bird species such as quail and pheasants are often introduced for hunting. Such introductions carry substantial risk of disease and parasite spread to sage grouse. Of all the threats to sage grouse, disease and parasitism are among the most poorly studied. However, other threats, such as livestock operations, agriculture and development, are known to have extremely negative effects on sage grouse. If funds are limited, they should be devoted to habitat recovery, not research into disease and parasitism.

D. Inadequacy of Existing Regulatory Mechanisms

A species must be listed if it "is endangered or threatened" because of "the inadequacy of existing regulatory mechanisms." 50 C.F.R.§ 424.11(c)(4); 16 U.S.C. § 1533(a)(1)(D). The Secretary must conduct a "review of the species' status." 50 C.F.R. § 424.11(c). The determination to list the species must be made "solely on the basis of the best scientific and commercial data." 16 U.S.C. § 1533(b)(1)(A); 50 C.F.R.§ 424.11(b). The Secretary may not consider actual or "possible economic or other impacts" in the listing decision. 50 C.F.R. § 424.11 (b).

Existing regulatory mechanisms are virtually non-existent. Existing management is inadequate to conserve the bird. Although sage grouse inhabit an environment subject to extraordinary variation, no management plans adjust themselves to such fluctuations. For example, the effects of drought on sage grouse populations can be severe (GBCP p. 45) and are compounded if land management practices remain unchanged during years with low soil moisture (GBCP, p. 45). Despite this, there are no regulatory mechanisms or management plans which require the alteration of land management practices in drought years.

Autenrieth, et al. (1982), Braun, et al. (1977), Call (1979), and Dalke, et al. (1963) provide guidelines for management of sage grouse and their habitat. However, their recommendations have often gone unheeded. Among the many other problems in management, existing management agencies are "too slow to respond with effective mitigation" when events call for it (Braun 1999a, p. 1). In particular, agencies are unwilling to adequately manage "domestic livestock grazing" and are unwilling to reduce "elk/deer numbers" when necessary (Braun 1999a, p. 1).

In 1995, the state of Colorado and the U.S. Department of the Interior entered into a memorandum of agreement regarding management of the many native species that are in trouble in Colorado (Colorado MOA 1995). This MOA requires no action other than cooperation and collaboration between state and federal agencies. To date, no implementation of on the ground actions to reverse sage grouse declines has been taken, even though sage grouse were specifically mentioned in the MOA. The MOA is ineffective to conserve the species.

1. Management on Bureau of Land Management (BLM) Lands

The Federal Land Policy and Management Act (FLPMA), 43 U.S.C. § 1701 – et seq. controls the activities of the Bureau of Land Management (BLM) in managing public lands under its purview. Sage grouse have declined significantly since FLPMA was enacted in 1976, thus it is obviously inadequate to protect the species.

There appear to be economic distortions in the management of funds by the BLM. The US Government Accounting Office found that BLM directs only 3% of its total appropriation to wildlife habitat management, and instead directs 34% of its budget to its three consumptive programs: range, timber, and energy and minerals (GAO 1988b). Such lack of funding constitutes additional evidence regarding the inadequacy of existing management programs.

The Bureau of Land Management has seriously mis-managed the public's lands: even when using the BLM's own definitions and rating system, over 68% of its lands are in "Unsatisfactory" condition (Wald and Alberswerth 1989, GAO 1991a).

BLM's treatment of Fruitland Mesa, an area of public land under its administration in Colorado, is well documented, and worthy of attention as an example of BLM management of sage grouse habitat. In 1983, the BLM conducted a "plow and seed" operation "for livestock grazing" (Anonymous 1995a) and to "increase livestock forage (Uncompahgre Basin Resource Area 1994, p. 4), thereby destroying large amounts of sage grouse habitat. Immediately thereafter, lek counts declined by 50% (Anonymous 1995b). Searchers were unable to see any sage grouse in the plow and seed areas (Ferguson 1986, p. 2) or even near the plow and seed areas (Bray 1981, p. 2). By 1994, BLM finally recognized that sage grouse had "declined sharply" in this "livestock emphasis area" and proposed to improve sage grouse habitat (Uncompahgre Basin Resource Area 1994; p. 5, p. 3). Unfortunately, BLM only proposed to enhance historic lek areas by brush beating, and completely ignored the need for winter habitat, nesting habitat, food sources, brooding habitat, and other components of sage grouse needs. The BLM assumed that since the use by cattle would be past "the peak time for of the sage grouse breeding season" that "no direct conflicts" would ensue (Uncompahgre Basin Resource Area 1994, p. 3). Of course, not all sage grouse are finished breeding by the peak of the season, so substantial direct impacts would occur to late nesting birds, including any that had to renest because of predation or disturbance. Worse, BLM completely neglected the high likelihood of indirect impacts by cattle grazing: removal of vegetation, erosion, and others detailed elsewhere in this report. Declines continued, and by 1996, BLM planned to interseed grasses and forbs into the areas that had been plowed and seeded with non-native species for cattle (Uncompahgre Basin Resource Area 1996). Cattle grazing was now recognized as such a severe problem that BLM proposed to spend huge amounts of money to erect and maintain electric fences in this remote location to keep cattle away from sage grouse areas. In this document, the BLM also reveals its "ultimate mission" – to "prevent wildlife species from being listed under the ESA" (Uncompahgre Basin Resource Area 1996). BLM personnel regard the potential listing of Gunnison sage grouse under the ESA as a "train wreck" (Stiles 1996). Nonetheless, BLM agrees that the bird exists in very "low numbers," has a "limited range," and has declined rangewide for over 40 years (Stiles 1996).

BLM mis-management at Fruitland Mesa is not an isolated instance; instead, it is symptomatic of BLM's treatment of sage grouse and other wildlife throughout its administrative reach. For example, BLM has proceeded with destruction of habitat for the Gunnison sage grouse in the Tomichi grazing allotment in the Gunnison Resource Area despite strong scientific criticism. Dr. Jessica Young, an expert on the Gunnison sage grouse, explained to BLM that the monitoring called for in its allotment management plan (AMP) was not sustainable and that cattle removal would not occur when needed. Nonetheless, BLM proceeded, and Dr. Young's concerns were realized (Young 1999, p. 1). This occurred despite unusually favorable range conditions that year – in more normal years, even worse degradation would occur (Young 1999, p. 1). Dr. Young also notes that BLM shows great solicitude, greater than it does for the public's wildlife, towards the grazing permittee – who has already received $100,000 from the government for his cattle operation (Young 1999, p. 3). Instead of protecting the public's wildlife, the BLM's actions have allowed overgrazing by cattle, have reduced the already sparse forb cover, and BLM has failed to analyze costs and benefits of rest-rotation grazing systems (in violation of NEPA). Consequently, almost none of the allotment meets standards for Public Land Health, and over half the area is static or getting worse (Young 1999, p. 2). The vast majority (over 85%) of the allotment is in poor or fair condition, and none was in excellent condition (Young 2000). Another example of BLM's attitude towards wildlife is illustrated in the Sims Mesa area, where Gunnison sage grouse showed severe declines. Instead of halting livestock grazing, BLM requested permitees to restrict their grazing somewhat, but did not bother to enforce these restrictions. BLM merely began "requiring an ... understanding" of how livestock grazing "will be managed to improve ... sage grouse habitat" (Belt 1998). But there is abundant scientific evidence as well as expert opinion, that the way to improve sage grouse habitat is to remove grazing.

As yet another example, the BLM has proposed to construct a haul road for radioactive waste through the middle of the nesting area for the "largest single colony" of Gunnison sage grouse (Guadagno 1992) which was of "particular importan[ce]" to the species, even though BLM had previously been informed by multiple experts that this group of birds was the last hope for the species (Young 1992b, p. 2). This road would have such an extreme volume of traffic that heavy trucks would pass the leks every 90 seconds, and would be built through critical nesting, brood rearing, and winter habitat. Besides the haul road, which would pass within 100 meters of key leks, the BLM proposed to store the radioactive mine tailings within 500 meters of the leks (Young 1992b, p. 2). The BLM even attempted to evade evaluation of the impacts of this action by refusing to prepare an Environmental Impact Statement (Guadagno 1992), and began work on the project, even though mitigation attempts were inadequate (Young 1992b, p. 3). The BLM did not only ignore individual sage grouse experts, who warned of a "devastating impact" continuing for decades (Young 1992b, p. 2), but also ignored the state Div. of Wildlife, which protested the project and warned that at least half the mating population in the area would be lost (Young 1992b, p. 2).

Fire is a serious threat to Gunnison sage grouse. For example, over 20% of the fire starts in the Uncompahgre area of Colorado are from human causes and fire has burned nearly 22,000 acres since 1989 (Uncompahgre Field Office Fire Management Plan 1999). Many fires are set intentionally by BLM, and its analysis of fire effects on sage grouse is inadequate. For example, despite the extreme danger to sage grouse habitat from fire, sage grouse habitat receives the second lowest of all precautionary classifications in the Uncompahgre fire plan, and "significant prescribed burning" is planned for these areas (Uncompahgre Field Office Fire Management Plan 1999, p. 7). Moreover, no analysis of fire return intervals or of the decades needed to restore sagebrush cover has been done. Instead, BLM appears to be using fire to remove oak and conifers from these areas (Uncompahgre Field Office Fire Management Plan 1999). But this removal could be accomplished by other, safer means, such as the cutting of trees. Reduction of over-mature sagebrush could be achieved by mechanical means. The EA for the Uncompahgre fire plan also fails to consider the likelihood of fire escape, cheatgrass invasion, or the myriad other effects of burning on sage grouse habitat (Uncompahgre Field Office Fire Management Plan, Environmental Assessment 1999).

2. Management on USFS Lands

Most Gunnison sage grouse habitat is on BLM or private lands; however, the Grand Mesa, Uncompahgre, and Gunnison National Forests recognize sage grouse as a Management Indicator Species (MIS). For a MIS, the Forest Service must evaluate and state planning alternatives "in terms of both amount and quality of habitat and of animal population trends of the management indicator species." 36 C.F.R. § 219.19(A)(2). However, various projects have been approved without evaluation of their effect on sage grouse, such as the Powerline Prescribed Burn. The Forest Service has also proposed projects to improve sage grouse habitat, but they involve fire and chemical treatment (rather than mechanical brush beating) and thus involve substantial risk to the grouse. The most important habitat improvement is to increase forb and grass cover by halting grazing, but the Forest Service has not proposed such actions. Instead, in its Gunnison Basin Range Project EA, the Forest Service has claimed that grazing levels on its lands do not harm sage grouse and that it will not restrict grazing.

One additional concern regarding the livestock management involves management for fish species on federal lands. Rather than simply reduce or eliminate grazing, the Forest Service is attempting to "attract cattle away from streams" (Duncan 1999, p. 2), including studying the use of "off-stream water systems used to attract cattle away from the stream. . . ." (Duncan 1999, p. 4). Inevitably, cattle will be attracted away from streams and into sage grouse habitat, thus degrading that habitat even more than its present damaged state. Such efforts are not limited to the Forest Service, but are threats on all lands, where managers attempt to improve riparian conditions while maintaining livestock.

3. Management on NPS Lands

Without the guidance of the Endangered Species Act, even the National Park Service has damaged sage grouse populations. Development of the Curecanti Recreation Area has caused brood habitat to become "almost totally lost," lek and nest habitats have been reduced, and winter habitat has been "reduced and/or compromised" (Braun 1999b, p. 1). At Black Canyon of the Gunnison National Monument, powerlines, raptor perches, pinyon/juniper invasion, interior fencing, and degraded sagebrush habitat are threats to the birds (Braun 1999b, p. 2).

Neither Black Canyon of the Gunnison National Monument nor Curecanti National Recreation Area has conducted or is conducting any research or other studies on the bird, and neither entity has a management plan for the species (NPS 1999c). Oddly, the NPS did not provide a copy of the letter written by Dr. Braun (Braun 1996b) in response to a FOIA request, instead claiming that it had no information regarding the bird. Two grant proposals have been submitted to conduct research on the Gunnison sage grouse, but support for even this minimal and late effort is "problematical at best" (NPS 1999c).

a) National Parks

Gunnison sage grouse are not known to occur on any lands in National Parks.

b) NPS Easements

The Gunnison sage grouse Crawford Area plan contemplates the acquisition of conservation easements by the National Park Service. Such easements, however, require that grazing and the maintenance of structures continue (such as fences, and water development structures that dewater streams and wet meadows) (CACP, p. 23). Thus, NPS easements cannot conserve the grouse, among other reasons, because they fail to address two of the greatest threats to the species.

4. Conservation Reserve Program

Conservation reserve program (CRP) set asides have been used to enhance some parcels of sage grouse habitat. The CRP was designed to reduce soil erosion, not protect wildlife. Although better than nothing, such programs have numerous problems. One problem is that most of the acreage is in parcels of less than 100 acres, and often they become population sinks, rather than sources, for birds. Predators can easily find these small parcels amid the cultivated fields in which they are embedded. In some cases, cultivation or livestock feeding operations may even attract more predators to the area than would otherwise be the case. For example, ravens are attracted by the grain spread in livestock feeding operations. Once in the vicinity, it is easy for these nest predators to locate any sage grouse nests nearby. Furthermore, the CRP program is not based upon wildlife values. A 100 acre plot in the middle of a wheatfield has tremendous edge effect, thereby allowing easy access for predators.

The CRP program is also very costly. In Montana, the public actually spends more on "renting" CRP lands than it would cost to buy those lands (George Wuerthner, personal communication). As Wuerthner states: "Farmers typically get $50 an acre in Montana (payment varies from place to place in the country so it's more in places like Iowa). But they get this for ten years. [i.e.] 50 x 10 equals $500/acre over ten years. You can often buy this same land for $100-200 an acre outright. So we are paying far more than the land is ultimately worth and we get no guarantees that these lands won't be turned back into wheat fields or whatever in ten years." Economic analyses of the CRP in other states have not been conducted, but this expense ratio is probably typical for most Western states.

The CRP appears to provide some benefit to sage grouse by providing some cover for nesting (NWEA 1999, p. 30 citing Schroeder, personal communication). The most beneficial CRP lands are those adjacent to remnant shrub-steppe patches. Much of the habitat needed by sage grouse is not enrolled in the CRP, nor do the CRP lands offer protections adequate to conserve the grouse. Brush control, chemical spraying, and conversion of sagebrush areas continue, causing additional loss and degradation of sage grouse habitat (Tirhi 1995, Hays, et al. 1998). Many CRP lands have been planted to crested wheatgrass, which is rarely used by sage grouse or other wildlife (Hofmann and Dobler 1988).

Moreover, CRP protections are temporary. Thousands of hectares of habitat currently enrolled in the CRP could be converted to agricultural fields as soon as 10 year long contracts expire. Perhaps most importantly – the CRP program has failed to halt the severe declines in sage grouse populations to date. There is thus no reason to expect that it will do so in the future

5. National Environmental Policy Act (NEPA)

The National Environmental Policy Act (NEPA) is merely a procedural act and requires no substantive outcome. Vermont Yankee Nuclear Power Corp. v. NRDC, 435 U.S. 519 (1978). It thus does not constitute a regulatory mechanism. Moreover, because substantial declines in sage grouse populations have occurred since NEPA was first passed, it has clearly been inadequate to conserve the species.

6. Management by the States

State conservation agreements are inadequate to conserve sage grouse. They are voluntary and unfunded or underfunded, and have a poor track record. Neither Colorado nor Utah has treated the decline in sage grouse with the gravity it deserves.

a) Management in Utah

Utah lags far behind Colorado in its attempts to arrest the decline of the Gunnison sage grouse. A Conservation Agreement for species in San Juan county is still unfinished, and a draft has been circulated for review. Mapping and delineation of sage grouse use areas has not even been carried out. The state wildlife agency and the Utah field office plan to pay $3,000-$4,000 for a technician to delineate sage grouse use areas. This technician, who will be employed part-time (if hired at all) will have the additional responsibilities of working with private landowners to enhance sage grouse habitat, and will monitor usage of enhancement projects. This is a very ambitious use of the small amount of funding provided, and all these activities will obviously not get accomplished. Moreover, nothing at all is planned for other parts of the Gunnison sage grouse's historical range in other counties in Utah.

A draft "concept" of a conservation plan has been written (San Juan Draft Concept Plan 1997); however, there has been little action taken on its provisions. These provisions merely contemplate the gathering of information without any action being taken to protect the species. Indeed, the concept plan explicitly lists "enhancement of personal income" as a goal. A conservation agreement has also been drafted (Utah Draft Conservation Agreement 1998) but it is unclear whether it is based on the concept conservation plan. The conservation agreement includes a goal to enhance sage grouse habitat, but the actions associated with this goal primarily involve mapping and delineation of various habitat and use areas (Utah Draft Conservation Agreement 1998). The conservation agreement is thus far from any on the ground actions, and the only management actions called for are extremely vague and non-specific. Overall, the conservation agreement simply does not contemplate specific actions adequate to conserve the species, even if it were implemented in its entirety.

b) Management in Colorado

Colorado attempts to manage sage grouse by regulating hunting. No other state regulatory controls exist. Colorado does not have a comprehensive land use planning system, and has few controls on development of any sort. Thus, suburbanization and ranchettes are likely to continue to eliminate remaining sage grouse habitat. Threats from disease and parasites are imminent and ongoing. The Colo. Div. Wildlife "allows releases of exotic/introduced species which are known to be carriers of parasites/diseases harmful to sage grouse into habitats where sage grouse live" (Braun 1999a, p. 1).

Moreover, it appears that the Colorado Dept. of Wildlife (CDOW) has been remiss in its general management of the Gunnison sage grouse. As late as 1978, the CDOW had failed to implement any systematic population assessments (CACP, p. 2). Instead the "searches and counts were sporadic," and the CDOW allocated personnel and funding elsewhere (CACP, p. 2). This all occurred despite the fact that CDOW had been requested to document sage grouse status and trends as early as the 1950s (CACP, p. 2). Perhaps an even more startling fact is that Gunnison sage grouse hunting in the Crawford Area was not ended until 1994, even though the number of grouse had sunk to less than 90. CDOW personnel must operate with only one eye on science -- the other eye is fixed on politics. For example, one memorandum notes that even though a critical population of Gunnison sage grouse will become extinct without active habitat management, that habitat manipulation may nonetheless not be possible "considering the present political climate" (Braun 1995g, p. 1). These facts make assertions of conservation actions to take place in the future suspect – either the CDOW lacks the interest in conserving the species, or it lacks the power. In either event, prompt listing under the ESA is a necessity.

Even though the present regulatory climate has brought the Gunnison sage grouse to the brink of extinction, neither federal nor state agencies have altered regulatory mechanisms within the range of the bird. Instead, federal or state agencies have begun to implement "conservation plans." State personnel admit that a major goal of such conservation plans is to "try to prevent

Federal action concerning the grouse" (Wait 1997). To date, only a few such conservation plans have been written (Braun 1996a). Indeed, there is still "reluctance" to "fully implement" conservation actions regarding grazing on some allotments in the Gunnison Basin (Braun 1996a). The conservation plans avoid conflicts over grazing by simply ignoring the issue. Instead, they assume that increased grass and forb production will – somehow – magically provide adequate habitat for both cattle and sage grouse.

The Gunnison Basin conservation plans "form a framework" for developing conservation actions. These consist of public education, research into causes of sage grouse declines, monitoring of populations, mapping and inventory of habitat, and similar assessments (Gunnison Basin Sage Grouse Conservation Plan 1997, p. 18). The conservation plans are thus useful tools to organize data collection and research, and may function to educate the public. They fall far short, however, of what is required to avoid a listing under the ESA.

These conservation actions and conservation plans are not regulatory mechanisms, the actions do not yet exist, and both the plans and actions they contemplate are inadequate to insure conservation of the species. They thus fail each test for adequacy when considering a listing under the ESA.

The conservation plans do not themselves require the implementation of any actions, and needed actions have not been implemented. For example, the Gunnison Basin Sage Grouse Conservation Plan (GBCP) contemplates that implementation of actions under the plan will not be completed for 15 years (Gunnison Basin Sage Grouse Conservation Plan 1997, p. 18). By then, Gunnison sage grouse will likely either be extinct or will be present in such small, scattered populations that it will not be possible to prevent the extinction of the species. The GBCP itself recognizes this time lag problem with conservation measures, although it does nothing to alleviate the problem. The plan states, "it may take several years for an actual increase in cover, and the establishment of desirable species" after implementing a "vegetation management plan" (GBCP, p.19). The plans even admit that some actions could prove ineffective. For example, "a drought could negate or reduce the positive effects" of "vegetation management through improved livestock grazing" (GBCP, p. 19). Despite this recognition, the plans do not provide for any safety margins or "fall-back" options in such cases. The San Miguel Basin Conservation Plan (SMBCP) is so far merely an "outline of the Draft Conservation plan" (SMBCP, front cover), and does not even estimate a time when conservation measures will be fully implemented except to note that it will "require a lengthy period" (SMBCP, p. 16). The San Miguel plan merely establishes a wholly voluntary "process" and "framework" in which, someday perhaps, a true plan will be implemented. Similarly, participation by private landowners in the Crawford Area Conservation Plan (CACP) "will be strictly on a volunteer basis" (CACP, p. iii). The conservation plans make no requirements on private landowners; instead, such action is purely voluntary (GBCP, p. 19; SMBCP, p. 3 "strictly voluntary"; CACP, p. 3 "strictly voluntary"). Even if private lands are needed for conservation of the species, all land uses will be permitted, apparently including subdivision, because landowner participation is strictly voluntary. While the plans rosy speculations of volunteerism are appropriate for a children's fairy tale, they will not conserve the sage grouse. Such vague agreements require nothing, and have been uniformly rejected by every court that has examined the issue.

Nor do the plans even assure funding for conservation actions: for example, the GBCP specifically contemplates that "[i]nadequate funding may preclude the completion of an action in a given period." In such cases, the "implementation sequence" would be "adjusted" – that is, deferred (GBCP, p. 19). The plans explicitly defer on the ground actions. For example, increased attempts to reduce poaching will not begin until 2009 (GBCP, p. 20). Mitigation of utility corridors – which already exist – will not begin until 2006 (GBCP, p. 20). Again, this deferral of action may itself be deferred if funding is inadequate (GBCP, p. 19).

The plans are not regulatory mechanisms in any sense. "The process or mechanism [to implement the plan] is generally to rely on each [working group] member or entity to implement to the best of their ability actions for which they have responsibility…." (GBCP, p.19). Thus, the actions in the plans are voluntary even if they are not explicitly deferred by the plan's timetable, or implicitly deferred by "inadequate funding." They will doubtless be deferred by the plans reliance on each entity being able to explain that they couldn't complete the actions for which they were responsible, but to the best of their ability, they did whatever they wanted. This is not a regulatory mechanism.

The San Miguel Plan mentions the authority of the county to regulate land use but does not explain the limits of that authority or the degree to which it has been exercised in the past (SMBCP, p. 29-30). In fact, one of the chief dangers to the bird is development (Braun 1998a). The county's authority over land development has not proven effective in the past. Thus, even if the authority to control land use were truly a regulatory mechanism, it has been shown inadequate. Without true regulations on land use, there is no guarantee that the county will exercise its authority in the future. The San Miguel Basin plans other assumptions also fail as adequate regulatory mechanisms. The plans impose no new regulatory scheme, instead relying on the same regulatory mechanisms – or lack thereof – that have allowed the severe declines in Gunnison sage grouse. The San Miguel Basin plan does mention the authority of the FWS under the ESA, but this presupposes that the bird has already been listed (SMBCP, p. 30). Thus, the plans cannot function as adequate regulatory mechanisms sufficient to prevent listing of the bird – the only true regulatory mechanism is listing under the ESA. The San Miguel Basin plan also notes the establishment of Memoranda of Agreement and of Memoranda of Understanding among various federal agencies and between FWS and the state of Colorado (SMBCP, p. 30). None of these qualify as regulatory mechanisms as a matter of law. Nor have the actions contemplated by the Memoranda even been drawn up and agreed to, much less implemented. The only regulatory program discussed at all by the San Miguel Basin plan is the ability of the Colorado Div. of Wildlife to regulate poaching and harassment (SMBCP, p. 29). This has been ineffective to conserve the Gunnison sage grouse as seen by the severe declines in the bird. Moreover, it can only address one of many threats.

Even if all of the conservation plans were completely implemented immediately, they would prove inadequate to conserve the Gunnison sage grouse. The Gunnison Basin plan contemplates a minimum spring population goal of 867 males for a total of population of 2,601 grouse. The plan contemplates an "optimum" spring population goal of 1,200 males for a total of population of 3,600 grouse (GBCP, p.37). There are numerous problems with this scheme. First, although the plan acknowledges that the best scientific data now show that minimum viable population sizes of 5,000 or more are required to ensure against species extinction (GBCP, <u>citing</u> Lande 1995), it does not incorporate this finding into its goals. Even restoring the population to its 1969 "optimum" of 3,600 birds is far short of an adequate population size, being only 72% of that number. The plan even acknowledges that in the past there may have been

10,000 birds in the Gunnison Basin, twice the number estimated in 1969 (GSCB, p. 37). Thus, the 1969 population was already greatly reduced from its historic numbers and may have not been large enough to assure viability in any event. The San Miguel Basin plan does not contemplate that population size will ever reach that of a viable population from the already extremely small population present there (SMBCP, p. 7). The San Miguel Basin plan hopes to achieve only 480 birds, even after 15 years. Even if it did achieve that goal, the genetic bottleneck effect found in small populations is likely to cause depressed reproductive success.

Second, the plans ignore effective population size (N_e) arising from the differential reproductive contributions among male birds or variance in female clutch. As discussed previously, N_e for sage grouse is far lower than that for populations with random mating. This is well established in the scientific literature, and even appears in undergraduate textbooks, yet the plans do not account for this factor in their goals, even though the GBCP acknowledges that inbreeding depression is likely in Gunnison sage grouse (GBCP, p. 6). Oddly, the San Miguel Basin plan, although written later than the Gunnison Basin plan, does not even acknowledge the reduction in effective population size. Instead, the San Miguel Basin plan makes an error in the opposite direction: it assumes that actual population sizes will be larger than the counted population because there are about "2 females for every male" (SMBCP, p. 6). But the studies it bases this assertion on are not cited. The Crawford Area Conservation plan repeats this estimate, asserting that "studies across western North America" have found this to be the approximate sex ratio in spring (CACP, p. 2). But, again no citations to the literature are given, and sex ratios of 1:1 are more likely in adult, breeding populations that are not hunted. It is not appropriate to use spring breeding numbers in any event as not all those grouse will breed.

Third, the plans make optimistic assumptions about the relation of the numbers of grouse counted to the actual numbers. As explained in the Methodology section above, Jenni and Hartzler (1978) cautioned that evening counts at leks do not properly represent morning lek counts, yet the plans do not specify when lek counts will be made. Jenni and Hartzler (1978) also cautioned that hens visit multiple leks, multiple times, and thus counts of hens will generate overly optimistic population estimates. Nor will counts of males at leks correctly represent population sizes (Jenni and Hartzler 1978), yet the plans all assert that their census numbers are conservative estimates.

Fourth, the plans rely on spring population sizes only. Not all grouse will mate, and not all females will successfully raise broods. Thus, spring population size alone is not an adequate measure of population viability; instead, spring census estimates represent the maximum number of birds present including "floaters" and other surplus birds from an evolutionary standpoint.

Fifth, the plans incorrectly assume that if a certain number of birds are present in a vast geographic area such as the Gunnison Basin, then those birds exist in a single population linked by gene flow. It is highly unlikely, however, that the grouse in the Gunnison Basin are a single population. Instead, they are almost surely fragmented into numerous small population isolates. In discussing "population" goals, the plans make no allowances for effects of habitat fragmentation on the birds, and instead only call for "well distributed" lek areas (GBCP, p. 37). It is not the distribution of lek areas that is the problem. As explained above, a major problem causing endangerment is the fragmentation of habitat causing fragmentation of populations into small, isolated groups of birds that no longer experience gene flow with other isolates. The plans have not adopted any goals to reduce habitat fragmentation or to restore movement corridors, and thus will surely fail to conserve the Gunnison sage grouse.

Finally, Dr. Braun appears to have been the impetus for the creation of these plans. He has since retired, and there is no assurance that the Colorado Div. of Wildlife will follow through on his hard work.

The ineffectiveness of these conservation plans, and their inadequacy as regulatory mechanisms, is evident when viewing what the advocates of these plans list as their accomplishments. For example, the table of accomplishments for the plans lists few on the ground actions to restore habitat or even arrest the imminent and ongoing threats to the bird (Gunnison Sage Grouse Conservation Plan Accomplishments 1998). Instead, the type of accomplishments listed in this table include such things as selling T-shirts, lecturing to kindergarten and elementary school students, paying ranchers not to graze small areas of the public's land, mapping vegetation, and printing color brochures. Most of these are fun and worthwhile activities, but rather than act to conserve the grouse, they merely distract from needed actions. As such, they could form a useful adjunct to recovery plans once the species is listed – they cannot substitute for a listing. Much hard work and negotiation has gone into these plans. Yet, far from assuring the conservation of the species, the Gunnison Sage Grouse Conservation Plans are plans for extinction of the Gunnison sage grouse.

7. Management by Private Parties

Within the historic range of the sage grouse, private land typically is more fertile, has more forb and grass cover, has better soils, and has better hydrological status than public lands (SMBCP, p. 25; DCCP, p. 26). Private lands are typically those located near streams (SMBCP, p. 25). It has been said that the public lands in the United States are those that no one wanted during the period of Western settlement and homesteading. It is thus not surprising that private lands impact sage grouse populations to a disproportionate degree.

Yet no regulatory mechanisms protect the birds on private lands (with the limited exception of hunting seasons). Besides being the best former habitat, private lands constitute nearly half (47%) of the range of the Gunnison sage grouse. Because private lands are so important to sage grouse (SMBCP, p. 25), especially for the very limited early brood rearing habitat, even perfect conservation efforts on all federal lands would be unlikely to ensure the continued survival of the species. Thus, listing under the ESA is essential to conserve sage grouse species.

X. Legal and Conservation Status

Gunnison sage grouse do not have any federal conservation status (SMBCP, p. 6), although various federal agencies consider it to be of special status. As detailed elsewhere, these agency designations have done little or nothing to conserve the species, and what purported protections are afforded by various agency regulations and organic acts are often violated.

A. Colorado

The Gunnison sage grouse is unprotected by a threatened or endangered listing by the state of Colorado; instead, it has been assigned to the category SC, state species of Special Concern (http://www.dnr.state.co.us/wildlife/T&E/list.asp), and is considered a sensitive species in Colorado. SC is a designation by the state Wildlife Commission, not a statutory category.

Neither status carries any regulatory significance, and neither provides any management actions adequate to conserve the species. County regulations, such as land use permitting and zoning, have been ineffective in halting, much less reversing threats to the species.

B. Utah

The Gunnison sage grouse is considered a state sensitive species in Utah. This status carries no regulatory significance, and provides no management actions adequate to conserve the species.

XI. Requested Administrative Action

Petitioners request that the Service list the Gunnison sage grouse as endangered under the Endangered Species Act. In the alternative, Petitioners request that the Service list the Gunnison sage grouse as Threatened. Because of the magnitude and severity of ongoing threats operating throughout the entire remaining range of the Gunnison sage grouse, the steep and rapid declines in population numbers, and the imminent risk the species faces, Petitioners request the use of the emergency listing powers and other emergency conservation powers to rescue the Gunnison sage grouse. This Petition incorporates by reference all citations in the Literature Cited and Selected References.

A. Request for Emergency Consideration

Petitioners request that the Service give emergency consideration to the listing of the Gunnison sage grouse under the Endangered Species Act, and assign this species the highest priority for evaluation and listing. In the alternative, petitioners request that the Service proceed with the utmost dispatch in following its internal procedures for listing.

The Gunnison sage grouse faces ongoing and immediate threats of such magnitude that the species could become extinct at any time. Even if the entire species were not rendered extinct immediately, such a significant proportion of the total population is faced with such imminent threats that the routine listing process is not sufficient to prevent large losses to the Gunnison sage grouse. These losses will likely lead to extinction.

B. Request for Designation of Critical Habitat

As this Petition demonstrates, designation of the current geographical area presently occupied by the species as critical habitat is clearly inadequate to ensure conservation of the species. Petitioners therefore request that the Service designate as critical habitat (1) all currently occupied lands, (2) such additional lands as are needed to assure viability of each population, and (3) lands that are adequate to assure gene flow among the different population isolates.

XII. Distinct Population Segment

In order to conserve biological diversity, the Congress required the Service to protect subspecies and "distinct population segments" (DPS) of any vertebrate species as if they were species themselves. 16 U.S.C. § 1532(16). The Service adopted this definition, 50 C.F.R.§ 81 1(h), but also imposed a series of stringent criteria to use in determining if a distinct population segment would meet the legal definition of a DPS. On February 7, 1996, the Service adopted its Policy Regarding the Recognition of Distinct Vertebrate Population Segments (61 FR 4722). All three criteria in the DPS Policy must be met, and are:

(1) "Discrete" – that is, markedly separated from other populations of the species by physical, physiological, ecological, behavioral, or other factors. However, complete reproductive isolation is not required. It would be both odd and illegal if it were required, as that would delimit a separate species. The Service also evaluates discreteness based on a population being delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act."

(2) "Significant to the species to which it belongs" – Here, the Service imposes a requirement of evolutionary significance, as if it were a god-like entity that could predict the future. The significance determination was adopted over the objections of the National Academy of Sciences and national Research Council, and "attempts to reflect" the Service's assumption that "populations commonly differ in their importance to the overall welfare of the species they represent." There is scientific support for this assertion, which is discussed under the Importance of Peripheral Populations section. Notably, the scientific support for the differential importance of certain populations for the overall welfare of the species to which they belong is precisely opposite to the way in which the Service has previously used this concept.

(3) "Conservation Status" of the population segment in relation to the Act's standards for listing, that is, whether the population segment itself is endangered or threatened.

The Service evaluates significance using four criteria, any one of which will satisfy the Service's requirement:

1. Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon,

2. Evidence that loss of the discrete population segment would result in a significant gap in the range of a taxon,

3. Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range, or

4. Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

The Service has also explained that a requirement of genetic distinctiveness "was never intended," although "quantitative measures of genetic or morphological discontinuity may provide evidence of this separation" (61 FR 4722).

A. The Gunnison Sage Grouse as a DPS

Even if the Service does not treat the Gunnison sage grouse as a separate species, it should recognize it as a subspecies deserving the protections of the ESA. Failing that, the Service should treat the Gunnison sage grouse as a distinct population segment because it is and was found in the southernmost portion of the range (an unusual ecological setting), differs markedly from other sage grouse (as described above), and because loss of the Gunnison sage grouse would leave all of southwest Colorado and southeast Utah devoid of sage grouse, thereby introducing a large and significant gap in the range of the sage grouse.

XIII. Monitoring Programs

Besides the collection of wings from wing barrels and other very limited measures of hunting take, few monitoring programs exist. The states have made a desultory effort to count birds at leks, but such programs are inhibited by lack of funding, poor standardization, and erratic effort. Dobkin (1995) criticized the data gathering methodology of the states, but there have been few changes made. Population monitoring is relatively advanced in Colorado as compared to Utah.

XIV. Acknowledgements

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