HABITAT RESTORATION FOR GUNNISON AND GREATER SAGE-GROUSE—A LITERATURE REVIEW

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OVERVIEW

Essential Elements of Restoration

! Active restoration is warranted if invasive species (e.g. cheatgrass or noxious weeds) or native species that are generally inconspicuous at a site (e.g., junipers or pinyon pines) have replaced dominant species (e.g. sagebrush, perennial bunchgrasses, and forbs) in the community.

! In the case of pinyon-juniper tree encroachment, as the site becomes dominated by the trees, sagebrush will die out, the herb layer may decline, and seed banks may become depleted.

! Following invasions of exotic annual grasses, the communities become susceptible to more frequent fires because of the increase in fuel that is more continuous across the soil surface than the pre-invasion community.

! Most species of sagebrush, except silver and threetip sagebrush, are intolerant of fires and require seed dispersal and germination to reestablish after a fire.

! Cheatgrass is known to be a successful competitor against native plants for resources necessary for the native plants to establish and grow.

! Site degradation in some locations may become so severe that soil erosion removes the upper soil horizons to such an extent that the potential for the site to support its former native plant community is impossible. In this case, restoration is no longer possible, but rehabilitation—an alternative to the historic native plant community that provides similar structure and function without allowing further degradation of the site—may be the only remaining alternative that might make the site usable by sage-grouse.

! In sagebrush grasslands, grazing during the growing season tends to favor sagebrush growth until sagebrush becomes so dense that the competition of sagebrush restricts recovery of herbaceous plants.

! Reductions in grazing will only show improvements in sage-grouse habitat quality if the vegetation community is a sagebrush grassland mix, retaining both sagebrush and the tall bunchgrass necessary for quality sage-grouse habitat. The release from livestock grazing should allow the full expression of vegetation height for hiding cover and nest protection. Improvements could be expressed in the next growing season, but might take 3 to 5 years for pre-existing plants to fully express themselves and 10 to 15 years for seed production and new plant recruitment to occur assuming the site is not fully occupied by other species.

! Prescribed fires kill, eliminate, or reduce the density of sagebrush and provide a temporary flush of nutrients that may result in increases in herbaceous plant responses—but may leave sites susceptible to soil erosion during the first years after the fire. This tool is being applied on lands where pinyons or junipers have encroached into sagebrush grasslands. It results in a loss of sagebrush dominance for 25-45 years depending on the location of seed sources.

- Herbicide applications of 2,4-D (2,4-dichlorophenoxy acetic acid) or tebuthiuron (–[5-(1,1- dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea) have been used to kill large expanses of sagebrush; risk of soil erosion is low but herbicide use during the growing season may kill or injure forbs.
- Control of pinyon and juniper through chaining, cabling, railing, or chain saw can have moderate to little impact on the shrub canopy— but uprooting techniques disturb the soil and add to the risk of post-treatment soil erosion. Such techniques may facilitate rapid recovery of the shrub and herb understory if adequate levels are present prior to treatment.
- Treatments such as mowing, roller chopping, rotobeating, and plowing will have a greater and longer lasting impact on the sagebrush shrub layer; it is critical that invasive annual grasses do not exist within the community.
- Tebuthiuron at low rates has been reported as a technique for thinning dense sagebrush and opening the community for herbaceous plants. Provided herbaceous perennial plants exist in the understory, this technique might yield immediate improvements to habitat quality; however, if exotic annual grasses exist in the community, then expansion and spread of these invasive plants might result. There are no empirical data on the response of sage-grouse to tebuthiuron.
- Browsing animals may be used as a biocontrol for reducing the densities of sagebrush and potentially increasing the herbaceous component. Several studies have shown long-term declines in threetip sagebrush with recovery of herbaceous vegetation at high elevation sites in Idaho; declines of Wyoming and mountain big sagebrush densities due to heavy deer or elk browsing have been noted in Utah and Montana.
- Cox and Anderson (2004) suggested this method for restoring a complete sagebrush grassland community: sites dominated by cheatgrass could be seeded with crested wheatgrass to control the cheatgrass. Later, sites dominated by introduced grasses could be prepared by a till, harrow, or with herbicides and then reseeded with native species.
- Rehabilitation and restoration techniques to transform lands currently dominated by invasive annual grasses into quality sage-grouse habitat have been largely unproven and experimental. Several components of the process are being investigated with varying degrees of success. The first aspect of the process will be the reduction in the competition that invasive annual grasses provide against native seedlings during the establishment phase. Proposed techniques to reduce cheatgrass densities include herbicides imazapic (Plateau) (Shinn and Thill 2002) and glyphosate (Whitson and Koch 1998), defoliation via livestock grazing (Hulbert 1955, Finnerty and Klingman 1961, Mosley 1996), pathogenic bacteria (Kennedy et al. 1991) and fungi (Meyer et al. 2001). Although prescribed fire alone is not recommended (Mosley et al. 1999), it may be an effective technique worth investigation if applied in combination with a spring glyphosate treatment and conducted either in late spring or autumn. The glyphosate will kill the current-year's plants, thus reducing or eliminating seed production, and will prepare a fuel bed for the fire that will reduce the litter seed bank. In addition to density reduction techniques, applications of carbon in a form readily available for microbial uptake in the soil may increase soil microbial content and cause the microbes to reduce the available

soil nitrogen, thus reducing the growth and competitive ability of cheatgrass (McLendon & Redente 1990, 1992, Young et al. 1996).

! Immediate revegetation is required after reduction of invasives; otherwise invasive annual grasses that escape treatments will grow unabated, produce large numbers of seeds, and quickly dominate a site again (Mack and Pyke 1983). Successful revegetation efforts are generally those where introduced forage grasses have been sown (Asay et al. 2001). Some evidence from wildfire rehabilitation studies shows that native plants can be sown and eventually coexists with invasive annuals, but these were generally sown in combination with introduced grasses (Pyke et al. 2003, Cox and Anderson 2004). Theoretical frameworks hypothesize that multiple native species representing a variety of growth and life forms may successfully compete with invasive plants where any one species would be unsuccessful (Sheley et al. 1996).

! Techniques for reseeding sagebrush have been successfully demonstrated, but surface sowing followed by compaction of the soil may be necessary for establishment. Establishment of forbs important to sage-grouse have also shown promise, but availability of seed tends to limit their widespread use on rangeland restoration and rehabilitation projects (McArthur 2004).

! Availability and cost of native seed is a major obstruction to the use of native seeds in revegetation projects (McArthur 2004). Equipment for sowing native seeds is not widely available. Native seeds, because of their differing sizes, will require mixing within the seed boxes on the drills to insure that equal proportions of all seeds are sown, or will require separate seed boxes to allow seeds of different sizes to be buried at different optimal depths.

! See Connelly et al. (2000) (and below; Extracted Paper B) for details on habitat restoration of (a) breeding, (b) summer-late brood-rearing, and (c) winter habitats.

SELECTED ABSTRACTS

*Whitson, T. D. and D. W. Koch. 1998. **Control of downy brome (*Bromus tectorum*) with herbicides and perennial grass competition.** Weed Technology 12:391-396.

Abstract.—Long-term control of downy brome with an integrated approach is needed in order to sustain range productivity. Studies were conducted to study the effectiveness of a combination of downy brome control practices. In two studies, glyphosate and paraquat were evaluated at various rates for up to three successive years for control of downy brome in rangeland. A third study evaluated the competitiveness of perennial cool-season grasses against downy brome in the absence of herbicides. Glyphosate, at 0.55 kg/ha, and 0.6 kg/ha paraquat provided selective downy brome control on rangeland when applications were combined with intensive grazing. Downy brome control was greater than 90% following two sequential years of 0.6 kg/ha paraqUat at either the two- to eight-leaf stage or bloom stage at both study locations. At one study location, 0.55 kg/ha glyphosate provided 97% control after the first application at both growth stages. In the second study, control averaged greater than 92% following three sequential applications of glyphosate. When perennial cool-season grasses were seeded in the spring following fall tillage (no herbicides) and allowed to establish for three growing seasons, three of the five species were effective in reducing the reestablishment of downy brome. 'Luna' pubescent wheatgrass, 'Hycrest' crested wheatgrass, 'Sodar' streambank wheatgrass, 'Bozoisky' Russian wildrye, and 'Critana' thickspike wheatgrass controlled 100, 91, 85, 45, and 32% of the downy brome, respectively. Yields of perennial grass dry matter were 1,714, 1,596, 1,135, 900, and 792 kg/ha. Replacing noncompetitive annual grasses with competitive cool-season perennials will provide a longer term solution to a downy brome problem than the use of herbicides alone or with intensive grazing.

*Aronson, J., C. Floret, E. Le Floc'h, C. Ovalle, and R. Pontanier. 1993. **Restoration and rehabilitation of degraded ecosystems in arid and semi-arid lands.** I. A view from the south. Restoration Ecology 1:8-17.

Abstract.—A general model is presented describing ecosystem degradation to help decide when restoration, rehabilitation, or reallocation should be the preferred response. The latter two pathways are suggested when one or more "thresholds of irreversibility" have been crossed in the course of ecosystem degradation, and when "passive" restoration to a presumed predisturbance conditions is deemed impossible. The young but burgeoning field of ecological restoration, and the older field of rehabilitation and sustainable range management of arid and semiarid lands (ASAL), are found to have much in common, especially compared with the reallocation of lands, which is often carried out without reference to pre-existing ecosystems. After clarifying some basic terminology, we present 18 vital ecosystem attributes for evaluating stages of degradation and planning experiments in the restoration or rehabilitation of degraded ecosystems.

*McLendon, T. and E. F. Redente. 1990. **Succession patterns following soil disturbance in a sagebrush steppe community.** Oecologia 85:293-300.

Abstract.—A study was begun in 1976 to measure succession patterns following soil disturbance within a sage-brush community in northwestern Colorado. The principal hypothesis was that type of disturbance affects the direction of succession, resulting in different plant communities

over time. Successional dynamics were studied through 1988. Four types of soil disturbance resulted in 3 early seral communities: one dominated by grasses, one by annuals, and one intermediate. The annual-dominated communities were opportunistic on these sites, lasting 3-5 years and not determining the direction in which succession proceeded following their replacement. Twelve years after disturbance, 3 communities (one grass-dominated, one shrub-dominated, and one intermediate) occupied the site, the characteristics of which were functions of type of initial soil disturbance.

***Sage-grouse brood-rearing habitat manipulation, sage-grouse use, and lagomorph herbivory, after two field seasons.** David Dahlgren, Utah State University, Department of Forestry, Range, and Wildlife Sciences, 5230 Old Main Hill, Logan, UT 84322, dkd@cc.usu.edu
The greater sage-grouse (*Centrocercus urophasianus*) population on Parker Mountain has seen a downward trend over the last couple of decades. In 1998-1999 the Parker Mountain Adaptive Resource Management (PARM) team funded a study to assess baseline information on sage-grouse. Based on 1998-1999 study, PARM proposed to treat 100-acre plots, containing approximately 40-70% big mountain sagebrush, with two mechanical treatments. In 2000 experimental plots were randomly allocated, with 4 replicates per treatment, of Dixie harrow, Lawson aerator, and control plots. Pre- and post-treatment data was taken using a variation of the point-intercept and line intercept methods. In October 2001 treatments were completed. In 2002 and 2003 post-treatment data was collected. In 2003 bird dog flush counts and sage-grouse pellet counts were conducted to assess use within treatment plots. In addition to sage-grouse research, we became interested in the effect of lagomorph herbivory on treatment response. In 2001 ungulate exclosures were erected due to grazing concerns. Researchers observed increased rabbit use within ungulate exclosures during late summer. In spring 2002 we constructed rabbit exclosures in each treatment type to determine the impact of lagomorph herbivory on the grass/forb component. In 2002 and 2003 data was collected using a daubenmire frame within exclosures. Data will continue to be collected through the 2004 field season. [From 24th Meeting of the Western agencies Sage and Columbian Sharp-tailed Grouse Technical Committee, Wenatchee, WA, 28 June–1July, 2004].

Gunnison sage-grouse in San Juan County, Utah: winter ecology, effects of grazing, and insect abundance. Sharon Ward, Utah State University, Department of Forest, Range, and Wildlife Science, 5230 Old Main Hill, Logan, Utah 84322, sharonward@cc.usu.edu; Terry A. Messmer, Quinney Professorship of Wildlife Conflict Management, Jack H. Berryman Institute, College of Natural Resources, Utah State University, Logan, 84322, terrym@ext.usu.edu
Gunnison sage-grouse (*Centrocercus minimus*) were recently reclassified as a separate species from Greater sage-grouse (*Centrocercus urophasianus*). Given their current limited range, and declining populations they have been identified by the U.S. Fish and Wildlife Service as a candidate species for listing under the federal Endangered Species Act. Currently, the only known populations are found in southwestern Colorado (Gunnison Basin) and southeastern Utah in San Juan County. A combined population estimate is 3,500-4,000 birds. Less than 10% of the population occurs in Utah. In 1996, a local organization, called The San Juan County Gunnison

Sage-grouse Working Group (SWOG) was formed to coordinate conservation efforts in the county. The group consists of private landowners and natural resource conservation agencies. To guide the conservation efforts, SWOG initiated a local research project to learn more about the species' habitat requirements. In response to severe drought conditions in 2002 in San Juan County, a number of landowners were given permission to graze agricultural lands enrolled in the Conservation Reserve Program (CRP). Many of these CRP fields are important Gunnison Sage-grouse habitat. This study is part of a larger collaborative effort involving the local community, private landowners, and government agencies to collect additional information necessary for preserving this species. The objectives of my research are to: 1) determine winter habitat use patterns for Gunnison sage-grouse, 2) determine nesting, brood-rearing, and reproductive success of Gunnison sage-grouse, 3) determine Gunnison sage-grouse use of grazed and ungrazed CRP fields; compare vegetation structure and percent canopy cover, and 4) compare insect abundance and diversity in brood locations to adjacent areas within the study site. [From 24th Meeting of the Western agencies Sage and Columbian Sharp-tailed Grouse Technical Committee, Wenatchee, WA, 28 June–1July, 2004].

Leonard K M; Reese K P; Connelly J W **Distribution, movements and habitats of sage grouse Centrocercus urophasianus on the Upper Snake River Plain of Idaho: Changes from the 1950s to the 1990s.** Wildlife Biology, 6(4): 265-270, 2000. ISSN: 0909-6396
Abstract.—The sage grouse *Centrocercus urophasianus* population level on the Upper Snake River Plain of Idaho has declined significantly over the past 40 years. We investigated migration patterns and seasonal ranges of these birds to compare to patterns from the 1950s and 1960s. Furthermore, we examined landscape changes that occurred between 1975 and 1992. Migration patterns have not changed since the 1950s. The grouse currently migrate up to 125 km and use an annual population range of at least 2,764 km^2. The major landscape change since 1975 that occurred in sage grouse habitat was a decline in the total amount of winter range. Between 1975 and 1992, 29,762 ha of sagebrush *Artemisia* spp. rangeland were converted to cropland, a 74% increase in cropland. Regression analysis suggested a relationship between sagebrush habitat loss and grouse population decline $r^2 = 0.59$, $P = 0.002$). Approximately 1,244 km^2 of privately-owned sagebrush on the study area could potentially be converted to cropland, which we predict would have serious negative implications for the sage grouse population.

*Danvir, R. E. 2002. **Sage-Grouse ecology and management in northern Utah sagebrush-steppe.** A Deseret Land and Livestock Wildlife Research Report, 2002. Deseret Land and Livestock Ranch and The Utah Foundation for Quality Resource Management (QRM).
Abstract (in part).—Grazing exclosure data suggest: a) grass production was strongly dependent on prior-year precipitation ($r^2 = 0.84$) and b) excluding livestock increased shrub production, reduced forb production and failed to increase plant species diversity. Hot, August wildfire burns in Wyoming sage sintering areas appeared detrimental, while cool-season controlled burns in summering areas appeared beneficial to grouse. Mechanical brush thinning and planting desirable forbs may be effective ways to improve grouse reproductive/summer nutrition, without severely reducing winter and nesting habitat. DLL lek counts increased significantly as forb abundance was increased on 5% of the DLL sage grouse summer range. Results of this study

suggest livestock grazing and brush management techniques can be used to enhance sagebrush habitats for sage grouse if used wisely.

*Wisdom M. J., M. M. Rowland, B. C. Wales, M. A. Hemstrom, W. J. Hann, M. C. Raphael, R. C. Holthausen, R. A. Gravenmier, and T. D. Rich. **Modeled effects of sagebrush-steppe restoration on Greater sage-grouse in the interior Columbia Basin, U.S.A.** Conservation Biology, 16(5): 1223-1231, 2002. ISSN: 0888-8892

Abstract.—Habitats of Greater Sage-Grouse (*Centrocercus urophasianus*) have declined across western North America, and most remaining habitats occur on lands administered by the U.S. Forest Service (FS) and U.S. Bureau of Land Management (B.M.). Consequently, managers of FS-B.M. lands need effective strategies to recover sagebrush (*Artemisia* spp.) habitats on which this species depends. In response to this need, we evaluated the potential benefits of two restoration scenarios on Greater Sage-Grouse in the interior Columbia Basin and adjacent portions of the Great Basin of the western United States. Scenario 1 assumed a 50% reduction in detrimental grazing effects (through changes in stocking rates and grazing systems) and a six-fold increase in areas treated with active restoration (e.g., prescribed burning, native seeds, wildfire suppression) compared with future management proposed by the FS-B.M. Scenario 2 assumed a 100% reduction in detrimental grazing effects and the same increase in active restoration as scenario 1. To evaluate benefits, we estimated the risk of population extirpation for sage grouse 100 years in the future under the two scenarios and compared this risk with that estimated for proposed (100-year) FS-B.M. management. We used estimates of extirpation risk for historical (circa 1850-1890) and current time periods as a context for our comparison. Under historical conditions, risk of extirpation was very low on FS-B.M. lands, but increased to a moderate probability under current conditions. Under proposed FS-B.M. management, risk of extirpation on FS-B.M. lands increased to a high probability 100 years in the future. Benefits of the two restoration scenarios, however, constrained the future risk of extirpation to a moderate probability. Our results suggest that expansive and sustained habitat restoration can maintain desired conditions and reduce future extirpation risk for sage grouse on FS-B.M. lands in western North America. The continued spread of exotic plants, however, presents a formidable challenge to successful restoration and warrants substantial research and management attention.

Wisdom. M. J., B. C. Wales, M. M. Rowland, M. G. Raphael, R. S. Holthausen, T. D. Rich, and V. A. Saab. **Performance of Greater sage-grouse models for conservation assessment in the Interior Columbia Basin, U.S.A.** Conservation Biology, 16(5): 1232-1242, 2002. ISSN: 0888-8892

Abstract.—Valid modeling of habitats and populations of Greater Sage-Grouse (*Centrocercus urophasianus*) is a critical management need because of increasing concern about population viability. Consequently, we evaluated the performance of two models designed to assess landscape conditions for Greater Sage-Grouse across 13.6 million ha of sagebrush steppe in the interior Columbia Basin and adjacent portions of the Great Basin of the western United States (referred to as the basin). The first model, the environmental index model, predicted conditions at the scale of the subwatershed (mean size of approximately 7800 ha) based on inputs of habitat density, habitat quality, and effects of human disturbance. Predictions ranged on a continuous scale from 0 for lowest environmental index to 2 for optimal environmental index. The second

model, the population outcome model, predicted the composite, range-wide conditions for sage grouse based on the contribution of environmental index values from all subwatersheds and measures of range extent and connectivity. Population outcomes were expressed as five classes (A through E) that represented a gradient from continuous, well-distributed populations (outcome A) to sparse, highly isolated populations with a high likelihood of extirpation (outcome E). To evaluate performance, we predicted environmental index values and population outcome classes in areas currently occupied by sage grouse versus areas where extirpation has occurred. Our a priori expectations were that models should predict substantially worse environmental conditions (lower environmental index) and a substantially higher probability of extirpation (lower population outcome class) in extirpated areas. Results for both models met these expectations. For example, a population outcome of class E was predicted for extirpated areas, as opposed to class C for occupied areas. These results suggest that our models provided reliable landscape predictions for the conditions tested. This finding is important for conservation planning in the basin, where the models were used to evaluate management of federal lands for sage grouse.

*Hemstrom, M. A., M. J. Wisdom, W. J. Hann, M. M. Rowland, B. C. Wales, and R. A. Gravenmier. **Sagebrush-Steppe vegetation dynamics and restoration potential in the Interior Columbia Basin, U.S.A.** Conservation Biology, 16(5): 1243-1255, 2002. ISSN: 0888-8892

Abstract.—We modeled the dynamics and restoration of sagebrush (*Artemisia* spp.) habitats for Greater Sage-Grouse (*Centrocercus urophasianus*) in the interior Columbia Basin and adjacent portions of the Great Basin (referred to as the basin). Greater Sage-Grouse have undergone widespread decline and are the focus of conservation on over 13 million ha of sagebrush steppe in the basin, much of which is managed by the U.S. Forest Service (FS) and U.S. Bureau of Land Management (B.M.). Consequently, we evaluated changes in the amount and quality of sage-grouse habitat on 8.1 million ha of FS-B.M. lands in the basin. Changes were estimated from historical to current conditions and from current conditions to those projected 100 years in the future under proposed management and under two restoration scenarios. These two scenarios were designed to improve long-term (100-year) projections of sage-grouse habitat on FS-B.M. lands in relation to current conditions and proposed management. Scenario 1 assumed a 50% reduction in detrimental grazing effects by livestock (through changes in stocking rates and grazing systems) and a six-fold increase in areas treated with active restoration relative to proposed management. Scenario 2 assumed a 100% reduction in detrimental grazing effects and the same level of active restoration as scenario 1. Under the two scenarios, the amount of FS-B.M. habitat for sage grouse within treated areas declined by 17-19% 100 years in the future compared with the current period, but was 10-14% higher than the 100-year projection under proposed management. Habitat quality under both scenarios was substantially improved compared with the current period and proposed management. Our results suggest that aggressive restoration could slow the rate of sagebrush loss and improve the quality of remaining habitat.

Commons, M. L., R. K. Baydack, and C. E. Braun. 1997. **Gunnison sage grouse *Centrocercus minimus* use of fragmented habitats in southwestern Colorado**. Wildl. Biol. 3:283.

Abstract.—Gunnison's sage grouse *Centrocercus minimus* historically occurred throughout sagebrush *Artemisia* rangelands in southwestern Colorado, southeastern Utah, and northern New Mexico. Because of the reduction of sagebrush habitat for the enhancement of livestock grazing, agricultural use, and other human activities, only a few remnant populations remain in highly fragmented habitat in southwestern Colorado and extreme southeastern Utah. In 1994 and 1995, two geographically isolated populations of sage grouse were studied in southwestern Colorado to identify seasonal movements and habitat use. Radio transmitters were fitted to 55 male and 8 female sage grouse in Dove Creek, Dolores County, and at Dry Creek Basin/Miramonte Reservoir, San Miguel County, Colorado. The Dolores County population was separated by the town of Dove Creek and movements occurred between the two sites. Sage grouse in Dolores County were in agricultural fields (alfalfa, bean, and wheat) from May through September, and sagebrush and Gambel Oak *Ouercus gambelii* from October through February. Sage grouse in Dry Creek Basin were in areas with low sage *A. arbuscula*, snakeweed *Gutierrezia sarothrae*, black greasewood *Sarcobatus vermiculatus*, and winterfat *Eurotia lanata* while sage grouse near Miramonte Reservoir were in sagebrush *A. tridentata*, *A. nova*, wet meadows, and Gambel Oak throughout the year. Hamilton Mesa between Dry Creek Basin and Miramonte Reservoir was also used by sage grouse. Dominant vegetation of this site included forbs, grass, gambel oak, and serviceberry *Amelanchier* spp. Extensive movements occurred from Dry Creek Basin to Hamilton Mesa and to Miramonte Reservoir. Management considerations must include all three sites in San Miguel County and both sites in Dolores County if sage grouse are to persist in southwestern Colorado.

A neglected component of greater sage-grouse brood habitat: nocturnal roost sites—Doris Hausleitner, Department of Fish and Wildlife Resources, University of Idaho, Moscow, ID 83844, dorishaus@shaw.ca; Kerry P. Reese, Department of Fish and Wildlife Resources, University of Idaho, Moscow, ID 83844 Anthony D. Apa, Colorado Division of Wildlife, 711 Independent Avenue, Grand Junction, CO 81505; R. Gerald Wright, USGS Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow, ID 83844
Abstract.—Declines in greater sage-grouse abundance may be associated with habitat degradation. Despite extensive research into the habitat requirements of the species, summer nocturnal habitat has received no attention. We investigated the vegetation characteristics of nocturnal roosts used by radio-marked female greater sage-grouse and compared diurnal and nocturnal habitat use during the brood-rearing period. Nocturnal roosts (n = 58) had less visual obstruction and bare ground, and greater percent forb cover than at random sites (n = 92). Mean shrub height and shrub cover at nocturnal roosts was shorter (31 vs. 58 cm) and less dense (9% vs. 22%) that at diurnal sites used by broods (n = 92). Females with broods moved a median of 397 m from the last diurnal location to nocturnal roost sites. This suggests that females with broods were required to move 3 times their median daily movement in order to find suitable nocturnal brood habitat. Literature estimates of daily and seasonal movements of females with broods may be biased low. Guidelines for the management of brood-rearing habitats address only diurnal habitat needs and should be modified to include the requirements of nocturnal habitat. [From 24th Meeting of the Western agencies Sage and Columbian Sharp-tailed Grouse Technical Committee, Wenatchee, WA, 28 June–1 July, 2004.]

***Restoration of sagebrush communities following mechanical treatments of pinyon-juniper woodlands—**Stephen B. Monsen, Retired Ecologist, Mapleton, UT 84664, smonsen5@cs.com; Pam Motley, Uncompahgre Project, Montrose, CO; Bob Welch, Montrose Field Office, B.M., Montrose, CO.
Abstract.—Pinyon-juniper have invaded and occupied extensive areas throughout the West as a result of a decrease in understory from grazing, changes in fire frequency, and associated management practices. Extensive loss of wildlife habitat has subsequently occurred, creating a decline in sage grouse and mule deer. Removal of tress and seeding introduced perennial grasses was a common practice beginning in the early 1960's. Numerous sites in Colorado were treated by anchor chaining and seeding as a means to enhance wildlife habitats and livestock grazing. Chaining practices have been questioned, but careful evaluation of the effects on wildlife habitat and plant community development has not been reported. This study was developed to evaluate the species composition, including the recovery of black sagebrush and Wyoming big sagebrush through natural recruitment approximately 40 years after treatment. Studies were located on old chainings and grass seeds of the Uncompahgre Plateau, Colorado. Chaining effectively reduced tree competition and allowed seeded species to successfully establish. In addition, natural recruitment of native herbs and shrubs has occurred to fully occupy the sites. Seeded grasses remain a part of the composition, but do not dominate in most situations. A full compliment of native broadleaf herbs and perennial grasses now occur as the principal species. Black sagebrush and Wyoming big sagebrush have regained dominance on soils and sites they are naturally adapted. Shrub density, age class composition, distribution, and presence of understory herbs appear adequate to sustain sage grouse and mule deer populations. Tree re-encroachment has been restricted by the presence of understory species. [From 24th Meeting of the Western agencies Sage and Columbian Sharp-tailed Grouse Technical Committee, Wenatchee, WA, 28 June–1July, 2004].

Landscape use by greater sage-grouse: effects of habitat fragmentation—Jay Shepherd, University of Idaho, P.O. Box 8623, Moscow, ID, 83843, shep9737@uidaho.edu; Kerry P. Reese, Department of Fish and Wildlife Resources, University of Idaho, Moscow, ID 83844; John W. Connelly, Idaho Department of Fish and Game, 1345 Barton Road, Pocatello, ID 83204
Abstract.—Probable causes of greater sage-grouse (*Centrocercus urophasianus*) declines include various forms of habitat degradation, reduction, and fragmentation. Prescribed fire and wildfire, mechanical or chemical treatments, or complete conversion to agricultural use has resulted in fragmentation of shrubsteppe. Many studies have attempted to understand local or microhabitat level habitat use by sage grouse. At larger scales, habitat use and fragmentation have been studied much less and using limited methods. Our objectives are to quantify greater sage-grouse habitat use and the levels of habitat heterogeneity within the landscape. We used remotely sensed vegetation data, measures of habitat composition, and landscape metrics designed to measure habitat heterogeneity. There is an increased need for the development of methods using remotely sensed data at the landscape level to understand larger scale habitat issues in an efficient manner. We used linear regression to explain habitat use variables such as size of core use area and mean daily movement with habitat composition and landscape metrics at several scales. Variables were obtained at several scales, including 150 and 450 meter buffered points, and core areas of use. Combinations of landscape metrics, cover types, and scales produced 30 landscape vegetation

variables, and with the use of gender produced 31 independent variables for use in explaining landscape use measurements. Using non-correlated variables, we explain relative measures of fitness such as mean daily distance moved and size of core use area with landscape level metrics of habitat composition and heterogeneity. [From 24th Meeting of the Western agencies Sage and Columbian Sharp-tailed Grouse Technical Committee, Wenatchee, WA, 28 June–1July, 2004].

Steven T. Knick, David S. Dobkin, John T. Rotenberry, Michael A. Schroeder, W. Matthew Vander Haegen, and Charles Van Riper III. 2003. **Teetering on the edge or too late? Conservation and research issues for the avifauna of sagebrush habitats.** Condor 105:611-634.

Abstract.—Degradation, fragmentation, and loss of native sagebrush (*Artemisia* spp.) landscapes have imperiled these habitats and their associated avifauna. Historically, this vast piece of the Western landscape has been undervalued: even though more than 70% of all remaining sagebrush habitat in the United States is publicly owned, <3% of it is protected as federal reserves or national parks. We review the threats facing birds in sagebrush habitats to emphasize the urgency for conservation and research actions, and synthesize existing information that forms the foundation for recommended research directions. Management and conservation of birds in sagebrush habitats will require more research into four major topics: (1) identification of primary land-use practices and their influence on sagebrush habitats and birds, (2) better understanding of bird responses to habitat components and disturbance processes of sagebrush ecosystems, (3) improved hierarchical designs for surveying and monitoring programs, and (4) linking bird movements and population changes during migration and wintering periods to dynamics on the sagebrush breeding grounds. This research is essential because we already have seen that sagebrush habitats can be altered by land use, spread of invasive plants, and disrupted disturbance regimes beyond a threshold at which natural recovery is unlikely. Research on these issues should be instituted on lands managed by state or federal agencies because most lands still dominated by sagebrush are owned publicly. In addition to the challenge of understanding shrubsteppe bird-habitat dynamics, conservation of sagebrush landscapes depends on our ability to recognize and communicate their intrinsic value and on our resolve to conserve them.

Colorado Division of Wildlife. **Gunnison sage-grouse**. Species Conservation, 2003; Special Issue: Publication of Colorado Division of Wildlife.

Abstract.—The Gunnison sage grouse is a newly-classified, unique species of sage grouse found south of the Colorado River. It is one-third the size of the common sage grouse, with males possessing conspicuous white tail feathers and filoplume. The female Gunnison's feathers resemble those of the common sage grouse, but the bird is one-third smaller in size. The Gunnison sage grouse traditionally occupied the entire southwestern region of Colorado and southeastern Utah. At present, however, the species is found in eight separate populations, with less than 4000 breeding numbers. The major community of approximately 2500 birds occurs in the Gunnison Basin. This unique species occupies diverse habitats consisting of vast stretches of sage, various grasses, forbs, and fertile riverbanks. Its diet is almost solely made up of sage, with the plant's fibrous leaves serving as a winter diet. The male bird entices the female with complex mating exhibitions. The nesting season extends from mid-April to July. Six to eight eggs are laid and incubated for a period of 25-27 days. Human activities and expanding deer and elk

populations are the causes of destruction of the bird's habitat. In order to protect and conserve the species, the Colorado Division of Wildlife prohibited hunting of the Gunnison sage grouse in the year 2000.

Lyon, Alison G.; Anderson, Stanley H. **Potential gas development impacts on sage grouse nest initiation and movement.** Wildlife Society Bulletin, 2003. pp. 486-491 (6 pp.). Vol. 31, No. 2 ISSN: 0091-7648

Abstract.—The decline of greater sage grouse (*Centrocercus urophasianus*) over the last 50 years has raised concern over how natural gas development might affect sage grouse populations. We examined the effects of vehicular activity due to gas-well development near Pinedale, Wyoming, on productivity and movements of sage grouse. In 1998-1999, we captured and radiomarked 48 female sage grouse on 6 leks classified as disturbed or undisturbed, based on the presence or absence of natural gas development within 3 km. The mean distance from disturbed leks to selected nest sites was greater ($P = 0.019$ with outliers removed, $P = 0.004$ with outliers included) than distance moved from undisturbed leks. Nest-initiation rate for hens from disturbed leks was 65%, while hens from undisturbed leks initiated nests 89% ($P = 0.07$) of the time. Nest success at both disturbed and undisturbed leks was 50%. Our results suggest that light traffic disturbance (1-12 vehicles/day) during the breeding season might reduce nest-initiation rates and increase distances moved from leks during nest-site selection. We recommend further investigation concentrating on hen behavior (i.e., distance moved from lek to nest site, breeding behavior, lek attendance), reproductive effort, and nest success in relation to natural gas development as development intensifies.

Beck, Jeffrey L.; Mitchell, Dean L.; Maxfield, Brian D. **Changes in the distribution and status of sage-grouse in Utah.** Western North American Naturalist, 63(2): 203-214; April 2003 ISSN: 1527-0904

Abstract.—Sage-grouse (*Centrocercus* spp.) were abundant in all of Utah's 29 counties at the time of European settlement wherever sagebrush (*Artemisia* spp.) occurred. Greater Sage-Grouse (*C. urophasianus*) inhabited areas north and west of the Colorado River, and Gunnison Sage-Grouse (*C. minimus*) occupied suitable habitat south and east of the Colorado River. The largest Greater Sage-Grouse populations in Utah are currently restricted to suitable habitats in Box Elder, Garfield, Rich, Uintah, and Wayne Counties. A remnant breeding population of Gunnison Sage-Grouse occurs in eastern San Juan County. We stratified Greater Sage-Grouse populations (1971-2000) by counties where the 1996 to 2000 moving average for estimated spring breeding populations was >500 (GT500) or <500 (LT500). Males per lek declined in all populations from 1971 to 2000; however, there were consistently more males observed on GT500 than on LT500 leks. Juveniles per adult hen (including yearling hens) Greater Sage-Grouse in the 1973-2000 fall harvest in Box Elder, Rich, and Wayne Counties did not differ from 2.25, a ratio suggesting sustainable or increasing sage-grouse populations. Declines are attributed to loss, fragmentation, and degradation of sagebrush habitat. Sage-grouse conservation ultimately depends on management and enhancement of remaining sagebrush rangelands in Utah.

Pedersen, E. K.; Connelly, J. W.; Hendrickson, J. R.; Grant, W. E**. Effect of sheep grazing and fire on sage grouse populations in southeastern Idaho.** Ecological Modelling, 165(1): 23-47; 1 July 2003 ISSN: 0304-3800

Abstract.—This paper describes the development, evaluation, and use of a model that simulates the effect of grazing and fire on temporal and spatial aspects of sagebrush community vegetation and sage grouse population dynamics. The model is represented mathematically as a discrete-time, stochastic compartment model based on difference equations with a time interval of 1 week. In the model, sheep graze through sage grouse breeding habitat during spring and fall, and different portions of the area can burn at different frequencies, creating a habitat mosaic of burned and unburned areas. The model was evaluated by examining predictions of (1) growth of sagebrush canopy cover after fire, (2) seasonal dynamics of grass and forb biomass under historical environmental conditions, and (3) sage grouse population dynamics associated with selected sagebrush canopy covers. Simulated changes in sagebrush canopy cover following fire correspond well with qualitative reports of long-term trends, simulated seasonal dynamics of herbaceous biomass correspond well with field data, and simulated responses of sage grouse population size and age structure to changing sagebrush canopy cover correspond well to qualitative field observations. Simulation results suggest that large fires occurring at high frequencies may lead to the extinction of sage grouse populations, whereas fires occurring at low frequencies may benefit sage grouse if burned areas are small and sheep grazing is absent. Sheep grazing may contribute to sage grouse population decline, but is unlikely to cause extinction under fire regimes that are favorable to sage grouse.

*Wirth, Troy A.; Pyke, David A. **Restoring forbs for sage grouse habitat: Fire, microsites, and establishment methods.** Restoration Ecology, 11(3): 370-377; September 2003 ISSN: 1061-2971

Abstract.—The decline and range reduction of sage grouse populations are primarily due to permanent loss and degradation of sagebrush-grassland habitat. Several studies have shown that sage grouse productivity may be limited by the availability of certain preferred highly nutritious forb species that have also declined within sagebrush ecosystems of the Intermountain West, U.S.A. The purpose of this study was to determine the suitability of three species of forbs for revegetation projects where improving sage grouse habitat is a goal. Species suitability was determined by evaluating the emergence, survival, and reproduction of *Crepis modocensis*, *C. occidentalis*, and *Astragalus purshii* in response to method of establishment (seeding or transplanting), site preparation treatment (burned or unburned), and microsite (mound or interspace) in an *Artemisia tridentata* ssp. *wyomingensis* vegetation association in south central Oregon. For seeded plants *A. purshii* had the lowest emergence (8%) of all three species. Both seeded Crepis species had similar overall emergence (38%). Significantly more Crepis seedlings emerged from shrub mounds in unburned areas (50%) than in any other fire-by-microsite treatment (33 to 36%). Approximately 10% more *Crepis* seedlings survived in mounds compared with interspaces. Nearly twice as many emerging *Crepis* seedlings survived in the burned areas as opposed to unburned areas ($P < 0.01$). This resulted in more plant establishment in burned mounds despite higher emergence in unburned mounds. *Astragalus purshii* seedlings also survived better in burned areas ($P = 0.06$) but had no differential response to microsite. Fire enhanced survival of both *Crepis* and *A. purshii* transplants ($P = 0.08$ and $P = 0.001$). We believe

additional research is needed to improve *A. purshii* emergence before it will become an effective plant for restoring sage grouse habitat. Conversely, we conclude that these *Crepis* species provide a viable revegetation option for improving sage grouse habitat in south central Oregon.

Aldridge, Cameron L.; Brigham, R. Mark **Sage-grouse nesting and brood habitat use in Southern Canada.** Journal of Wildlife Management, 66(2): 433-444; April 2002 ISSN: 0022-541X

Abstract.—Greater sage-grouse (*Centrocercus urophasianus*) populations have declined from 66 to 92% during the last 30 years in Canada, where they are listed as endangered. We used radiotelemetry to examine greater sage-grouse nest and brood habitat use in Alberta and assess the relationship between habitat and the population decline. We also identified the patch size at which sage-grouse were selecting nest and brood-rearing sites. Nest areas were in silver sagebrush (*Artemisia cana*) stands that had greater amounts of tall cover ($P < 0.001$) at a patch size of 7.5 to 15 m in radius. Within those sagebrush stands, nests were located beneath the densest sagebrush present. Areas used for brood rearing had greater amounts of taller sagebrush cover in an area >15 m in radius than at random locations. Brood locations were not selected based on forb content; mesic areas containing forbs (20-40% cover) as a food resource for chicks were limiting (only 12% cover available). Overall cover of sagebrush is considerably lower in Canada (5-11%) compared with sagebrush (*Artemisia* spp.) cover in other areas throughout the range of greater sage-grouse (15-25%). If management goals are to provide suitable nesting and brood-rearing habitat, efforts should be directed toward protecting and enhancing sagebrush stands >30 m^2 and increasing overall sagebrush cover. Management strategies also should focus on increasing the availability of mesic sites and increasing the abundance of sites with >10% forb cover, to enhance brood rearing habitat.

Gilbert, Steve **Coal bed methane: boom for industry, bane for wildlife**. Intermountain Journal of Sciences, 8(4): 252. 2002 ISSN: 1081-3519

Abstract.—Associated with coal seams in southeast Montana is natural gas referred to as coal bed methane (CBM), held there by water pressure. To get the gas, the water must first be removed. There is great interest by industry and state and federal administrations to pump and use this resource. It will take only 10-20 years of boom and bust development to drain Montana of its methane resource. This will have severe impacts to wildlife in perpetuity. CBM development will negatively affect Montana's water and lands forever, regardless of "reclamation." Aquifers, springs and seeps depended upon by farmers, ranchers and wildlife will be dried up. Water pumped from these aquifers, although drinkable by humans and wildlife, is very salty and kills vegetation. This water will be sprinkled across the land and pumped to leaking discharge pits killing vegetation and soil. Surface destruction by this industry will be massive. Thousands of miles of powerlines, pipelines, and access roads will lace sagebrush-grasslands of southeast Montana supporting pronghorn, mule deer and white-tailed deer and dwindling population so sage grouse. Huge noisy compressors will drown the calls of many bird species including sage and sharp-tailed grouse. Well pads with access roads will dot the countryside, and trucks of every size will careen down dusty roads 24 hours a day. Fragmentation of wildlife habitat will occur from this resource development at levels never before experienced in Montana. Tens of thousands of acres of sagebrush-grassland habitats will

be destroyed. It is unlikely any will be reclaimed in kind or function. There will be soil compaction, weed encroachment, and the cut-and-run philosophy will once again leave Montana citizens holding the reclamation bag, and wildlife populations the victims of lost and fragmented habitat.

Dusek, Gary L.; Eustace, Charles D.; Peterson, Joel G. **The ecology and status of sage grouse in Montana.** Intermountain Journal of Sciences, 8(2): 67-81. 2002 ISSN: 1081-3519
Abstract.—We describe the ecology and status of the greater sage grouse (*Centrocercus urophasianus*) in Montana as part of an effort to develop a species conservation plan. Sage grouse are primarily associated with big sagebrush (*Artemisia tridentata*)-grassland although the original range has been greatly reduced or fragmented by a variety of human uses and activities. Efforts by the State's wildlife agency to delineate distribution of sage grouse in Montana during the 1960s and 1970s suggested that sage grouse occupied about 4.4 million ha in eastern and southwest Montana although more recent efforts to assess sage grouse habitat suggest occupied habitat could be as much as 10.9 million ha. Findings from studies during that period suggested that year-long distribution and movements reflect regional or local conditions. That is, sage grouse tend to be nonmigratory in eastern Montana, where close interspersion of seasonal habitats rarely requires large movements, and migratory in the intermountain valleys of southwest Montana. Habitat requirements of sage grouse vary seasonally, in terms of structure and composition, to accommodate successful breeding and brood rearing and over-winter survival. Yearly precipitation patterns, in addition to habitat quality, can affect nesting success and chick survival. Data from statewide wing collections suggest that productivity of sage grouse declined from an average of 2.63 juveniles/hen during 1962-1979 to an average of 2.08 juveniles/hen during 1980-1992; drought conditions were more frequent during the latter period. An estimate of mortality of sage grouse during the first year of life approaches 85% of which about two-thirds occurs prior to the opening of the upland bird hunting season in September. Sage grouse populations in southwestern Montana have declined from the 1960s through the 1980s following a period of large-scale sagebrush manipulation and conversion of native range to cropland. Numbers of birds remain relatively abundant throughout areas of central and eastern Montana that continue to support large, unfragmented stands of big sagebrush. Several state-initiated programs offer incentives to private landowners to maintain or enhance habitat quality for sage grouse and other wildlife species.

Hockett, Glenn A. **Livestock impacts on the herbaceous components of sage grouse habitat: a review.** Intermountain Journal of Sciences, 8(2): 105-114. 2002 4 figs. ISSN: 1081-3519
Abstract.—Sage grouse are a bird of climax vegetation. Productive sage grouse habitat is more than a "sea of sagebrush." The grass/forb understory supplies food and cover components seasonally. Within the sagebrush community, a dense, residual herbaceous understory increases the likelihood of sage grouse nest success. Forbs and insects are essential foods for sage grouse from early spring to early fall. Although riparian areas typically make up less than two percent of the sagebrush landscape, interspersed springs, streams, and meadows offer watering and feeding sites for sage grouse during summer and early fall. Livestock selectively remove grasses and forbs within the sagebrush landscape while showing a strong preference for riparian meadows once upland vegetation cures. Livestock use can impact the amount and composition of

herbaceous understory depending on the class of livestock, season of use, and grazing intensity. I reviewed the literature regarding sage grouse habitats and livestock impacts to the herbaceous understory. Ungrazed comparison areas, based on the seasonal needs of sage grouse, are lacking. Controls are recommended to advance our understanding of grazing impacts.

Roscoe, James W. **Sage grouse movements in southwestern Montana.** Intermountain Journal of Sciences, 8(2): 94-104. 2002 3 tables; 4 figs. ISSN: 1081-3519

Abstract.—Sage grouse (*Centrocercus urophasianus*) populations have declined throughout the western United States and in southwestern Montana since the 1970s. Conservation efforts rely on knowledge of seasonal habitat distribution and sage grouse movement patterns between these habitats. Both of these factors are poorly understood and undocumented in southwestern Montana. An ongoing, cooperatively study was initiated in 1999 to radio-track sage grouse in Southwestern Montana to identify resident and migratory populations, key habitats, and movement patterns relevant to local sagebrush and sage grouse conservation. Thirty-seven sage grouse were fitted with radio transmitters and monitored < or = 24 months in Horse Prairie, Sweetwater Basin, and Big Sheep Creek Basin in Beaverhead and Madison Counties near Dillon, Montana. Data collection included aerial monitoring supplemented with ground relocations obtained between flights. Results indicated that some groups of sage grouse were resident within a particular habitat complex while others traveled greater distances to utilize suitable breeding, summer, and winter habitat. This study helped identify locally important brood-rearing and summer habitats. Annual mortality of radio-tracked birds has averaged 58% over three years, with 50-83% losses for males (n = 20) and 14-50% losses for females (n = 4).

Moynahan, Brendan J.; Lindberg, Mark; Thomas, Jack Ward **Understanding relationships between greater sage-grouse habitat and population dynamics in eastern Montana.** Intermountain Journal of Sciences, 8(4): 258-259. 2002 ISSN: 1081-3519

Abstract.—The long-term decline of greater sage grouse (*Centrocercus urophasianus*) over much of their historic range is of concern to managers of sagebrush (*Artemisia* spp.) habitats. A petition has been submitted to list the Washington population of sage grouse under the Endangered Species Act (SEA) and a range-wide listing petition is expected in the near future. That habitat quality is related to demographics of populations is a fundamental assumption of the practice of managing species via managing habitat. However, few studies explicitly acknowledge this relationship, and still fewer explicitly attempt to define this relationship on a species-specific basis. There currently is no way to reliably determine the nature of the interaction between sage grouse population status (as indicated by estimated vital rates) and habitat condition. This research will use a combination of well-established population demography tools and state-of-the-art analysis methods to elucidate relationships between Sage-Grouse populations and habitat at six sites in eastern Montana. Mark-resight and radio telemetry methods will be employed to estimate vital rates of sage grouse populations. Sensitivity analysis will identify which rate(s) has the greatest influence on population growth rate (lambda) under different habitat conditions. Habitat condition at each site will be assessed by several critical habitat characteristics. A regression approach will quantify the relationship between individual vital rates and each of the measured habitat characteristics. The research will provide crucial

information to federal and state wildlife professionals charged with managing for sage grouse and will be of particular use in the event of a petition to list sage grouse under the SEA.

Watters, Megan E.; McLash, Tammy L.; Aldridge, Cameron L.; Brigham, R. Mark **The effect of vegetation structure on predation of artificial Greater sage-grouse nests.**
Ecoscience, 9 (3):314-319; 2002 ISSN: 1195-6860
Abstract.—In Canada, Greater Sage-Grouse (*Centrocercus urophasianus*) are considered an endangered species by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC), due to declining population numbers and distribution. Encroachment of agriculture and subsequent destruction of suitable sagebrush (*Artemisia* spp.) habitat is thought to be responsible for historical population declines. However, subtle changes in habitat quality may also result in reduced escape and nesting cover, which may lead to increased levels of predation. We examined the influence of vegetation cover and height on the fate of artificial Greater Sage-Grouse nests. Because most natural sage-grouse nests are associated with sagebrush, we predicted that sagebrush height and cover would be crucial to the success of nests. Lateral cover is important in protecting nests from detection by predators, and thus we predicted that nests surrounded by shorter grass would suffer greater predation rates than nests with taller grass. To experimentally test this hypothesis, we trimmed grass surrounding some artificial nests. Richardson's ground squirrels (*Spermophilus richardsonii*) were the primary predators of artificial nests, with some predation by corvids and badgers (*Taxidea taxus*). Successful nests tended to be surrounded by shorter sagebrush, taller grasses, and taller, denser forbs than predated nests. Trimming grass around nests did not affect nest fate. However, ground squirrels typically attacked nests with less forb cover and fewer sagebrush, and avian predators tended to destroy nests at inactive leks with greater lateral cover. Thus, lateral cover provided by forbs and sagebrush appeared to be important for protecting nests from mammalian predators. These results suggest implementing management strategies that improve sagebrush habitat by providing tall, dense forbs and sagebrush, which could increase Greater Sage-Grouse nest success and recruitment.

LaMontagne, Jalene M.; Irvine, Robyn L.; Crone, Elizabeth E. **Spatial patterns of population regulation in sage grouse (*Centrocercus* spp.) population viability analysis.**
Journal of Animal Ecology, 71(4): 672-682; July 2002 ISSN: 0021-8790
Abstract.—1. Population viability analyses (PVAs) are commonly used to identify species of concern. Many PVA techniques assume that all populations are regulated by a single mechanism. 2. We compared population viability predictions for three subspecies of sage grouse (*Centrocercus* spp.) based on the assumptions that: (I) population regulation was density-independent vs. dependent on more complex feedback mechanisms; (ii) the mechanism of population regulation was homogeneous within a region vs. heterogeneous among leks; (iii) environmental variation was spatially correlated within regions vs. uncorrelated among leks. 3. We used sage grouse as a model species for this analysis because counts of lekking male grouse are available in some areas since the 1950s, these counts are known to fluctuate widely, and sage grouse appear to be declining throughout their range. 4. We fit population regulation models to data including density-independence, density-dependence, delayed density-dependence and a simplified version of Turchin & Taylor's (1992) response surface model. 5. We show that the

best-fit models typically include spatial heterogeneity in mechanisms of population regulation. Inclusion of spatial heterogeneity increased expected time for population persistence, and changed the rank order of risk of extinction for different regions. 6. We suggest that it is important to consider multiple models of population regulation when applying population viability analysis techniques because viability projections are influenced strongly by model structure.

Weidensaul, Scott **Sage grouse strut their stuff**. Smithsonian, 32(3): 56-63; 2001 ISSN: 0037-7333
Abstract.—North America's sage grouse population is declining due to the unrestrained exploitation of its primary habitat, the Snake River plain and the big desert regions of southern Idaho. A study was conducted in these areas to get an insight into the crisis. In this article the author provides life history information as well as insights into the reasons for the decline. The sage grouse may be on its way to the federal endangered species list due to vast destruction of its sagebrush- and grass-dominated ecosystem by livestock grazing, agricultural croplands, and wildfires. The farmland has also inhibited the movement of these highly mobile birds. The huge distances covered by these wanderers necessitate the protection of large areas of their habitat. The consequence of range fires is not restricted to the obliteration of sagebrush. The complexity surrounding the revival of burned sagebrush is worsened by the growth of certain exotic weed species. The increased use of pesticides has also caused reduction in the availability of the grouse hatchlings' protein-rich diet of insects and plants reducing the chick survival rate. The formation of the Gunnison Sage Working Group comprised of representatives of all major stakeholders has led to the development of local conservation plans to reverse the decline and restore the sagebrush and lek territories along with managing the needs of livestock. Prohibition on sage grouse hunting has also alleviated the problem to a certain extent. A more enduring solution should be found in order to generate public awareness of the importance of the sagebrush ecosystem.

*****Oyler-McCance, Sara J.; Burnham, Kenneth P.; Braun, Clait E. **Influence of changes in sagebrush on Gunnison sage grouse in southwestern Colorado.** Southwestern Naturalist, 46(3): 323-331, 2001. 5 tables; 2 figs. ISSN: 0038-4909
Abstract.—The decline in abundance of the newly recognized Gunnison sage grouse (*Centrocercus minimus*) in southwestern Colorado is thought to be linked to loss and fragmentation of its habitat, sagebrush (*Artemisia*) vegetation. We documented changes in sagebrush-dominated areas between the 1950s and 1990s by comparing low level aerial photographs taken in these time periods. We documented a loss of 20% or 155,673 ha of sagebrush-dominated areas in southwestern Colorado between 1958 and 1993. The amount of sagebrush-dominated area was much higher and loss rates were much lower in the Gunnison basin. We also found that 37% of plots sampled underwent substantial fragmentation of sagebrush vegetation. If current trends of habitat loss and fragmentation continue, Gunnison sage grouse (and perhaps other sagebrush-steppe obligates) may become extinct. Protecting the remaining habitat from further loss and fragmentation is paramount to the survival of this species.

*****Connelly, J. W., M. A. Schroeder, A. R. Sands, and C. E. Braun. 2000. **Guidelines to manage sage grouse populations and their habitats.** Wildlife Society Bulletin 28:967-985.
Abstract.—The status of sage grouse populations and habitats has been a concern to sportsmen and biologists for >80 years. Despite management and research efforts that date to the 1930s, breeding populations of this species have declined throughout much of its range. In May 1999, the western sage grouse (*Centrocercus urophasianus phaios*) in Washington was petitioned for listing under the Endangered Species Act because of population and habitat declines (C. Warren, United States Fish and Wildlife Service, personal communication). Sage grouse populations are allied closely with sagebrush (*Artemisia* spp.). Despite the well-known importance of this habitat to sage grouse and other sagebrush obligates, the quality and quantity of sagebrush habitats have declined for at least the last 50 years. Braun et al. (1977) provided guidelines for maintenance of sage grouse habitats. Since publication of those guidelines, much more information has been obtained on sage grouse. Because of continued concern about sage grouse and their habitats and a significant amount of new information, the Western States Sage and Columbian Sharp-tailed Grouse Technical Committee, under the direction of the Western Association of Fish and Wildlife Agencies, requested a revision and expansion of the guidelines originally published by Braun et al. (1977). This paper summarizes the current knowledge of the ecology of sage grouse and, based on this information, provides guidelines to manage sage grouse populations and their habitats.

Beck, Jeffrey L.; Mitchell, Dean L. **Influences of livestock grazing on sage grouse habitat.** Wildlife Society Bulletin, 2000. pp. 993-1002 (10 pp.). Vol. 28, No. 4 1 table. ISSN: 0091-7648
Abstract.—Livestock grazing has been identified as one factor associated with the widespread decline and degradation of sage grouse (*Centrocercus urophasianus*) habitat. We identified *n* = 17 positive and negative impacts of livestock on sage grouse and habitat. Little information is currently available concerning the directs impacts of livestock grazing on sage grouse habitat. Indirect impacts are better understood than direct impacts. Chemical and mechanical treatments intended to provide increased quantities of grass forage for livestock have indirectly reduced the acceptability of sagebrush (*Artemisia* spp.) rangelands for sage grouse. Our paper examines: 1) potential mechanisms whereby livestock grazing in big sagebrush (*A. tridentata*) communities can modify sage grouse habitat and 2) the indirect influences of livestock production on sage grouse habitat. Overall, livestock grazing appears to most affect productivity of sage grouse populations. Residual grass cover following grazing is essential to conceal sage grouse nests from predators. Future research needs are identified and management implications related to livestock grazing in sage grouse habitats are included.

Nelle, Pamela J.; Reese, Kerry P.; Connelly, John W. **Long-term effects of fire on sage grouse habitat.** Journal of Range Management, 53(6): 586-591, 2000. 3 tables. ISSN: 0022-409X
Abstract.—This study documented the long-term (> 10 years) impact of fire on sage grouse (*Centrocercus urophasianus* Bonaparte) nesting and brood-rearing habitats on the Upper Snake River Plain in southeastern Idaho. The habitat of the study area is primarily mountain big sagebrush (*Artemisia tridentata vaseyana* Rydb.)-grassland. Twenty different-aged burns were

sampled from 1996 to 1997, ranging from wildfires which burned during the 1960s to prescribed fires set during the 1990s. Canopy coverage and height of vegetation, and relative abundance of invertebrates, were estimated at burned and unburned sites within burns. Fourteen years after burning, sagebrush had not returned to preburn conditions. No difference was detected in forb abundance between different-aged burns. Relative abundance of ants and beetles was significantly greater in the 1-year old burn category but had returned to unburned levels by 3-5 years postburn. No benefits for sage grouse occurred as a result of burning sage grouse nesting and brood-rearing habitats. Burning created a long-term negative impact on nesting habitat because sagebrush required over 20 years of postburn growth for percent canopy cover to become sufficient for nesting.

Connelly, John W.; Reese, Kerry P.; Fischer, Richard A.; Wakkinen, Wayne L. **Response of a Sage Grouse Breeding Population to Fire in Southeastern Idaho.** Wildlife Society Bulletin, 2000. pp. 90-96 (7 pp.). Vol. 28, No. 1; Contrib. 776, Univ. of Idaho Coll. of Forestry, Will. and Range Exper. Sta. 3 tables. Project Number: ID W-160-R ISSN: 0091-7648
Abstract.—Prescribed burning is a common method to eliminate sagebrush (*Artemisia* spp.) and has been suggested as a tool to enhance the habitat of sage grouse (*Centrocercus urophasianus*). Effects of this practice on sage grouse have not been evaluated rigorously. The authors studied effects of prescribed fire on lek (traditional breeding display areas) attendance by male sage grouse occupying low-precipitation (< 26 cm) sagebrush habitats in southeastern Idaho from 1986 through 1994. During the preburn period (1986-89), average declines for male attendance were 48% and 46% for treatment and control leks, respectively. Lek counts were similar for treatment and control leks during the preburn years (G-test, $0.25 > P > 0.10$). During the postburn period (1990-94), male attendance at treatment leks declined 90% and control leks declined 63%. Although declines were similar between treatment and control leks during the preburn period, postburn declines were greater for treatment than control leks ($0.05 < P < 0.10$). The authors rejected the null hypothesis that for the two largest leks in both the treatment and control areas, counts were independent of years for preburn ($0.05 < P < 0.1\ 0$) and postburn ($P < 0.05$) periods and concluded that breeding population declines became more severe in years following fire. Prescribed burning negatively affected sage grouse in southeastern Idaho and should not be used in low-precipitation sagebrush habitats occupied by breeding sage grouse.

Hupp, J. W., and C. E. Braun. 1989. **Topographic distribution of Sage Grouse foraging in winter.** Journal of Wildlife Management 53:823-829.
Abstract.—We studied sagebrush (*Artemisia* spp.) exposure above snow and topographic distribution of sage grouse (*Centrocercus urophasianus*) foraging sites in winter (Jan-Mar) in the Gunnison Basin, Colorado. Sage grouse feeding activity ($n = 157$ foraging sites) was not proportionally distributed among 5 topographic categories ($P < 0.001$). Most (46 and 75% of foraging sites in 1985 and 1986, respectively) feeding activity occurred in drainages and on slopes with south or west aspects. Use of slopes with north or east aspects was less than expected. Distribution of sage grouse feeding activity was influenced by topographic variation in snow depth and mountain big sagebrush (*A. tridentata vaseyana*) exposure above snow. During a severe winter in 1984, < 10% of the sagebrush vegetation in the Gunnison Basin was exposed above snow and available to sage grouse. During milder winters in 1985 and 1986, exposure of

sagebrush was 84 and 79%, respectively. We recommend that sagebrush be maintained in drainages and on slopes with south or west aspects.

Oyler-McCance, S. J. 1999. **Genetic and habitat factors underlying conservation strategies for Gunnison Sage Grouse.** Ph.D. dissertation. Colorado State University. 162 pages.
Notes.— Developed a simple habitat-based model to predict occupancy by sage grouse, with three variables: distance to nearest road from the center of the habitat patch, size of the habitat patch (patch area, as a measure of habitat quantity), and percentage of the patch in "habitat" (are in suitable winter, breeding and nesting or summer habitat). The best model had habitat patch size and distance to the nearest road. The genetics work supported the species designation of the Gunnison sage grouse in southwestern Colorado. These populations are extremely isolated and fragmented, as are their habitats. This is reflected in the low numbers of haplotypes in these grouse. They are much less genetically diverse than are more northern grouse, with low heterogeneity and little gene flow evident.

Oyler-McCance, S. J., K. P. Burnham, and C. E. Braun. 2001**. Influences of changes in sagebrush on Gunnison Sage Grouse in Southwestern Colorado.** The Southwestern Naturalist 46(3):323-331.
Abstract.—The decline in the abundance of the newly-recognized Gunnison sage grouse (*Centrocercus minimus*) in southwestern Colorado is thought to be linked to loss and fragmentation of its habitat, sagebrush (*Artemisia*) vegetation. We documented changes in sagebrush-dominated areas between the 1950's and 1990's by comparing low-level aerial photographs taken in these time periods. We documented a loss of 20% or 155,673 ha of sagebrush-dominated areas in southwestern Colorado between 1958 and 1993. The amount of sagebrush-dominated area was much higher and loss rates were much lower in the Gunnison Basin. We also found that 37% of plots sampled underwent substantial fragmentation of sagebrush vegetation. If current trends of habitat loss and fragmentation continue, Gunnison sage grouse (and perhaps other sagebrush-steppe obligates) may become extinct. Protecting the remaining habitat from further loss and fragmentation is paramount to the survival of this species.

Young, J. R. 1994. **The influence of sexual selection on phenotypic and genetic divergence among Sage Grouse populations.** Ph.D. dissertation. Purdue University, West Lafayette, IN. 123 pages.
Abstract.—I studied the mating behavior, ecology, and genetics of an isolated population of sage grouse (*Centrocercus urophasianus*) in the Gunnison Basin, Colorado. Sage grouse have a lek mating system in which only a small percentage of males mate. Sexual selection in such a mating system can lead to rapid evolution of sexual dimorphism in size, plumage characteristics and mating behavior as well as associated female preferences for such male traits. As a result, I predicted that sexual selection could increase population divergence as well as reduce population persistence. Field observations indicated that traits important to male mating success, such as mating vocalizations, had diverged in the Gunnison population relative to other sage grouse populations. To determine the effect of this divergence in male mating vocalizations on female behavior, I conducted reciprocal field playback experiments at two leks, one in Gunnison and the

other in a nearby, but allopatric, northern Colorado population. Females in each population avoided male vocalizations from the other population, suggesting the existence of a premating barrier. While female mating behavior differed between populations, my investigation of female nesting ecology and summer habitat use showed that Gunnison females are ecologically similar to females in other sage grouse populations. Females in Gunnison (a) chose nest sites with more sagebrush density and structure than random sites, (b) had higher nesting success in areas with greater shrub density and forb and grass cover, and (c) used flat, mesic areas with extensive grass and forb components when rearing broods. Genetic analyses of four sage grouse populations revealed moderately higher bandsharing and F_{st} values compared to nonlekking bird species. In addition, some genetic differentiation exists among the four populations and between leks in Gunnison. My results demonstrate the Gunnison population is distinct in secondary sexual traits, but not female ecology. These results are consistent with the view that sexual selection can have a direct role in the initial stages of population divergence leading to speciation. My results also suggest that lek mating species may have reduced genetic variation relative to nonlekking species and subsequently are more vulnerable to environmental changes.

EXTRACTED PAPERS—A

A. (Extracted from Conservation Assessment of Greater Sage-Grouse and Sagebrush Habitats, Chapter 7, Sagebrush Ecosystems: Current Status and Trends)

Restoration and Rehabilitation

Background

Sage-grouse depend on various characteristics of sagebrush ecosystems for their survival. During the spring nesting and brood rearing, locations with a codominance of a subspecies of big sagebrush and mid to tall perennial bunchgrass species generally provide the most important habitat. Summer and autumn habitats vary from farmland to wet meadows to sagebrush lands. In winter, sage-grouse require big sagebrush cover and food, but can use low, black, fringed, or silver sagebrush for food (Connelly et al. 2000*a*).

Restoration of sagebrush habitats can take two different forms, passive and active. Passive forms of restoration do not require human-aided revegetation because desired species exist at the site as plants or seeds. Restoration of the desired plant community, including factors such as, community structure (plant height and cover) and ecosystem processes (e.g. nutrient cycling), can be achieved by changing current management practices to accomplish the relative dominance of species or the desired vegetation structure in the community through the normal successional process. If the desired species and their source of propagules are eliminated from the site and are too far for natural revegetation in a desired time frame, then active restoration may be necessary.

Provided that degradation of habitat quality has not been too severe and that the community has remained within the upper state (Figure 7.33), passive restoration may achieve the desired vegetation changes. However, the loss of dominant species, such as tall bunchgrasses, from a community, even if they are not replaced by invasive species, may require active restoration because the community no longer has an adequate seed bank to draw upon. The plant composition that defines these thresholds among states is unknown and is an active area of research in the region.

Active restoration is warranted if invasive species (e.g. cheatgrass or noxious weeds) or native species that are generally inconspicuous at a site (e.g., junipers or pinyon pines) have replaced dominant species (e.g. sagebrush, perennial bunchgrasses, and forbs) in the community. In the conceptual diagram of species dynamics (Figure 7.33), the site has progressed along a transition into a new vegetation state and degradation of the site has occurred. Note the transitions between states are unidirectional and do not return to the previous state.

In the case of pinyon-juniper tree encroachment, as the site becomes dominated by the trees, sagebrush will die out, the herb layer may decline, and seed banks become depleted (Koniak and Everett 1982, Miller et al. 2000). Natural disturbances such as fire become rare as these trees age and as they dominate a site (Miller and Tausch 2001). If fires do occur, they tend to be severe crown fires of high intensity. On relatively cool wet sites, recovery of native species often occurs slowly following these intense fires. However, on warmer sites high intensity fires are capable of causing shifts from woodlands to introduced annual communities (Tausch 1999*a*,*b*).

Following invasions of exotic annual grasses, the communities become susceptible to more frequent fires because of the increase in fuel that is more continuous across the soil surface

than the pre-invasion community. In the pre-invasion community (upper most state Fig. 7.33), the fine fuels would be distributed in patches represented by the perennial bunchgrasses in the community. Exotic annual grasses tend to fill interspaces among these bunchgrasses providing greater continuity of fuels for fires (Whisenant 1990). Most species of sagebrush, except silver and threetip sagebrush, are intolerant of fires and require seed dispersal and germination to reestablish after a fire. Cheatgrass is known to be a successful competitor against native plants for resources necessary for the native plants to establish and grow (Harris 1967, Melgoza et al. 1990, Booth et al. 2003).

Site degradation, in some locations, may become so severe that soil erosion (lower left state, Fig. 7.33) removes the upper soil horizons to such an extent that the potential for the site to support its former native plant community (upper state Figure 7.33) is impossible. In this case, restoration is no longer possible, but rehabilitation (defined as an alternative to the historic native plant community that provides similar structure and function without allowing further degradation of the site [adapted from Bradshaw 1983 and Aronson et al. 1993]) may be the only remaining alternative that might make the site usable by sage-grouse.

We examine the past and current forms of revegetation used within the assessment area, to examine alternatives (including experimental approaches) available to land managers when faced with degradation and loss of habitat for sage-grouse. The alternatives include combinations of passive and active restoration and rehabilitation techniques. Lastly, bottlenecks restricting restoration success will also be examined.

Past and Current Vegetation Manipulation Approaches

Because most lands in the assessment area are federally managed, vegetation manipulations done in the past have reflected mandated federal policies. The Public Rangelands Improvement Act (PRIA) of 1978 recognized the continued need to improve rangeland conditions on public lands. The major source of measuring land condition was based on a technique that organized plants into categories based on their responses to livestock grazing (increasers, decreasers and invaders) (Pyke and Herrick 2003). Although PRIA explicitly stated the need for improvements in condition for multiple uses, the methods used to implement these improvements tended to rely on the current science of the day. The principal textbook of that time (Valentine 1971) defined range improvements as “special treatments, developments, and structures used to improve range forage resources or to facilitate their use by grazing animals.” The focus of many revegetation efforts was to increase forage production for livestock and to decrease the abundance of undesirable forage and invasive annuals that provided unreliable forage. Undesirable forage included the major invasive plant, cheatgrass (Young et al. 1972), and sagebrush, which is still treated as a weed in some books (Whitson 1996).

Livestock grazing modifications. Passive rangeland improvement approaches sought improved vegetation composition and amount through adjustments livestock grazing seasons and animal unit months. Adjustments were achieved by constructing new fences or developing additional water sources which spread livestock use over larger areas. The greatest change was the shift from year-long grazing to seasonal uses by livestock throughout the sagebrush grassland biome (Crawford et al. 2004), however the seasons of use often differed between the intermountain and the Great Plains regions west and east of the Rocky Mountains with Wyoming and the Colorado

Plateau being somewhat intermediate. Year-long grazing still is practiced in some parts of the sagebrush biome.

Differences between the two regions were largely dictated by the amount of cool-season (C_3 photosynthetic pathway) *vs.* warm-season (C_4 pathway) grasses respectively in the two regions. Cool season grasses tolerate grazing from mid-summer through winter (Crawford et al. 2004) while adjustments in grazing seasons were more rotational so that no single plant life form would be detrimentally harmed. In sagebrush grasslands, herbivory of herbaceous plants during the growing season tends to favor sagebrush growth until sagebrush becomes so dense that the competition of sagebrush restricts recovery of herbaceous plants (Reichenberger and Pyke 1990).

Adjustments to grazing seasons or reductions in numbers of livestock will only show improvements in sage-grouse habitat quality if the vegetation community is a sagebrush grassland mix (middle vegetation community in upper state, Figure 7.33) before grazing changes are implemented. This community retains both the sagebrush and the tall bunchgrass necessary for quality habitat. The release from livestock grazing should allow the full expression of vegetation height for hiding cover and nest protection. Improvements could be expressed in the next growing season, but might take 3 to 5 years for pre-existing plants to fully express themselves and 10 to 15 years for seed production and new plant recruitment to occur assuming the site is not fully occupied by other species. Any other community whether in this vegetation state or in another state (Figure 7.33) will require either additional manipulations to the community to adjust the vegetation composition, or may require additions of life forms through revegetation to improve the habitat (see below).

Sagebrush Removal. Removal of sagebrush to increase herbaceous forage and allow grasses to dominate has been a common habitat treatment practice. Several techniques were used to accomplish this conversion with differing impacts on the structure and function of the ecosystem.

Prescribed fires kill, eliminate, or reduce the density of most sagebrush species, especially big sagebrush species, and provide a temporary flush of nutrients that may result in increases in herbaceous plant responses, but may leave sites susceptible to soil erosion during the first years after the fire (Wrobleski and Kaufmann 2003, Stubbs 2000, Blank et al. 1994). This tool is one that is currently being applied on lands where pinyons or junipers have encroached into sagebrush grasslands as a technique to eliminate the trees. It also results in a loss of sagebrush dominance from the community for 25-45 years (Watts and Wambolt 1996, Wambolt et al. 2001) depending on the location of seed sources.

Herbicide applications of 2,4-D (2,4-dichlorophenoxy acetic acid) or tebuthiuron (–[5-(1,1- dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea) were used to kill large expanses of sagebrush leaving the standing dead skeletons of the shrubs with low risk of soil erosion. However, herbicides, if used full strength during the growing season, also killed or injured many forbs (Crawford et al. 2004).

Mechanical techniques ranged from those designed to remove the aboveground portion of the plant (mowing, roller chopping, and rotobeating) to uprooting the plant from the soil (grubbing, bulldozing, anchor chaining, cabling, railing, raking and plowing) (Scifres 1980). Of these techniques, the uprooting techniques create the greatest soil disturbance thus adding to the risk of post-treatment soil erosion. Control of pinyon and juniper through chaining, cabling, railing, or chain saw can have moderate to little impact on the shrub canopy. The removal of tree

competition should also facilitate rapid recovery of the shrub and herb understory if adequate levels are present prior to treatment. However, treatments such as mowing, roller chopping, rotobeating and plowing will have a greater and longer lasting impact on the shrub layer. Critical for the success of these techniques is that the community remains in the upper state of Fig. 7.33 and that invasive annual grasses do not exist within the community.

Tebuthiuron at low rates has been reported as a technique for thinning dense sagebrush and opening the community for herbaceous plants, including forbs, to respond (Olson and Whitson 2002). Provided the herbaceous perennial plants exist in the understory, this technique might yield immediate improvements to habitat quality, however if exotic annual grasses exist in the community then expansion and spread of these invasive plants might result. However, no empirical data are available to document the response of sage-grouse to these treatments.

Lastly, livestock may be used as a biological control of sagebrush. Bork et al. (1998), Laycock (1967) and Mueggler (1950) have shown long-term declines in threetip sagebrush with recovery of herbaceous vegetation high elevation sites in Idaho. Declines of Wyoming and mountain big sagebrush densities due to heavy deer or elk browsing have been noted in Utah and Montana (Smith 1949, Austin et al. 1986, McArthur et al. 1988, Patten 1993, Wambolt 1996). These all suggest the potential of browsing animals to be used as a biocontrol for reducing the densities of sagebrush and potentially increasing the herbaceous component. However, the response of the herbaceous component needs further study in big sagebrush communities since this has only been noted in threetip sagebrush communities.

Revegetation

Historic revegetation on most sagebrush grasslands had the goal of improving livestock forage (which included replacing invasive forbs and annual grasses such as cheatgrass and halogeton with perennial grasses) while protecting soils from erosion. Early experimental trials comparing native *vs.* introduced grasses in several locations within the assessment area found that native species often did not establish or produced less forage, therefore recommendations during the early phases of rangeland improvements favored the use of introduced grasses, such as crested wheatgrass (*Agropyron* sp.) to meet the combined goal of forage production and erosion control (see citations in Asay et al. 2001). Many of these early trials were conducted on abandoned wheat and rye fields at the end of the homestead era.

Wildfire rehabilitation is a major source of revegetation in the Great Basin. The mandated goal of these projects is to reduce the loss of soil and plant species, be palatable to livestock, and to reduce the spread of invasive species. Total restoration of the ecosystem with a complete suite of plant life forms is not a designated objective for expenditure of funds. Although federal policies have advocated the use of native plants in revegetation efforts when natives are available, only modest increases in the use of native plants were seen in a recent evaluation of the U.S. Bureau of Land Management's Emergency Fire Rehabilitation program. Out of the average of 5 species used on a rehabilitation project, the number of native species has increased from 1 to 2 and the proportional increase in the weight of native bulk seeds has been from 20 to 40 % (Pyke et al. 2003). Land managers cited the poor competitiveness and poor establishment of natives compared with introduced grasses as the main reasons why they elected to use introduced species (McArthur 2004) and the high cost of seed.

Most revegetation projects that use introduced forage grasses may not provide quality sage grouse habitat because their goals were not focused on restoring a complete sagebrush grassland community. However, Cox and Anderson (2004) suggested methods for improving these sites: sites dominated by cheatgrass could be seeded with crested wheatgrass to control the cheatgrass. Later, sites dominated by introduced grasses could be prepared by a till, harrow, or with herbicides then reseeded with native species.

In an attempt to become proactive in its battle against invasive annual grasses and the loss of sagebrush grasslands, the U.S. Bureau of Land Management has begun the Great Basin Restoration Initiative. The strategy of this program is to use a three step process to achieve effective restoration in the region (Pellant 2003). The first step is to use spatial data to prioritize areas for conservation and restoration (Pyke and Knick 2003), with special emphasis on sage-grouse habitat needs. Second, they will coordinate protection and restoration plans with land users, scientists and interested people to ensure environmentally sound treatments that do not create undue hardships for local land users while using the best science to maximize restoration and conservation success. Lastly, restoration and conservation activities will target landscapes where native plant communities already exist to ensure maximize the retention of lands that remain within the nature dynamics of the sagebrush system (upper state Fig. 7.33). After these areas are protected, they will begin treatments to restore sites currently dominated by invasive plants.

Rehabilitation and restoration techniques to transform lands currently dominated by invasive annual grasses into quality sage-grouse habitat have been largely unproven and experimental. Several components of the process are being investigated with varying degrees of success. The first aspect of the process will be the reduction in the competition that invasive annual grasses provide against native seedlings during the establishment phase. Therefore methods to reduce cheatgrass densities are necessary. Proposed techniques include herbicides imazapic (Plateau) (Shinn and Thill 2002) and glyphosate (Whitson and Koch 1998), defoliation via livestock grazing (Hulbert 1955, Finnerty and Klingman 1961, Mosley 1996), pathogenic bacteria (Kennedy et al. 1991) and fungi (Meyer et al. 2001). Although prescribed fire alone is not recommended (Mosley et al. 1999), it may be an effective technique worth investigation if applied in combination with a spring glyphosate treatment and conducted either in late spring or autumn. The glyphosate will kill the current-year's plants, thus reducing or eliminating seed production, and will prepare a fuel bed for the fire that will reduce the litter seed bank. In addition to density reduction techniques, applications of carbon in a form readily available for microbial uptake in the soil may increase soil microbial content and cause the microbes to reduce the available soil nitrogen, thus reducing the growth and competitive ability of cheatgrass (McLendon & Redente 1990, 1992, Young et al. 1996).

Immediate revegetation is required after any of these density reduction techniques, otherwise invasive annual grasses that escape treatments will grow unabated and produce large numbers of seeds and will quickly dominate a site again (Mack and Pyke 1983). No evidence for complete elimination of invasive annual grasses with control techniques and revegetation has been noted. However, successful revegetation efforts that have controlled invasive annual grass populations and have maintained perennial plants are generally rehabilitation projects sown with introduced forage grasses (Asay et al. 2001). Some evidence from wildfire rehabilitation studies shows that native plants can be sown and eventually coexists with invasive annuals, but these

were generally sown in combination with introduced grasses (Pyke et al. 2003, Cox and Anderson 2004). Theoretical frameworks hypothesize that multiple native species representing a variety of growth and life forms may successfully compete with invasive plants where any one species would be unsuccessful (Sheley et al. 1996). Current studies are being conducted to investigate this potential in combination with cheatgrass and other invasive plants in the Great Basin.

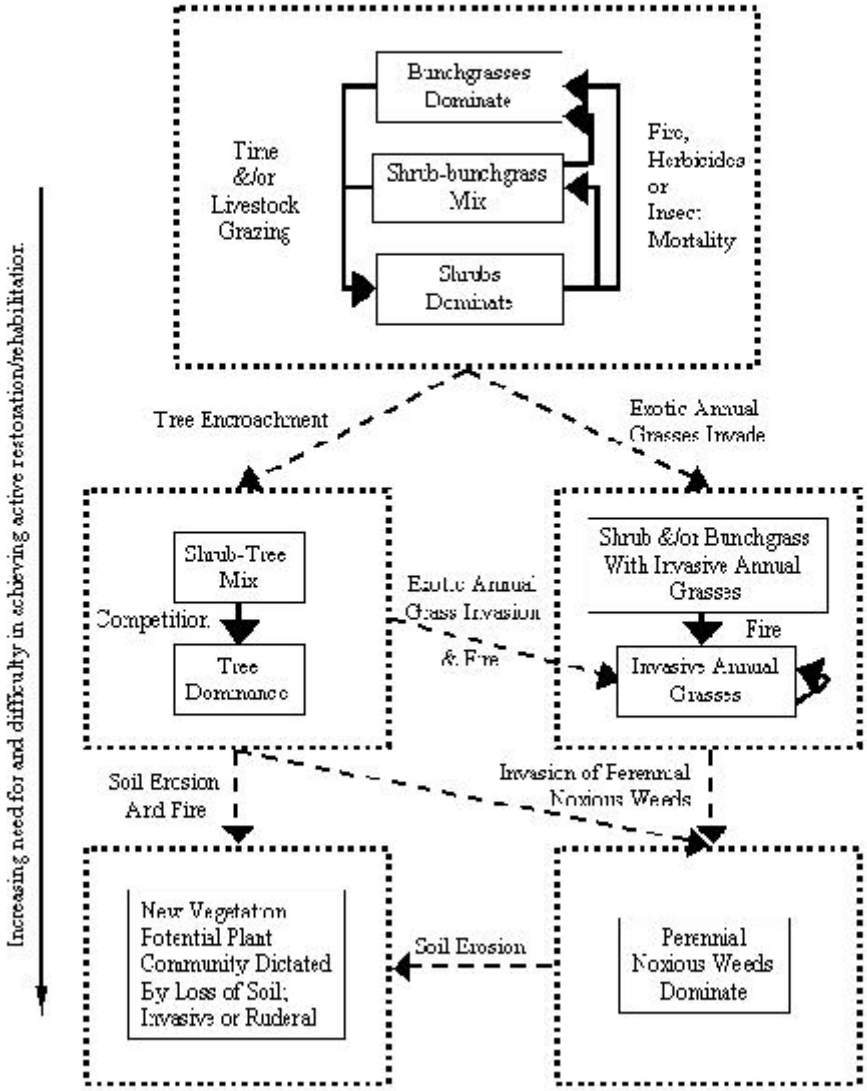
For quality sage-grouse habitat, sagebrush and forb establishment and maturity are necessary. Techniques for reseeding sagebrush have been successfully demonstrated, but surface sowing followed by compaction of the soil may be necessary for establishment. Establishment of forbs important to sage-grouse have also shown promise, but availability of seed tends to limit their widespread use on rangeland restoration and rehabilitation projects (McArthur 2004).

Bottlenecks to Success

Availability and cost of native seed is a major obstruction to the use native seeds in revegetation projects (McArthur 2004). The difficulties and the vagaries of collecting, growing and selling native seeds that historically have not been used within sagebrush ecosystems tends to raise the price and increase the risk to both the seller and buyer (Dunne 1999, Roundy et al. 1997, Currans et al. 1997, Bermant and Spackeen 1997) relative to tested and released plants that are widely available (Currans et al. 1997).

Equipment for sowing native seeds is not widely available. Most revegetation projects in the region use rangeland drills that were developed for the rough terrain of wildland environments and for the ease of seeding the introduced forage grasses. Many native seeds because of their differing sizes will require mixing within the seed boxes on the drills to insure equal proportions of all seeds are sown on a site or will require separate seed boxes to allow seeds of different sizes to be buried at different optimal depths. All these requirements will either require the purchase of new seed drills or the retrofitting of the old drills to accommodate these needs.

Fig. 7.33. Conceptual model showing plant dynamics using state and transition (dotted boxes and dashed lines) in a typical shrub grassland site within the sage-grouse range. Solid boxes and arrows within states are plant communities and pathways.



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EXTRACTED PAPERS—B

B. (Extracted from Connelly, J. W., M. A. Schroeder, A. R. Sands, and C. E. Braun. 2000. Guidelines to manage sage grouse populations and their habitats. Wildlife Society Bulletin 28 (4):967-985.)

Effects of habitat alteration

Range management treatments

Breeding habitat. Until the early 1980s, herbicide treatment (primarily with 2,4-D) was the most common method to reduce sagebrush on large tracts of rangeland (Braun 1987). Klebenow (1970) reported cessation of nesting in newly sprayed areas with <5% live sagebrush canopy cover. Nesting also was nearly nonexistent in older sprayed areas containing about 5% live sagebrush cover (Klebenow 1970). In virtually all documented cases, herbicide application to blocks of sagebrush rangeland resulted in major declines in sage grouse breeding populations (Enyeart 1956, Higby 1969, Peterson 1970, Wallestad 1975). Effects of this treatment on sage grouse populations seemed more severe if the treated area was subsequently seeded to crested wheatgrass (*Agropyron cristatum*, Enyeart 1956).

Using fire to reduce sagebrush has become more common since most uses of 2,4-D on public lands were prohibited (Braun 1987). Klebenow (1972) and Sime (1991) suggested that fire may benefit sage grouse populations. Neither Gates (1983), Martin (1990), nor Bensen et al. (1991) reported adverse effects of fire on breeding populations of sage grouse. In contrast, following a 9-year study, Connelly et al. (1994, 2000*b*) indicated that prescribed burning of Wyoming big sagebrush during a drought period resulted in a large decline (>80%) of a sage grouse breeding population in southeastern Idaho. Additionally, Hulet (1983) documented loss of leks from fire and Nelle et al. (2000) reported that burning mountain big sagebrush stands had long-term negative impacts on sage grouse nesting and brood-rearing habitats. Canopy cover in mountain big sagebrush did not provide appropriate nesting habitat 14 years after burning (Nelle et al. 2000). The impact of fire on sage grouse populations using habitats dominated by silver sagebrush (which may resprout following fire) is unknown.

Cheatgrass (*Bromus tectrorum*) will often occupy sites following disturbance, especially burning (Valentine 1989). Repeated burning or burning in late summer favors cheatgrass invasion and may be a major cause of the expansion of this species (Vallentine 1989). The ultimate result may be a loss of the sage grouse population because of long-term conversion of sagebrush habitat to rangeland dominated by an annual exotic grass. However, this situation largely appears confined to the western portion of the species' range and does not commonly occur in Wyoming (J. Lawson, Wyoming Department of Game and Fish, personal communication).

Mechanical methods of sagebrush control have often been applied to smaller areas than those treated by herbicides or fire, especially to convert rangeland to cropland. However, adverse effects of this type of treatment on sage grouse breeding populations also have been documented. In Montana, Swenson et al. (1987) indicated that the number of breeding males declined by 73% after 16% of their study area was plowed.

Brood-rearing habitats. Martin (1970) reported that sage grouse seldom used areas treated with herbicides to remove sagebrush in southwestern Montana. In Colorado, Rogers (1964) indicated that an entire population of sage grouse appeared to emigrate from an area that was subjected to several years of herbicide application to remove sagebrush. Similarly, Klebenow (1970) reported that herbicide spraying reduced the brood-carrying capacity of an area in southeastern Idaho. However, application of herbicides in early spring to reduce sagebrush cover may enhance some brood-rearing habitats by increasing the amount of herbaceous plants used for food (Autenrieth 1981).

Fire may improve sage grouse brood-rearing habitat (Klebenow 1972, Gates 1983, Sime 1991), but until recently, experimental evidence was not available to support or refute these contentions (Braun 1987). Pyle and Crawford (1996) suggested that fire may enhance brood-rearing habitat in montane settings but cautioned that its usefulness requires further investigation. A 9-year study of the effects of fire on sage grouse did not support that prescribed fire, conducted during late summer in a Wyoming big sagebrush habitat, improved brood-rearing habitat for sage grouse (Connelly et al. 1994, Fischer et al. 1996*a*). Prescribed burning of sage grouse habitat
did not increase amount of forbs in burned areas compared to unburned areas (Fischer et al. 1996*a*, Nelle et al. 2000) and resulted in decreased insect populations in the treated area compared to the unburned area. Thus, fire may negatively affect sage grouse brood-rearing habitat rather than improve it in Wyoming big sagebrush habitats (Connelly and Braun 1997), but its effect on grouse habitats in mountain big sagebrush communities requires further investigation (Pyle and Crawford 1996, Nelle et al. 2000).

Sage grouse often use agricultural areas for brood-rearing habitat (Patterson 1952, Wallestad 1975, Gates 1983, Connelly et al. 1988, Blus et al. 1989). Grouse use of these areas may result in mortality because of exposure to insecticides. Blus et al. (1989) reported die-offs of sage grouse that were exposed to methamidiphos used in potato fields and dimethoate used in alfalfa fields. Dimethoate is used commonly for alfalfa, and 20 of 31 radiomarked grouse (65%) died following direct exposure to this insecticide (Blus et al. 1989).

Winter habitat. Reduction in sage grouse use of an area treated by herbicide was proportional to the severity (i.e., amount of damage to sagebrush) of the treatment (Pyrah 1972).

In sage grouse winter range, strip partial kill, block partial kill, and total kill of sagebrush were increasingly detrimental to sage grouse in Montana (Pyrah 1972) and Wyoming (Higby 1969).

In Idaho, Robertson (1991) reported that a 2,000-ha prescribed burn that removed 57% of the sagebrush cover in sage grouse winter habitat minimally impacted the sage grouse population. Although sage grouse use of the burned area declined following the fire, grouse adapted to this disturbance by moving 1 to 10 km outside of the burn to areas with greater sagebrush cover (Robertson 1991) than was available in the burned area.

Recommended guidelines

Breeding habitat management

For migratory and nonmigratory populations, lek attendance, nesting, and early brood rearing occur in breeding habitats. These habitats are sagebrush-dominated rangelands with a healthy herbaceous understory and are critical for survival of sage grouse populations. Mechanical disturbance, prescribed fire, and herbicides can be used to restore sage grouse habitats to those conditions identified as appropriate in the following sections on habitat protection. Local biologists and range ecologists should select the appropriate technique on a case-by-case basis. Generally, fire should not be used in breeding habitats dominated by Wyoming big sagebrush if these areas support sage grouse. Fire can be difficult to control and tends to burn the best remaining nesting and early brood-rearing habitats (i.e., those areas with the best remaining understory), while leaving areas with poor understory. Further, we recommend against using fire in habitats dominated by xeric mountain big sagebrush (*A. t. xericensis*) because annual grasses commonly invade these habitats and much of the original habitat has been altered by fire (Bunting et al. 1987).

Although mining and energy development are common activities throughout the range of sage grouse, quantitative data on the long-term effects of these activities on sage grouse are limited. However, some negative impacts have been documented (Braun 1998, Lyon 2000). Thus, these activities should be discouraged in breeding habitats, but when they are unavoidable, restoration efforts should follow procedures outlined in these guidelines.

Habitat restoration

1) Before initiating vegetation treatments, quantitatively evaluate the area proposed for treatment to ensure that it does not have sagebrush and herbaceous cover suitable for breeding habitat (Table 3). Treatments should not be undertaken within sage grouse habitats until the limiting vegetation factor(s) has been identified, the proposed treatment is known to provide the desired vegetation response, and land-use activities can be managed after treatment to ensure that vegetation objectives are met.

2) Restore degraded rangelands to a condition that again provides suitable breeding habitat for sage grouse by including sagebrush, native forbs (especially legumes), and native grasses in reseeding efforts (Apa 1998). If native forbs and grasses are unavailable, use species that are functional equivalents and provide habitat characteristics similar to those of native species.

3) Where the sagebrush overstory is intact but the understory has been degraded severely and quality of nesting habitat has declined (Table 3), use appropriate techniques (e.g., brush beating in strips or patches and interseed with native grasses and forbs) that retain some sagebrush but open shrub canopy to encourage forb and grass growth.

4) Do not use fire in sage grouse habitats prone to invasion by cheatgrass and other invasive weed species unless adequate measures are included in restoration plans to replace the cheatgrass understory with perennial species using approved reseeding strategies. These strategies could include, but are not limited to, use of pre-emergent herbicides (e.g., Oust®, Plateau®) to retard cheatgrass germination until perennial herbaceous species become established.

5) When restoring habitats dominated by Wyoming big sagebrush, regardless of the techniques used (e.g., prescribed fire, herbicides), do not treat >20% of the breeding habitat (including areas burned by wildfire) within a 30-year period (Bunting et al. 1987). The 30-year period represents the approximate recovery time for a stand of Wyoming big sagebrush. Additional treatments should be deferred until the previously treated area again provides suitable breeding habitat (Table 3). In some cases, this may take <30 years and in other cases >30 years. If 2,4-D or similar herbicides are used, they should be applied in strips such that their effect on forbs is minimized. Because fire generally burns the best remaining sage grouse habitats (i.e., those with the best understory) and leaves areas with sparse understory, use fire for habitat restoration only when it can be convincingly demonstrated to be in the best interest of sage grouse.

6) When restoring habitats dominated by mountain big sagebrush, regardless of the techniques used (e.g., fire, herbicides), treat <20% of the breeding habitat (including areas burned by wildfire) within a 20-year period (Bunting et al. 1987). The 20-year period represents the approximate recovery time for a stand of mountain big sagebrush. Additional treatments should be deferred until the previously treated area again provides suitable breeding habitat (Table 3). In some cases, this may take <20 years and in other cases >20 years. If 2,4- D or similar herbicides are used, they should be applied in strips such that their effect on forbs is minimized.

7) All wildfires and prescribed burns should be evaluated as soon as possible to determine whether reseeding is necessary to achieve habitat management objectives. If needed, reseed with sagebrush, native bunchgrasses, and forbs whenever possible.

8) Until research unequivocally demonstrates that using tebuthiuron and similar-acting herbicides to control sagebrush has no long-lasting negative impacts on sage grouse habitat, use these herbicides only on an experimental basis and over a sufficiently small area that any long-term negative impacts are negligible. Because these herbicides have the potential of reducing but not eliminating sagebrush cover within grouse breeding habitats, thus stimulating herbaceous development, their use as sage grouse habitat management tools should be examined closely.

Table 3. Characteristics of sagebrush rangeland needed for productive sage grouse habitat.

	Breeding		Brood-rearing		Winter[e]	
	Height (cm)	Canopy (%)	Height (cm)	Canopy (%)	Height (cm)	Canopy (%)
Mesic sites[a]						
Sagebrush	40-80	15-25	40-80	10-25	25-35	10-30
Grass/forb	>18[c]	≥25[d]	variable	>15	N/A	N/A
Arid sites[a]						
Sagebrush	30-80	15-25	40-80	10-25	25-35	10-30
Grass/forb	>18[c]	≥15	variable	>15	N/A	N/A
Area[b]	>80		>40		>80	

[a] Mesic and arid sites should be defined on a local basis; annual precipitation, herbaceous understory, and soils should be considered (Tisdale and Hironaka 1981, Hironaka et al. 1983).
[b] Percentage of seasonal habitat needed with indicated conditions.
[c] Measured as "droop height"; the highest naturally growing portion of the plant.
[d] Coverage should exceed 15% for perennial grasses and 10% for forbs; values should be substantially greater if most sagebrush has a growth form that provides little lateral cover (Schroeder 1995).
[e] Values for height and canopy coverage are for shrubs exposed above snow.

Summer–late brood-rearing habitat management

Sage grouse may use a variety of habitats, including meadows, farmland, dry lake beds, sagebrush, and riparian zones from late June to early November (Patterson 1952, Wallestad 1975, Connelly 1982, Hanf et al. 1994). Generally, these habitats are characterized by relatively moist conditions and many succulent forbs in or adjacent to sagebrush cover.

Habitat restoration

1) Use brush beating or other mechanical treatments in strips 4–8 m wide in areas with relatively high shrub-canopy cover (>35% total shrub cover) to improve late brood-rearing habitats. Brush beating can be used to effectively create different age classes of sagebrush in large areas with little age diversity.

2) If brush beating is impractical, use fire or herbicides to create a mosaic of openings in mountain big sagebrush and mixed-shrub communities used as late brood-rearing habitats where

total shrub cover is >35%. Generally, 10–20% canopy cover of sagebrush and <25% total shrub cover will provide adequate habitat for sage grouse during summer.

3) Construct water developments for sage grouse only in or adjacent to known summer-use areas and provide escape ramps suitable for all avian species and other small animals. Water developments and "guzzlers" may improve sage grouse summer habitats (Autenrieth et al. 1982, Hanf et al. 1994). However, sage grouse used these developments infrequently in southeastern Idaho because most were constructed in sage grouse winter and breeding habitat rather than summer range (Connelly and Doughty 1989).

4) Whenever possible, modify developed springs and other water sources to restore natural free flowing water and wet meadow habitats.

Winter habitat management

Sagebrush is the essential component of winter habitat. Sage grouse select winter-use sites based on snow depth and topography, and snowfall can affect the amount and height of sagebrush available to grouse (Connelly 1982, Hupp and Braun 1989, Robertson 1991). Thus, on a landscape scale, sage grouse winter habitats should allow grouse access to sagebrush under all snow conditions (Table 3).

Habitat restoration

1) Reseed former winter range with the appropriate subspecies of sagebrush and herbaceous species unless the species are recolonizing the area in a density that would allow recovery (Table 3) within 15 years.

2) Discourage prescribed burns >50 ha, and do not burn >20% of an area used by sage grouse during winter within any 20–30-year interval (depending on estimated recovery time for the sagebrush habitat).

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ONLINE RESOURCES

A GIS Database for Sage Grouse and Shrubsteppe Management in the Intermountain West
http://www.sagemap.wr.usgs.gov/

Sage Grouse Conservation Project–Team Resources
http://www.ndow.org/wild/sg/resources/index.shtm

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