

SAGE GROUSE ECOLOGY AND MANAGEMENT IN NORTHERN UTAH SAGEBRUSH-STEPPE



**Sage Grouse Ecology and Management in
Northern Utah Sagebrush-Steppe**

**A Deseret Land and Livestock Wildlife Research
Report, 2002**

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Published by:

Deseret Land and Livestock Ranch

And

The Foundation for Quality Resource Management

Sage Grouse Ecology and Management in Northern Utah Sagebrush-Steppe.

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Synopsis: Observations of sage grouse (*Centrocercus urophasianus*) movements, habitat-use and population demographics were obtained 1985-2001 in Rich County, Utah.

Winter ecology: Grouse winter flock sizes averaged 8.3 and 63.7 birds/flock for male and mixed sex flocks, respectively. Grouse dispersed 0.2-65 km (mean 11.8 km) to spring breeding areas. 87% of winter observations occurred on slopes < 5%. Homer (1993) used GIS techniques to classify winter grouse habitat, and found Rich county sage grouse generally selected shrubs of medium height (40-60 cm) and medium cover (20-30%). However, grouse used shorter sagebrush (*Artemisia spp.*) on flats and ridge-tops when snow was < 30 cm deep, and taller sagebrush in draws when snow depths exceeded 30 cm. Brush height was correlated with snow depth at winter flock locations ($r^2=0.47$). Grouse preferred brush cover protruding 25 cm above snow. At snow depths \geq 30 cm, sage grouse, mule deer (*Odocoileus hemionus*) and whitetail jackrabbits (*Lepus townsendii*) concentrated in < 5% of the winter range, in patches of Wyoming and Basin big sagebrush. These brush patches are considered critically important for survival of these species in deep snow winters. Grouse populations declined (as did mule deer and whitetail jackrabbits) following two deep snow winters. Grouse population change (male lek attendance, N_t/N_{t-1}) correlated negatively with mean winter snow depth ($r^2=0.50$). Percent grouse population change also correlated negatively with the number of wintering golden (*Aquila chrysaetos*) and bald eagles (*Haliaeetus leucocephalus*) observed on Audubon Christmas Bird counts ($r^2=0.31$). It appeared grouse were more visible, more frequently flushed by predators and suffered greater mortality rates when deep snow covered the Wyoming sagebrush. 65% of grouse examined post-mortem were predated by raptors November–May (primarily golden eagles) and 18% died following collisions with fences. Estimated annual survival rate of radio-tagged grouse was 47%. Increasing coyote abundance during the study period coincided with reduced observations of red fox (*Vulpes fulva*), whitetail jackrabbits, Uinta ground squirrels (*Citellus armatus*) and with golden eagle nesting success. Golden eagle nesting success was negatively correlated with, and appeared dependent on the abundance of jackrabbits and ground squirrels ($r^2=0.81$ and 0.67 , respectively). Coyotes may have aided grouse survival by reducing prey abundance and eagle production.

Breeding ecology: We observed little inter-lek movement of tagged male sage grouse. Leks occasionally moved 0.1-1 km between years. Some leks became inactive during population lows, then reappeared. The date of peak male attendance on leks was correlated with the melting of the winter snow pack ($r^2=0.43$). Peak male attendance occurred later than peak hen attendance in years when yearling males were abundant. Peak hen attendance generally occurred about 1 April, the date of peak hen attendance was also positively correlated with melting of the winter snow pack ($r^2=0.71$). Wyoming sagebrush vigor declined in areas receiving winter browsing by elk (*Cervus elaphus*) and pronghorn (*Antilocapra americana*), but improved in areas where grasses were purposely overgrazed by cattle.

Summer ecology: 82% of hens nested within 4 km of the capture lek. Mean distance traveled from capture lek to nest was 2.8 km, the mean distance between study leks was

3.1 km. Mean distance between subsequent nests for hens monitored > one year was 0.5 km. Radio-tagged hens generally remained within five km of nesting areas throughout the summer. Males moved an average of 8.3 km from leks to summer use areas (range 3-13 km). Male flocks used sparse lowland and mountain sagebrush in summer. Hens without broods used dense lowland sagebrush. Broods used meadows, spring burns and plantings containing broad-leafed forbs. Grouse were often observed along edges of forb-rich meadows, burns, plantings and roadsides. Use of lowland sagebrush was greatest April-June; use of meadows and mountain sagebrush increased July-August. Grouse use of meadows varied between years, and was correlated with annual April-September precipitation ($r^2=0.56$). In dry summers, grouse concentrated in meadows, on north slopes and at higher elevations. In contrast, grouse were widely dispersed among habitat types and throughout the study area in wet summers. Lek counts increased following wetter summers, but failed to increase following dry summers. 83% of 36 hens nested in Wyoming sagebrush stands, in patches > 100m in diameter. Hunnicutt (1992) used GIS techniques to classify summer grouse habitat use. Hens selected dense brush cover (> 17%) with sparse herbaceous cover (< 8%) for nesting. Hens with young broods (June) preferred dense brush with > 8% herbaceous cover; older broods (July-September) preferred sparse brush with dense herbaceous cover. Combined nesting success of 36 hens was 30.6%. Nesting success and chick: hen ratios were greater in diverse habitats than in species-poor sage-crested wheatgrass (**S-CW**) habitats. Mean brood sizes increased as forb availability increased due to burning and planting. Artificial nests were used to compare nesting success with vegetative characteristics. 86% of artificial nest predation was by mammalian predators. Nest predation increased as shrub height, herbaceous and horizontal cover increased. Arthropod biomass was highest in habitats having greatest herbaceous cover. Lowest arthropod abundance occurred in dense, Wyoming sagebrush with sparse herbaceous cover. Billaux (1996) measured foraging rates of hand-reared sage grouse chicks in various habitats. Foraging rates were significantly correlated with forb abundance across habitat types ($r^2=0.69$). Chicks selected both native and introduced forbs when available, avoided grasses, and always ate some shrubs. Percent forb cover was consistently lower in **S-CW** than in any other habitat, and appears to explain the low chick: hen ratios observed in **S-CW** habitats. Wilson (2000) studied grouse use of various vegetation treatments and controls on DLL. Grouse, and broods in particular, readily used portions of burns and plantings having broad-leafed forbs and within 60 m of brush patches.

Habitat management: Time-controlled grazing practices at DLL since 1979 have increased herbaceous cover on rangelands, and slowed the rate of sagebrush increase. 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 wintering 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.

Table of Contents

Introduction	1
Study Area	2
Methods	4
Winter Ecology	4
Flock characteristics and dispersal from wintering areas to leks.....	4
Topography of sage grouse winter use sites.....	5
Vegetation characteristics at winter use sites.....	5
Relationship between deep snow, predation and population change.....	6
Grouse mortality.....	7
Survival estimates of radio-marked grouse.....	9
Predator–prey relationships.....	10
Lek fidelity.....	11
Male attendance at leks.....	11
Hen attendance at leks.....	12
Discussion regarding lek attendance.....	12
Impacts of herbivory on grouse winter habitat.....	12
Impacts of fire on grouse winter habitat.....	13
Mechanical impacts on grouse winter range.....	14
Summer Ecology	14
Distance traveled by hens from leks to nests.....	14
Movement to summer use areas.....	15
Summer habitat use.....	15
Nest habitat.....	16
Summer habitat selection vs. availability.....	17
Nesting success.....	19
Production estimates.....	20
Predation of artificial sage grouse nests.....	20
Estimates of arthropod abundance by vegetation type.....	21
Foraging ecology of grouse chicks in relation to vegetation types.....	22
Effects of precipitation on herbaceous forage nutrient quality.....	23
Phenology and availability of herbaceous plants.....	23
Use of sagebrush treatments by sage grouse.....	25
Effects of time-controlled grazing and wildlife herbivory on grouse habitat.....	27
Time-controlled grazing and breeding bird abundance and diversity.....	29
Impacts of fire on summer grouse habitat.....	30
Impacts of plantings on summer grouse habitat.....	30
Effects of brush-thinning treatments.....	31
Effects of brush removal on diversity and abundance of other wildlife.....	31
Synthesis and management implications.....	31
The importance of privately owned wildlands as sage grouse habitat.....	35
Literature cited.....	35

List of Tables

Table 1.	Sizes of winter sage grouse flocks	4
Table 2.	Winter sagebrush class descriptions and grouse selection	5
Table 3.	Causes of mortality of 22 radio marked and 105 unmarked sage grouse.....	7
Table 4.	Annual survival rate of radio marked sage grouse	10
Table 5.	Distance travelled by 17 sage grouse hens from leks to nest sites	15
Table 6.	Summer habitat use by sage grouse flocks.....	15
Table 7.	Percent shrub cover at 36 sage grouse nests.....	16
Table 8.	Rangeland cover classes	17
Table 9.	Rangeland cover classes selected by sage grouse in early and late summer.....	18
Table 10.	Early and late season selection of habitat diversity by sage grouse	18
Table 11.	Nesting success of 36 sage grouse hens	19
Table 12.	Moisture, protein and TDN in herbaceous forage samples	23
Table 13.	Green herbaceous plant height by month	24
Table 14.	Forb phenology and richness compared to grouse reproductive chronology.....	24
Table 15.	Percent forb cover by habitat type, June and Aug-Sep	25
Table 16.	Breeding bird abundance and species richness on BBS transects.....	28

List of Figures

Figure 1.	Study area location.....	3
Figure 2.	Correlation between snow depth and brush height at grouse locations	6
Figure 3.	(a) Mean winter snow depth and mean winter brush height used by grouse. (b) Availability and use of short and tall brush types in low and deep snow depths.....	6
Figure 4.	Snow depth and eagle abundance correlate with grouse population change	6
Figure 5.	Influence of jackrabbit and ground squirrels on eagles and coyote.....	8
Figure 6.	Lek counts as population trend index	12
Figure 7.	Snow melt dates correlate with peak grouse lek attendance.....	13
Figure 8.	Effects of herbivory and fertilization on sagebrush vigor	14
Figure 9.	(a) Mean summer precipitation correlates with % meadow use by grouse, and (b) Availability and use of habitats by grouse in wet and dry summers.....	17
Figure 10.	Vegetation height and diversity at grouse nests, early and late brood sites.....	19
Figure 11.	Brood sizes and chick:hen ratios. Chick:hen ratios in S-CW and NS	20
Figure 12.	Brood size correlates with chick:hen ratio and population change.....	21
Figure 13.	Arthropod biomass in six vegetation types over six years.....	22
Figure 14.	Forb availability and grouse chick diet selection.....	23
Figure 15.	Sage grouse use of RSD and BRN habitats, relative to distance from edge	26
Figure 16.	Comparison (a) grouse densities, treatments and controls (b) chick production by vegetation types (c) grouse use of S-CW before and after forb interseeding.....	27
Figure 17.	Shrub and herbaceous production in cattle exclosures and controls.....	29
Figure 18.	Forb and grass production in NS herbivore exclosures and controls.....	30
Figure 19.	Precipitation correlates with BBS bird abundance and species richness	30
Figure 20.	Response of selected bird species at RSD and controls	32

Appendices

Appendix A.	Map of DLL bio-areas.
Appendix B.	Estimated percent grass, forb, shrub, litter and bare ground cover by habitat.
Appendix C.	Grouse dispersal from winter range to summer range.
Appendix D.	Grouse winter range under various snow depths.
Appendix E.	Peak annual male grouse counted on leks.
Appendix F.	Population trend and weather data.

SAGE GROUSE ECOLOGY AND MANAGEMENT IN NORTHERN UTAH SAGEBRUSH-STEPPE

Introduction

Maintaining sagebrush habitats for sage grouse (*Centrocercus urophasianus*) and the diverse mix of species they co-exist with requires understanding the complex interactions between habitat, weather, livestock and other wildlife species within the sagebrush-steppe ecosystem. Sage grouse winter habitat use patterns may vary depending on snow depth (Beck 1977). Deep snow can significantly reduce available sagebrush for food and hiding cover (Hupp and Braun 1989), potentially increasing grouse vulnerability to predation. Predator abundance may affect grouse winter survival rates (Bergerud and Gratson 1988), potentially compounding the effects of deep snow. Brush management practices that decrease winter sagebrush availability may also decrease winter sage grouse survival.

The quality of sage grouse nesting and brood-rearing habitat influences population fecundity and abundance. Weather, fire, herbivory by livestock and wildlife, and non-native plant species introductions may affect sage grouse nesting and brood rearing success positively or negatively. Large-scale conversion of sagebrush-steppe areas to crops or introduced forage grasses has generally resulted in reduced grouse production and abundance (Connelly et al. 2000). Loss of plant diversity, particularly the loss of broad-leafed perennial forbs, is believed to be a cause of poor chick production and survival in many areas (Connelly et al. 2000).

Observations of south Rich County sage grouse over the past 16 years suggest that weather drives sage grouse population dynamics and predators take a toll. It also appears, however that the way we manage sagebrush-steppe ecosystems can magnify or minimize the effects of droughts, severe winters and predation on sage grouse populations.

Sage grouse investigations in south Rich County began in 1984, in response to declining populations during the previous ten years. Primary objectives were to identify areas and vegetation types used by grouse in the winter, breeding and summer seasons, obtain estimates of grouse production, recruitment and mortality, and try to gain a basic understanding of how weather, land use practices and other wildlife might affect sage grouse. Funding and support for this project have come from Deseret Land and Livestock (DLL), the Utah Division of Wildlife Resources (DWR), the Bureau of Land Management (BLM), Utah State University (USU), Pheasants Forever (PF-Golden Spike Chapter) and Private Lands Consulting (PLC).

The following personnel have collaborated in data collection and analysis: Shane Davis, Gregg Simonds, Bill Hopkin, Steve Kearn, Ken Vernon, Anis Aoude, Bob Wharff, Pat Hogle and Lisa Prudden (DLL); Kirk Gardner (BLM); Mike Welch, George Wilson, Jim Gregory, Scott McFarlane, LeVon Thomas, and Ray Owens (DWR); Collin Homer, Mary Hunnicutt, Anne Billaux, Cass Bromley, Eric Gese, Tom Edwards, Winnie Seidel, Mark Ritchie and Mike Wolfe (USU); Mark Stackhouse (Westwings); Tim Gorman (Evanston Audubon); Ken Clegg and Brad Peacock (PLC). Thanks also to Dean Mitchell, Clait Braun and Jack Connelly for research and management advice.

Study Area

Rich County is located in northern Utah, bordering Idaho and Wyoming (figure 1). The Bear River flows through the county from south to north, is flanked by sagebrush-steppe communities on either side, bounded by the Wasatch Mountains to the west and the Bear River divide to the east. The Bear River valley is largely privately owned; principal land-use is irrigated grass-hay, alfalfa and beef production. Elevations range from 1800 – 2600 m.

Prevailing winds in the south Rich study area are from the southwest, resulting in heaviest snow accumulations and more mesic plant communities on north and easterly aspects. Annual precipitation is highly variable but averages about 50 cm (20 in) at higher elevations and 23 cm (9 in) at the lowest elevations. The wettest months are September, May and June. Mean annual temperature in nearby Woodruff, Utah is 4⁰ C (40⁰ F); summer temperatures in excess of 32⁰ C (90⁰ F) and winter temperatures below -29⁰ C (-20⁰ F) are not uncommon. Most herbaceous forage growth occurs during approximately 45 frost-free days, late-May through early July.

Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) dominates the lower elevations and milder slopes adjacent to the river valley. Interspersed within this matrix of Wyoming big sage are patches of basin big sagebrush (*A. t. tridentata*) in draws, patches of black sagebrush (*A. nova*) on gravelly ridges, patches of low sagebrush (*A. arbuscula*) in alkaline-clay basins, and riparian vegetation along streams and in moist lowlands. Low rabbitbrush (*Chrysothamnus viscidiflorus*) is present wherever Wyoming sagebrush occurs, horsebrush (*Tetradymia spp.*) and winterfat (*Ceratoides lanata*) occasionally co-dominate. Higher elevation, steeper mountain foothills are dominated by mountain big sagebrush (*A. t. vaseyana*) intermixed with other brush species such as bitterbrush (*Pursia tridentata*), serviceberry (*Amalanchier alnifolia*) snowberry (*Symphoricarpos alba*) and juniper (*Juniperus spp.*), with scattered patches of aspen (*Populus tremuloides*) on mesic sites. During the past 40 years, some of the sagebrush-steppe has been plowed and converted to dryland grain farms or introduced grasses (primarily crested wheatgrass (*Agropyron desertorum*)). Upland areas are primarily publicly owned in the northern part of the county (BLM and State Lands) and privately owned in the southern part (primarily DLL). Most of the long-term data presented here was collected on DLL by ranch biologists. However three areas in the southern half of the county (DLL, Dog Hollow and Dry Hollow) and three areas in the northern half of the county (Otter creek, Big creek and a portion of the Bear Lake Plateau) were monitored during various phases of this study.

Deseret Land and Livestock (DLL) grazes approximately 36,500 ha (90,000 acres) of privately owned and 5300 ha (13,000 acres) of BLM lands in south Rich County. Revenues funding research and management are generated from beef production and wildlife-recreation programs (big-game hunting, fishing and birding). Four major vegetation types dominate the DLL study area. The northern quarter consists of about 9000 ha (20,000 acres) of upland range disked and seeded to crested wheatgrass 30-40 years ago. These low elevation rangelands are repopulating with sagebrush, and are called the sagebrush-crested wheatgrass (**S-CW**) habitat (Appendix A). Annual precipitation averages 20-25 cm (8-10 in). Elevations range from 1920-2012 m (6300-6600 ft). The topography is predominantly flat, with moderately dense stands of Wyoming big sagebrush on upland sites and 2000 ha (5000 acres) of broad irrigated hay meadows in the lowlands. A few irrigated fields contain alfalfa (*Medicago sativa*). Patches of low sagebrush dominate a few alkaline-clay basins. Other shrubs include rabbitbrush, winterfat, horsebrush and greasewood (*Sarcobatus vermiculatus*). Cover values range from 0-25% for shrubs and 5-

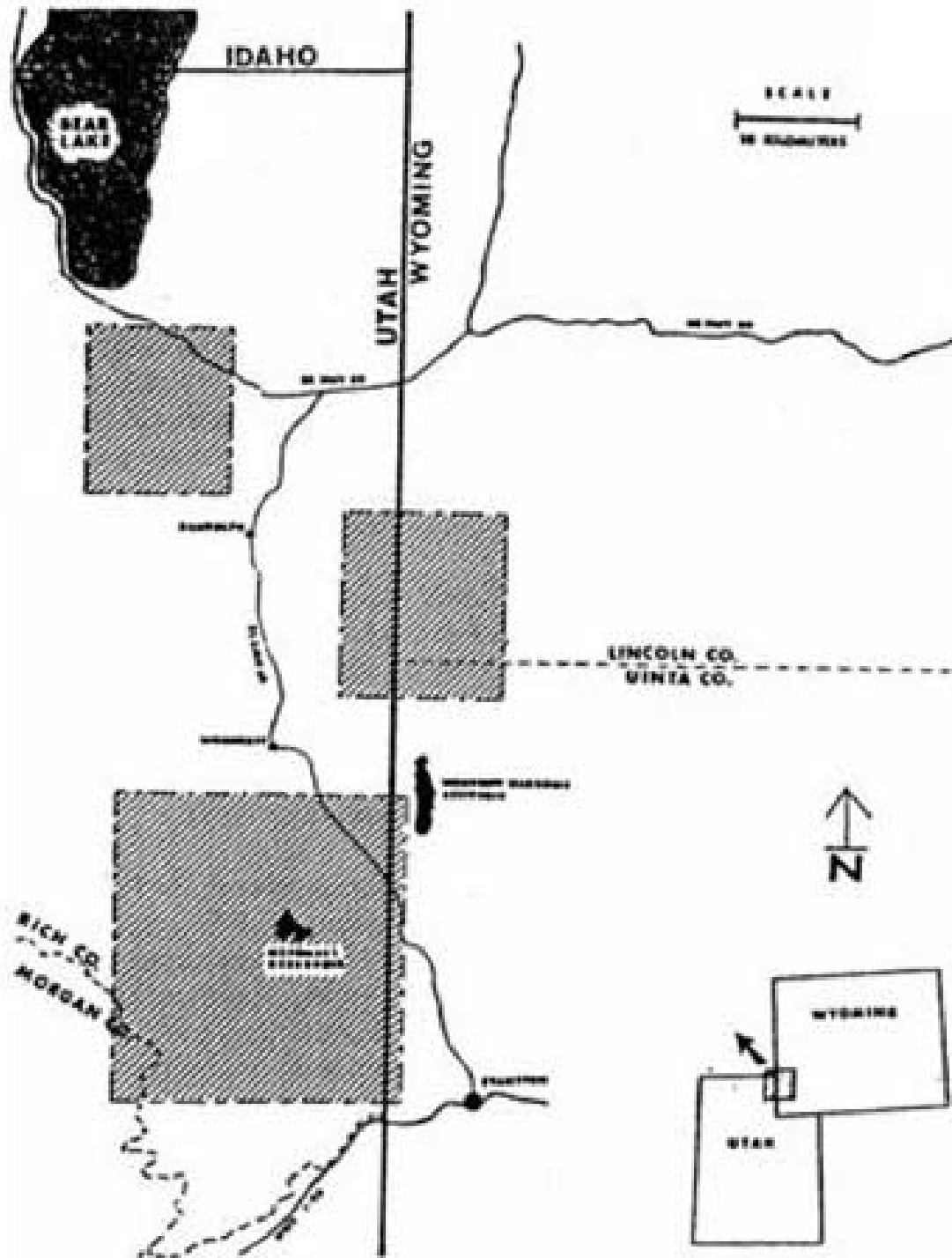


Figure 1. Study area location

40% for herbaceous plants (primarily crested wheatgrass) (Appendix B). Perennial forbs are conspicuously absent from this area, averaging less than 7% cover (Appendix B). Predominant perennial forbs include woody species such as *Phlox longifolia* and *Eriogonum* spp.

The middle quarter of the study area (mid-elevation) is native sagebrush (**NS**). Annual precipitation averages 25-30 cm (10-12 in). The topography is largely sagebrush flats and ridges ranging from 1980-2070 m (6500-6800 ft). Uplands are dominated by mature to decadent Wyoming or basin big sagebrush and native herbaceous vegetation. Dominant grasses include western wheatgrass (*Agropyron smithii*), bluebunch wheatgrass (*A. spicatum*), needlegrass (*Stipa* spp.), Sandberg's bluegrass (*Poa secunda*) Great Basin wildrye (*Elymus cinereus*) and ricegrass (*Oryzopsis hymenoides*). Bitterbrush, serviceberry and juniper occasionally co-dominate with sagebrush on ridges. More xeric draws are dominated by basin big sagebrush; wetter draws contain native meadows. Cover values range from 10-40% for shrubs and 5-30% for herbaceous plants. Perennial forb cover ranges from 5-20%. Plant species richness is significantly greater here than in the **S-CW** area. Common perennial forbs include species of the genera: *Achillea*, *Agoseris*, *Allium*, *Antennaria*, *Astragalus*, *Crepis*, *Erigeron*, *Eriogonum*, *Euphorbia*, *Lepidium*, *Lomatium*, *Medicago*, *Oxytropis*, *Penstemon*, *Phlox*, *Senecio*, *Solidago*, *Spaeralcea*, *Taraxacum* and *Trifolium*.

The southern quarter of the study area (Wasatch) is predominantly sparse-sage grassland (**SSG**). This portion of the study area is a series of alternating low ridges and moist draws. Annual precipitation averages 28-36 cm (11-14 in). Elevations range from 2012-2103 m (6600-6900 ft). Uplands are predominantly native grasses and forbs (listed above) interspersed with scattered patches of Wyoming or basin big sagebrush. Draws are dominated by native meadow grasses and forbs. Upland herbaceous vegetation exceeds 50% coverage, with 10-25% being perennial forbs. Shrub cover ranges from 0-25% (generally <10%).

The western quarter of the DLL study area is mountain sagebrush (**MS**). Elevations range from 2042-2375 m (6700-7800 ft). Annual precipitation averages 38-50 cm (15-20 in). Topography is dominated by relatively steep ridges (> 20% slope). Mountain big sagebrush is the dominant shrub, with bitterbrush, serviceberry and snowberry locally abundant. Shrub coverage is generally >30%. Scattered patches of aspen dominate mesic (snowdrift) sites. Herbaceous vegetation is dense (>40% coverage), diverse and similar in species composition to the native sage and sparse-sage grassland areas.

DLL is grazed using time-controlled grazing principles (Savory 1988), whereby a few, large herds of cattle and sheep intermittently graze pastures. Pastures are grazed for short periods of time when forage is rapidly growing (May-July) and longer periods of time when forage is dormant or growing slowly. Pasture grazing season is varied between years, and pastures are periodically rested for a full growing season.

Resident predators of adult sage grouse include golden eagle (*Aquila chrysaetos*), coyote (*Canis latrans*), bobcat (*Lynx rufus*) and red fox (*Vulpes fulva*). Bald eagles (*Haliaeetus leucocephalus*) are present November –April. Nest predators include coyote, badger (*Taxidea taxus*), least chipmunk (*Eutamias minimus*), Uinta ground squirrel (*Citellus armatus*) and black-billed magpie (*Pica pica*).

Methods

We periodically captured and fitted sage grouse with radio-transmitters or visual markers to assess movements, survival, nesting success and habitat use by grouse (Giesen, 1982). However most of the habitat use, lek attendance and chick production estimates were obtained from periodic searches for and chance observations of unmarked birds. We determined cause of death by comparing remains of birds found afield to remains of grouse and pheasants (*Phasianus* spp.) fed to captive eagles. Coyote abundance was estimated as the number of coyote observed/ 100 hours effort while counting leks March – May. Jackrabbit and ground squirrel abundance was counted along permanently established routes on dirt roads. Habitat classifications and sage grouse use/availability indices were developed using line-transect, point-transect and GIS techniques (Hunnicuttt 1992, Homer et al. 1993). Artificial nests (brown chicken eggs) were used to estimate nest survival within habitats (Ritchie et al. 1994). Sage grouse chicks were hand-reared to study diet selection and foraging rates (Billaux 1996) and insect abundance was estimated using pitfalls, sweep nets and an insect-vacuum. Sage grouse use of burns (**BRN**), disked and reseeded areas (**RSD**) and untreated controls were obtained by recording birds observed/ hour by horse-mounted observers aided by pointing bird dogs (Wilson 2000). Temperature and rainfall data are from the Woodruff, Utah reporting station (Utah Climatological Data, NOAA). Snow depth was measured on the 1st, 10th and 20th of each month, November – March at the north end of the study area, and at sites used by wintering sage grouse.

Winter Ecology

Flock characteristics and dispersal from wintering areas to leks

A total of 309 sage grouse flocks, (10,246 grouse) were observed by DLL biologists on the south Rich wintering areas (primarily on DLL), 1 November - 31 March, from 1984 - 2000. A range of winter flock sizes was observed (table 1, after Beck 1977). Flock size did not vary significantly with snow depth. Male-only flocks were generally smaller than mixed sex flocks (8.3 and 63.7 grouse/flock, respectively, 1984-90).

Table 1. Size classes of 309 sage grouse flocks observed on DLL, 1984-2000, south Rich County Utah (after Beck, 1977).

	number of birds in flock				
	1	2-25	26-50	51-100	>100
number flocks observed	14	170	69	35	19
% of flocks observed	4.5	55	22.7	11.7	6.1
% of birds observed	0.001	16.9	25.5	27.3	30.2

Sage grouse radio-marked 1984-1986 on the south Rich wintering area dispersed 0.2 – 65 km (mean = 11.8 km) to spring breeding areas (Appendix C). Sixty-seven percent of adult hens moved <5 km, and none moved >15 km from winter to breeding areas. At least three hens captured in Utah spent the summer in Wyoming. One yearling hen and one adult male each traveled > 55 km from the south Rich wintering area to breeding areas. We do not know if

these were dispersal movements or annual migrations. Mule deer and pronghorn summering in western Wyoming and southern Idaho are known to migrate into south Rich County during deep snow winters, perhaps grouse do as well. Five hens monitored >1 year each exhibited strong fidelity to breeding and wintering sites, unless deep snow covered sagebrush making it unavailable.

Topography of sage grouse winter use sites

Percent slope, aspect and topography (flat, ridge or draw) was recorded at 297 winter flock sites. Sage grouse were generally observed on areas of low slope; 87% of winter observations were on slopes of <5 %. Grouse were more commonly found on flat areas, easterly or northerly aspects than on southerly or westerly aspects. Grouse more often used southerly and westerly aspects in late winter (Feb-Mar) than early (Nov-Jan), perhaps because snow generally began melting on south and west slopes by mid-February. Seventy-eight percent of flocks used flat areas or ridge tops when snow depths were less than 30 cm (12 in). When snow depths exceeded 30 cm, however 73% of flocks used taller basin big sagebrush in draws.

Vegetation characteristics at winter use sites

Homer et al. (1993) developed a sagebrush habitat model (table 2), based on sagebrush height and percent coverage at 168 winter grouse flock locations in Dry hollow, Dog hollow (south Rich county) and Otter creek (north Rich county), 1989-90 (two winters-one of moderate and one of low snow depth). Brush at sage grouse use sites was classified into 7 shrub classes (based on brush height and percent canopy). Sagebrush height was categorized as very high, >60 cm; high, 50-59 cm; medium 40-49 cm; and low, < 39 cm. Shrub canopy cover was categorized as dense, >29%; moderate, 22-28%; low, 15-21%; and sparse, <14%.

Sage grouse preferred shrub classes 40-60 cm high and 20-30% shrub canopy (table 2). Shrubs of medium height and low canopy cover were highly preferred. During these two winters, grouse did not select shrub classes of low (<30 cm) or very high (>64 cm) sagebrush height.

Table 2. Sagebrush class descriptions and preference by sage grouse in Rich County, Utah, 1989-90. (from Homer et al. 1993).

shrub class height -% canopy	mean shrub canopy (%)	sagebrush height	% total habitat	preference/ avoidance
very high - dense	31.1	64.6	2.2	not preferred
high - dense	29.6	56.0	7.7	preferred
medium - moderate	24.1	40.3	9.6	preferred
medium - low	20.4	42.1	18.7	highly preferred
medium - sparse	11.5	47.8	1.5	avoided
low -sparse Wyoming	9.6	32.4	7.0	not preferred
low - sparse black	12.0	22.0	6.3	avoided
no shrub	0.0	0.0	47.0	avoided

The model was then tested with additional winter flock observations from the north area (1989-90) and the south area (1985-90, primarily DLL data). The model predicted grouse use

quite well, with the exception grouse on the south area occasionally selected short, sparse Wyoming and low sagebrush (in more open, low snow winters) or tall, dense Wyoming and basin big sagebrush (during periods of deep snow accumulation).

Sagebrush height was correlated with snow depth at 309 sage grouse winter flock locations in the south area ($r^2=0.47$, figure 2a). Grouse used shorter brush at low snow depths, and progressively taller brush as snow depths increased. It seemed that grouse were selecting sagebrush patches such that the height of sagebrush cover protruding above snow averaged about 25 cm (10 in) (figure 2b). This may be an optimum height, i.e. tall enough to hide grouse from predators yet short enough to allow grouse to spot approaching danger in time to react.

Similarly, mean annual sagebrush height at winter grouse-use sites correlate with mean Nov-Mar snow depth ($r^2=0.59$, figure 3a). When snow depths were < 30 cm (12 in), grouse used low, black or Wyoming big sagebrush patches (from <100 m to >100 ha in size) on upper ridges or flat areas. Wyoming big sagebrush plants growing in **S-CW** habitats were seldom taller than 45 cm (18 in). When snow depths exceeded 30 cm these shrubs became snow-covered and unavailable. Grouse then used tall or very tall-dense patches of Wyoming or Basin big sagebrush in draws when snow depths exceeded 35 cm.

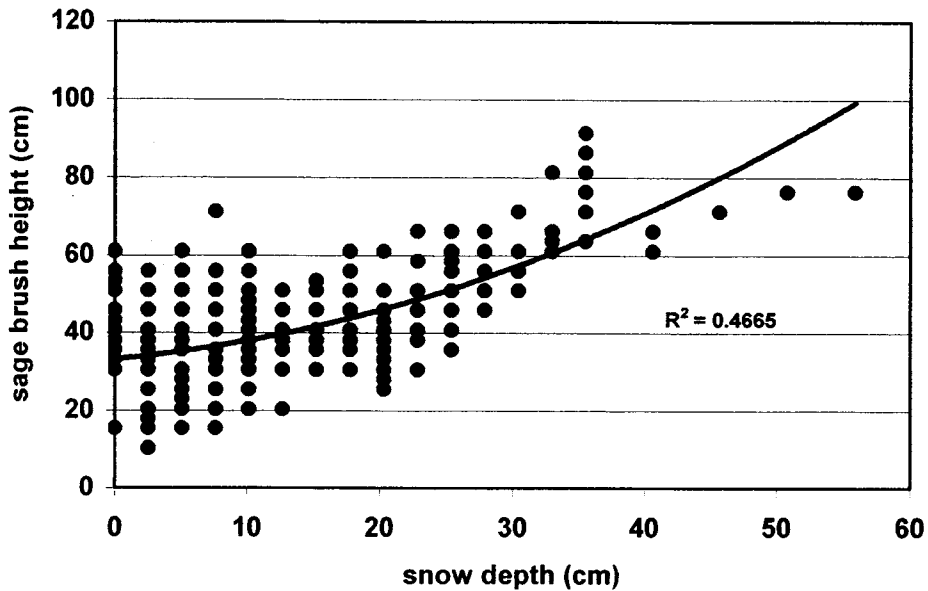
Appendix D depicts winter range use based on snow depth. Figure 3b summarizes availability of short (< 56 cm) and tall (>56 cm) sagebrush types on DLL and Dog hollow, as well as percent sage grouse use of these types in deep (≥ 30 cm) and low (< 30 cm) snow conditions. At lesser snow depths grouse used these two sagebrush classes as available. As snow depth exceeded 30 cm, however, grouse selected and concentrated in tall sagebrush classes.

Few sagebrush plants remained above snow on the low elevation (northern quarter) portion of the study area when snow depths exceeded 30 cm. Wyoming sagebrush patches have repopulated the crested wheatgrass plantings in this low-elevation winter range during the past 30 years. In deep snow, sage grouse flocks concentrated in patches of taller, (generally older) undisturbed sagebrush. As an example, multiple flocks, totaling 442 grouse, were counted on a single 3-mile walk through a band of tall sagebrush bordering the Chapman canal in January of 1986. Mule deer (*Odocoileus hemionus*) and whitetail jackrabbits also concentrated in these patches of tall sagebrush under deep snow conditions. On occasion, when snow covered big sagebrush at lower elevations, we observed sage grouse that had migrated upward to find patches of taller mountain big sagebrush exposed above snow (generally on ridges and south slopes).

Relationship between deep snow, predation and population change

While most winter sage grouse observations occurred in sagebrush of medium height, the relatively small acreage of taller sagebrush classes in south Rich seemed critically important as cover for sage grouse, jackrabbits and mule deer at least once in 5 years (i.e. severe winters). Male sage grouse attendance at DLL leks increased following open winters, and declined following deep snow winters. Using lek attendance (Appendix E) as an index of population size, percent population change (N_t / N_{t-1} , Appendix F) was negatively correlated with mean snow depth ($r^2 = 0.50$, figure 4). Male grouse counted on DLL leks, following the deep snow winters of 1985-86 and 1992-93, declined 38% and 49% respectively.

Relationship between sagebrush height and snow depth at 309 sage grouse flock locations (10246 birds) 1984-2000.



Mean sagebrush height above snow at various snow depths.

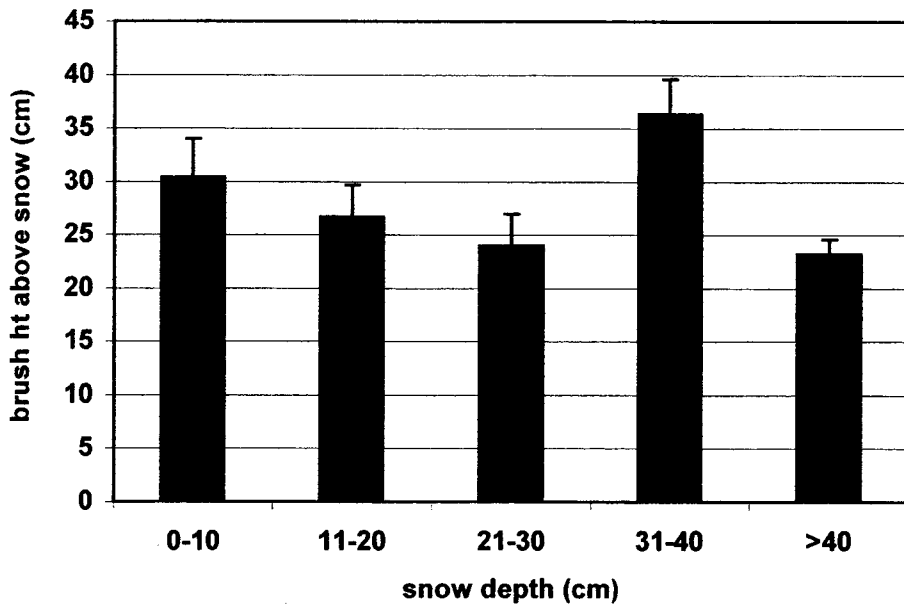
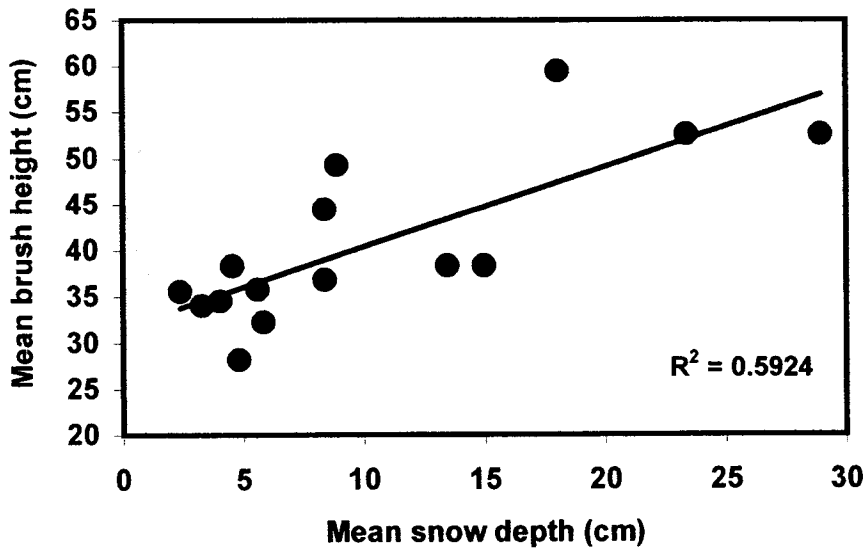


Figure 2. a) Correlation between snow depth and brush height at 309 grouse flock locations. b) Mean brush height (std. err.) above snow at 309 grouse flock locations at various snow depths.

Mean sagebrush height used by sage grouse flocks, NOV-MAR vs. mean winter snow depth, DLL, 1984-98.



Percent of tall (>56 cm) and short (<56 cm) sagebrush types available, and % use by 309 sage grouse flocks in low (< 30 cm) and deep (> 30 cm) snow depths, DLL, 1984-2000.

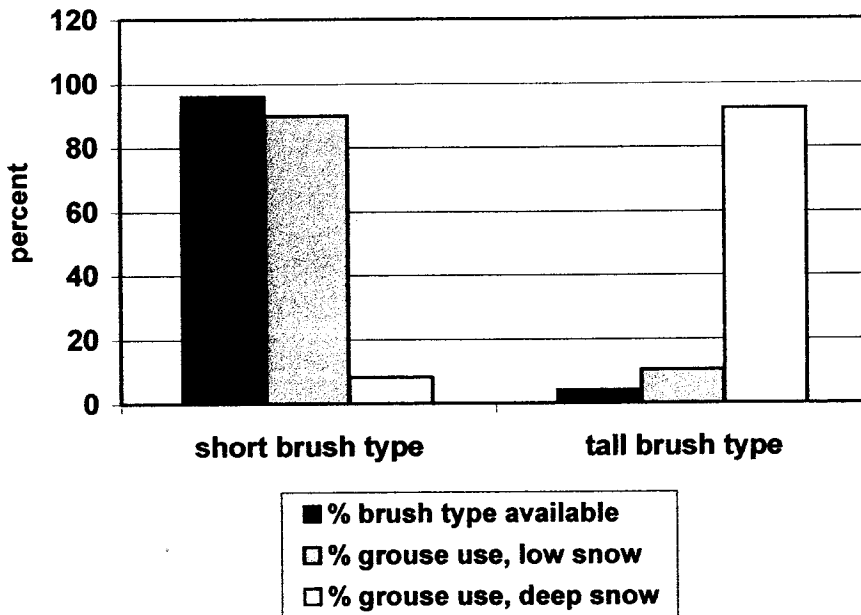
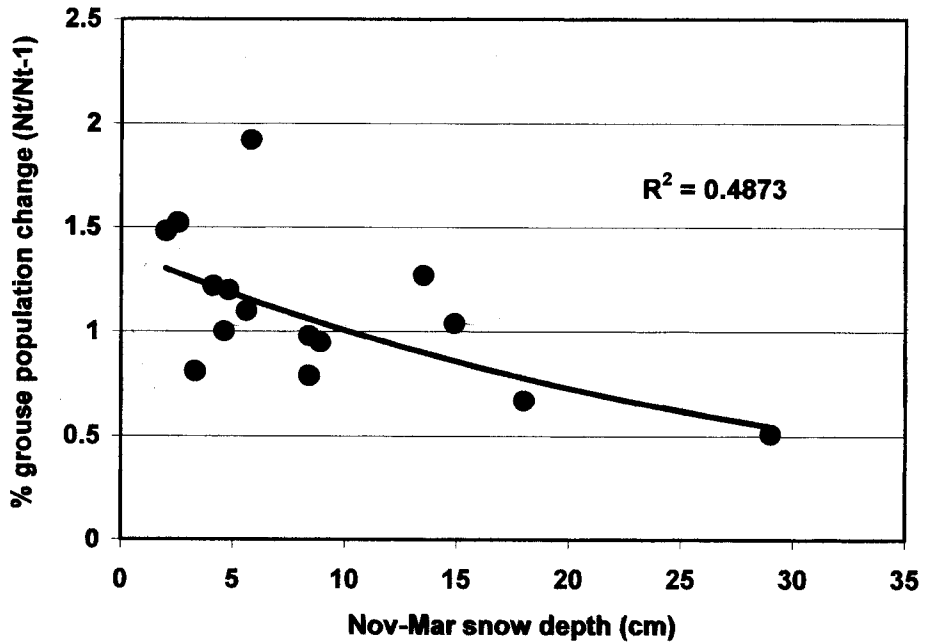


Figure 3. (a) Relationship between mean winter sagebrush height and mean winter snow depth used by sage grouse flocks. (b) Availability and use of short and tall sagebrush types by grouse in low and deep snow depths.

Winter snowdepth vs. sage grouse population change



Winter eagle count vs. sage grouse population change

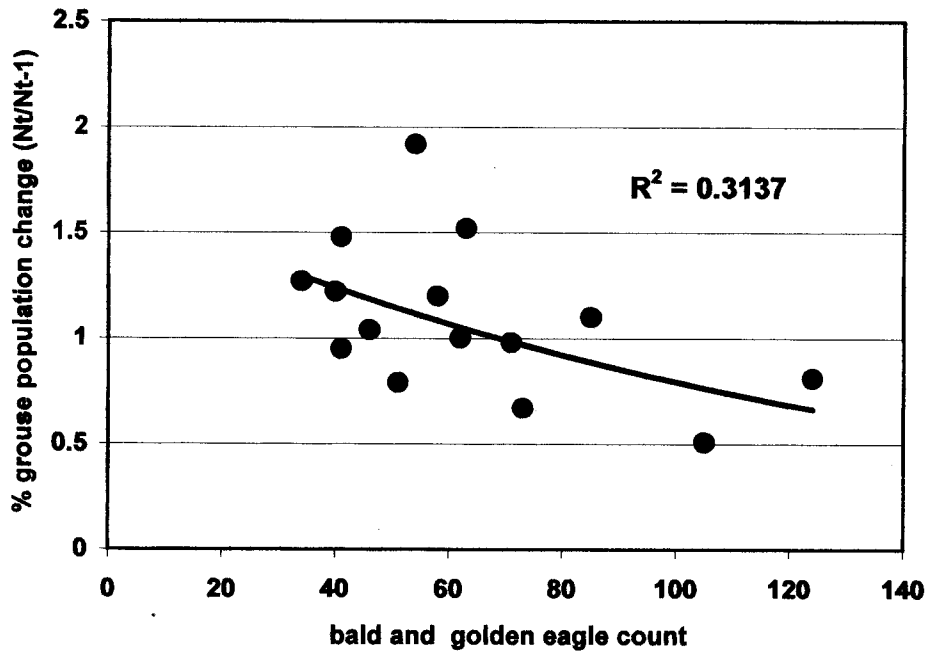


Figure 4. Relationships between winter snow depth and sage grouse population change and between eagle abundance and grouse population change, DLL, 1985-2000.

Percent population change was also negatively correlated ($r^2 = 0.31$, figure 4) with the number of wintering bald and golden eagles counted annually in the Evanston, Wyoming Audubon Christmas Bird Count circle (which includes the south Rich wintering areas). The number of bald eagles counted ranged from 24-121, and the number of golden eagles ranged from 3-30, 1984-2000.

It seemed grouse were more visible, more frequently flushed by predators, and suffered greater mortality rates as birds became concentrated by deep snow. Golden eagles were routinely observed flying low over sagebrush, flushing and pursuing grouse flocks and jackrabbits on the winter range. During periods of deep snow, flocks flushed by eagles were observed flying >2 km to reach the next nearest tall sagebrush patch. Based on observations of predators and tracks, golden eagles and coyotes concentrated hunting efforts near tall brush patches where prey concentrated. Twelve of twenty-two radio-marked grouse (54.6%) examined post-mortem were eaten by raptors (probable golden eagle kills). Five of 20 radio-marked sage grouse captured 12 February - 21 March 1985 and 6 unmarked grouse were found eaten (presumably killed) by eagles between 15 March – 10 April 1985, when snow depths exceeded 35 cm.

The negative relationship between snow depth and apparent changes in grouse population size may have resulted from multiple factors. Grouse may simply have emigrated from the area, although our telemetry data suggests otherwise. Males in poor condition following these tough winters may not have attended leks (Emmons and Braun 1984). We suspect, however, that grouse survival rates declined due to increased predation rates, increased time spent flushing and fleeing predators (increased energy expenditure), and increased competition with jackrabbits, mule deer and other grouse for the patchy, more chemically-defended basin big sagebrush foliage available above snow. The ultimate factor appeared to be a lack of tall sagebrush forage and cover in winters of above average snow depth.

Grouse mortality

Forty radio-marked grouse (8 adult male, 7 juvenile hens and 25 adult hens) were captured between February 1985 and May 1987. We were able to locate and examine the remains of 22 radio-marked and 105 unmarked sage grouse post-mortem. Twelve (54.6%) radio-marked and 69 (65.7%) unmarked grouse were eaten by raptors (table 3).

Table 3. Causes of mortality of 22 radio-marked and 105 unmarked sage grouse, Rich County, Utah, 1984-2000.

	raptor predation	mammalian predation	fenceline collision	hunter harvested	trough drownings	unknown causes	total
radioed grouse	12 57.2%	2 9.5%	0	5 23.8%	0	2 9.5%	21 100.0%
unmarked grouse	69 65.7%	7 6.7%	19 18.1%	unknown	6 5.7%	4 3.8%	105 100.0%
total	81	9	19	5	6	6	126

Golden eagles were the raptor species most commonly observed hunting and killing sage grouse. Bald eagles were not often observed hunting grouse, however a group of three bald eagles were observed killing a sage grouse on one occasion on winter range (the grouse carcass was then stolen by a golden eagle). Immature bald eagles were occasionally observed hunting and stooping on grouse at leks, no kills were observed. All adult and most immature bald eagles migrated north before the lekking season. Grouse were occasionally seen flushing as harriers or buteos hunted through leks, however no kills were observed.

Although golden eagles were observed hunting (low-level flying) over wintering flocks in most winters, they were seldom successful. We only observed two successful golden eagle-kills. On a third occasion a hunting golden eagle flushed a winter grouse flock, then tail-chased and hit a grouse in the air (but did not catch it). Golden eagles were observed killing male grouse on leks on three occasions, although observed stooping unsuccessfully at strutting grouse on numerous occasions. One radio-marked hen was predated by a golden eagle at her nest while incubating eggs.

The response of sage grouse to soaring or stooping eagles was to either freeze, or flush and fly to another location. Eagles tried to kill grouse on or near the ground. Once airborne, grouse outmaneuvered eagles. Flushed grouse usually landed in sagebrush providing some screening cover, but allowing grouse to observe pursuers at a distance. Grouse responded to pursuing falcons differently. The more maneuverable falcons posed a threat to airborne grouse. Grouse sometimes dived into tall, dense cover (such as willow thickets and dense stands of basin big sagebrush) and tried to lose pursuing falcons on the ground.

Nine of 12 radio-marked grouse (11 female and 1 male) eaten by raptors apparently died during winter (Nov-Mar) one was killed on her nest in May and time of death of the other two were unclear. Of 69 unmarked grouse eaten by raptors, 29 (42%) died in winter, 39 (57%) died during the breeding season (Apr-May), time of death of four was unclear. All raptor-eaten grouse at leks were males. Strutting activity normally ceased when eagles flew within 0.3 km of leks. Eagles observed hunting or stooping at leks typically flushed the grouse and strutting ceased for the day. Although eagles were a continuous threat to strutting males, they did not appear to be overly successful grouse hunters. We searched six leks and surrounding brush immediately following the breeding season in 1989, and found the remains of only 8 raptor-predated male grouse. At least 250 males attended those same six leks in 1989. Eagles appeared to hunt sage grouse most actively during periods of the year when grouse were most visible and concentrated (leks and winter flocks) and perhaps more abundant relative to alternate prey. It may be that eagles were more successful during deep snow periods, since grouse were either exposed on open snowfields or concentrated in draws of tall sagebrush. Grouse using tall brush in a draw may be less likely to spot low-flying eagles in time to flee, since the tall, dense vegetation in these stands reduces horizontal visibility (making it difficult for grouse to spot distant predators).

We found little evidence of adult grouse predation by mammals. Three radio-marked (13.6%) and seven unmarked grouse (6.7%) appeared to have been eaten by mammalian predators. No evidence of sage grouse remains was observed in the occasional coyote scat or den site examined. On eight occasions, coyotes were observed crossing leks with actively strutting males. On only one occasion did the coyote try and capture a grouse, flushing the birds. Normally, strutting activity did not cease when coyotes were present; in fact little interest was

shown on the part of either specie for the other. Coyotes generally appeared to be travelling through, ‘mousing’ or hunting jackrabbits. On two occasions jackrabbits flushed as coyotes crossed the leks; all coyotes present embarked in hot pursuit.

Red fox are believed to have predated at least two of the three mammal-killed radio-marked grouse. On one occasion sage grouse remains were observed in a red fox scat. A red fox was observed stalking a strutting male (unsuccessfully). Waterfowl and small mammal parts were the most commonly identified remains at fox dens, however sage grouse parts were observed on two occasions.

Nineteen unmarked sage grouse (18.1%) died following collisions with barbed-wire fences. Fence-collisions were the second most commonly observed cause of sage grouse mortality (second only to raptor predation). Two additional grouse were observed adjacent to fences with lacerated breasts and broken wings. Fence-line collisions were most commonly noted along fences near leks and commonly used wintering grounds. Collisions probably occur as grouse are flying to or from leks, and during flight from predators. Thirteen fence-line strikes (skin and feathers attached to barb-wire) and seven carcasses were counted along 8.3 km of barbed wire fence (fence-line within 0.8 km of active leks) during May 1989 (1.6 strikes / km). Collisions were most frequent within 0.2 km of leks, and ceased beyond 0.8 km. Strikes and carcasses were only seen in association with barbed wire, never with smooth-wire fence. Similarly, 16 strikes were observed along 2.4 km of barbed wire fence in a heavily used winter area (6.7 strikes/km). No carcasses were observed along this fence. It is possible that some of the grouse captured and eaten by raptors and mammals were first wounded or killed by fence-line collisions.

Six sage grouse drowned in water troughs during Aug-Sep 1988. This was the driest summer of the study; moist forbs were practically non-existent. Two of the drowned birds were adults, and four were chicks.

Hunters harvested five radio-marked sage grouse. The Rich County shotgun season is held mid-September, and sage grouse may be hunted with falcons September –February. Known shotgun and falconry harvest averaged 15-30 grouse annually on DLL.

Survival estimates of radio-marked grouse

Twenty-two sage grouse were monitored from capture until death. Five died during the first 15 days following capture (killed by golden eagles). We felt that grouse were particularly vulnerable to predation during the two weeks following capture, while recovering from capture stress and adjusting to the radio-package. Of the 16 grouse which survived the first two weeks post-capture, five lived > 2 years, one of which survived nearly six years. The average monitoring period from capture to death was 15.4 months (range 2-69 months). Assuming yearlings (captured Dec-Feb) were at least 0.6 years old at capture and adult grouse were at least 1.6 years old, mean age at death was at least 2.6 years. Although an extremely small sample, a simple life-table analysis using these 16 radio-marked sage grouse suggests average annual survival was 47% (table 4). This estimate is comparable to estimates of 40-60% in Montana and Colorado (Connelly et al. 2000).

Table 4. Survival of 16 sage grouse monitored 1985-1991, Rich County, Utah.

year	number alive	number dying	percent dying	percent alive
1	16	10	0.625	0.375
2	6	1	0.160	0.840
3	5	4	0.800	0.200
4	1	0	-	1.00
5	1	0	-	1.00

Mean annual survival rate, years 1-3 = 0.472.

Predator – Prey Relationships

Although golden eagles actively hunt and kill sage grouse on DLL, jackrabbits, ground squirrels and even waterfowl were more abundant than grouse in prey remains examined at eagle nests and in regurgitated eagle pellets. Golden eagle nesting success (percent of nests with chicks) on DLL was strongly correlated with both whitetail jackrabbit ($r^2 = 0.85$) and Uinta ground squirrel ($r^2 = 0.68$) abundance (figure 5). Jackrabbits were noticeably more abundant before the severe winter of 1983-84 than for several years following this winter (Mitchell and Roberson 1992). Coyotes were seldom seen during the early 80's, presumably due to coyote control efforts and low prey numbers. Jackrabbit and ground squirrel populations rebounded in 1991, and coyote populations seemingly increased in response to the abundant prey (figure 5). Although prey populations declined following the severe winter of 1992-93, coyotes remained abundant.

These abundance indices suggest golden eagle production and coyote densities increased as prey became more abundant. It may also be that the higher coyote abundance post-1991 slowed the “recovery” of jackrabbit and ground squirrel populations.

Prior to 1990 red fox were commonly observed in irrigated pastures, and occasionally observed in sagebrush uplands. As coyote abundance increased, red fox observations declined. We counted 0.23 red fox/mile on DLL spotlight transects in 1987, as compared to 0.08 red fox/mile in 1992. Red fox are rarely observed now, mainly in irrigated meadows near human habitation.

Coyote abundance appears to have remained relatively stable on DLL, 1992-2000 (figure 5). Little coyote hunting occurred during investigations of coyote – sheep ecology on DLL, 1997-2000. Bromley (2000) estimated coyote densities at 2.8 coyotes per 17 km² on DLL sagebrush-steppe during 1998 – 1999. Bromley felt that all, or nearly all, available habitat on the study area was occupied by breeding coyote pairs. During this period (1997-2000), sage grouse lek counts increased nearly 500%. It may be that the presence of mated coyote pairs positively affected sage grouse populations by reducing densities of other potential nest predators (foxes, ground squirrels and others). Studies in chaparral (Soule et al. 1988), grasslands (Vickery et al. 1992), shortgrass prairie-shrublands (Henke and Bryant 1999) and wetlands (Sovada et al. 1995) suggest that coyotes can significantly reduce the abundance of small mammalian herbivores (rodents, jackrabbits and squirrels) and “mesopredators” (fox, bobcat, badger and

striped skunk (*Mephitis mephitis*). Several of these studies showed that nest-predator densities and nest-predation rates (of ground-nesting birds) increased significantly in areas with intensive coyote control compared to areas with little or no control.

Whitetail jackrabbits appear to be a major prey species of both golden eagles and coyotes on the south Rich study area. Black-tailed jackrabbit (*Lepus californicus*) abundance appears to be regulated by coyote predation in arid habitats (Wagner and Stoddart 1972, Henke and Bryant 1999). Predation by coyotes and eagles may limit whitetail jackrabbit and ground squirrel numbers and, in turn, tend to stabilize coyote and eagle densities by reducing predator production and abundance. This relationship appears to be inducing “stasis” in the system. The predator-prey relationships observed post-1991 appear to have benefited sage grouse (and perhaps, other ground nesting birds) by reducing the density of jackrabbits, other nest predators, and golden eagles.

Lek Fidelity

Male sage grouse generally began congregating and displaying at leks by mid-March. We observed some inter-lek movements by grouse through the strutting season. One of three radio-marked adult males likely visited more than one lek (he was located near three leks during his 65 km dispersal-journey to Idaho). Of 48 additional males captured on leks in 1985 and outfitted with ponchos or colored leg bands, only three were later observed on other leks (although one moved 40 km). Since many of the currently used DLL leks were not discovered until 1988, some inter-lek movement with these leks may have occurred. However most DLL leks have been counted two or more times weekly since 1988. We observed few inter-lek movements by males once hens arrived at leks. Two of six radio-marked hens (one adult and one yearling) visited more than 1 lek in 1985. Four of five radio-marked hens monitored through two or more nesting seasons attended only one lek each year. One hen, monitored for four years, attended two leks / year in two of the four years.

Male attendance at leks

We attempted to count each lek at least once per week mid-March through mid-May. Most leks were counted multiple times per week; a few less accessible sites were counted as conditions permitted. We consider these counts to be our best estimate of minimum male population, and of the grouse population trend through time.

Peak (maximum annual) male counts on leks are summarized in Appendix E and figure 6. At the outset of the study, we knew of only two leks on DLL. In 1988 five additional leks were counted, in 1989 two more were added. Since then, three more leks have been found and counted (one each in 1992, 1999 and 2000). Males displaying at smaller, peripheral or transient “satellite” areas were included in the grouse count at the nearest large or more permanent lek site. On five occasions, leks shifted location 0.1 – 1.0 km during a one - two year period. Occasionally, declining lek attendance indicated leks were changing location. On three occasions (during periods of low population) leks became inactive for one or more years, reappearing in the same location as populations rebounded. The South Dixon hole lek is a good example. Thirteen males were counted in 1991. Lek attendance subsequently declined, with no males observed in 1993. By 1996 (following forb plantings) attendance increased, 76 males were counted in 2000.

Strutting activity by males on leks generally commenced in early March and continued into early May. The date of peak male attendance ranged from 20 March to 22 April (1985-2000), and correlated positively with melting of the winter snow pack ($r^2=0.43$, figure 7). The date of peak male attendance was also dependent on the abundance of yearling males. Specifically, the date of peak male attendance occurred 5-20 days after the peak of hen attendance in years when yearlings were abundant, and the population was increasing. (Conversely, peak male and hen attendance coincided in years when the population didn't increase, i.e. years with poor yearling recruitment). Chronologically, it seemed that adult males arrived first on leks, and yearling males arrived somewhat later with the females (after having wintered with the hens). Yearling males appeared unskilled in lek "etiquette" upon first arrival. They were quickly educated (attacked and chased by resident males), and soon stopped wandering like hens among the displaying males. Within a week or so following the peak attendance by hens, yearling males began displaying in peripheral areas of leks (Patterson 1952).

Hen attendance at leks

Hen sage grouse began arriving at leks in late March. While a few hens could be observed on leks any day from late March through April, approximately 80% of hens were observed attending leks during a two-week period each year. The peak date of hen attendance usually occurred about 1 April, but varied from 20 March to 15 April (1985-2000). Through the years, the date of peak hen attendance was positively correlated with melting of the winter snow pack on DLL ($r^2 = 0.71$, figure 7).

Discussion regarding lek attendance

While the date of peak hen attendance was correlated with melting of the winter snow pack (as noted with other grouse species in Bergerud and Gratson 1988), the date of peak male attendance was also related to yearling recruitment. That is, peak male attendance occurred 1-3 weeks after peak hen attendance in years when a substantial number of yearling males were recruited into the breeding population.

Peak male attendance on leks may be used as an index of population size if leks are monitored one or more times weekly from 20 March through 25 April. We did not see much variation in the number of males attending any given lek mid-March through mid-April, unless the lek was vacated due to rain, wind or predator activity. Counting leks less than 4 times per year may result in under-estimates of male attendance and population trend (see Beck and Braun 1980).

Impacts of herbivory on grouse winter habitat

Sage grouse winter ranges were livestock-grazed during the herbaceous growing season (Ap-Sep). Time-controlled grazing demands short grazing periods when plants are growing rapidly, to minimize re-biting of plants. Overgrazing is defined here as biting plants multiple times during the growing season without providing periods of recovery between grazing bouts (Savory 1988). Cattle did reduce sagebrush cover by browsing and animal impact (see figure 17). However the biggest impact of cattle grazing on sagebrush vigor was by indirectly affecting competition between shrubs and grass (Urness 1990). We compared sagebrush vigor between paired S-CW pastures on DLL in 1997 (figure 8). For several years three pastures were cattle-grazed 2-3 times annually (overgrazed) in the growing season. Each of these three

pastures included both Wyoming sagebrush uplands and irrigated meadows. Cattle grazed in both meadow and sagebrush, but bedded in the sagebrush. The sagebrush sites received significant animal impact (mechanical damage to sagebrush from bedding and trampling) and fertilization via dung and urine transported from the adjacent meadows.

The other three pastures (entirely upland **S-CW**) were cattle-grazed once each year (in March or April), prior to the onset of rapid herbaceous growth (dormant season grazed). One of these three pastures also received an application of commercial urea fertilizer at 100 lbs./acre. Adding urea increased twig and flower production on sagebrush. All six pastures received either severe or moderate winter browsing by pronghorn and elk (*Cervus elaphus*).

Greater sagebrush leader (twig), foliage and flower production was observed in the three overgrazed sagebrush/meadow pastures than in the three pastures grazed prior to rapid growth. Improved shrub vigor in the overgrazed pastures (grazed multiple times per growing season) was gained at the expense of grasses and forbs; herbaceous cover declined and bare ground increased. Areas receiving moderate big-game winter browsing plus dormant season cattle grazing showed moderate production of sagebrush twigs and flowers. Low elevation **S-CW** pastures severely browsed by elk and pronghorn during winter, then dormant season cattle-grazed gained crested wheatgrass cover and lost sagebrush vigor (twig, leaf, flower and seed production). Wambolt et al. (1996) reported similar declines of Wyoming sagebrush vigor from browsing by wild ungulates. Where elk were supplemented at DLL with alfalfa hay, severe browsing killed sagebrush plants within 0.5 km of the supplement. From the 1940's –1960's (when grouse were relatively abundant) Rich County-ranchers often winter-supplemented domestic sheep with alfalfa or grain to increase sagebrush intake and reduce brush cover.

Herbivory by jackrabbits can also reduce sagebrush cover. Ritchie and Wolfe (unpublished data) observed severe (>80%) winter browsing of sagebrush plants by high densities of whitetail jackrabbits on DLL in 1991. Jackrabbits were “pruning” (but not consuming) the annual leader growth, then consuming several centimeters of prior years' growth. In some cases, defoliation was severe enough to kill the plant.

In 2001 Dr. Neil West and Dr. Fred Provenza (USU) began experiments at DLL to use livestock herbivory (supplemented with protein and energy) to reduce sagebrush canopy coverage and increase herbaceous cover in selected areas. Treatments using sheep and cattle were completed in the winter of 2001-2002. Plant community composition, production and chemical defenses will be compared pre and post treatment.

Impacts of fire on grouse winter habitat

Five hot-season (late July-August) wildfire burns occurred in Wyoming sagebrush sites, and two hot wildfire burns occurred in mountain big sage on DLL, 1988-1996. All were caused by lightning strikes during hot, dry summers. One of the Wyoming and both of the mountain sagebrush sites are >150 ha (370 ac) in size, the other five are <40 ha (100 ac). There is very little sagebrush re-population occurring in the Wyoming big sage wildfires, most new plants establish near “mother” plants along the burn edge or in the few unburned sagebrush islands. On the other hand, one of the mountain sagebrush burns rapidly recovered sagebrush cover. Burned in 1992, the Spring Canyon burn regained a 10% sagebrush cover within five years. The Blue Ridge burn (July-1988) has yet to regain sagebrush cover. The intense heat generated

by hot-season wildfires often leaves few unburned patches and (apparently) few viable sagebrush seeds. Consequently, it may take many years for sagebrush plants to reestablish in burned areas hundreds of meters from a sagebrush seed source.

In the past eight years, DLL has ignited several cool season (April-May) burns, both in Wyoming and mountain sagebrush. These burns range in size from <1 ha to >100 ha. Cool season burns resulted in a good mosaic, having a lot of interspersed, edge and unburned patches within the burn perimeter. While results are preliminary (most of these burns are <3 years old) it does not appear that sagebrush re-establishment is occurring at a rate greater than in the hot season burns. However, it is probable that the high percentage of edge and unburned islands in the cool-season burns will increase sagebrush seed abundance and re-population of the burned areas.

Mechanical impacts on grouse winter range

It seems that mechanical damage (resulting from large animal impacts, wheeled vehicles, disks, chains, aerators, etc.) tends to kill larger, older, woody plants while “releasing” smaller, younger more flexible plants to produce vigorous growth. This type of brush manipulation is most preferred by sage grouse managers (Connelly et al. 2000). DLL has experimentally used disking, chaining and pasture aerators to mechanically thin sagebrush stands. There appear to be several advantages of mechanical treatments vs. burning. Mechanical treatment allows managers to thin or remove specific brush patches and still graze the pasture in the treatment year (unless seed is introduced during the treatment). Mechanical treatments can be designed to disturb soil (creating a seedbed) allowing seed to be added during the process. Finally, shrub vigor (foliage, twig and flower production) increases on the surviving sagebrush plants. Initial observations suggest light-moderate mechanical damage to sagebrush plants can stimulate vegetative growth. In Wyoming sagebrush traditionally exhibiting poor recruitment following fire, mechanical treatment methods may provide a reliable means of periodically reducing shrub cover and stand age, while allowing brush to remain and repopulate. This type of sagebrush stand management should be thoroughly explored and documented.

Summer Ecology

Distance traveled by hens from leks to nests

Table 5 summarizes distance traveled by 17 hens from the lek where captured to nest sites. 82% of these hens nested within 4 km (2.5 miles) of the capture lek. The mean distance traveled between the capture lek and the nest site was 2.8 km (1.7 miles) (range = 0.5-8.0 km). The mean distance between South Rich study leks is 3.1 km (1.9 miles) (range = 2.1-4.8 km). Of five hens monitored for two or more years each, the average distance between subsequent nests was 0.5 km (range 0.1-13 km).

Table 5. Distance traveled by 17 sage grouse hens from lek to nest site, South Rich study.

	Distance moved (km)							
	0-0.9	0.9-1.7	1.7-2.5	2.5-3.3	3.3-4.1	4.1-4.9	4.9-5.7	>5.7
# hens	2	6	4	1	1	0	0	3
accrued percent	11.8	47.1	70.6	76.5	82.4			100.0

Movement to summer use areas

Radio-marked hens generally remained within five km of nesting areas throughout the summer. We did not observe long (>5 km) movements of radioed hens with broods from nesting to brood-rearing areas as reported in other studies (Connelly et al. 2000), however our sample size was small. Radioed males generally moved upward in elevation after leaving leks, five marked males moved 3-13 km to summer areas (mean 8.3 km).

Summer habitat use

DLL biologists recorded 844 observations (4501 grouse) of summer (1 April-31 October) habitat use by sage grouse, 1985-2001. Additional observations obtained by Hunnicutt (1992), Wilson (2000) and grouse seen at leks are not included in table 6. Flocks were recorded as males, hens, hens with broods, or mixed sex (most mixed flocks were hens and chicks observed Aug-Oct). Percent of observations are summarized by cover type, flock type and month in table 6. Cover types include sparse lowland sagebrush (<15% brush cover), dense lowland sagebrush (\geq 15% brush cover), mountain big sagebrush (higher elevation and generally >15% brush cc), meadow (native riparian and irrigated) and (post-1993) spring burns and plantings.

Table 6. Summer habitat use by sage grouse flocks, 1985-2001, South Rich study.

flock type	% use by flock type					(N)
	sparse sagebrush	dense sagebrush	mountain sagebrush	meadow	burns and plantings	
males	31.1	24.3	36.5	5.4	2.7	148
hens	16.4	46.5	24.3	10.7	2.1	140
broods	10.8	28.5	33.1	23.0	4.6	305
mixed	11.9	33.1	35.1	19.1	0.8	251
combined	15.6	32.1	32.9	16.7	2.7	844

month	% use by month					(N)
	sparse sagebrush	dense sagebrush	mountain sagebrush	meadow	burns and plantings	
APR-MAY	26.5	53.0	18.1	2.4	0.0	83
JUN	13.7	39.3	26.5	17.6	2.9	102
JUL	15.4	27.2	30.2	23.0	4.3	305
AUG	11.2	20.7	45.3	19.8	3.0	232
SEP-OCT	13.7	28.8	41.1	16.4	0.0	73

Male flocks were most commonly observed in sparse lowland and mountain sagebrush. Hens without broods were most commonly observed in dense lowland sagebrush. Broods were commonly observed in dense lowland, mountain sagebrush and meadows. Broods were the most commonly observed flocks in meadows and spring burns and plantings. Summer grouse, particularly broods, were often observed along sagebrush-meadow edge and along the edges of forb-rich burns, plantings and roadsides where forbs and cover occurred in close proximity. Grouse were most commonly observed on easterly aspects, least often on southerly aspects. 92% of observations were on <20% slopes. Use of topographic features differed somewhat by flock type, male flocks used ridges more than the other flock types, hen flocks used ridges, flat areas and draws equally, while broods used draws (meadows) more than the other flock types.

Use of sparse lowland sagebrush (particularly low elevation **S-CW** areas) was greatest Apr-May. Seventy-eight percent of grouse observations in low-elevation **S-CW** areas Jun-Oct were in irrigated pastures and adjacent sagebrush. Use of dense lowland sagebrush types was greatest in early summer (Apr-Jun). Use of meadows and mountain sagebrush increased Jul-Aug, as vegetation in drier lowland sagebrush cured. Grouse use of meadows differed between years, and was correlated with Apr-Sep precipitation ($r^2=0.56$, figure 9). Grouse flocks (including broods) were most commonly observed in sagebrush habitats during wetter summers. During drier summers, grouse flocks (particularly broods) concentrated in riparian areas, on north slopes and at higher elevations. Several grouse flocks were observed using aspen patches in mountain big sagebrush stands in late summer of the driest years. In 1986, a wet summer, grouse used **S-CW**, **NS** and **MDW** types proportional to availability (figure 9). In the dry summer of 1988, however, grouse used **S-CW** less than and **MDW** greater than available. In wet summers nearly the entire study area appeared to be summer grouse habitat (useable space), whereas in dry summers grouse concentrated their activities in the more mesic portions of the study area (meadows and mountain sagebrush). Several mid-elevation and mountain burns and plantings (particularly those with deep-rooted dryland alfalfa) were used by grouse in both dry and wet years (Wilson 2000). Management of vegetation to increase the availability and distribution of succulent forbs in dry summers should benefit grouse, by reducing the need for grouse to migrate and concentrate. Strutting ground counts on the study area suggest the grouse population tended to increase following wet summers (1986, 1993, 1995, 1998) and failed to increase following dry summers (1988, 1985, 1992, 1994) (figure 6).

Nest habitat

Table 7 summarizes the shrub cover values at 36 sage grouse nest sites on the study area. All 36 nests were found on upland flat areas or ridges, none occurred in draw bottoms.

Table 7. Percent shrub cover at 36 sage grouse nests, South Rich study.

	percent shrub cover						
	0-10%	11-15%	16-20%	21-25%	26-30%	31-35%	>35%
# nests	4	2	9	7	8	5	1
% nests	11.1	5.6	25.0	19.4	22.2	13.9	2.8

Nest sites were usually situated in patches of dense shrub and moderate herbaceous (forb/grass) cover. Eighty percent of nests occurred in 20-35% shrub cover and 86% occurred in herbaceous cover <20%. Nests were generally placed under Wyoming sagebrush. Seventy-eight percent of nests were found under shrubs > 63 cm (25 in) tall, 90% were under shrubs >50 cm (20 in) tall (range = 38-90 cm, n=20 nests). Eleven of the 36 nests occurred in low elevation sagebrush-crested wheatgrass (S-CW) habitats. Six of eleven hens nested under sagebrush shrubs within stands of Wyoming big sagebrush having 15-30% shrub cover. Three nested in sparse sagebrush stands (< 15% shrub cover). One of these three nested under a greasewood shrub. One hen nested under a broom snakeweed (*Xanthocephalum sarothrae*) shrub and the eleventh hen nested under the leaves of a great-basin wildrye grass. All nest sites located under plants other than sagebrush were within 50 m of Wyoming big sagebrush stands.

Twenty-one hens nested in old-growth Wyoming big sagebrush stands over a native herbaceous understory (NS). Shrub cover was generally > 25% (range 22-40%). Eighteen hens nested under Wyoming big sagebrush shrubs, two nested under bitterbrush shrubs, and one nested under a big rabbitbrush shrub (*C. nauseosus*). Four hens nested within mountain big sagebrush (MS) stands over a dense herbaceous understory (>15% cover). All four hens nested under mountain big sagebrush, one nest was also overhung by a serviceberry bush.

All but three of 36 nests occurred in shrub patches > 100m in diameter. At least eight nests were within 100 m of a road edge or grassy opening. Using GIS methods to compare use relative to availability, Hunnicutt (1992) determined that hen sage grouse in Rich County selected rather monotypic stands of sagebrush for nesting. Seventeen nesting hens selected shrub stands having > 17% shrub cover and < 8 % herbaceous cover within a 50 m radius. Patterson (1952) in Wyoming, similarly described hens nesting in short (14 in. tall) medium-dense sagebrush on drier sites, rather than taller sage in moist draws.

Summer habitat selection vs. availability

Hunnicutt (1992) used GIS technology to develop rangeland cover classes and determine habitat selected by sage grouse during the nesting and brood-rearing seasons in South Rich and Morgan counties. She analyzed early (April-June) and late (July-September) season habitat use by male flocks, hens without broods, nests, and broods. Range and riparian sites were classified into one of six categories, based on percent shrub and herbaceous cover (table 8).

Table 8. Rangeland cover classes, South Rich study (from Hunnicutt 1992).

rangeland cover class	% shrub cover	% forb/grass cover
SS-sparse shrub, sparse forb/grass	<17	<8
SM-sparse shrub, medium forb/grass	<17	8 to 20
SD-sparse shrub, dense forb/grass	<17	>20
DS-dense shrub, sparse forb/grass	>17	<8
DM-dense shrub, medium forb/grass	>17	8 to 20
DD-dense shrub, dense forb/grass	>17	>20

Cover classes were determined at locations of 74 male flocks, 176 hens without broods, 17 nests, and 110 broods. The cover class is the predominant cover in a 90 x 90 m area (9-30 x 30 m pixels) centered on the pixel containing the grouse location. The cover class as determined at each observation site was then compared to the cover classes available in all other pixels in a one-mile radius (to determine use vs. availability). Results are presented in table 9.

Table 9. Rangeland cover classes selected by sage grouse broods, hens, males and nests, 1986-87, in early and late summer, South Rich study (from Hunnicutt 1992).

cover class	early		summer (APR-JUN)		late	summer (JUL-SEP)	
	broods	hens	males	nests		broods	hens
SS	ns	ns	avoided	ns	ns	avoided	avoided
SM	ns	avoided	ns	avoided	selected	ns	selected
SD	avoided	avoided	avoided	avoided	selected	selected	selected
DS	ns	selected	selected	selected	avoided	avoided	avoided
DM	selected	avoided	ns	ns	ns	avoided	ns
DD	ns	avoided	ns	ns	ns	ns	ns

ns = not selected or avoided. selected or avoided at $p < 0.05$.

This analysis suggested DS was selected by males, hens and for nesting in early summer. Hens preferred 20-40% shrub cover, while males and nests were generally found in 30-40% shrub cover (Hunnicutt 1992). Hens selected mature, monotypic stands of sagebrush at least 90 m in diameter for nesting. Hens with young broods also preferred dense shrub, but greater herbaceous cover. In late summer males, hens and hens with broods selected meadows having sparse shrub cover with high herbaceous cover (SM and SD types).

Next, Hunnicutt compared the degree of cover class diversity between the nine 30 x 30 meter pixels at each observation site. The goal was determining whether grouse choose areas with a high or low degree of cover class diversity during early or late summer. These data are summarized in table 10.

Table 10. Early and late season selection of habitat diversity by sage grouse broods, hens, males and nests, 1986-87, South Rich study (from Hunnicutt 1992).

diversity value	early season				diversity value	late season		
	broods	hens	males	nests		broods	hens	males
1	avoided	selected	ns	selected	1	avoided	ns	avoided
2	ns	avoided	ns	avoided	2	ns	avoided	ns
3	ns	ns	ns	ns	3	selected	ns	selected
4	selected	ns	ns	ns	4	selected	ns	ns
5	avoided	ns	ns	avoided	5	ns	ns	ns

diversity value = # of cover classes within a 3 x 3 pixel window centered on grouse location

The habitat diversity value is simply a count of the number of different cover classes within the 3 x 3 pixel window (nine 30 x 30 meter pixels) centered on the grouse location. So a value of one suggests a monotypic stand, i.e. all nine pixels were the same cover class. Conversely, a value of five suggests a diverse area, there are at least five different cover classes in the 9-pixel area. Combining the information in tables 9 and 10 allows us to determine both cover class selection and habitat diversity in the area surrounding the grouse location.

While hens selected monotypic dense sagebrush stands for nesting in early summer (diversity value=1), early broods were found in areas having higher diversity (diversity value=4, areas having dense brush interspersed or adjacent to grassy openings and meadows). Broods continued to select high diversity sites in late summer as well, but in sparser shrub cover.

In summary, Rich county sage grouse selected mature, dense sagebrush stands for both winter and nesting habitat. Hens with young broods selected areas with dense sagebrush interspersed with sparse sagebrush and denser herbaceous cover, which provided opportunities for hens with young broods to obtain both hiding cover (shrubs) and food (insects and forbs) in close proximity (figure 10).

Nesting success

Seventeen clutches of eggs at nest sites were counted. Mean clutch size was 7.3 eggs/clutch (range 6-9 eggs/clutch). Success of 36 nesting hens is summarized in table 11. Six of 24 radio-marked hens (25%) and 5 of 12 unmarked hens (41.7%) appeared to successfully hatch clutches. Twenty-two nests appeared predated, evidence suggested mammalian predators. Nest predation of radioed hens occurred between 5 May and 7 June, generally after May 15th. Three radio-marked hens abandoned nests. One hen abandoned due to human disturbance, one after cattle were herded through the brush stand containing the nest and the third after sheep bedded at the nest site. Combined nesting success of all 36 hens was 30.6%. Bergerud and Gratson (1988) believed average nesting success for sage grouse to be about 35%. We observed greater nesting success in (NS) habitats (33%) than in S-CW habitats (25%).

Table 11. Nesting success of 36 sage grouse hens, South Rich study.

	hens nesting	nests predated	nests abandoned	nests hatched
radioed hens	24	15 62.5%	3 12.5%	6 25.0%
unmarked hens	12	7 58.3%	0	5 41.7%
combined	36	22 61.1%	3 8.3%	11 30.6%

Production estimates

Mean annual brood sizes (Jun-Aug) and chick: hen ratios are presented in figure 11. Juvenile: hen ratios did not vary significantly between **NS**, **SSG** and **MS**. J:H ratios in **S-CW** were only half the production ratio seen in other habitats (1.20 vs. 2.55, figure 11). Mean annual brood size and annual juvenile: hen ratios were positively correlated (figure 12). Mean brood size was weakly positively correlated with following year lek attendance by males (i.e. correlated with population change, figure 12). Mean brood sizes increased post 1993 (4.69 vs. 3.38) when we actively began increasing upland forb availability on 5% of DLL summer grouse habitat by spring burning, chemical and mechanical brush thinning, and planting of desirable forbs.

Predation of artificial sage grouse nests

We tested the apparent lower nest survival in **S-CW** (25%) than **NS** (33%) habitats by examining differential predation rates on artificial nests (Ritchie et al. 1994). In May of 1991 (the grouse nesting season) we placed 120 artificial nests, consisting of three brown chicken eggs each, along 12 randomly selected transects radiating from three established sage grouse leks on DLL. Six transects were placed in **S-CW** habitats and six in **NS** habitats. Artificial nests were examined after 15 days. We measured vegetation characteristics at nest sites (percent shrub and herbaceous cover, shrub height and horizontal visibility) and indexed abundance of lagomorphs, small mammals and badger diggings (Ritchie et al. 1991). We hypothesized that predation rates would be greater on nests placed in the sparser, younger shrub cover in the **S-CW** types than in the older, denser **NS** shrub types, perhaps explaining the observed differences in juvenile: hen ratios of unmarked grouse between the two habitats (figure 11). In fact, the results were the opposite. Predation rates varied by moisture, vegetation type and lek. Only 16.7% of nests were predated in the **S-CW** type, while 55% of nests in the **NS** type were predated. Nest predation rates differed significantly between leks, ranging from 66.7% at the moister, **NS** dominated North Dip lek to 6.7% at the drier, **S-CW** dominated Neponset lek.

Differences in nest predation rates were correlated with vegetative characteristics of the nest transects. Our analysis suggested predation rates increased with shrub height, herbaceous and horizontal cover, but not with shrub cover. We counted greater numbers of lagomorph pellets (particularly jackrabbit) and badger diggings in the taller, denser **NS** types than in the shorter, sparser **S-CW** types. Small mammals (particularly deer mice - *Peromyscus maniculatus*) were more abundant in **S-CW** types. We identified likely predators at 43 of 57 predated nests, 37 appeared to be mammalian predators and six appeared to be avian.

Nest predation rates were greatest where badgers and jackrabbits were most abundant. We suspect that **NS** habitats having greater horizontal and herbaceous cover supported greater densities of mammalian nest predators, thus greater nest predation rates. Patterson (1952) similarly noted increased mammalian predation rates in taller, denser sagebrush. Had we experienced greater densities of visually hunting avian predators (i.e. ravens or magpies) the results may have differed (Autenrieth 1981).

The highest predation rates of artificial nests occurred in moist cover, forb and insect-rich sagebrush draws. These areas were frequented by potential nest predators, and were avoided by nesting sage grouse in this study. Predation rates on artificial nests suggest the observed differences in brood production in **S-CW** and **NS** were not due to differential nesting success.

Estimates of arthropod abundance by vegetation type

In June of 1992 and 1993, we sampled arthropod biomass using pitfall traps randomly placed in **S-CW**, **NS**, **BS** and **MDW** (three sites per habitat type). In the dry summer of 1992, arthropod biomass was significantly greater in **MDW** than other types, and significantly greater in **NS** and **BS** than in **S-CW** types (T-test, $p=0.05$). In the wet summer of 1993, however, arthropod biomass did not differ significantly between the four habitats (P. Hogle and L. Prudden unpublished undergraduate research data).

From 1995-2000 we estimated arthropod biomass in **S-CW**, **NS**, **SSG**, **MDW**, **BRN** and **RSD** habitats on DLL. In 2001 we added additional **RSD**, tebuthiuron (**CBT**-chemically brush-thinned) and sampling sites treated with a Lawson aerator (**MBT**-mechanically brush-thinned). All treatments occurred two or more years prior to sampling. We sampled three sites per vegetation type, during the first week of June each year (the first week of June is the peak of hatching for Rich county sage grouse). Arthropods were collected with an insect vacuum (the “bug-sucker”) at random spots at each sampling site. Specimens were dried, sorted by order and weighed. Specimens included spiders (arachnids) and the following insect orders: diptera (flies), coleoptera (beetles), hymenoptera (mainly ants), collembola (springtails), lepidoptera (moths), hemiptera (true bugs) and orthoptera (grasshoppers). Large arthropods (by weight) included grasshoppers, spiders and beetles; mid-sized insects included true bugs, moths and ants; small insects included springtails and flies. During 1998 and 1999, Aoude (2001) also sampled arthropod biomass in **BRN**, **RSD** and **CBT** (treated areas) and **NS** (control areas) on DLL using sweep nets.

Figure 13 presents average arthropod biomass by vegetation type, and annual variation in biomass observed 1995-2000 (using the “bug-sucker”). Arthropod biomass was generally greater in habitats having greater herbaceous plant cover (figure 13). Greatest arthropod abundance occurred in native meadow (**MDW**) and native grassland (**SSG**) habitats. These two habitats averaged greater herbaceous cover than **NS** or **S-CW** habitats. Lowest arthropod abundance occurred in dense Wyoming sagebrush (**NS**), which had the lowest herbaceous cover of all habitats sampled. **BRN** and **S-CW** areas had greater arthropod abundance than either **RSD** or **NS** sites. The range seeding data seemed oddly arthropod poor, given the high production and diversity of herbaceous plants in most DLL range seedings. Aoude (2001) found greater insect abundance in **RSD** than in **BRN** or **CBT** treatments. The **RSD** sites sampled 1995-2000 (the Five-Springs **RSD**) were forb-poor and dominated by crested and tall wheatgrass (*Agropyron elongatum*). In 2001, we sampled three additional forb-rich plantings; three **CBT** and three **MBT** treated sagebrush sites. The 2001 data suggested arthropod biomass in plantings, and brush-thinned areas were comparable to levels present in burns, and greater than in **S-CW** or **NS** habitats. Monitoring of arthropod abundance in **RSD**, **BRN**, **CBT**, **MBT**, **NS** and **SC-W** should continue for three more years.

Abundance of both large and mid-sized arthropods was greater in areas with abundant herbaceous and least in dense **NS** stands (lacking herbaceous cover). Similarly, arthropod biomass was greater in the more plant-species rich **BRN**, mechanically and chemically thinned sagebrush, and **RSD** areas sampled in 2001 than in the species-poor **S-CW** habitats. Aoude (2001) found **RSD** and **CBT** treatments increased plant species richness relative to controls, while spring and fall burns did not. Among treatments, Aoude (2001) also found greatest insect biomass in **RSD**, but greater insect species richness (number of species) in **BRN** than in **RSD** or **CBT** treated sites.

We noted significant between year variation in arthropod abundance (figure 13). Arthropod abundance was not correlated with precipitation. While 1997 was a wet year with high arthropod abundance, 1998 was also a wet year with low arthropod abundance. Mean brood size was poorly correlated with arthropod abundance, however small mean brood sizes occurred during years of least arthropod abundance.

Taken collectively, it appears a combination of burning, tebuthiron and forb-rich plantings can increase diversity and abundance of herbaceous plants and arthropods, potentially enhancing chick nutrition and survival (Drut et al. 1994). However, the observed differences in arthropod abundance do not appear to fully explain the significant difference in juvenile: hen ratios observed between **S-CW** and **NS** habitats on DLL.

Foraging ecology of grouse chicks in relation to vegetation types

During June of 1993 (a wet year) and June-July of 1994 (a dry year), Billaux (1996) measured foraging rates of hand-reared sage grouse chicks in four habitat types: **S-CW**, **NS**, **BRN** and alfalfa plantings (**RSD**). Available plant biomass and plant species eaten were estimated at each feeding trial site. In both June and July, foraging rates of chicks, forb biomass and the proportion of forbs in the diet were consistently higher in planted alfalfa patches, followed by burns, native Wyoming sage (**NS**) and finally **S-CW** habitats. Foraging rates were positively correlated with forb biomass across all sites and habitat types (Billaux 1996). The relationship between forb availability and chick foraging rates in the dry summer (July) of 1994 are presented in figure 14.

In both 1993 and 1994, forb biomass was ten times greater in **NS** than in **S-CW** habitats. In July of 1994, green forb biomass in **S-CW** virtually disappeared. In 1994, June foraging rates were 64% greater and July rates were 52% greater in **NS** than in **S-CW**. Foraging rates were greater in **BRN** than in **NS**, but only significantly so in July of 1994. Foraging rates were significantly correlated with forb biomass across all sites and habitat types in both months ($r = 0.82$, June and $r = 0.84$, July).

Forbs made up 76% of chick diets in **NS** and 36% in **S-CW** in June of 1994. In July 1994, forbs made up 24% of chick diets in **NS** and 2% in **S-CW**. Dominant forbs-eaten in **NS** habitats included three species of milkvetch (*Astragalus* spp.), bird's beak (*Cordylanthus ramosus*), and long-leafed phlox (*Phlox longifolia*). Forbs eaten in **S-CW** included clover (*Trifolium* spp.), long-leafed phlox and buckwheat (*Eriogonum* spp.). Shrubs dominated the diet in **S-CW** habitats. Shrubs eaten in both habitats included low rabbitbrush, sagebrush and horsebrush. Chicks actually preferred low rabbitbrush to some forb species.

In burns, forbs made up 81% of chick diets in June and 40% in July. The main species eaten included milkvetch, bird's beak, Douglas knotweed (*Polygonum douglasii*), long-leafed phlox, and the introduced species sainfoin (*Onobrychis viciifolia*) and small burnett (*Sanguisorba minor*). In the alfalfa patches, chicks ate primarily alfalfa (>95%) and dandelions.

Chicks were highly selective for forbs, avoided grasses and always ate some shrubs. Chicks actually selected and consumed some shrubs on burns, where shrubs were scarce. Foraging rates increased with time. Foraging rates doubled in July from June, across all habitats. It appeared older, more experienced chicks foraged at greater rates.

The second part of the study examined the functional response of chicks to multiple food types (Billiaux 1994). In May and early June, chicks and various densities of ants were introduced into small enclosures in **S-CW** and **NS** habitats. Chicks preferred ants to forbs; chick foraging rates on ants were dependent only on ant density (i.e. regardless of forb density). Ants were easily spotted and captured in both habitats, regardless of cover and structure. In a similar experiment, chicks were introduced into enclosures having varying densities of forbs, shrubs and grasses. Chicks selected forbs over shrubs or grass. Foraging rates on forbs were dependent only on forb density. Foraging rates on shrubs increased as time in the field increased, chicks apparently learned to forage on shrubs with experience.

Results of this study suggest young, inexperienced chicks in forb-poor habitat may have to forage over large areas, increasing their risk of predation (Potts 1986). (Billiaux reported chicks foraging in **S-CW** habitats during the dry July period in 1994 searched so far, so fast they were difficult to keep up with). Chicks in forb-poor habitats will eventually consume higher percentages of lower quality shrubs, in lieu of nutritious forbs. Lower foraging rates and lower quality forage negatively influence laying hen nutrition, chick growth and survival (Johnson and Boyce 1990, Barnett and Crawford 1994, Drut et al. 1994). Heavy, early-chick mortality should occur frequently in habitats virtually lacking insects and forbs. We believe the low chick: hen ratios observed in **S-CW** habitat reflect the poor availability of forbs. We suspect many hens avoid **S-CW** habitats for nesting and brood rearing. Those that try to use **S-CW** habitats likely lose chicks at a greater rate than in other habitats, due to malnutrition and increased predation while foraging.

Effects of precipitation on herbaceous forage nutrient quality

Herbaceous forage samples were collected and analyzed for available moisture, dry matter protein and total digestible nutrients (TDN) at 12 sampling sites in mid-July 1993 and 1994 (table 12). Moisture, crude protein, and TDN were all significantly greater in the cooler, wetter summer of 1993 (t-test, p=0.000).

Table 12. Available moisture, dry matter protein and total digestible nutrients (TDN) from herbaceous forage samples collected at 12 sample sites, mid-July 1993 and 1994, DLL.

Year	Precipitation (cm)	Temperature (°C)	Percent Moisture	% Crude Protein	Percent TDN
1993	17.6	10.4	54.5	11.1	68.7
1994	7.7	12.9	38.6	5.3	60.0

Phenology and availability of herbaceous plants

Height and phenological stage of development of growing herbaceous plant species were monitored during breeding and nesting near leks and nesting areas. Herbaceous growth began in early March in snow-free areas, steadily increasing in height through May (table 13). Commencement, amount and rate of plant growth varied with temperature and soil moisture between years. The range of plant heights presented in table 12 reflects differences in temperature and moisture, topography, plant species, and shrub density.

Table 13. Green herbaceous plant height, by month, DLL, south Rich County UT.

	Date					
	March		April		May	
	1-15	16-31	1-15	16-30	1-15	16-31
mean height (cm)	1.9	4.3	6.1	9.4	11.2	12.7
range (cm)	1.3-2.6	1.3-6.4	1.3-7.6	5.1-11.4	5.1-17.8	5.1-25.4

Residual herbaceous cover (prior year’s growth) was generally greatest in areas with sparse brush and areas rested from grazing after about May 1 of the prior year (allowing an opportunity for plant re-growth). In upland sagebrush areas having <15% shrub cover, residual bunchgrasses were generally robust in growth form, providing horizontal cover for nesting. In sagebrush habitats of >20% shrub cover (i.e., habitats selected by nesting hens in this study) however, bunchgrasses were generally smaller and finer leaved. These less robust plants tended to be flattened by winter snow; thus did not supply much horizontal cover. This contrasting grass morphology was quite apparent when comparing spring burns, **RSD**, **CBT** and **MBT** treatments (where brush had been recently killed) with untreated controls. These characteristically shorter, finer-leaved grasses also occurred within the **NS** livestock grazing exclosures on DLL (areas rested from grazing for ten years).

Several species of native and introduced forbs were observed green and growing in February on steeper south slopes in low and mid elevation pastures. Green vegetative forb growth began appearing on flatter areas in early March. The first green forbs to appear included small annuals (such as bur buttercup), and the perennial forb genera *Lomatium*, *Allium*, *Phlox* and *Euphorbia*. The first forb to flower each year was a biscuitroot (*Lomatium dissectum*), flowering in early April, about the time of peak hen attendance on leks. The introduced forbs alfalfa, small burnett and sainfoin appeared to green-up earlier than most native forb species, significantly increasing the amount of green, broad-leaved forb growth in early April. The phenology and richness of forb genera in low and mid elevation pastures are presented in table 14. These genera are primarily (>90%) perennial forb species.

Table 14. Forb phenology and richness relative to sage grouse reproductive chronology, DLL, south Rich County UT.

	Date						
	March		April		May		June
	1-15	16-31	1-15	16-30	1-15	16-31	1-30
# forb genera growing	<5	5-8	10-15	15-20	15-25	15-25	15-25
# forb genera flowering	0	0	1	5-10	12-18	18-22	15-20
grouse nesting chronology	pre- nest		egg- laying		incub ation		early brood

Forb vegetative growth and flowers were most abundant during nest incubation and early brood-rearing. Forbs were much less abundant pre-nesting and during early egg-laying. Forb availability in July and August in low and mid elevation range sites varied with summer

weather. In cooler, wetter summers, green vegetative and even flowering forbs could be found on the range. In hotter, drier summers, forbs had already gone to seed or desiccated on range sites by mid-July, therefore green forbs were only found in meadows, at higher elevations, and on a few **RSD** areas.

Estimates of forb availability in **S-CW**, **NS**, **SSG**, **BRN**, **RSD**, and **MDW** were collected from three or more sites per habitat type in June of 1998 and in Aug-Sep of 1996. Results are summarized in table 15. **S-CW** had significantly lower forb availability than all other habitats (t-test, p=0.05). **BRN** and **RSD** had higher forb cover than **NS** or **SSG**, but not significantly so. **MDW** had significantly higher forb availability than any other habitat in Aug-Sep.

Table 15. Percent forb cover by habitat type, June 1998 and Aug-Sep 1996, DLL, south Rich County, UT.

habitat type	S-CW	NS	SSG	BRN	RSD	MDW
% forb cover Jun	4.7	16.3	26.5	22.3	17.2	25.5
% forb cover Aug-Sep	3.4	10.1	11.2	14.2	14.8	33.0

Perennial forbs were particularly lacking in **S-CW** habitats, > 50% of forbs in **S-CW** were annuals. During a few years of above average precipitation, we observed “blooms” of *Cordylanthus* and other palatable annual forbs. Chick: hen ratios in **S-CW** habitats increased with wet-summer annual forb blooms, and were similar to chick: hen ratios in other habitats.

If sage grouse production and recruitment are limited by a scarcity of forbs in **S-CW** habitats (and perhaps other forb-poor areas); then adding forbs to these areas should increase grouse use, increase brood size and chick: hen ratios and perhaps increase grouse attendance at nearby leks. In 1993 we began adding forb plantings in **S-CW** habitats, as well as implementing controlled burns, plantings and brush-thinning treatments in dense **NS** and **MS** habitats. Our intent was to proceed with an adaptive management strategy, adding forbs in areas where lacking, and monitoring abundance and habitat use by grouse. These projects were intended to benefit multiple wildlife species, as well as cattle, by increasing both structural and plant species diversity. Goals included increasing herbaceous forage for summer-cattle and winter-elk grazing (in brush dominated areas), increasing brush species diversity and height in key pronghorn, deer and sage grouse wintering areas, and increasing forb abundance (particularly deep-rooted forbs such as alfalfa) ranch-wide to increase summer nutrition in dry years.

Use of sagebrush treatments by sage grouse

Wilson (2000) documented sage grouse use of treated areas and controls Jun-Sep, 1996-1999. Using horses and pointing dogs, he monitored five **RSD** areas (and untreated controls) in **NS** habitats, one spring and two fall burns (and untreated controls), one set of forb strips disk/seeded into **S-CW** habitat (he compared grouse use before and after treatment) and three **SSG** areas on DLL. The untreated **SSG** habitats were monitored to document grouse density and use in this relatively forb-rich but shrub-poor native habitat, and to observe changes in grouse use as cattle grazed (removed herbaceous cover). An additional study area of **NS** habitat was monitored off-ranch, on BLM managed range to compare DLL’s time-controlled grazing

management with more traditional season-long grazing management. Wilson sampled each study site several times each summer, during morning and evening peaks of grouse activity. Flush locations, distance to sagebrush patches or distance to treatment, number of birds in flock, age and sex of flock members, and dominant plant species at flush sites were recorded at each observation site. Data were used to evaluate grouse densities (grouse/hr) in the various habitats and describe use of treatments relative to their size and shape.

Wilson found that 80% of grouse flocks observed in treatments (**BRN** and **RSD**) were within 60 meters of sagebrush (either sagebrush “islands” or the treatment edge) and 50% were within 30 m of the edge (figure 15). Similarly, 75% of grouse flocks flushed in sagebrush stands surrounding treatments were within 30 m of treatment edge (figure 15). Grouse used sagebrush adjacent to treatments for loafing midday. Alfalfa was the most consistently occurring plant species at observation sites; grouse selected alfalfa when present in the **RSD** areas. **RSD** areas used by grouse had a good broad-leafed forb component (>15%) and only moderate densities of tall forage grasses. Forb-poor plantings, and plantings which were too densely packed with tall grasses, were infrequently used by grouse. Wilson postulated that high densities of tall bunchgrasses interfered with movement and detection of predators by grouse. He recommended treatments dominated by tall forage grasses be grazed down periodically to promote forb abundance and allow access by grouse. In large diameter plantings (>300 m wide) Wilson recommended leaving sagebrush islands within the planting to promote grouse use. He further recommended planting a grass-poor seed mix dominated by alfalfa (both taprooted and rhizomatous varieties), and other broad-leafed forbs in a band 30m wide along the edge of plantings and adjacent to sagebrush islands. Forb abundance would then be highest where observed grouse use was greatest.

Wilson (2000) found significantly greater grouse densities at treatments than at untreated control study sites (figure 16 a). Figure 16 (b) compares observed brood sizes and juvenile: adult grouse ratios between **BRN**, **RSD**, **NS**, **SSG**, and **S-CW** habitats on DLL, and **NS** on BLM lands in North Rich county 1996-1999. Juvenile: adult ratios were significantly greater on **BRN** and **RSD** than other areas, indicating the preference of hens with broods for these habitats. Highest brood sizes were observed in **BRN**, **RSD** and **NS** habitats. Lowest brood sizes and juvenile: adult ratios were observed on BLM managed **NS** types, even lower than in DLL managed **S-CW** habitats.

Figure 16 (c) depicts changes in summer grouse density, 1996-1999 in a mid-elevation **S-CW** study site (adjacent to an active lek) in which forb strips (5 m wide) were added in April of 1997. No grouse were observed in 1996, prior to the treatment. One adult male and two adult females were observed using the strips in 1997 and 1998, feeding on the native annuals and newly sprouted perennial forbs on the strips. By 1999 both annual and perennial forbs were abundant on the strips, and several hens with broods were observed feeding along the strips.

Wilson (2000) and two independent consultants (Jack Connelly and Clait Braun pers. comm.) urged caution in the size and placement of burns and plantings to “enhance” sage grouse habitat. We believe this to be sound advice. Our own observations suggest too many large-scale reductions in sagebrush canopy cover and height in important winter, nesting and early brood-rearing areas could well reduce survival and production of sage grouse and other avian sagebrush obligate species. However we have also seen that the addition of alfalfa and other deep-rooted broad-leafed forbs can increase the amount of useable landscape to grouse during

droughts, reducing their need to concentrate in riparian habitats. Increased forb abundance is also associated with higher pronghorn fawn production (Danvir 2000). Pronghorn does and fawns select these forb-rich **BRN** and **RSD** habitats in summer, and pronghorn carrying capacity has increased since treating 2630 ha (6500 acres) or 6% of DLL's pronghorn habitat (Aoude and Danvir 2002). Finally, the addition of tall forage grasses within mid-elevation ranges has increased forage for cattle and wintering elk, reducing our dependence on hay in the winter. Our approach has been to increase plant diversity throughout the ranch, i.e. maintain or increase brush in critical nesting and wintering areas where brush is lacking and create openings and herbaceous plants in heavily brush dominated areas. This requires knowing how and where grouse use the landscape throughout the year. Success or failure of these treatments must be evaluated by annual monitoring of lek location and attendance, and by monitoring summer abundance and location of grouse, particularly broods.

Effects of time-controlled grazing and wildlife herbivory on grouse habitat

Sagebrush rangelands on DLL have been managed for twenty years using time-controlled grazing practices. This means controlling both the length of time plants are exposed to grazing and the time of year or season of use (Savory 1988). This approach recognizes that plant health is the key to having well functioning watersheds. Ideally, the goal is to limit the length of the grazing period in a given pasture so that each herbaceous plant is bitten only one time. The pasture should then be rested long enough to allow those bitten plants to re-grow and produce seed. Livestock herds are large; several thousand cattle will graze a single 810 ha (2000-acre) pasture at once. This concentrates livestock, with >90% of the cattle grazing <10% of the ranch area at any given time. One aspect of high-density-short-duration grazing often overlooked by managers is that while the cattle herd is concentrated in and affecting a relative small area at any given time, the majority of the range is livestock free and rested from grazing. As a result of the higher stock density, a higher proportion of the herbaceous plants in a pasture are bitten, including less palatable plants, plants on steeper slopes, and plants more distant (>1km) from water sources. There is evidence that more palatable herbaceous plants (including broad-leaved forbs) can persist, even increase in dominance on arid lands by applying a combination of intermittent herbivory by large herds, interspersed with periods of rest and recovery (Augustine and McNaughton 1998).

During the past 20 years, low elevation **S-CW** pastures were generally grazed fall-spring, when herbaceous plants were dormant or growing at a slow rate. Less than 30% of these pastures were rested from grazing each year. These pastures are used by sage grouse as wintering and breeding (lek) habitats, and to a lesser extent for nesting and brood-rearing. Mid-elevation Wyoming **NS** pastures were generally grazed < 7 days, May-July, when herbaceous vegetation was rapidly growing. About 35% of these pastures were rested from grazing each year. These pastures are important to sage grouse year-round, especially as nesting and brood-rearing habitats. The **SSG** pastures were generally grazed July-November, as herbaceous plants were completing seed production and growing slowly. Over 80% of these pastures were grazed annually. These areas are used by sage grouse for breeding, nesting and brood-rearing. **MS** pastures were generally grazed July-November, and are used by grouse for nesting and brood-rearing. Sixty percent of **MS** pastures were grazed annually.

Range monitoring studies conducted by NRCS personnel documented an increase in riparian cover and a six percent increase in rangeland herbaceous plant cover on DLL 1980-1986

(Wolfe et al. 1996). R. W. Allen (Ph.D. dissertation, 2002) also documented a 5-8% concurrent increase in shrub cover, 1970-1999. Since 1990, Ritchie and Wolfe (1994) and Ritchie (unpublished progress report, 1998) have been monitoring the effects of total rest, herbivory by wild herbivores only, and herbivory by both wild and domestic herbivores on DLL rangeland plant communities using a series of 90 x 90 meter exclosures in NS pastures. Pastures (including the grazed controls) are generally grazed in May or June. Biomass estimates are collected in July, **after** cattle have already grazed the pastures. Results thus far indicate grass production is dependent on moisture. Yearly grass production correlates positively with prior year (October –July) precipitation ($r^2=0.84$). Shrub production (primarily sagebrush) increased when cattle were excluded (figure 17). Conversely, herbaceous production in cattle grazed-controls generally equaled or exceeded herbaceous production where cattle were excluded (figure 17). Forb production and species richness was generally greater in grazed than excluded areas, and grass production was consistently highest when both rabbits and cattle were excluded (figure 18). Plant species diversity did not differ between cattle grazed and cattle excluded areas (Ritchie and Wolfe unpublished progress report 1998). These findings agree with past exclosure research, both old (Lang 1945) and new (Rambo and Faeth 1999), which suggest that grass production depends on precipitation, and long-term livestock grazing exclusion actually reduces plant species richness (by reducing forbs).

At high densities, white-tailed jackrabbits appeared to have a significant impact on both grass and forb availability. During a jackrabbit population peak in 1991, jackrabbits on DLL were consuming an estimated 25% of available herbaceous biomass in NS stands (Ritchie and Wolfe, unpublished data).

Cattle or bison generally grazed the three northernmost leks (Neponset, Dixon Hole and North Dip) in April (1985-2001), often during the peak of hen attendance. At least five other leks were often grazed in April. We observed no change in grouse attendance or behavior during or subsequent to the presence of cattle or bison. Of 24 radioed nesting hens monitored, none abandoned while cattle or bison grazed in the nest-pastures. One hen however abandoned her nest when a cattle herd was trailed (bunched and pushed) through the draw where her nest was located. She moved, and re-nested further south. Another hen abandoned her nest when a band of sheep bedded next to the nest-bush. She did not re-nest. Patterson (1952) noted frequent nest abandonment by hens in late April and early May due to sheep bedding near nests. As part of the artificial nest study (Ritchie et al. 1994), we placed one transect with 10 nests (30 eggs) in a sagebrush pasture having high cattle density (nearly two cow/calf pairs/acre). The purpose was to document egg damage from trampling. Cattle tracks averaged 6-9 hoof prints/ ft² in the spaces between shrubs. Of the 30 eggs, only one was stepped-on by cattle. Nest trampling does not appear to increase with time-controlled grazing (Guthery and Bingham 1996).

Wilson (2000) reported that summer grouse use of brush-poor, herbaceous dominated burns, seedings and native grasslands on DLL sometimes declined after herbaceous cover was removed by cattle. Grouse moved to adjacent pastures, and later returned if herbaceous cover resprouted. Morage (1998) observed small mammals (at DLL) using herbaceous burns less and brushy unburned areas more after grazing removed herbaceous cover. Wilson also reported that grouse use of recently seeded areas declined through the years as litter and standing biomass of ungrazed bunchgrasses increased. In this case, herbaceous cover appeared too dense, resulting in decreased brood use (even though alfalfa and other preferred perennial forbs remained abundant). He suggested that cattle grazing could be used to “open” the stand; i.e. reduce

standing dead herbaceous cover and increase preferred annual and other disturbance-caused forbs (such as birdsbeak, prickly lettuce (*Lactuca*), salsify (*Tragapogon*), dandelion and yellow sweetclover (*Melilotus officinalis*)).

In summary, we observed both positive and negative effects of livestock grazing on sage grouse. The most important impact on grouse habitat by grazing livestock was positive, decreased bare ground and increased herbaceous cover in riparian and range habitats after initiation of time-controlled grazing. Time controlled grazing may enhance the nutritional quality of the range for grouse, as many of the forb species preferred by grouse increase with disturbance. Less selective intermittent grazing by herded ungulates (cattle, bison and sheep) may help offset the impact of continuous, selective grazing by lagomorphs on preferred plant species. Time controlled grazing by large ungulates may be an effective, economical method to increase cycling of nitrogen and high cellulose, coarse grasses (such as often occur on CRP and other seeded areas) enhancing the nutritive value for grouse and native ungulates. Grazing can also reduce grouse use of shrub-poor late-summer herbaceous foraging areas temporarily, by removing tall bunchgrasses used as cover by grouse broods in **RSD** and **SSG** habitats. The greatest long-term negative effect of cattle grazing we observed was the mortality of adult birds resulting from fence-line collisions. Properly placed fences (relative to seasonal grouse activities) and increased top-wire visibility should reduce collision mortality.

Time-controlled grazing and breeding bird abundance and diversity

Breeding bird diversity and abundance have been monitored on DLL since 1995 using three North American Breeding Bird Survey (BBS) transects. Each of the three-25 mile long transects includes 50 sampling stops. Transects cover **MDW**, **S-CW**, **NS**, **SSG** and **MS** habitats on the ranch. Bird abundance and species richness have maintained or slightly increased 1995-2001 under time controlled grazing (table 16).

Table 16. Bird abundance and species richness on BBS transects, DLL, 1995-2001.

Year	transect		name		total species	total birds		
	Saleratus		Neponset					
	# species	# birds	# species	# birds				
1995	65	872	72	726	56	839	119	2437
1996	62	1098	71	701	73	1392	114	3191
1997	64	811	63	650	68	1144	123	2605
1998	69	835	60	651	69	1586	123	3072
1999	57	1074	64	616	70	1819	127	3509
2000	62	1149	69	839	75	1608	110	3596
2001	63	969	64	719	63	1335	124	3023

As was observed with grass production, breeding bird abundance is dependent on moisture. The number of birds counted annually on DLL-BBS transects is positively correlated with prior year (Apr-Sep) growing season precipitation ($r^2=0.69$, figure 19). The number of species observed annually varies less, and is poorly correlated with precipitation ($r^2=0.19$).

Impacts of fire on summer grouse habitat

Hot, summer wildfire burns in Wyoming **NS** habitats generally appeared to negatively effect grouse summer habitat. Aoude (2001) found these burns to have low herbaceous production and diversity. Wilson (2000) saw little use of these areas by grouse adults or young. Wildfire burns tended to burn relatively large areas (150-1500 ha) and remove all brush within the fire perimeter, leaving few sagebrush islands. While these **NS** areas will likely become useful to sage grouse eventually, sagebrush regeneration is slow. Sagebrush is actually repopulating **RSD** areas faster than hot summer burns. Burning out large areas of Wyoming sagebrush can significantly reduce resident grouse populations (Connelly et al. 2000). We saw mixed results in hot summer burns in **MS** habitats. One of two large (>150 ha) burns quickly (<10 years) repopulated with sagebrush and native forbs, and we have observed grouse using the burn. The other burn has good herbaceous growth, but little brush recruitment or grouse use.

Cool, spring burns, in contrast, appear to have positive value for sage grouse in **NS** and **MS** habitats. The cool burns are smaller in size, irregularly shaped and create sagebrush islands. Herbaceous growth is vigorous, arthropod abundance is good (Aoude 2001, this report) and grouse are using the areas well (Wilson 2000).

Impacts of plantings (RSD) on summer grouse habitat

We have planted forb strips in five low elevation **S-CW** pastures. Establishment has been generally good. While we have not seen dramatic increases in grouse abundance on strips, we have observed use by adults and chicks on four of the five. The size of treatments can influence treatment success, as small strips or plots attract and concentrate herbivory by native and domestic grazers.

Grouse commonly used forb-rich plantings in dense **NS** within 60 m of brush (Wilson 2000). Grouse use of these areas seems to depend on the shape, amount of brushy islands, forb abundance and grass height and density. Thus far, lek counts adjacent to these large plantings (> 200 acre) have maintained or increased. Five-200 acre blocks of **NS** habitat were disked and reseeded within 2.5 km of the North and South Dip leks in 1993, and 500 acres were reseeded within 2 km of the Lake Ridge lek in 1995. Lek counts have maintained or increased since the treatment (Appendix C). Multiple large blocks (> 200 acre) of important nesting/winter habitat were left interspersed with plantings and brush-thinned areas within the treated pastures. We recommend planting <35% of important winter, nesting and early brood-rearing **NS** pastures. Persistence of perennial forbs in these plantings is highly variable, forbs have remained abundant for many years in some areas and not in others. Small exclosures should be placed within plantings to monitor forb establishment and survival without herbivory. Further experimentation and monitoring is needed to better understand the effects of seed source, weather and herbivory on subsequent forb survival. Studies by Aoude (2001) and data collected on BBS (Breeding Bird Survey) transects on DLL (1995-2001) suggest bird abundance and species richness did not decline in **RSD** habitats. Sagebrush obligate avian species continue to use **RSD** areas where sagebrush islands were incorporated into the planting.

Effects of brush-thinning treatments

Mechanical brush-thinning (**MBT**) may be the most sage grouse-friendly method of opening up dense (>30% cover) brush stands to increase the amount of herbaceous forage and young sagebrush plants. Recall that 15-20% brush canopies were highly preferred sage grouse winter habitat (Homer et al. 1993), and (if herbaceous cover was also present) brood habitat (Hunnicuttt 1992). We now have several hundred acres of **NS** and **MS** habitats thinned with a Lawson pasture aerator. The technique allows the operator to sculpt the size and shape desired, while avoiding areas better left alone. Sagebrush twig, leaf and flower production increase dramatically in thinned areas. Seed can be added in the process, several species of broad-leafed forbs have been established in these treatments. While the treatment-year expense exceeds that of burning, **MBT** offers an economic advantage over burning by not requiring prior-year rest from grazing to build fuel, nor post-treatment rest (unless seeds are added). In much of the **MS** habitat treated, native herbaceous response was ample, and no seed was added. We have seen grouse use on both **NS** and **MS** brush-thinned sites. Preliminary surveys show significantly greater grouse winter pellet group counts on aerator-thinned strips in **NS** winter habitats than on adjacent controls.

In 2001, Scott Walker (UDWR) and Steve Kearl (DLL) began a study comparing various mechanical brush-thinning methods (disking, chaining, Dixie harrow, Lawson aerator) in a Wyoming **NS** pasture on DLL. Results of this M.S. thesis through Brigham Young University should be available by 2004.

Aoude (2001) noted increased forage production and plant species diversity on **CBT** (tebuthiuron) treated **NS** sites. In **CBT** treatments within **MS** habitats, both herbaceous plants and other shrub species (sevicheberry, bitterbrush, snowberry) have increased in abundance as sagebrush died. Although we have observed grouse using these treated areas we have not yet documented whether they attract broods as **BRN** and **RSD** areas do (Wilson 2000).

Effects of brush removal on abundance and diversity of other wildlife

Aoude (2001) found no difference in avian diversity between treatment types (**RSD**, **BRN**, **CBT**) or their respective controls. Similarly, we found no significant difference in richness and abundance of shrub and-ground nesting avian species between treated (**RSD**) and **NS** controls on DLL breeding bird surveys (figure 20). Brewer's sparrow (*Spizella breweri*) abundance, however declined more on treated (**RSD**) than on control areas (figure 20).

Moroge (1998) found highest small mammal diversity in burns with an interspersion of brushy cover and herbaceous seed-producing areas. Aoude (2001) found reduced small mammal species richness and diversity on fall burns. He found no significant change in richness or diversity on spring burns or **RSD**'s, and found increased richness and diversity on **CBT** plots.

Pronghorn on DLL generally avoided dense **NS** stands in summer (Danvir 2000), as has been reported elsewhere (Amstrup 1978, Yoakum 1980). However summer doe-fawn pronghorn groups on DLL selected brush-thinned (**RSD**, **BRN** and **CBT**) treatments in dense **NS** stands (Aoude and Danvir 2002). Summer mule deer abundance increased in two locations following **RSD** and **BRN** treatments in sagebrush-steppe. Elk quickly find and utilize the abundant forage in ungrazed treatments during winter.

Synthesis and management implications

The South Rich county sage grouse population seems to be driven largely by the interplay between weather and habitat. The population declined when deep-snow winters concentrated grouse in small patches of tall sagebrush, and failed to increase when dry summers reduced forb availability on sagebrush uplands, concentrating grouse in lowland riparian (MDW) and MS habitats. It appears that the extremes in weather drive the system, that the frequency of dry summers and deep snow winters limit the reproductive rate and survival of grouse. Management strategies that maintain or increase available sagebrush above snow in deep snow winters, or increase forb availability in droughts should reduce grouse mortality in poor weather years, maintaining larger populations to rebound in favorable weather years.

Adult sage grouse generally express fidelity in their seasonal use of landscapes (Connelly et al. 2000). Individuals tend to return to the same leks, nesting, brood-rearing and wintering areas year after year. If the annual pattern of use works one year (i.e. the predators weren't too bad, the hen survived, perhaps even raised a brood), then why not do it again? In order to survive inevitable weather extremes and environmental change, however grouse populations must also (to some degree) be able to modify their seasonal use patterns in response to events such as drought, deep snow, and fire. We see some evidence of this as well. We saw grouse find and exploit burns and plantings repeatedly (Wilson 2000). And new leks tend to pop up in years when yearling birds are abundant.

Depending on severity and scale, land management practices may help or hinder grouse. Can sagebrush-steppe be managed to simultaneously generate profit (in our case livestock grazing and wildlife recreation), yet maintain a rich, diverse community of plant and animal species? Our observations suggest these two goals are not mutually exclusive.

Wintering sage grouse in Rich County used a diversity of brush cover and height, depending on snow depth. Sage grouse survival and abundance in south Rich County seems to depend on the amount and distribution of tall brush (>56 cm), winter eagle abundance and the frequency with which the population experiences severe winter "climatic bottlenecks". The widespread disking and planting of crested wheatgrass in the past 40 years has reduced plant species diversity and sagebrush height in essential south Rich winter habitat. Competition from crested wheatgrass for growing season moisture, coupled with dormant season browsing, reduces sagebrush cover and height.

Sage grouse winter habitat (and sage grouse populations) in south Rich County may be conserved if the following strategies are implemented. Identify and maintain tall sagebrush patches within pastures currently used by grouse in deep snow winters. Beyond protecting essential areas, however we need to learn best management practices for thinning and rejuvenating decadent sagebrush. Experiment with various thinning techniques in some non-essential decadent stands. Preferred herbaceous plants can be economically inter-seeded during some mechanical thinning techniques. Learn to use time and timing of livestock grazing to influence interspecific plant competition, nutrient and water cycling to achieve desired range conditions. To increase herbaceous plants (in summer grouse habitats), either alternate rest with short growing-season grazing bouts, or graze in the dormant-season. To enhance shrub vigor (in winter habitats), use longer grazing periods (i.e. overgraze) during rapid grass-growth. Monitor the effects of winter browsing by jackrabbits and big game; reduce winter big game

and jackrabbit densities when necessary through big game hunting and predator management strategies that consider the effect of predators on the whole system.

In **S-CW** pastures where sagebrush is dying, disk and fallow (to reduce crested wheatgrass density and vigor), then seed with adapted sagebrush and a diverse herbaceous seed mix. Experimentally replant basin big sagebrush, basin wildrye (*Elymus cinereus*) and preferred forbs in deep-soiled draws to provide deep-snow winter habitat for grouse, pronghorn and mule deer, nesting habitat for other avian species and year-round cover for smaller mammals, such as mountain cottontails (*Sylvilagus nuttalli*) and pygmy rabbits (*Sylvilagus idahoensis*).

Conserving and rejuvenating key winter habitats in south Rich County will undoubtedly benefit multiple species, including sage grouse, lagomorphs, pronghorn, elk and mule deer that commonly use the same wintering areas. The strategies outlined above to maintain sage grouse through a deep snow winter will in particular benefit mule deer in tough winters, offering an opportunity to match grouse conservation and big game restoration funds.

Chick growth and survival depend on finding and exploiting forb and insect-rich food sources, without becoming “exploited” by predators in the process (Bergerud and Gratson 1988). The ideal situation seems to be one of small grassy openings and healthy, grassy riparian areas adjacent to or intermixed with sagebrush hiding and resting cover. If forbs, beetles, ants and grasshoppers are abundant and available in grassy areas near sagebrush cover, birds can fill up fairly quickly early each morning, and be back in hiding as the raptors begin hunting. If a predator comes by while they are out and feeding, the chicks can scatter and hide under the nearby brush or bunchgrass. If insects and forbs are few and far between, chicks must travel farther, be moving and visible for a longer period of time each day, and compete with each other for a limited food supply. As a result, chicks will be undernourished, grow poorly or starve, and be more susceptible to cold weather and predation.

S-CW habitats do not have adequate forb abundance to produce broods. Crested wheatgrass seeds and plants will grow at cooler temperatures than most native species (Aoude 2001). Crested out-competes native forbs for moisture, resulting in poor forb abundance and diversity. Many of the lowest elevation, driest **S-CW** pastures on the study area do not appear to be essential brood habitats; management efforts should be directed toward enhancing their value to wintering grouse. However, increasing plant species diversity by adding more competitive early greening forbs (such as alfalfa, sainfoin, small burnett) may not only benefit pronghorn and livestock, but may enhance pre-laying condition of hens, potentially improving clutch sizes, egg viability and chick survival (Barnett and Crawford 1994). A 25% increase in digestible protein in the diet of laying domestic chickens can increase egg viability by 50% (Barnett and Crawford 1994). Arthropod abundance generally increases with forb abundance (Potts 1986). Finally, we saw increased summer grouse activity (including broods) in nearly all of the low elevation **S-CW** pastures where diverse forb mixes were introduced.

Low elevation **S-CW** habitats often border irrigated **MDW** habitats. Abundant alfalfa and meadow clovers within the outer 60 m of these fields bordering brushy cover should be encouraged county-wide, as a drought reserve for sage grouse and other species. A program similar to the “Conservation Headlands” program in Great Britain (Sotherton et al. 1989), whereby farmers received compensation for managing field-edges for gamebirds, might increase grouse and big game survival in dry years and avoid depredation issues.

Mid-elevation Wyoming **NS** habitats are used by sage grouse year-round, and are essential to grouse for winter, nesting and early brood habitat. These areas can provide good brood habitat in all but the driest of summers. Since shrub cover is often >30% in these areas, small spring burns and mechanical brush-thinning plus planting desirable grasses and forbs (particularly alfalfa) in widely scattered strips and patches seems the best strategy for enhancing brood habitat values while maintaining winter and nesting habitat values. Use methods that promote young sagebrush growth to replace the older, decadent shrubs being removed. Investigate low-tech brush-thinning methods, such as herbivory by supplemented livestock and elk to reduce brush and increase herbaceous cover. Monitor changes in plant community composition, production and plant chemistry before and after treatment to gauge success.

Large plantings to increase cattle and elk forage in **NS** and **SSG** habitats can also create or improve late brood rearing habitat if properly designed and placed. Plantings should be diverse, including preferred forbs and shrubs for brood food and cover. Sagebrush islands should be left (or planted) within **RSD**'s. Treat no more than 35% of large sagebrush stands, in 200-300 acre blocks, to minimize negative impacts to sage grouse. In **SSG** habitats, where sagebrush is lacking, protecting established sagebrush stands and adding additional shrubs will increase nesting and loafing cover, enhancing value for grouse.

Cool season burns and mechanical brush-thinning in **MS** habitats may maintain sage grouse values while enhancing habitat for deer, elk, moose and livestock. Maintain a brush-dominated matrix, with irregularly shaped treatments having multiple sagebrush islands within the treatment boundaries. Preferred forbs can be added during brush-thinning activities if lacking.

No set of brush management guidelines can replace knowing how grouse are currently using a given landscape. Telemetry studies provide great information, but don't undervalue field observations. Use what you have, get out in the field and look.

Grazing management should provide appropriate rest and recovery periods to maintain herbaceous cover and species diversity. Rest periods should be built into the grazing strategy to allow shorter-lived forbs to produce seed every other year. Lowland riparian areas are essential to brood survival, particularly in drought years. Grazing strategies should minimize over-biting of riparian vegetation in **NS** and **SSG** habitats; these pastures should receive periodic season-long rest. Increase rest of mid-elevation and Wasatch bio-area pastures by 20%.

Management of rangelands can be viewed as the selective application of rest and disturbance to the system to achieve desired range conditions. Our monitoring suggests that both season-long grazing and long-term rest from disturbance in sagebrush steppe promote dominance of long-lived, chemically defended woody species. Season-long grazing can also result in excessive bare ground, erosion and loss of desirable perennial grasses and forbs in high-use areas. It is not surprising that, as a result of poor grazing practices and large-scale conversions of native sagebrush ranges to monocultures of cropland or introduced grasses, many managers and citizens alike argue for total rest from grazing and banning intentional brush management practices. Unfortunately, our research would suggest that neither season-long grazing nor total livestock removal is the optimum strategy for managing sagebrush-steppe for watershed health and wildlife diversity and abundance.

Diversity and abundance of wildlife requires diversity within the plant community. Sage grouse rely on patches of healthy sagebrush plants year-round as food, nesting, hiding, resting and thermal cover. In extremely dry summers, long-lived woody plants likely provide critical nutrition for surviving grouse. However, nutritious forbs, grasses and insects are essential (April through August) for reproduction and population growth. Sage grouse will not persist without an acceptable mix of both sagebrush and herbaceous plants. Periodic disturbance maintains or increases many high-protein forb species. Potentially beneficial practices include; intermittent herbivory, rest, appropriately-scaled low-intensity burns, mechanical and chemical sagebrush thinning, and mechanical soil disturbance and seeding.

Land managers must counter undesirable, invasive non-native plants like cheatgrass (*Bromus tectorum*), Dyers woad (*Isatis tinctoria*), leafy spurge (*Euphorbia esula*) and spotted knapweed (*Centaurea maculosa*) which can dominate rangelands and reduce species richness. On the other hand, many preferred grouse foods now include non-native forbs that have integrated the sagebrush system. Introduced species such as alfalfa, salsify, sainfoin, prickly lettuce, and dandelion tend to increase plant species richness and range nutrition. They tend not to out-compete native perennials and form monocultures. These broad-leafed, digestible forbs provide critical nutrition to species such as grouse, pronghorn and mule deer. Several rangeland alfalfa and sainfoin plantings have persisted >20 years on DLL despite intermittent cattle grazing and continuous herbivory from wildlife. If we are to maintain sage grouse in the system, we should maintain these “benevolent” plant species in the system.

Of equal importance is the need to develop affordable and dependable seed sources of plant species native to sagebrush-steppe. Agencies and organizations concerned with wildlife conservation and sage-steppe restoration should fund the development of native seed “farms” on private agricultural lands (and provide a dependable market) to fulfill this ecological need and provide a profitable, alternative commodity for agricultural producers.

The importance of privately owned wildlands as sage grouse habitat

We need to maintain privately owned ranches as working wildlands as we strive to improve their condition and management. Many of the privately owned lands in the Bear River valley are seasonally essential to many native wildlife species. While sage grouse populations may not thrive on poorly managed rangelands, they generally vanish when working ranches become ranchettes (Mitchell et al. 2002).

As wildlife depend on privately owned working wildlands for survival, so do many private ranches depend on public rangelands for survival. Recent history in the intermountain west clearly shows that when adjoining public and privately owned rangelands are not viewed and managed as a system, private wildlands become residential lands, no longer providing habitat to hundreds of migratory wildlife species (Thomas and Gripne 2002). Man and grouse each lose an irreplaceable value.

Privately owned rangelands must generate revenues to continue to exist as open space. Currently, revenues come primarily from livestock grazing, dryland farming and wildland recreation (mainly hunting, and fishing). These farmers and ranchers are producers; their livelihood involves producing income-generating commodities from the land. When producers

view wildlife habitat as a safe, valuable, long-term asset, they will manage for it. Wildlife professionals and citizens who value wildlife and wildlife habitat must initiate research and dialogue to increase trust and understanding of how wildlife and agriculture can coexist synergistically on the landscape. Programs respectful of private property rights, and that promote wildlife habitat conservation and management through training, technical and economic assistance, offer private landowners the means and motivation to preserve and enhance wildlife habitat.

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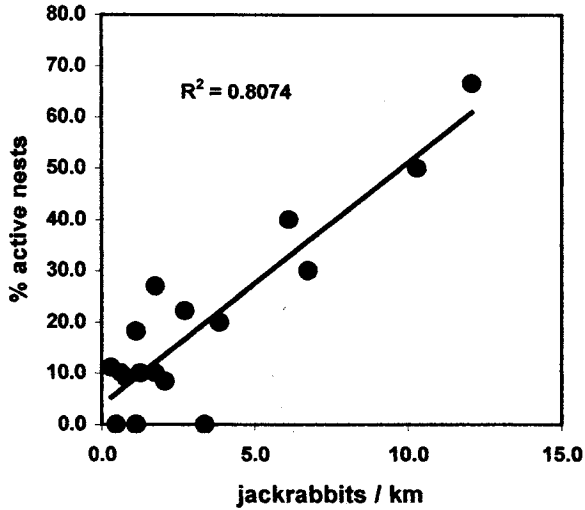
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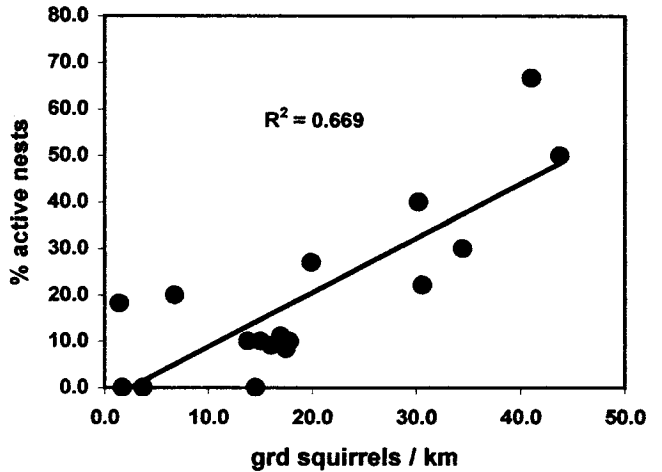
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Eagle nests vs. jackrabbits



Eagle nests vs. ground squirrels



Grd squirrel, jackrabbit and coyote abundance, 1984-2000.

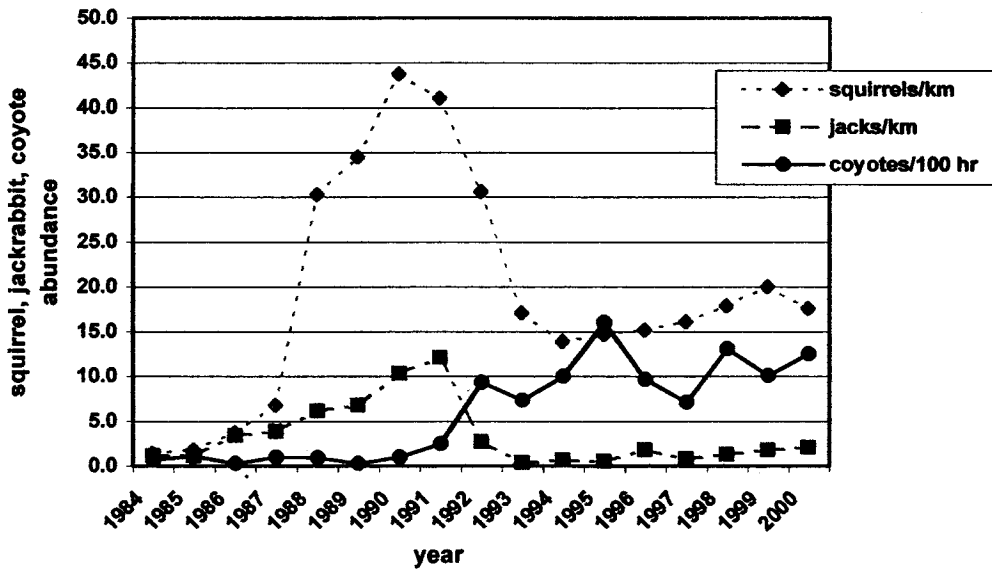


Figure 5. Relationships between whitetail jackrabbit and Uinta ground squirrel abundance (count/km) vs. golden eagle nesting activity and coyotes observed/100 hrs, DLL, 1984-2000.

Male sage grouse attendance on leks, DLL 1985-2000

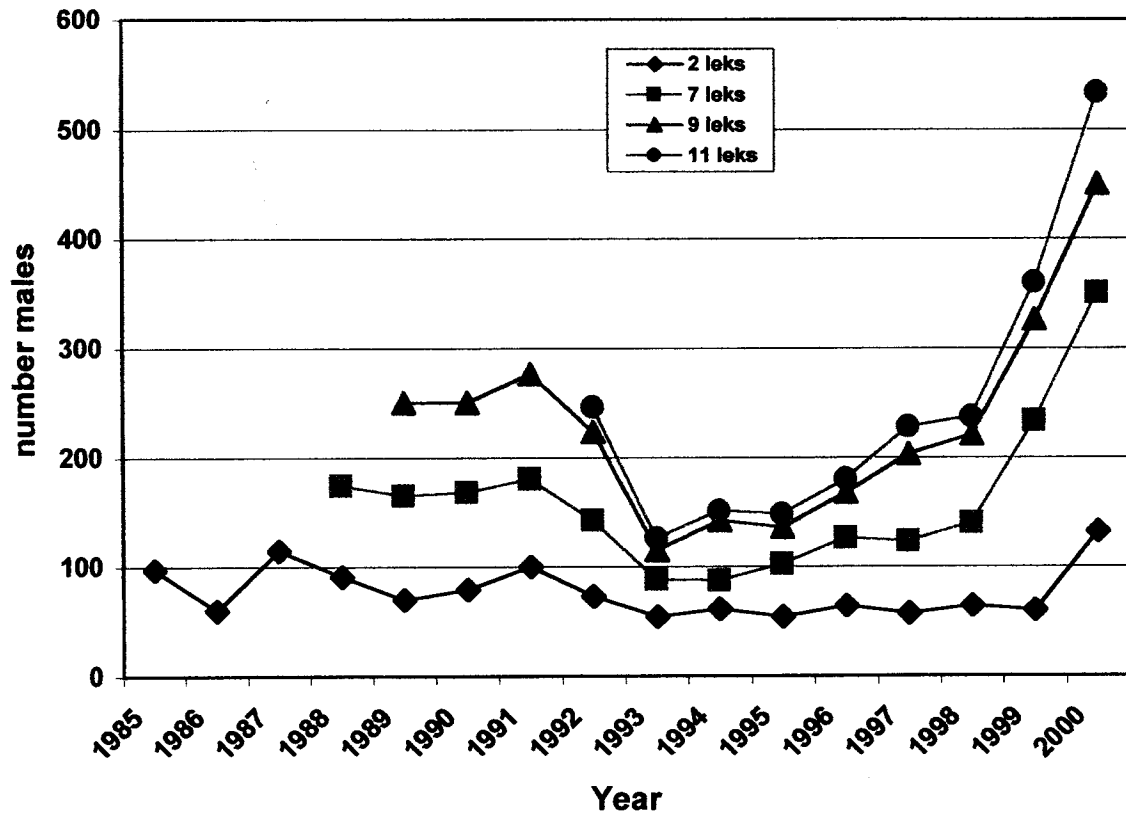
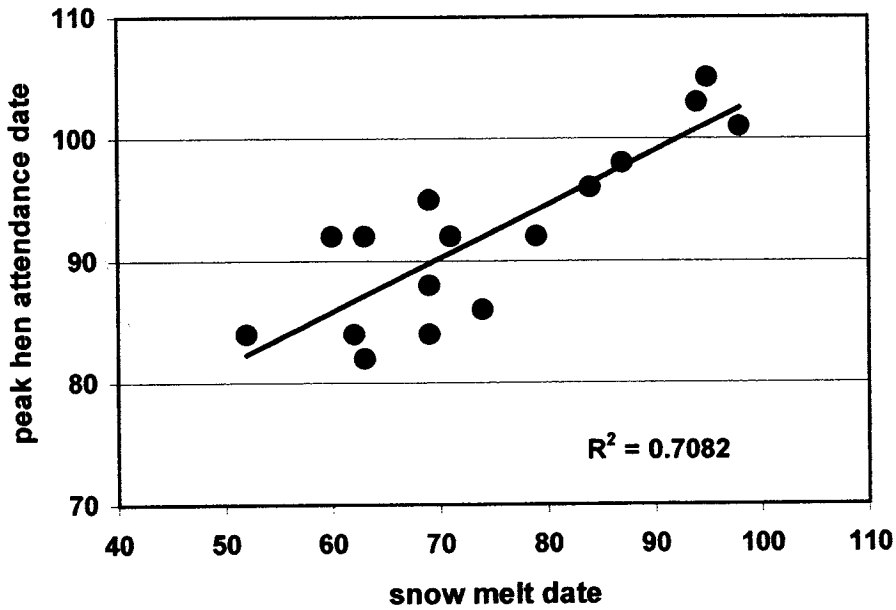


Figure 6. Sage grouse strutting ground counts as an index of population trend, DLL, 1985-2000. Only two leks were known in 1985, by 1993 there were 11 leks known. The four lines represent trend as new leks were added to the count.

Peak hen attendance date vs. snow melt date



Peak male attendance date vs. snow melt date

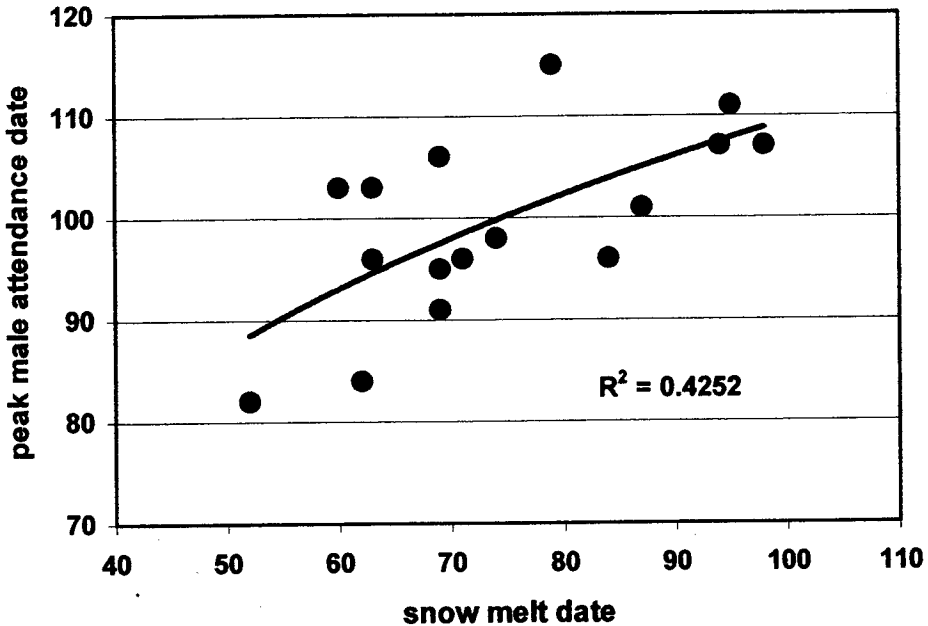
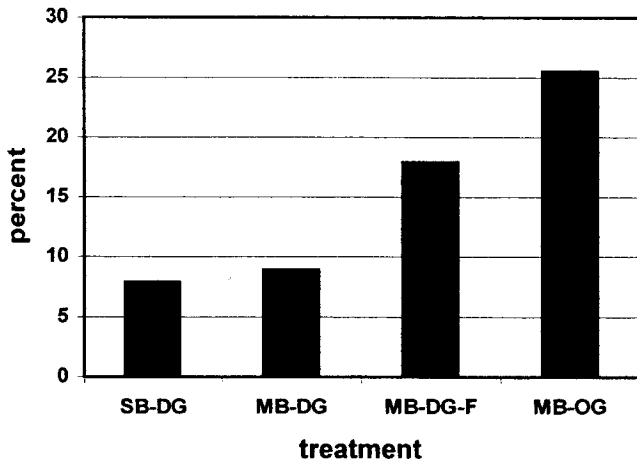
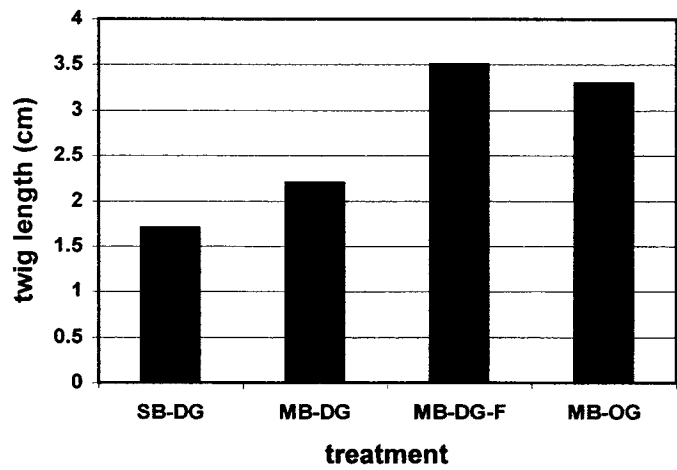


Figure 7. Relationship between disappearance of winter snow and peak attendance by male and female sage grouse on DLL leks, 1985-2000. (March 1 = Julian date 60, April 1 = J. date 92).

Mean percent of plant flowering



Mean length of new twig growth



Percent dead or dying shrubs

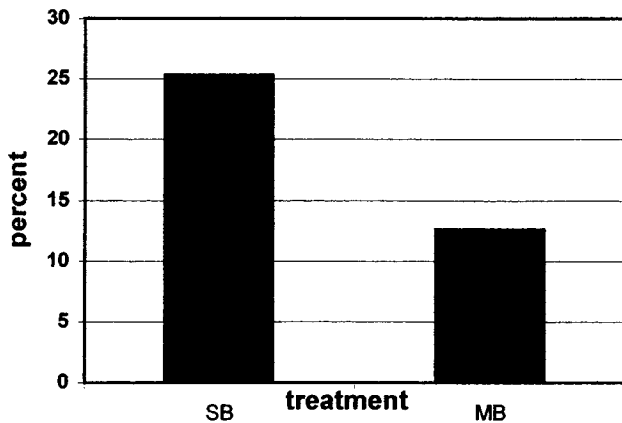
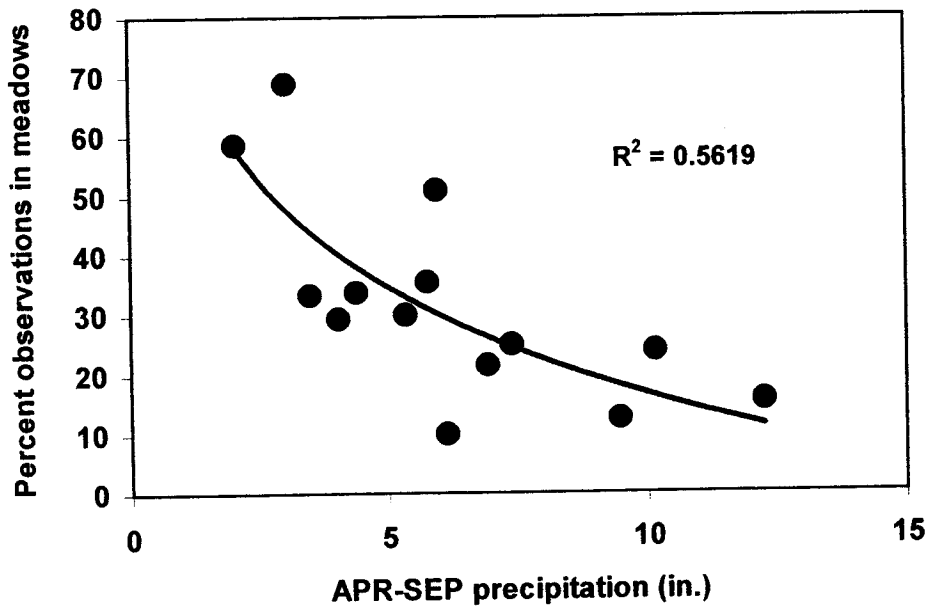


Figure 8. Mean % of plant flowering, twig length, and %shrubs dying with severe or moderate browsing (SB,MB), dormant season grazing (DG), summer overgrazing (OG) and with fertilizer added (F), DLL, 1997-98.

Use of meadows by sage grouse flocks, 15 JUN-15 SEP vs. summer precipitation, 1985-98 (n = 598 flocks, 3483 grouse).



Percent vegetation type use (by grouse) and availability in a wet and dry year (DLL).

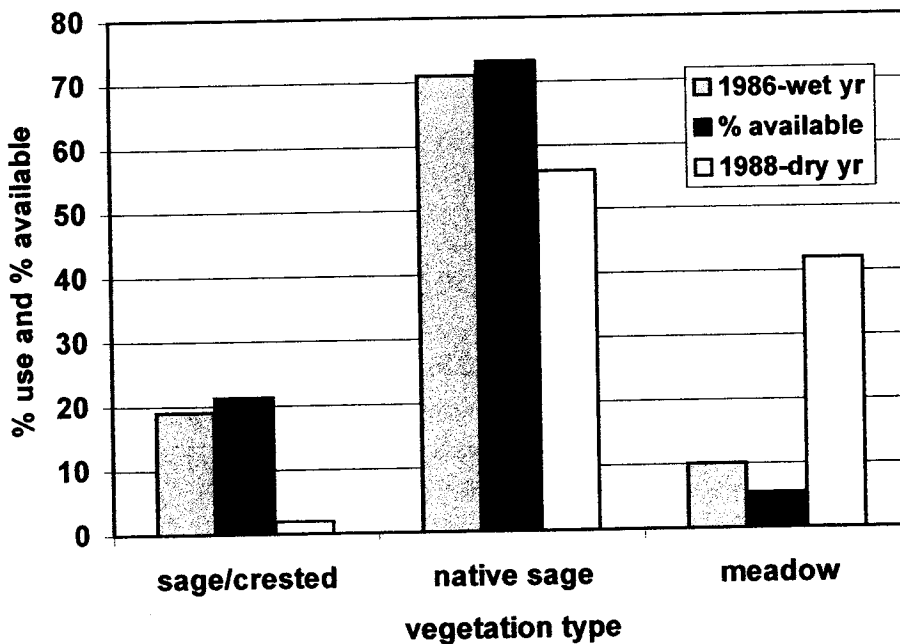
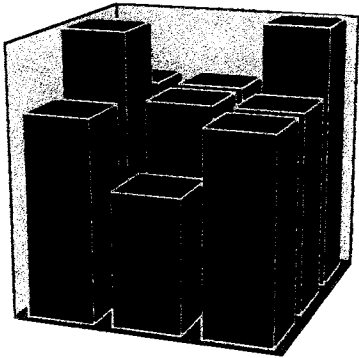
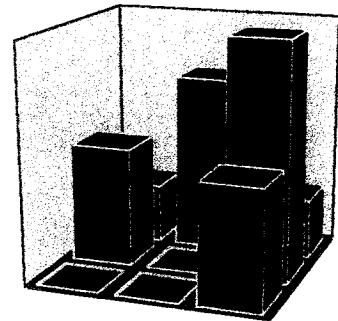


Figure 9. (a) Relationship between mean summer precipitation and percent grouse use of meadows. (b) Grouse use of vegetation types and availability in a wet and dry summer.

Nesting



Early Brood



Late Brood

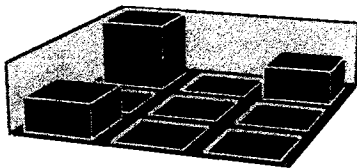
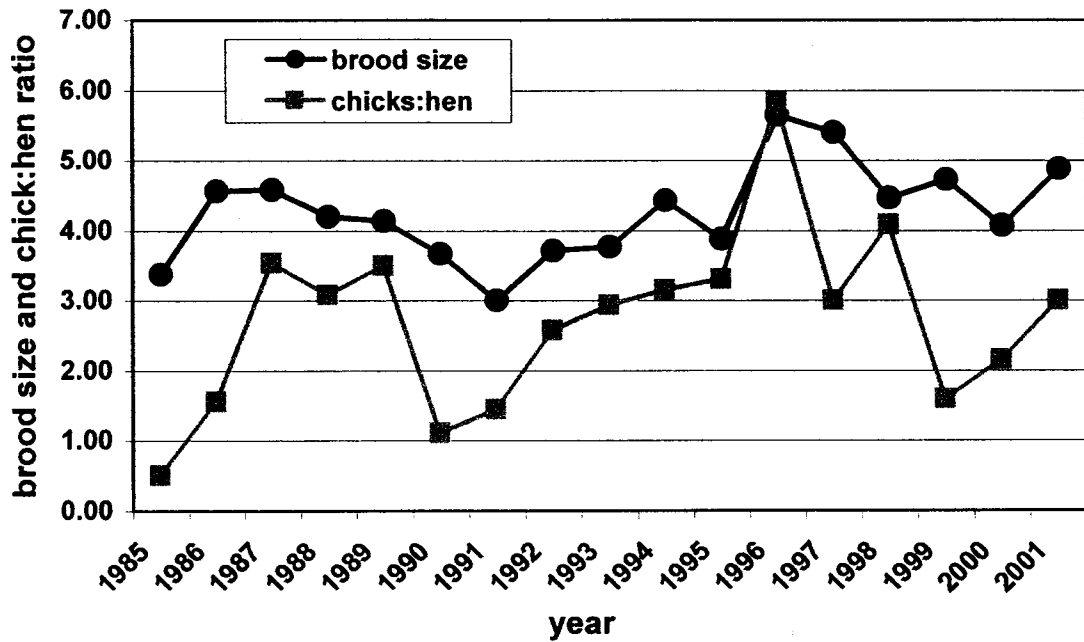


Figure 10. Structural diversity used by sage grouse hens (Hunnicut 1992). Center block is the nest or brood site pixel, surrounded by the 8 adjacent 30 x 30 m pixels. Taller blocks represent greater brush height and cover.

Mean brood sizes and juvenile:hen ratios observed annually, 1985-2001, D L&L, south Rich County UT.



Mean juvenile:hen ratio in sagebrush-crested wheatgrass (S-CW) and other (NS, SSG, MS) areas, 1985-2001, DL&L, south Rich County UT.

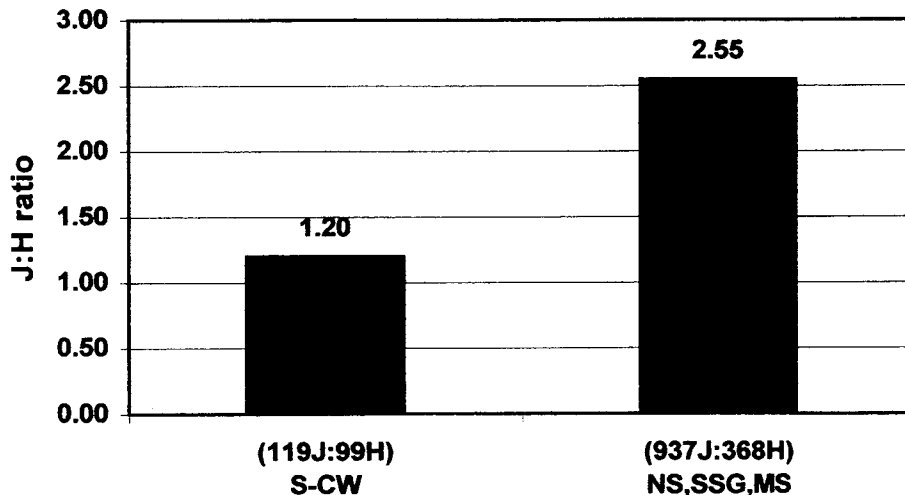
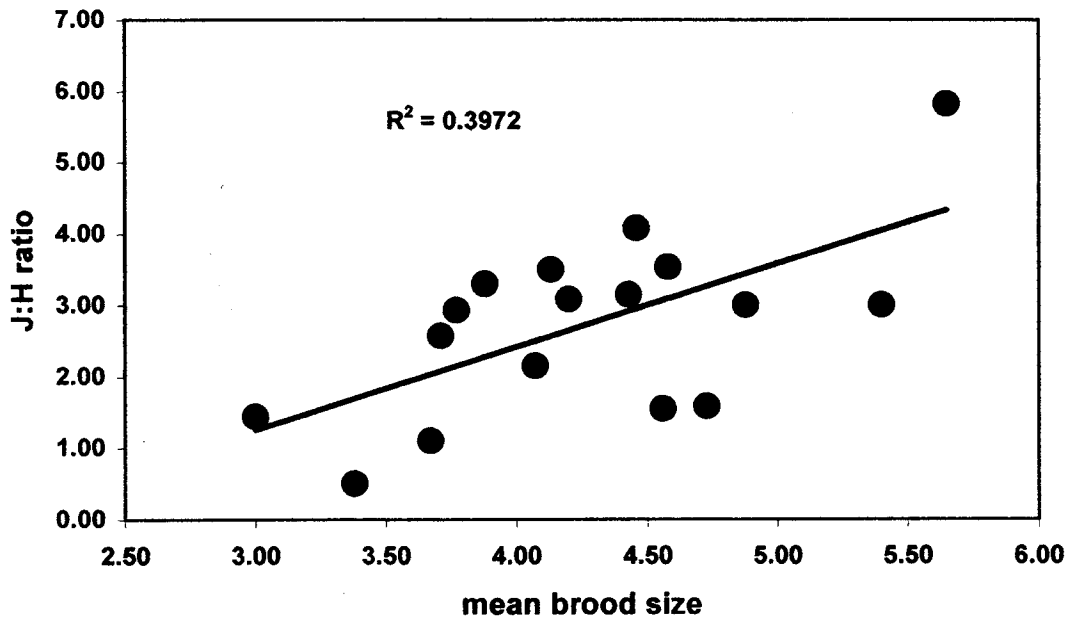


Figure 11. Mean brood sizes and chick:hen ratios; and comparison of chick:hen ratios, S-CW and NS, 1985-2001, south Rich Co., UT.

Correlation between mean brood size and juv:hen ratios observed annually, 1985-2001, DLL, South Rich county UT.



Correlation between mean brood size and population change, 1985-2001, DLL, South Rich county UT.

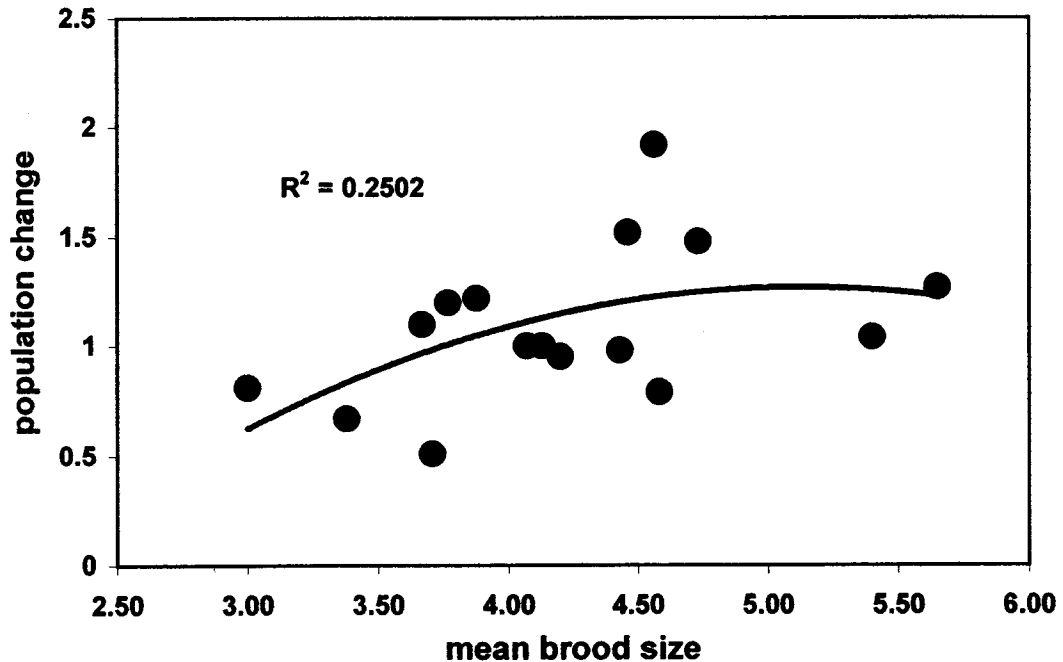
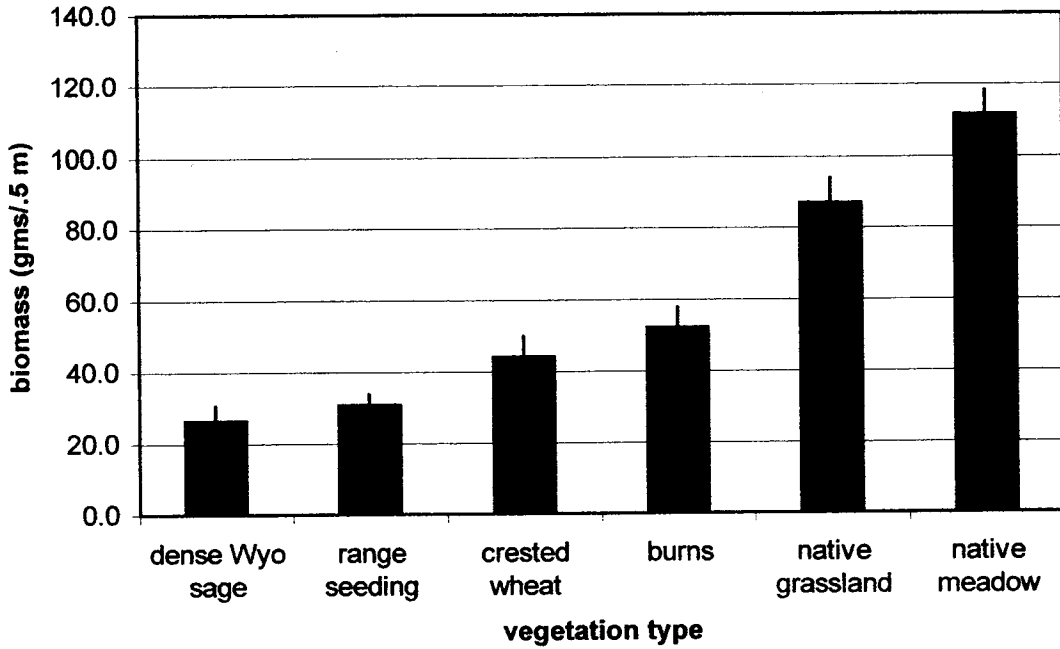


Figure 12. Correlations between mean brood size and chick:hen ratios; and brood size and population change, 1985-2001, south Rich Co. UT.

June 1 arthropod biomass by vegetation type, 1995-2001, DLL.



Arthropod biomass by veg type and year, DLL.

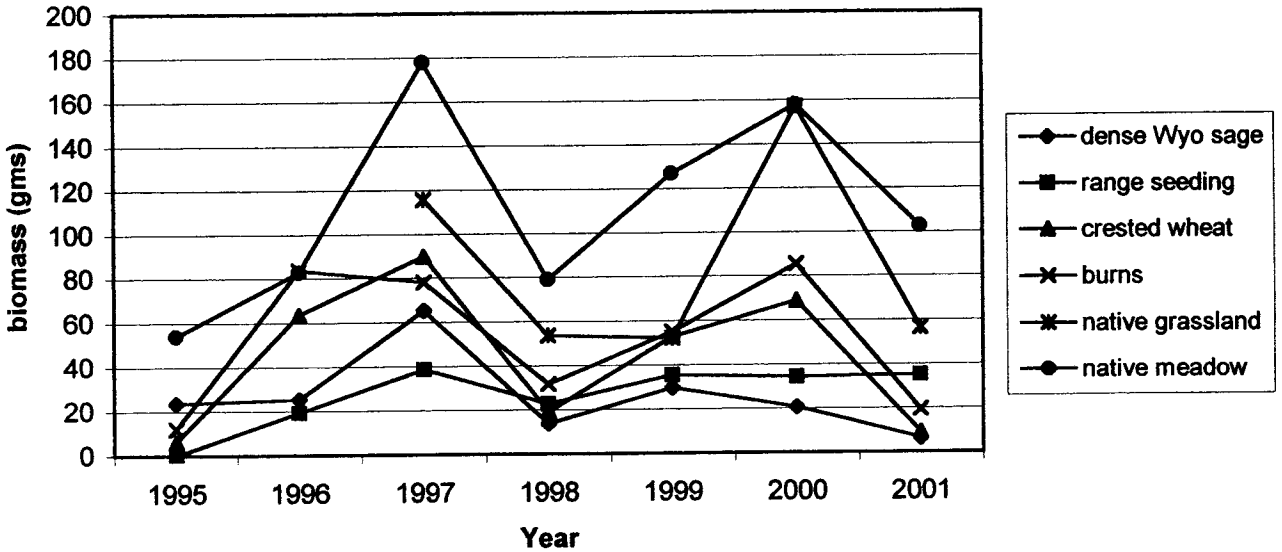
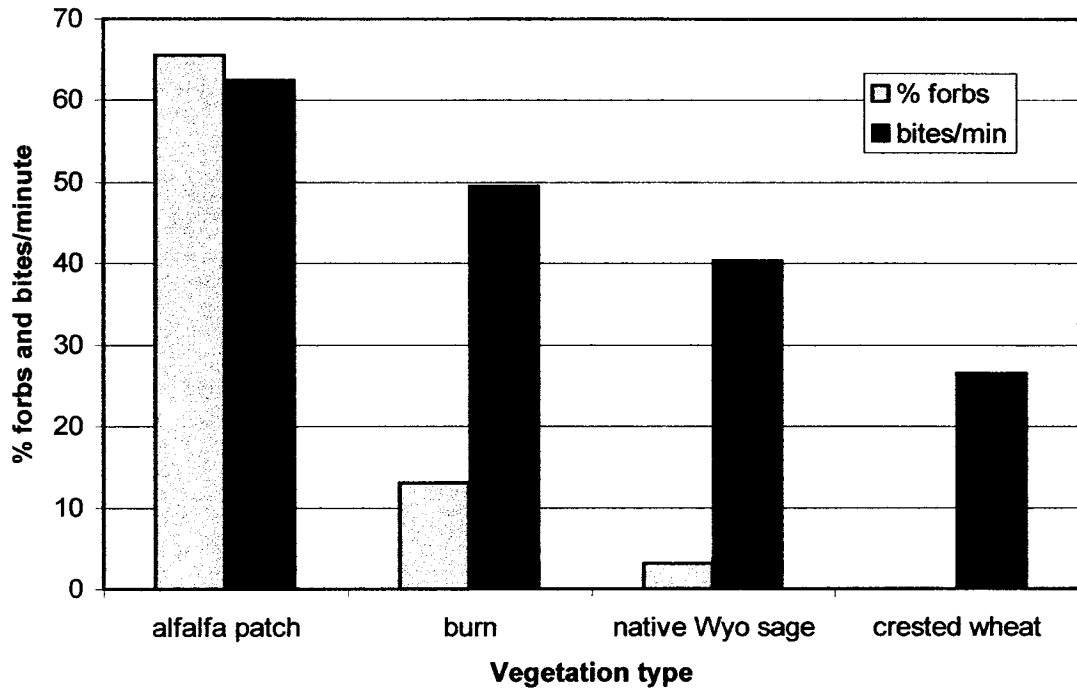


Figure 13. Insect biomass (vacuum sampling) in 6 vegetation types over 7 years on DLL.

Relationship between forb availability and foraging rate of sage grouse chicks in dry summer (late July 94), DLL.



Percent forbs in chick diets June and July 1994 in NS and S-CW habitats, DLL.

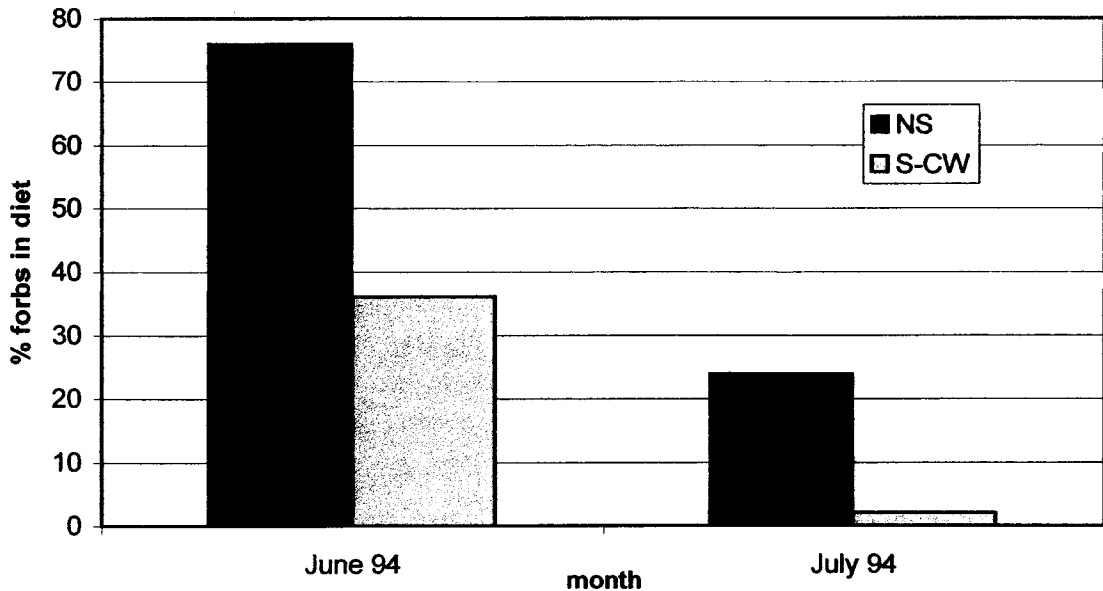


Figure 14. Relationships between forb availability, grouse chick foraging rate and diet selection on DLL, 1994 (from Billaux, 1996).

**Percent of sage grouse flushes in burns and seedings (treatments)
and in adjacent sagebrush cover relative to distance from
sagebrush/treatment edge, DLL, 1996-1999.**

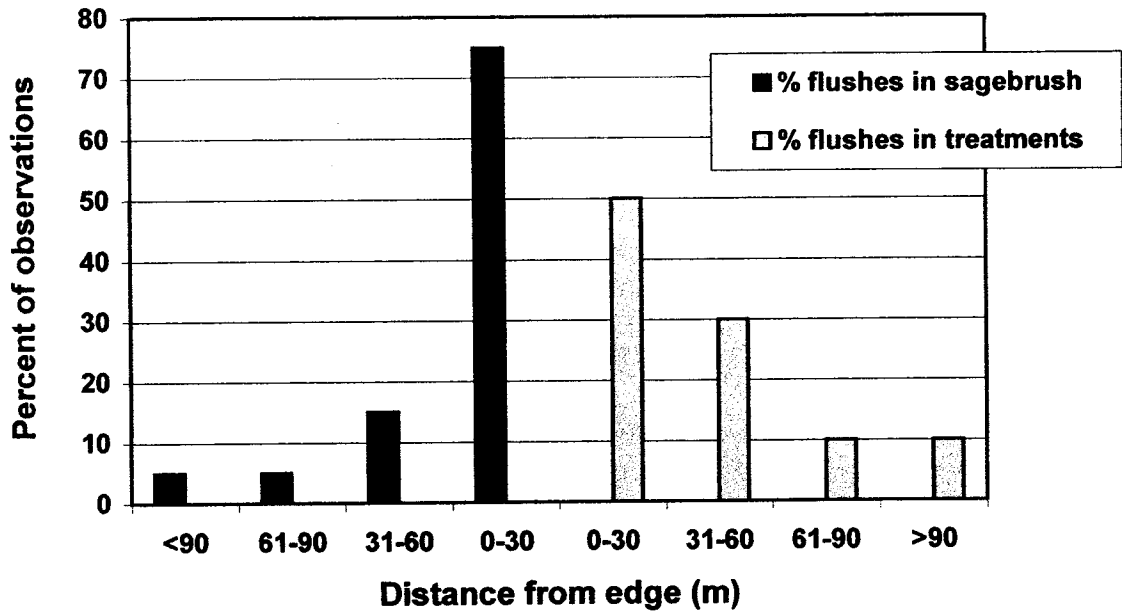
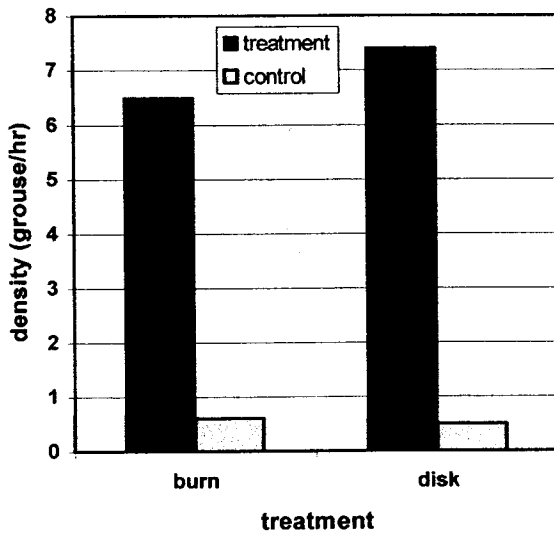
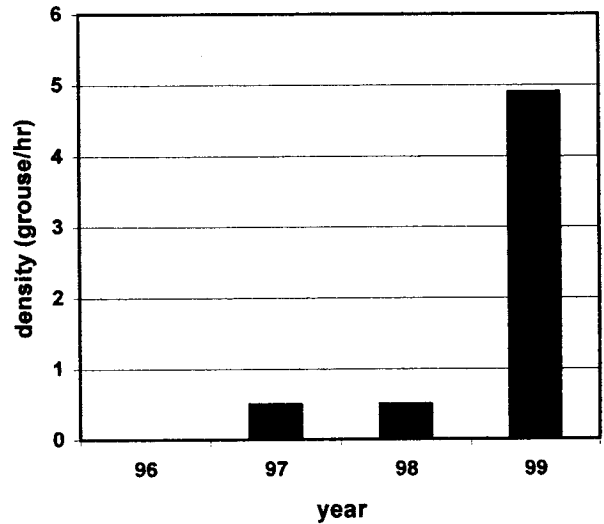


Figure 15. Percent of sage grouse flushes, relative to distance from sagebrush-treatment edge in BRN and RSD, DLL, 1996-99. (from Wilson, 2000).

(a) Grouse densities, treatments vs. controls



(c) Change in grouse density pre-treatment (96,97) treatment yr (98) and post-treatment (99) in crested wheatgrass



(b) Mean brood size and J:A ratios by vegetation type. BRN=burn, RSD=reseeding, NS= native sage, SSG=sparse sage-grassland, S-CW=sage-crested wheatgrass.

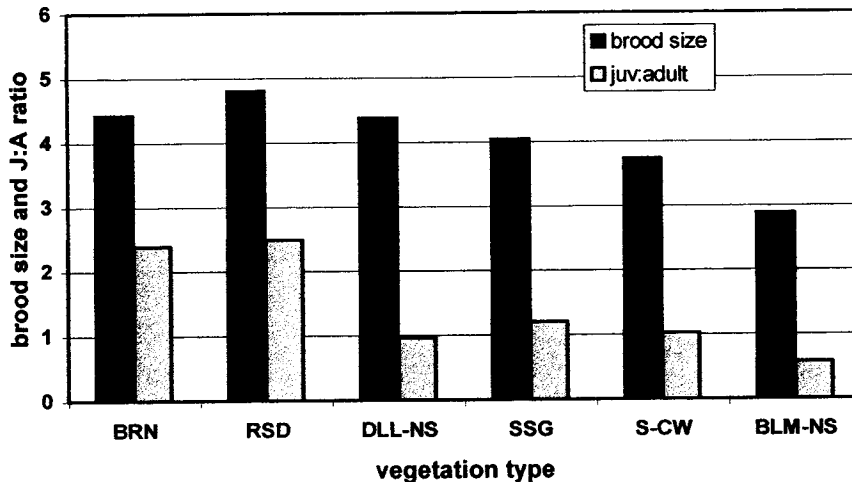
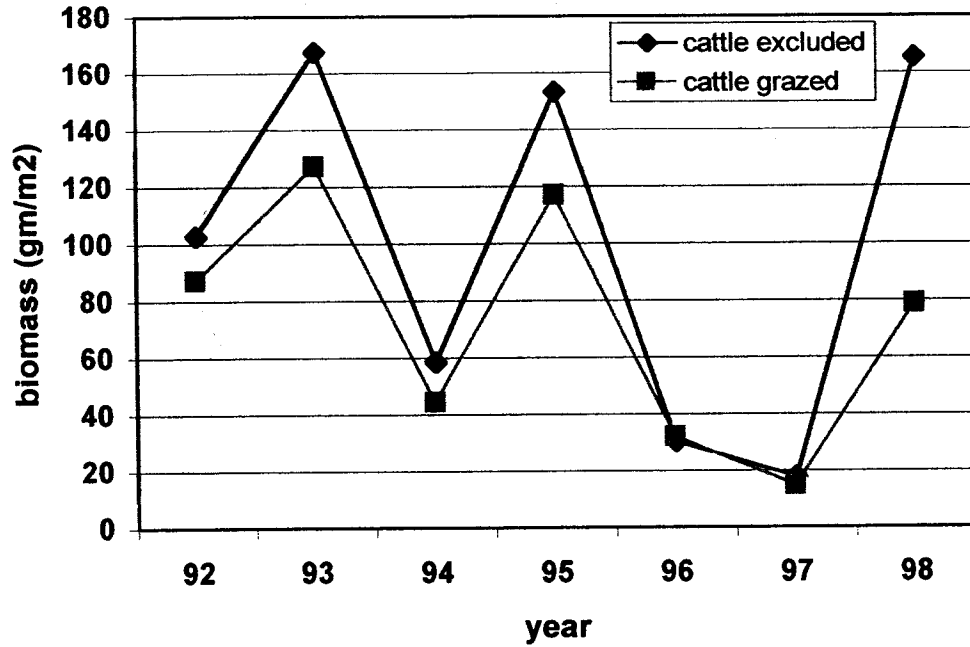


Figure 16. Comparison of (a) grouse densities between treatment and controls, (b) chick production indices between vegetation types and (c) grouse use of crested before and after forb-interseeding, DLL 1996-99 (from Wilson 2000).

Shrub production



Herbaceous production

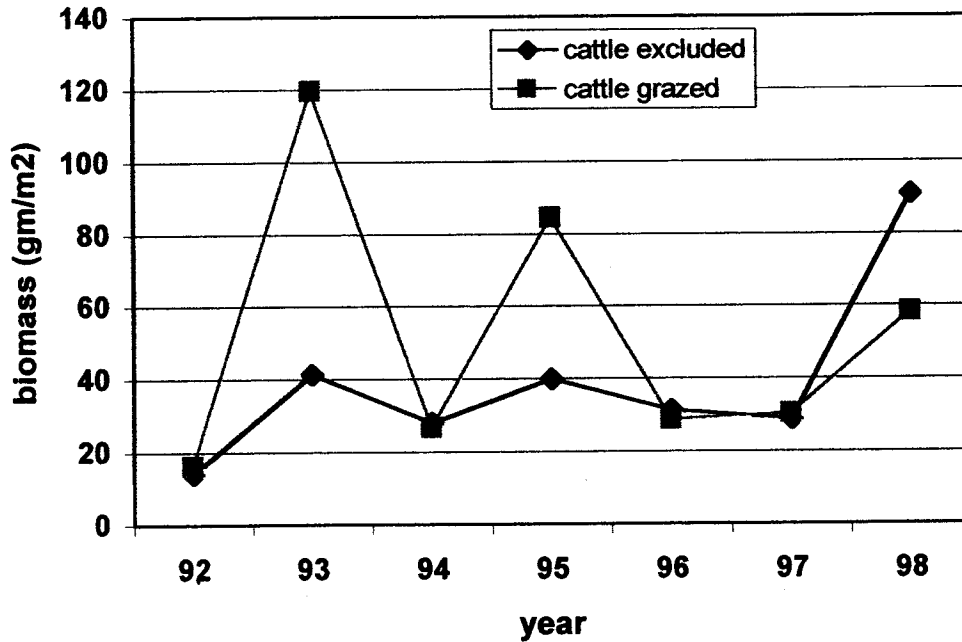
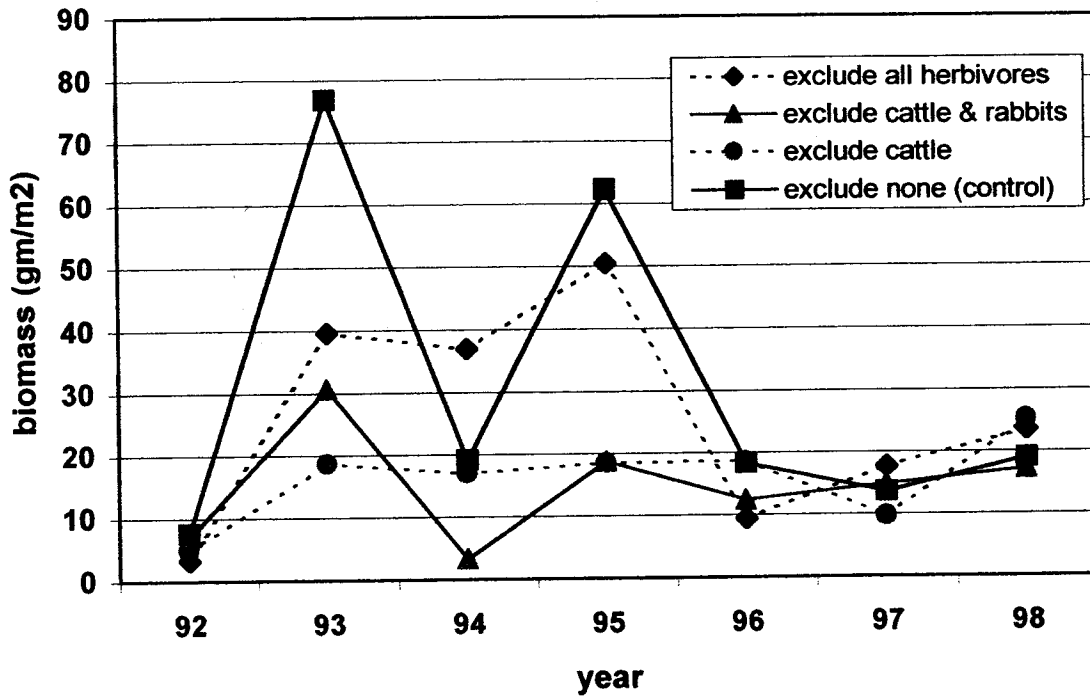


Figure 17. Shrub and herbaceous production in NS cattle grazing exclosures vs. cattle excluded areas, 1992-1998, DLL.

Forb production



Grass production

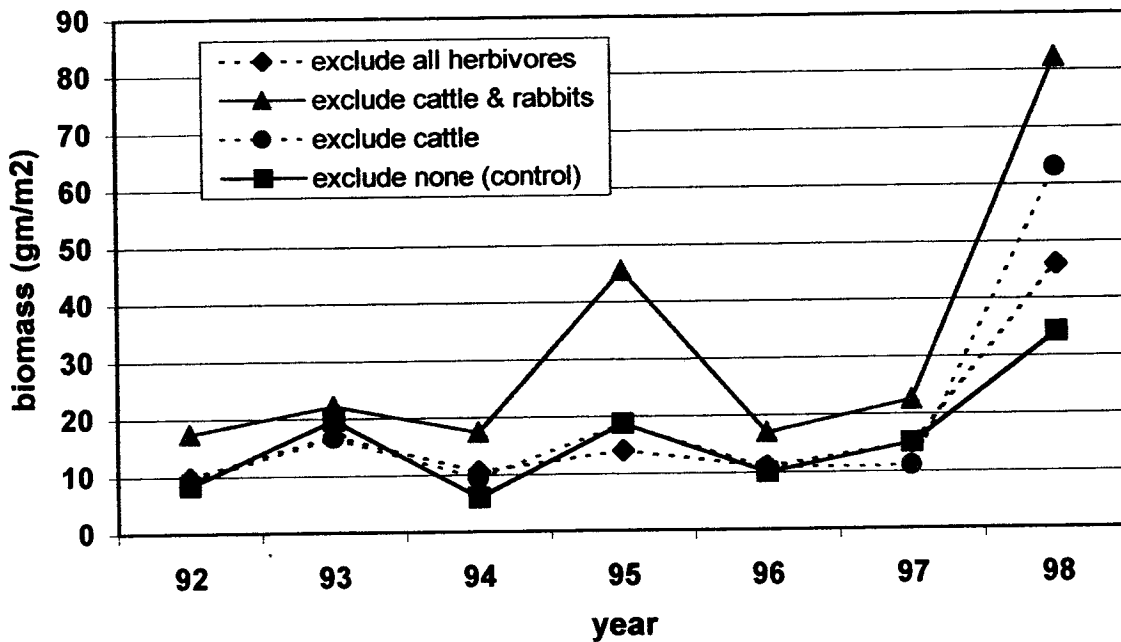
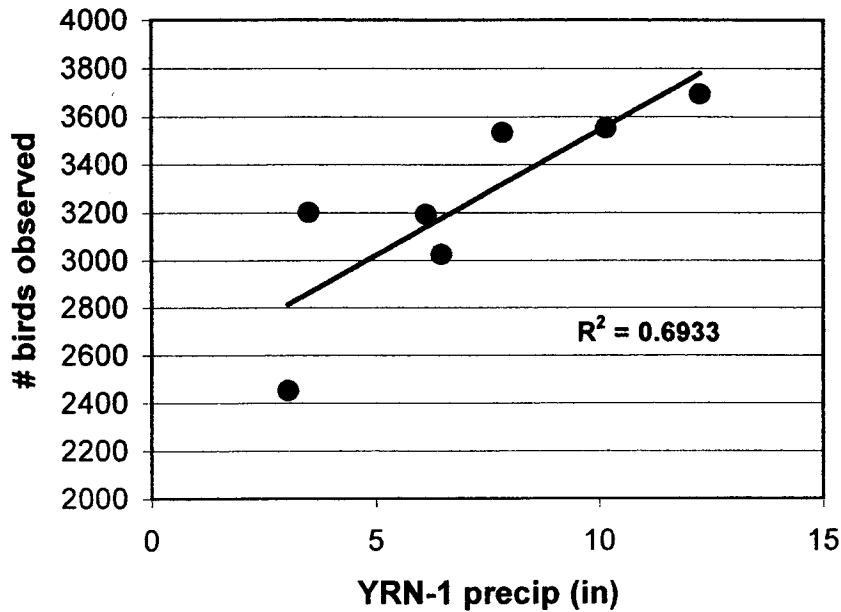


Figure 18. Estimates of forb and grass production in NS controls and with various combinations of herbivores excluded, 1992-1998, DLL.

Total # birds counted on all three DLL-BBS transects vs. prior year summer precipitation, 1995-2001.



Number of bird species observed on all three DLL-BBS transects vs. prior year summer precipitation, 1995-2001.

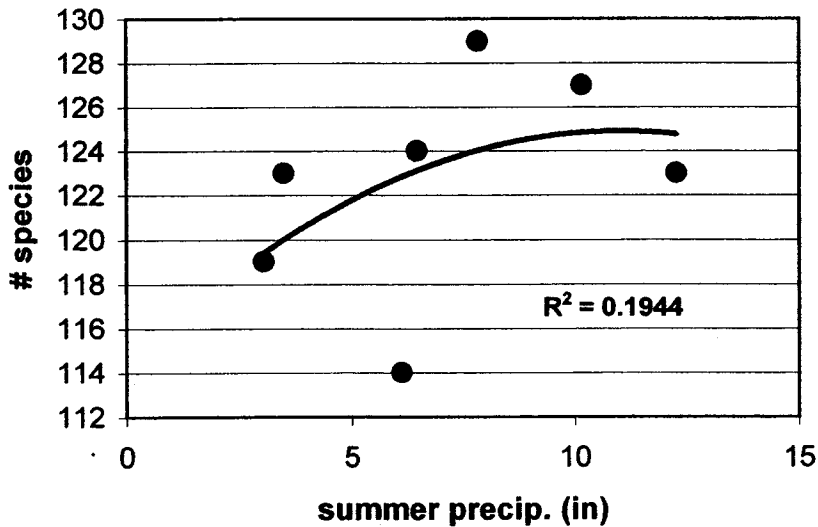
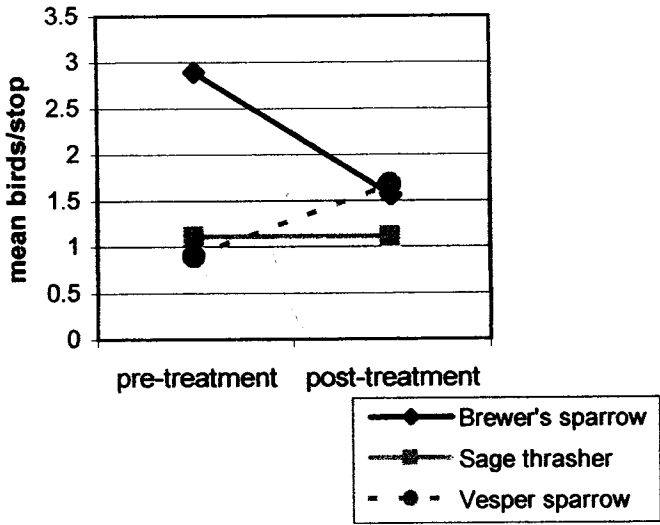
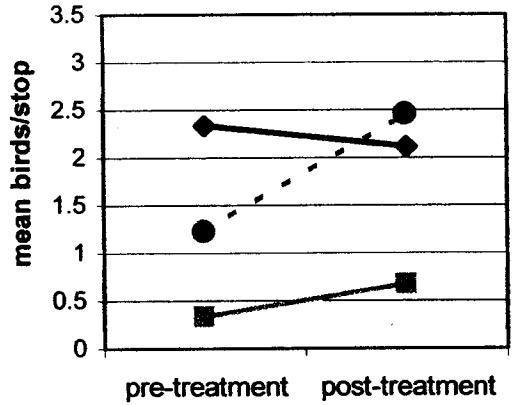


Figure 19. Relationship between prior year (Apr-Sep) precipitation, abundance and species richness on breeding bird surveys, DLL, 1995-2001.

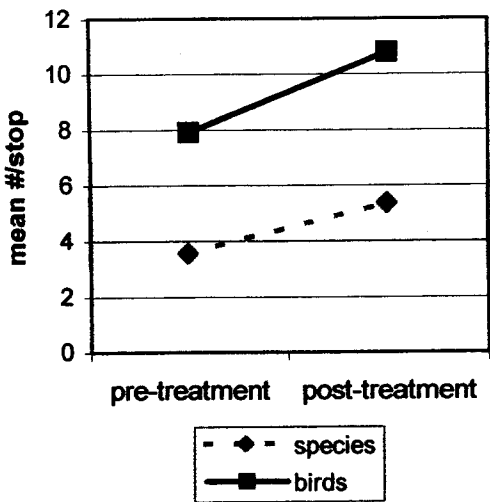
Treatment area (partially reseeded)



Control (untreated area)



Treatment area



Control area

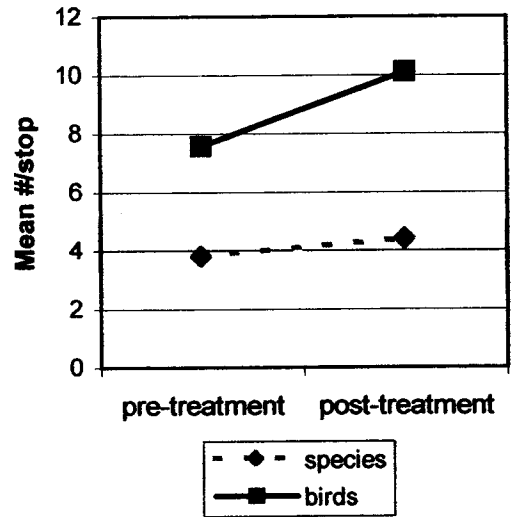


Figure 20. Response of selected species, mean species/stop and birds/stop at three treated (disked and seeded) BBS stops and three untreated stops, pre (95-97) and post (98-2000) treatment on the Crane reservoir RSD, DLL.