AN ABSTRACT OF THE THESIS OF

Dawn M. Davis for the degree of Master of Science in Wildlife Science presented on June 6, 2002.

Title: Breeding Season Habitat Use and Response to Management Activities by Greater Sage-Grouse on Sheldon National Wildlife Refuge, Nevada.

Abstract approved: Redacted for privacy

John A. Crawford

Greater Sage-Grouse (*Centrocercus urophasianus*) have experienced declines throughout their range over the last 50 years. Long-term declines in sage-grouse abundance in Nevada and Oregon have been attributed to reduced productivity. From 1995-1997, sage-grouse production on Sheldon National Wildlife Refuge (SNWR), Nevada was greater compared to Hart Mountain National Antelope Refuge (HMNAR), Oregon. Specific causes for the difference were unknown. Thus, the objectives were to: 1) Determine sage-grouse breeding season habitat use (especially with regard to wildfire) on SNWR; 2) Evaluate reproductive parameters to discern differences between SNWR and HMNAR; 3) Compare habitat components which may relate to differences in sage-grouse reproductive success on SNWR and HMNAR; and 4) Establish hematological and serum chemistry reference ranges for sage-grouse hens to assess physiological condition.

Cover type was important in selection of nest sites at SNWR; however, nest cover did not affect nesting success and nest-site selection was not related to experience. Vegetative characteristics at successful nest sites were similar to unsuccessful nests but nest sites had greater amounts of tall residual grass ($\geq$ 18 cm) and medium height shrub cover (40-80 cm) than at random sites. Broods used areas with greater forb cover than random sites, indicating use was influenced by availability of forbs.

Plant communities in wildfire and associated control sites did not differ appreciably in species composition. Although burning had little stimulatory effect on total forb cover 10-12 years post-burn, alteration of the sagebrush community did not limit sage-grouse use for successful nesting and brood-rearing. Fire did not negatively impact arthropod abundance.

Differences in habitat use and sage-grouse productivity between SNWR and HMNAR may be related to differences in forb availability. Forb cover was greater at HMNAR than at SNWR for all cover types. Correspondingly, home range size for sage-grouse broods was greater on SNWR than at HMNAR. Nutrient analysis of forbs indicated higher crude protein, potassium, and magnesium levels at HMNAR than at SNWR; however, these nutrients are not likely to be deficient in most sage-grouse diets. Thus sagebrush-steppe communities supporting these forbs likely meet the dietary nutritional requirements of sage-grouse. Although blood calcium and uric acid levels were greater in sage-grouse hens on HMNAR than at SNWR, differences were attributed to capture date. Furthermore, physiological condition did not affect a hen's ability to nest successfully, nor was condition related to a hen's ability to recruit chicks to 1 August.

Causes of sage-grouse decline are varied, but ultimately they are habitat based. Comparisons of reproductive parameters and habitat evaluations, combined with sage-grouse physiology data, may provide insight into habitat differences between study areas not previously recognized. Land management practices (e.g., prescribed fire) which recast the balance of native herbaceous species in degraded big sagebrush communities, may be necessary in the restoration of sagebrush-steppe ecosystems, and ultimately, the recovery of sage-grouse populations.

Breeding Season Habitat Use and Response to Management Activities by Greater Sage-Grouse on Sheldon National Wildlife Refuge, Nevada

By

Dawn M. Davis

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CHAPTER 1. INTRODUCTION

Formerly one of the most abundant game birds in the western United States and southwestern Canada, Greater Sage-Grouse (*Centrocercus urophasianus*) have experienced declines through much of their range (Johnsgard 1983, Connelly and Braun 1997). Current sage-grouse distribution extends from central Washington to southern Alberta and Saskatchewan, east to western North and South Dakota, and south to northeastern California, Colorado, Montana, Nevada, Oregon, Utah, and Wyoming (Johnsgard 1983, Drut 1994) closely paralleling the distribution of big sagebrush (*Artemisia tridentata* Nutt.) ecosystems (Autenrieth 1981). Since Euro-American settlement of the West, sage-grouse have been extirpated from Arizona, British Columbia, Kansas, Nebraska, New Mexico, and Oklahoma (Connelly and Braun 1997, Braun 1998).

The decline in sage-grouse numbers has been attributed to alteration of sage-grouse habitats by expanding agriculture, urban development, sagebrush control programs, and altered fire regimes (Dalke et al. 1963, Call 1979, Johnsgard 1983). Klebenow (1972) noted the decline in sage-grouse populations coincided with the period of maximum use of native rangelands by domestic livestock from 1900-1915. Historic overgrazing was associated with alteration of sagebrush habitats that resulted in shrub dominance at the expense of the herbaceous understory (Blaisdell et al. 1982, West and Hassan 1985, Laycock 1991, Winward 1991, Miller and Rose 1995).

Declines in sage-grouse abundance in Nevada and Oregon were attributed to reduced productivity (Crawford and Lutz 1985, Klebenow 1985). Factors influencing declines in productivity included: reduced consumption of forbs by pre-laying hens (Barnett and Crawford 1994); reduced nest success associated with inadequate residual grass cover (Gregg et al. 1994, DeLong et al. 1995, Sveum et al. 1998); and lowered chick survival associated with reduction of forbs and insects used for food (Drut et al. 1994).

Although considered sagebrush obligates (Braun et al. 1977), sage-grouse require forbs and insects during spring and summer for successful nesting and brood-rearing (Johnson and Boyce 1990, Barnett and Crawford 1994, Drut et al. 1994). Forbs composed 20-50% of the pre-laying diet of hens (Barnett and Crawford 1994). Forbs were higher in nutrient content (protein, calcium, phosphorous) than sagebrush, which suggested consumption of forbs may affect reproductive success by improving the physiological condition of hens (Barnett and Crawford 1994). Invertebrates dominated the diet of sage-grouse chicks during the first 3 weeks after hatching (Johnson and Boyce 1990). Klebenow and Gray (1968) found that invertebrates composed 52% of the diet of chicks ≤ 7 days old, whereas, forbs were the major component of chick diets 2-10 weeks after hatching. Drut et al. (1994) suggested lower consumption of forbs and insects and increased dependence on sagebrush negatively affected chick survival.

The selection of food items by juvenile sage-grouse coincides with plant phenology (Klebenow and Gray 1968). Brood movements were associated with forb succulence and availability (Klebenow 1969, Oakleaf 1971). Drought conditions may affect sage-grouse distribution, contributing to the decline in sage-grouse populations (Patterson 1952). Conversely, increased precipitation leads to greater forb production and delayed desiccation (Oakleaf 1971). Increased quantity and quality of forbs during years of high precipitation resulted in increased chick growth and survival, which may be reflected in recruitment rates (Patterson 1952).

Nutrient analysis of phlox [*Phlox stansburyi* (Torr.) Heller] and other forbs identified by Evans (1986) in Nevada indicated that food preference of juveniles resulted in high protein diets (Oakleaf 1971). A comparison of chemical composition of succulent and mature forbs found a decrease in protein levels as the plant matured (Oakleaf 1971). Oakleaf (1971) identified protein as an important nutrient obtained by sage-grouse chicks from meadow vegetation, but other nutrients (e.g., calcium, phosphorous) and availability may affect use of forbs by juvenile sage-grouse. Little is known about the basic nutritional requirements of free-ranging sage-grouse thus, further studies should include nutritional analysis of the plant parts consumed by sage-grouse, variation in nutritional values of forbs, and a comparison of nutritional values of forbs in different management strategies, such as prescribed burning.

Prescribed fire is controversial in sage-grouse management (Dalke et al. 1963, Braun et al. 1977, Connelly et al. 1981). Big sagebrush is temporarily eliminated from the community following burning and, therefore, results in short-term losses of cover for sage-grouse (Blaisdell 1953). However, burning small areas may produce a mosaic of food and cover suitable for sage-grouse (Klebenow 1972). Fischer et al. (1996) found the short-term effects of prescribed fire may negatively impact brood-rearing habitat and may have been detrimental to ants (Formicidae), which are important in sage-grouse chick diets. However, spring and fall prescribed burns did not adversely affect most insects and increased total forb cover and diversity of sagebrush-bitterbrush [*Purshia tridentata* (Pursh) DC.] stands in Oregon (Pyle and Crawford 1996).

Before Euro-Americans arrived in the West, fire regularly occurred in some sagebrush habitats (Gruell 1995). Historically, the natural fire interval in sagebrush communities averaged 12-25 years in mountain big sagebrush [*A. t.* Nutt. ssp. *vaseyana* (Rydb.) Beetle; Houston 1973, Burkhardt and Tisdale 1976, Gruell et al. 1994, Miller and Rose 1999] and 50-100 years in Wyoming big sagebrush (*A. t.* Nutt. ssp. *wyomingensis* Beetle & Young; Wright and Baily 1982). Evidence of scarring on trees and remote sensing data indicated that fire regimes on Sheldon National Wildlife Refuge (SNWR), Nevada historically restricted the encroachment of curlleaf mountainmahogany (*Cercocarpus ledifolius* Nutt.) and western juniper (*Juniperus occidentalis* Hook.) into sagebrush-steppe communities (Gruell 1995). In the last 130 years, juniper encroachment into mountain big sagebrush and low sagebrush (*A. arbuscula* Nutt.) cover types throughout the sage-grouse range has resulted in loss of sage-grouse habitat as trees gain dominance and shrubs and associated understory species are lost (Miller and Wigand 1994, Miller and Eddleman 2000). Juniper density likely dictates the level of use by sage-grouse; however, the stage of woodland encroachment at which use by sage-grouse is reduced or ceases has not been determined (Miller and Eddleman 2000).

Historic sagebrush communities of Nevada likely were composed of open stands of sagebrush with an understory of grasses and forbs (Hazeltine et al. 1961). Anecdotal evidence indicated the Long Valley area of northwestern Nevada, adjacent to the western boundary of SNWR, contained nearly pure wildrye (*Elymus* L. spp.) stands (Hazeltine et al. 1961). Before Euro-American settlement in the West, perennial grasses composed the bulk of vegetation on Badger Mountain at SNWR (Gruell 1995). With the introduction of domestic livestock in the 19th century, the herbaceous understory was unable to support increased grazing pressures, causing rapid deterioration of understory species and movement toward a sagebrush dominated landscape (Laycock 1991).

Practices that reduce herbaceous cover in sagebrush communities may adversely affect sage-grouse nesting and brood-rearing habitat. Prolonged livestock grazing of upland meadows in northern Nevada reduced rangeland forbs and was detrimental to sage-grouse (Neel 1980). The reduction or removal of livestock grazing and management practices (e.g., prescribed burning) may promote recovery of degraded sagebrush communities. However, livestock removal alone may not increase forbs because continued shrub dominance inhibits recovery of the herbaceous understory (Young and Evans 1978, Miller et al. 1994). Prescribed fire may increase availability of forbs in shrub dominant sagebrush habitats (Pyle and Crawford 1996). Further information about the relationship between prescribed burning and sage-grouse use of sagebrush-steppe habitat is needed.

In the early 1990s, the U.S. Fish and Wildlife Service (USFWS) implemented a program of prescribed burning as its primary form of land management to alter plant succession on SNWR. From 1995-1997, sage-grouse recruitment on SNWR ($\bar{x}$ = 64% immatures in fall harvest, 2.47 chicks/hen, *n* = 446 wings) was greater than on surrounding areas in Humboldt and Washoe counties, Nevada ($\bar{x}$ = 46% immatures in fall harvest, 1.48 chicks/hen; USFWS 1997, Sage-grouse Production Report, Lakeview, Oregon, USA) and the long-term average for sage-grouse in Oregon during the past 15 years ($\bar{x}$ = 43% immatures in the fall harvest, *n* = 6,438 wings; Crawford and Torland 2000). How prescribed fire affects habitat use by sage-grouse is not fully understood and remains controversial (Dalke et al. 1963, Braun et al. 1977, Benson et al. 1991).

Because sage-grouse production and harvest ratios of immatures were higher on SNWR then areas adjacent to the Refuge, elements of this study were directed toward features that relate to higher chick survival, and ultimately, recruitment into the fall population. Specifically, the objectives of this study were to:

1) Determine breeding season habitat use by sage-grouse on SNWR (Chapter 3);
2) Assess the short-term effects of wildfire on habitat characteristics necessary for fulfilling some of the life history needs of sage-grouse (Chapter 4);
3) Evaluate sage-grouse reproductive parameters to discern differences between SNWR and areas surrounding the Refuge (Chapter 5);
4) Compare habitat components (e.g., forbs, tall residual grass, and shrub cover) that may be related to differences in sage-grouse reproductive success on SNWR and Hart Mountain National Antelope Refuge, Oregon (Chapter 5); and

5) Establish hematological and serum chemistry reference ranges for sage-grouse hens to assess physiological condition (Chapter 5).

CHAPTER 2. STUDY AREA

This study was conducted on 2 areas (Figure 2.1): Sheldon National Wildlife Refuge (SNWR) and Hart Mountain National Antelope Refuge (HMNAR), both administered by the U.S. Fish and Wildlife Service (USFWS).

Sheldon National Wildlife Refuge encompasses approximately 232,994 ha in northwestern Nevada adjacent to the Oregon-Nevada border. Topography was characterized by flat expanses of big sagebrush (*Artemisia tridentata* Nutt.), narrow canyons, interspersed upland meadows, and broad rimrock tables dominated by low sagebrush (*A. arbuscula* Nutt.) communities. Annual precipitation averaged 33 cm in the eastern portion of the Refuge. Mean maximum temperature is 38 C°; average minimum annual temperature is –12 C°. Rogers and Tiehm (1979) identified 3 predominant vegetation zones on SNWR: the lower Desert Zone, Shrub-Steppe Zone, and higher Western Juniper (*Juniperous occidentalis* Hook.) Zone (Appendix A). Sagebrush communities on SNWR included low sagebrush, Wyoming big sagebrush (*A. tridentata* Nutt. ssp. *wyomingensis* Beetle & Young), and mountain big sagebrush [*A. t.* Nutt. ssp. *vaseyana* (Rydb.) Beetle], which together comprised > 90% of SNWR (Gruell 1995). At elevations above 1,829 m, curlleaf mountainmahogany (*Cercocarpus ledifolius* Nutt.) and western juniper communities were common (Rogers and Tiehm 1979).

On SNWR, domestic livestock grazing averaged 16,317 animal unit months (AUMs) from 1980-1989, which was reduced to 1,565 AUMs annually from 1990-1993. Before 1980, the Refuge was managed, in part, with a deferred grazing system, with the remainder under season-long grazing until a rest-rotation grazing system was established

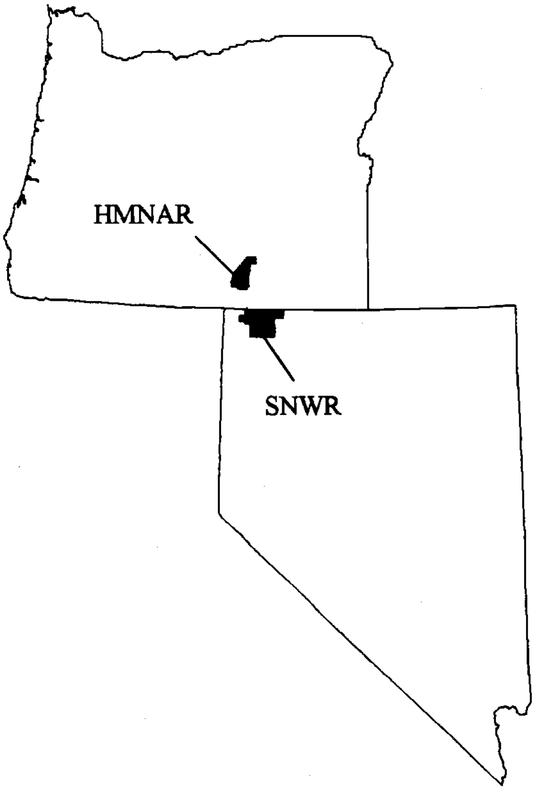

Figure 2.1. Location of Sheldon National Wildlife Refuge, Nevada (SNWR) and Hart Mountain National Antelope Refuge, Oregon (HMNAR).

(Klebenow and Burkhart 1982). In 1994, livestock grazing was suspended on SNWR (Gruell 1995).

Since 1994, prescribed fire has been the primary tool of land managers to manipulate sagebrush-steppe vegetation and improve wildlife habitat on SNWR. However, < 6% of the Refuge has been burned by wild or prescribed fire during the last 15 years. This study evaluated plant response to wildfire on 2 sites: Bald Mountain and Catnip Mountain. In 1988, the Bald Mountain fire, started by a lightning strike, burned 864 ha. Elevation of the Bald Mountain burn unit was from 1,850 to 2,290 m. The 1996 Catnip Mountain wildfire resulted from escape of the West Rock Springs prescribed burn and burned 2,074 ha. Elevation of the Catnip Mountain burn unit varied from 1,952 to 2,135 m. The soils on both sites had medium textured surface layers and medium to moderately fine textured subsoils (Refuge Files, USFWS, Lakeview, Oregon, USA). Soils were generally stony or gravelly on the surface and had gravelly to cobbly subsoils in which the amount of gravel or stone increased with depth. Native vegetation on these sites included: big sagebrush, bitterbrush [*Purshia tridentata* (Pursh) DC.], bluegrass (*Poa* L. spp.), fescue (*Festuca* L. spp.), mountain dandelion (*Agoseris* Raf. spp.), arrow-leaf balsamroot [*Balsamorhiza sagittata* (Pursh) Nutt.], hawksbeard (*Crepis* L. spp.), milkvetch (*Astragalus* L. spp.), long-leaf phlox (*Phlox longifolia* Nutt.), and groundsel (*Senecio* L. spp.).

Hart Mountain National Antelope Refuge, located northwest of SNWR in Lake County, Oregon, comprises 114,375 ha. Elevation ranged from 1,500 m to 2,450 m. The topography of HMNAR consisted of flat sagebrush plains interrupted by rolling hills, ridges, and draws. At Refuge Headquarters annual temperature averaged 6 C° and ranged from – 22 C° in winter to 36 C° in summer. Mean annual precipitation was 29 cm. Dominant cover types consisted of low sagebrush, big sagebrush, and bitterbrush. High elevation stands included western juniper, curlleaf mountainmahogany, and aspen (*Populus tremuloides* Michx.). Common annual and perennial forbs included: mountain dandelion, milkvetch, hawksbeard, lupine (*Lupinus* L. spp.), and phlox (*Phlox* L. spp.). Grasses consist largely of bluegrass, bluebunch wheatgrass [*Agropyron spicatum* (Pursh) Scribn. & J.G. Sm.], needlegrass (*Stipa* L. spp.), fescue, and basin wildrye (*Elymus cinereus* Scribn. & Merr.).

Livestock grazing was eliminated from HMNAR in December 1990. Before 1991, grazing by domestic livestock averaged approximately 12,000 AUMs and was allocated from 15 April-15 December in a rest rotation, deferred grazing system (Gregg 1991).

CHAPTER 3. GREATER SAGE-GROUSE PRODUCTIVITY AND BREEDING SEASON HABITAT USE ON SHELDON NATIONAL WILDLIFE REFUGE, NEVADA

INTRODUCTION

Historically, the range of Greater Sage-Grouse (*Centrocercus urophasianus*) closely paralleled the distribution of sagebrush-steppe ecosystems (Beetle1960, Autenrieth 1981). Current sage-grouse distribution extends from central Washington to southern Alberta and Saskatchewan, east to western North and South Dakota, and south to northeastern California, Colorado, Montana, Nevada, Oregon, Utah, and Wyoming (Johnsgard 1983, Drut 1994). Since Euro-American settlement of the West, sage-grouse have been extirpated from 5 states and 1 Canadian province (Connelly and Braun 1997, Braun 1998).

Declines in sage-grouse populations have been attributed to habitat loss and fragmentation by: expanding agriculture and urban development, sagebrush (*Artemisia* L. spp.) control programs, historic overgrazing by domestic livestock, and altered fire regimes (Dalke et al. 1963, Call 1979, Johnsgard 1983, Klebenow 1985). Range-wide declines in sage-grouse abundance began during the early 1900s (Hornaday 1916, Bent 1932, Gabrielson and Jewett 1940, Rush 1942, Patterson 1952:12, Rogers, 1964, Autenrieth 1981). Reduction of sage-grouse populations after the 1930s coincided with unfavorable habitat conditions resulting from drought and overgrazing by domestic livestock throughout the Intermountain West (Patterson 1952:15, Schneegas 1967). Declines during the 1960s and 1970s were associated with sagebrush removal programs (Wallestad 1975, Swensen et al. 1987). Additional losses were reported in the late 1980s and early 1990s from prolonged drought throughout western rangelands (Fischer 1994, Hanf et al. 1994).

Currently, breeding populations for sage-grouse in Nevada are <15,000 individuals (Braun 1998). Sage-grouse in Nevada declined in abundance and distribution during the mid-1960s, and numerical trend data collected by the Nevada Division of Wildlife (NDOW) indicated declines in sage-grouse productivity (chicks/hen) from 1965-1975 (Zunino 1984). More recently, sage-grouse in Nevada have declined approximately 40% from the long-term average (NDOW 1999). In 1985, sage-grouse production on Sheldon National Wildlife Refuge (SNWR) was greater than on areas surrounding the Refuge (Klebenow 1985). Presently, spring sage-grouse populations on SNWR have been estimated to be 1,569 individuals (J.K. Barnett, U.S. Fish and Wildlife Service, personal communication).

Long-term declines in sage-grouse abundance in northwestern Nevada have been attributed to reduced productivity (Klebenow 1985). Availability of habitat components used for nesting and brood-rearing were considered the primary determinants of sage-grouse productivity (Klebenow 1969, Blake 1970, Autenrieth 1981). Factors that may influence sage-grouse production include: potential lowered reproductive success associated with the reduced consumption of forbs in pre-laying hens (Barnett and Crawford 1994); reduced nest success associated with inadequate residual cover (Gregg et al. 1994, DeLong et al. 1995, Sveum et al. 1998); and lowered chick survival associated with reduction of forbs and insects used for food (Drut et al. 1994).

Several studies have described sage-grouse nesting habitat, selection of habitat components by hens, and the relationship of nest site characteristics with habitat availability (Patterson 1952, Gray 1967, Klebenow 1969, Wallestad and Pyrah 1974, Hulet et al. 1986). In Montana, successful nests had greater shrub cover surrounding the nest site and were associated with cover types with higher density of shrub cover than unsuccessful nests (Wallestad and Pyrah 1974). Other authors noted percent grass cover (Klebenow 1969) and grass height (Wakkinen 1990) were related to nest-site selection. Gregg et al. (1994) and DeLong et al. (1995) identified relationships between vegetational cover and successful nesting by sage-grouse.

Earlier studies also reported habitat structural characteristics and availability of insects and succulent forbs as primary determinants of habitat selection by hens with broods (Klebenow 1969, Peterson 1970, Wallestad 1971, Autenrieth 1981). In Idaho, shrub height, canopy cover, and availability of forbs influenced brood site selection (Klebenow 1969). Similarly, Dunn and Braun (1986) suggested habitat juxtaposition and shrub cover influenced summer habitat selection by hens with broods. In Montana, forb availability affected sage-grouse distribution and habitat selection (Peterson 1970). Wallestad (1971, 1975) and Pyle (1992) also noted availability of forbs influenced brood habitat selection. Furthermore, lower consumption of forbs and insects and increased reliance on sagebrush negatively affected chick survival in southeastern Oregon (Drut et al. 1994).

The objectives of this study were to: 1) Determine sage-grouse breeding season habitat use on SNWR; and 2) Develop management recommendations designed to improve sage-grouse habitats and enhance our understanding of the life history needs of sage-grouse. Special emphasis was placed on those factors that most directly influence recruitment of sage-grouse chicks into the population (e.g., habitat components such as forbs, grasses, and shrubs at nest, brood, and random locations within selected cover types).

METHODS

Trapping, Radio-Marking, and Monitoring of Hens

Sage-grouse were captured from mid-March to mid-April, 1998-2000 by spotlighting techniques (Giesen et al. 1982, Wakkinen et al. 1992). Sage-grouse hens were fitted with a serially-numbered aluminum leg band and a 20-g necklace-mounted ATS radio transmitter (Advanced Telonics Systems, Inc., Insanti, MN, USA). Sex and age of radio-tagged birds were classified by plumage characteristics and wing molt (Crunden 1963, Dalke et al. 1963).

Nest initiation rates, nest success, clutch size, brood success, and brood size were estimated from observations made at locations of radio-collared hens. Sage-grouse were monitored 2 times/wk with a hand-held antenna and portable receiver throughout the spring to identify habitats used for nesting and cover type use. When monitoring revealed that a hen had initiated a nest, the hen was approached until observed on the nest. Subsequently, nesting hens were monitored remotely (>25 m) to avoid disturbance. Once monitoring revealed a hen had moved from the nest and incubation had likely ceased, the nest was examined to ascertain fate. Nests were classified as successful if $\geq$ 1 egg hatched. Depredated nests were distinguished from successful nests by the presence of a firmly attached shell membrane in broken eggs (Wallestad and Pyrah 1974). Unsuccessful hens were monitored to ascertain renesting activities.

Radio-marked hens with broods were located 3 times/wk. Visual locations of hens with broods were obtained by circling the brood within a 25-m radius using a hand-held antenna and portable receiver. Brood locations were marked with a flag and served as a site for habitat sampling. Habitat sampling was conducted at each brood site ≤ 7 days after obtaining the brood location. Broods were monitored until a breakdown of brood integrity or if the brood was lost. Hens were considered successful if ≥1 chick survived to 1 August.

Home range estimates were obtained using the Animal Movement Analysis extension in ArcView GIS 3.2a (Environmental Systems Research Institute, Inc., Redlands, CA, USA). Home ranges for each brood were delineated using the 100% minimum convex polygon method (Mohr 1947) and included all locations from hatch through 1 August (Wallestad 1971). Sample size (i.e., minimum observations per brood < 50) precluded the use of other home range estimators (e.g., kernel estimates; Seaman et al. 1999).

REPRODUCTIVE SUCCESS

Measures of reproductive success included: nest initiation rate, nesting success, clutch size, brood success, and chicks/hen. Nest initiation rates were defined as the number of hens that initiated nests divided by the total number of radio-marked females still alive at the onset of the nesting season. Nesting success was calculated by dividing the number of successful nests by the total number of nesting hens. Clutch size was estimated after hatching by examination of the eggshell fragments. Brood success was obtained by dividing the number of hens that recruited $\geq$ 1 chick to 1 August divided by the total number of successful nests. Recruitment (chicks/hen) was calculated as the number of chicks that survived to 1 August divided by the total number of radio-marked hens still alive at the onset of nesting. A two-sample *t* test was used to compare clutch size between initial nests and renests (Zar 1999:122).

HABITAT CHARACTERISTICS

Nesting and brood-rearing cover for radio-marked hens were classified into 1 of 12 cover types (Appendix A). Wildfire and prescribed burn sites were treated collectively as distinct cover types. Canopy cover of shrubs at nest and brood locations was measured using the line intercept method (Canfield 1941) along 2 (10-m) perpendicular transects intersecting at the nest or center of use. Transect lengths were determined from results in southeastern Oregon, which defined foraging sites as a circle within a 10-m radius (Barnett and Crawford 1994) and indicated nest-site selection was based on vegetative structural components in a relatively small area (3-m^2), regardless of cover type (Gregg 1991; Figure 3.1).

The height of each intercepted shrub was measured from the ground to the top of the canopy and classified as: short (< 40 cm), medium (40-80 cm), or tall (> 80 cm). Shrub canopy cover was recorded separately for each height class and identified to species. Species composition, cover (i.e., ocular estimates to the nearest percentage point), and frequency of grasses and forbs were estimated at 5 (20- x 50-cm) rectangular plots spaced equidistantly along each transect (Daubenmire 1959). Tallest droop height of grasses (excluding flower stalks) was measured in each plot and was classified as short (< 18 cm) or tall (≥ 18 cm). Grass height was determined from results in Idaho, which reported mean grass height of 18 cm at sage-grouse nests (Wakkinen 1990). Dominant grasses and forbs were defined as those with cover ≥ 1% or a frequency ≥ 25% (Crawford et al. 1992).

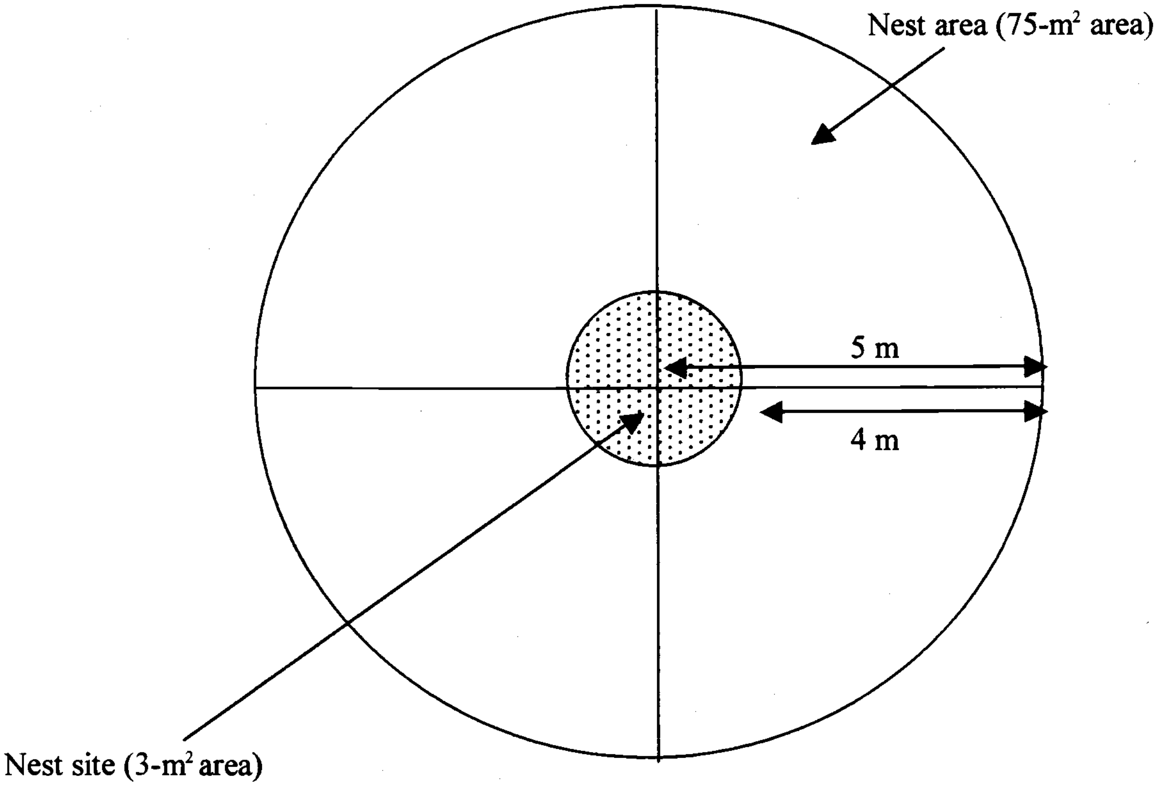

Figure 3.1. The 78-m^2 area on which habitat components were measured at sage-grouse nests at SNWR. The nest site represents the 3-m^2 area surrounding the nest shrub. The nest area represents the 75-m^2 area surrounding the nest (adapted from Crawford et al. 1992).

Grasses and forbs were identified to genus (species when possible). Forbs were categorized as those known to be prevalent in sage-grouse hen and chick diets and total forbs. Hen forbs were defined as those that composed > 1% of the diet by weight (Barnett and Crawford 1994) and included: Desert parsley (*Lomatium* Raf. spp.), hawksbeard (*Crepis* L. spp.), long-leaf phlox (*Phlox longifolia* Nutt.), pussytoes (*Antennaria* Gaertn. spp.), mountain dandelion (*Agoseris* Raf. spp.), clover (*Trifolium* L. spp.), milkvetch (*Astragalus* L. spp.), and buckwheat (*Eriogonum* Michx. spp.). Chick forbs were identified from examination of crop contents and were defined by aggregate mass of ≥ 1% or frequency of occurrence ≥ 10% (Drut et al. 1994; Table 3.1). Plant nomenclature followed Hitchcock and Cronquist (1991).

Table 3.1. Main food items in crops of sage-grouse chicks collected at Hart Mountain National Antelope Refuge, Oregon (adapted from Drut et al. 1994).

	Food items	
Forbs	Arthropods	Shrubs
Astragalus spp.	Scarabeidae	*Artemisia* spp.
Agoseris spp.	Tenebrionidae	
Crepis spp.	Formicidae	
Microsteris gracilis		
Taraxacum officinale		
Trifolium spp.		
Lomatium spp.		
Orbanche spp.		
Aster spp.		
Blepharipappus spp.		

Habitat components were also measured at random locations within each cover type used for nesting and brood-rearing within the SNWR complex. Random sites were selected from cover type maps of the study area. The position of the first transect was assigned from a randomly selected compass bearing and placed > 50 m from the road system or edge of cover type. Habitat sampling at nest sites was performed ≤ 7 days after hatching for successful nests and after the predicted hatch date for unsuccessful nests. Analyses of brood-rearing cover types and habitat characteristics were conducted for 2 periods: early (hatching through 6 weeks) and late (7 to 12 weeks after hatching). The early and late brood-rearing periods were based on changes in habitat use of hens with 6-week-old broods (Martin 1970) and from Peterson (1970) who found a dietary change in juvenile sage-grouse chicks 6 weeks after hatching.

Percent cover of forb, grass, and shrub species measured at random locations were compared with cover types at nest sites to identify habitat components used selectively by sage-grouse. To identify the scale of selection of vegetative features by sage-grouse, the 78-m^2 plots were divided into 2 components: 1) the nest site, which encompassed a 3-m^2 area at the nest, and 2) the nest area, which encompassed the surrounding 75-m^2 area (Gregg 1994; Figure 3.1). The spatial scale of nest plots was based on results from southeastern Oregon, which indicated nest-site selection was based on a relatively small area (3-m^2) and that nest sites had greater cover of medium height shrubs and tall grass than the immediate area (75-m^2) surrounding the nest (Gregg 1994). Additional studies in Idaho compared nest site characteristics within a 2-m radius of the nest to the surrounding area (10-m radius around the nest) and to dependent and corresponding independent random plots to determine whether sage-grouse selected nest sites based on stand characteristics (Musil et al. 1994, Apa 1998). Thus, comparisons of habitat components were made between the nest site, nest area, and random sites.

When necessary, variables were transformed to approximate normal distributions before statistical analysis; however, transformations did not normalize all of the data. Therefore, Kruskal-Wallace single-factor analysis of variance (ANOVA) was used for all comparisons (Zar 1999:197). If a significant ANOVA was found, nonparametric multiple comparisons ($\alpha = 0.05$) were used to identify which habitat components contributed to the difference (Zar 1999:223). Chi-square analysis of contingency tables was used to assess effects of nest cover on nesting success and to test whether there were differences between hen age and the type of nest cover used for nesting (Zar 1999:488).

To identify habitat components used by broods, comparisons were made between brood sites and random locations within each cover type used for brood-rearing. Cover type use by hens with broods was compared between early and late brood-rearing periods to determine changes in habitat use associated with brood age. Kruskal-Wallace single-factor ANOVA was used to examine which habitat components contributed to the difference. Nonparametric tests were used because assumptions of parametric tests (e.g., normality and homoscedasticity) were not met (Zar 1999:197). The level of significance for statistical tests was defined as $P \leq 0.05$.

RESULTS

Trapping, Radio-Marking, and Monitoring of Hens

Eighty sage-grouse hens ($n = 32$ in 1998, $n = 19$ in 1999, $n = 29$ in 2000) were captured at 6 lek locations within the SNWR complex: Andy's Place, Bald Mountain Lake, Mud Lake, South Gooch Lake, South Horse Lake, and West Sage Hen. The age ratio was: 43 yearling female: 37 adult female. Observations of the same hens, in consecutive years, were considered to be independent samples for measures of: nest initiation rate, nesting success, brood success, and chicks/hen. Therefore, the total sample size was 103 hens. Thirteen hens were depredated prior to nesting, 61 were known to have initiated nests (25 yearlings, 36 adults), and 29 were unaccounted for or monitored remotely. Thirty-three of the initial 61 nests were depredated, 5 were abandoned, and 22 clutches hatched. Nine hens renested (3 yearlings, 6 adults); 4 renests were depredated and 5 were successful. The average distance from lek sites that the hen was captured on to initial nest locations was 4.73 km ± 0.50 (SE); $n = 49$. Seven females nested an average of 457 m ± 0.09 (SE) from the preceding year's nest. The remaining females, for which consecutive year nesting data were available ($n = 4$), nested > 1 km from the proceeding year's nest (range = 1.61 km – 8.22 km).

Location data was collected for 14 broods, which consisted of 324 visual locations during the brood-rearing period (Table 3.2). Mean number of observations per brood was 23.14 ± 2.56 (SE; range = 8 –38 observations per brood). Sample sizes did not warrant separate analyses of early and late brood-rearing home ranges; therefore, early and late brood-rearing locations were pooled. Mean home range size for 14 broods was 19.63 km^2 ± 6.90 (SE; range = 0.33 -71.86 km^2). Mean home range size was lower in 1998 ($\bar{x} = 0.56$ km^2 ± 0.23 (SE); $n = 2$) than 1999 ($\bar{x} = 27.94$ km^2 ± 10.54 (SE); $n = 7$) and 2000 ($\bar{x} = 15.63$ km^2 ± 11.65 (SE); $n = 5$).

Table 3.2. Home range estimates for 14 sage-grouse broods, Sheldon National Wildlife Refuge, Nevada, 1998-2000.

Brood ID	Tracking period	Number of locations	Home range (km^2)
0.040	4 June-13 July 1998	12	0.80
0.303	8 July-24 July 1998	8	0.33
0.170	23 May-30 June 1999	15	3.13
9.302	24 May-26 July 1999	19	1.54
9.411	22 June-20 July 1999	25	10.03
9.813	31 May-23 July 1999	15	46.46
9.979	12 June-26 July 1999	30	12.04
0.220	5 June-21 July 1999	19	50.50
0.280	31 May-26 July 1999	21	71.86
9.282	19 May-26 July 2000	33	62.01
9.429	15 May-20 July 2000	19	0.40
9.572	29 May-20 July 2000	34	4.29
9.661	28 May-26 July 2000	36	7.46
9.782	27 May-20 July 2000	38	4.00

Reproductive Success

Nest initiation rate was 94% (61/65) and initial nest success was 36% (21/61; Table 3.3). Thirteen hens depredated before the onset of the breeding season, 5 unaccounted for hens, and 24 females monitored remotely were not included in nest initiation calculations. Females moved an average of 0.90 km ± 0.28 (SE); $n = 8$, to renest and established the second nest in 12.75 days ± 2.62 (SE); $n = 8$ (Table 3.4). Renesting rate was 25% (9/36) and renest success was 56% (5/9; Table 3.3). Three females killed on their initial nest were not included in calculations of renest initiation. Mean clutch size of renests (6.57 eggs ± 0.20 (SE)) did not differ from the initial nest (7.83 eggs ± 0.31 (SE); $t_{0.05(1),11} = 1.98$; $P = 0.214$; P (0.47 eggs $\leq \mu_1 - \mu_2 \leq$ 2.05 eggs) = 0.95). Renesting accounted for 21% (3/14) of total broods alive 1 August. Seventeen of 27 (63%) successful females recruited broods to 1 August. Approximately 69%

(119/172) of the chicks died between hatching and recruitment into the fall population. Brood success rate was 68% (17/25). Two successful hens were not included in calculations of brood success due to radio failure during the early brood-rearing period.

Table 3.3. Reproductive parameters of radio-marked females, Sheldon National Wildlife Refuge, Nevada, 1998-2000.

Parameter	1998	1999	2000
Nest initiation, % (*n*)	100 (11/11)	84 (21/25)	100 (29/29)
Nest success, % (*n*)	50 (3/7)	33 (4/12)	12 (2/17)
Renesting rate, % (*n*)	36 (4/11)	33 (7/21)	38 (11/29)
Renest success, % (*n*)	33 (1/3)	50 (2/4)	100 (2/2)
Brood success, % (*n*)	50 (2/4)	88 (7/8)	62 (8/13)
Total chicks recruited	10	21	22
Chicks/hen from radio-marked sample, (*n*)	0.91 (10/11)	0.84 (21/25)	0.76 (22/29)
Chicks/hen from harvest data	1.10	2.12	2.07

Table 3.4. Renest results for radio-marked sage-grouse hens on Sheldon National Wildlife Refuge, Nevada, 1998-2000.

Frequency	Interval between nests (days)	Distance between nests (km)	Clutch size	
			Initial	Renest
165.044	12	0.55	7	7
160.110	9	2.66	8	6
160.090	≤12	0.15	--	--
164.303	--	--	9	--
159.282	5	0.31	8	6
159.979	9	0.41	7	6
159.390	9	1.01	4[a]	7
159.411	17	1.12	3[a]	7
159.692	29	1.02	8	7

[a] Excluded from statistical comparison of mean clutch size between initial nests and renests.

Habitat Characteristics

Females nested in 5 cover types (Table 3.5). Correspondingly, habitat components for random sites were measured in: Wyoming big sagebrush (*A. tridentata* Nutt. ssp. *wyomingensis* Beetle & Young), mountain big sagebrush [*A. t.* Nutt. ssp. *vaseyana* (Rydb.) Beetle], low sagebrush (*A. arbuscula* Nutt.), mountain shrub, and the Bald Mountain burn site. Of known initial nests, 65% (35/54) were located under big sagebrush (Wyoming big sagebrush: $n = 4$; mountain big sagebrush: $n = 50$). Bitterbrush [*Purshia tridentata* (Pursh) DC.; $n = 7$], low sagebrush ($n = 8$), gray horsebrush (*Tetradymia canescens* DC.; $n = 1$), curlleaf mountainmahogany (*Cercocarpus ledifolius* Nutt.; $n = 1$), and western juniper (*Juniperous occidentalis* Hook.; $n = 1$) were the only other shrubs associated with nests. One hen nested under basin wildrye (*Elymus cinereus* Scribn. & Merr.). Nest success did not appear to be influenced by nest cover ($X^2 = 1.30$, df = 3, $P > 0.05$; Table 3.6). There was no difference between age of hen and the type of nest cover used for nesting ($X^2 = 1.04$, df = 3, $P > 0.05$); however, big sagebrush had a higher proportion of use by sage-grouse hens than other cover at nest sites (Table 3.7).

Table 3.5. Nest success and cover types used by radio-marked female sage-grouse on Sheldon National Wildlife Refuge, Nevada, 1998-2000.

Cover type	Initial nests	Renests	Successful nests	Successful renests
Mountain big sagebrush	26	3	9	1
Wyoming big sagebrush	4	0	2	0
Low sagebrush	8	2	2	1
Mountain shrub	19	2	6	2
Bald Mountain burn	3	0	2	0
Unknown	1	2	1	1
Totals	61	9	22	5

Table 3.6. Nest success of sage-grouse using sagebrush and other types of nest cover on Sheldon National Wildlife Refuge, Nevada, 1998-2000.

	Nest cover							
	Big sagebrush		Low sagebrush		Non-sagebrush		Unknown	
Fate	*n*	%	*n*	%	*n*	%	*n*	%
Successful	15	21	3	4	6	9	2	3
Depredated	21	30	7	10	6	9	5	7
Abandoned	3	4	0	0	0	0	2	3
Total	39	55	10	14	12	18	9	13

Table 3.7. Number of initial sage-grouse nests under sagebrush and other shrubs on Sheldon National Wildlife Refuge, Nevada, 1998-2000.

Age of hen	Big sagebrush	Low sagebrush	Other shrubs
Yearling	15	2	3
Adult	20	6	7
Totals	35	8	10

Total forb cover did not differ between successful and unsuccessful nest sites ($n =$ 40), areas immediately surrounding nests, and random locations ($H_{0.05, 21, 18, 121, 21, 19} =$ 3.60, $P = 0.461$). Random sites had greater hen forb cover compared to successful and unsuccessful nest areas and nest sites ($H_{0.05, 21, 18, 121, 21, 19} = 20.32$, $P \leq 0.001$). Successful and unsuccessful nest areas had greater hen forb cover compared to nest sites (Table 3.8). Chick forbs were greater at successful nest areas and random sites compared to successful and unsuccessful nest sites and unsuccessful nest areas ($H_{0.05, 21, 18, 121, 21, 19} = 40.34$, $P \leq 0.001$). Tall grass cover was greater at successful and unsuccessful nest sites compared to nest areas ($H_{0.05, 21, 18, 121, 21, 49} = 26.41$, $P \leq 0.001$). Random sites had less tall grass cover than successful and unsuccessful nest sites and nest areas (Table 3.8). There was no difference between tall shrub cover at nest sites or nest areas on successful nests compared to nest sites and nest areas of unsuccessful nests (Table 3.8). However, tall shrub cover at random sites was less than tall shrub cover at both nest sites and nest areas for successful and unsuccessful nests, respectively ($H_{0.05, 21, 18, 106, 18, 16} = 12.27$, $P = 0.015$). Medium shrub cover did not differ between successful nest sites and nest areas or unsuccessful nest sites (Table 3.8). Medium shrub cover was greater at successful nest sites, successful nest areas, and unsuccessful nest sites compared to unsuccessful nest areas and random sites ($H_{0.05, 21, 18, 106, 19, 19} = 39.37$, $P \leq 0.001$). Short shrub cover at successful nest sites was greater than successful and unsuccessful nest areas but less than short shrub cover at unsuccessful nest sites and random sites ($H_{0.05, 21, 18, 106, 21, 19} = 43.35$, $P \leq 0.001$). Short shrub cover at unsuccessful nest sites and random sites were not different (Table 3.8). Total shrub cover did not differ between successful and unsuccessful nest sites but was greater at nest sites compared to nest areas and random locations ($H_{0.05, 21, 18, 112 ,21, 19} = 70.58$, $P \leq 0.001$).

Table 3.8. Habitat characteristics (% cover) at successful and unsuccessful nest sites, area immediately surrounding nests of radio-marked sage-grouse hens, and random locations, Sheldon National Wildlife Refuge, Nevada, 1998-2000.

	Successful nests ($n = 21$)				Unsuccessful nests ($n = 19$)				Random ($n = 121$)	
	Nest site		Nest area		Nest site		Nest area			
Characteristic	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Hen forbs	2.86A[a]	0.78	3.54B	0.51	2.16A	0.67	2.76A	0.52	5.97B	0.36
Chick forbs	2.40A	0.74	3.31C	0.57	2.74A	0.81	2.99C	0.66	5.24B	0.42
Total forbs	13.55	2.33	15.84	1.57	12.40	1.89	15.58	2.18	15.13	0.74
Tall grass	19.24B	5.04	13.68A	2.22	16.82B	4.09	15.28A	2.68	6.35B	0.64
Short grass	7.00	2.10	7.85	1.39	6.03	3.25	5.16	1.00	7.19	0.53
Tall shrub	15.61A	4.12	5.08C	1.07	12.20A	5.40	4.25C	1.53	1.43B	1.03
Medium shrub	36.88A	6.01	16.64A	3.05	26.82A	5.69	11.83B	2.21	5.89B	0.86
Short shrub	12.23C	6.53	3.92A	1.70	24.45B	5.60	5.04A	1.62	15.69B	0.45
Total shrub	57.94A	3.50	25.64B	2.93	53.43A	3.70	21.12B	2.71	22.20B	1.50

[a] Means followed by the same letter within a row do not differ ($P \geq 0.05$).

Habitat sampling was completed for 128 brood sites. One hundred sixty total random sites were sampled during spring and 160 during the summer, respectively. Hens with broods were observed predominantly in low sagebrush habitats the first 1-2 weeks after hatching. They moved into big sagebrush or mountain shrub communities approximately 3 weeks after hatching. Forty percent (158/390) of brood locations were in low sagebrush, 19% (76/390) in the Bald Mountain burn, 16% (61/390) in mountain shrub, 13% (49/390) in mountain big sagebrush, 3% (13/390) in the Catnip Mountain burn, 3% (13/390) in mixed sagebrush cover types, 2.5% (7/390) in meadows, 1.5% (6/390) in Wyoming big sagebrush, and 1% (4/390) in other burn sites (Table 3.9).

Table 3.9. Habitat use by sage-grouse broods on Sheldon National Wildlife Refuge, Nevada, 1998-2000.

	1998		1999		2000		Totals	
Cover type	*n*	%	*n*	%	*n*	%	*n*	%
Mountain big sagebrush	0	0	33	22	16	8	49	13
Wyoming big sagebrush	2	5	3	2	1	<1	6	2
Low sagebrush	24	65	64	44	70	34	158	40
Mountain shrub	5	14	13	9	43	21	61	16
Bald Mountain burn	0	0	10	7	66	32	76	19
Catnip Mountain burn	0	0	13	9	0	0	13	3
Other burns	0	0	4	3	0	0	4	1
Meadow	3	8	0	0	7	3	10	3
Mixed sagebrush	3	8	7	5	5	2	15	4
Totals	37	100	147	100	208	100	392	100

Total forb cover was greater in mountain big sagebrush ($H_{0.05,18,30} = 16.13$, $P \leq 0.001$) and Wyoming big sagebrush ($H_{0.05,5,30} = 9.10$; $P = 0.003$) brood locations than at random sites (Table 3.10). Hen forb cover was greater in mountain big sagebrush ($H_{0.05,18,29} = 4.90$; $P = 0.027$), Wyoming big sagebrush ($H_{0.05,,5,30} = 12.55$; $P \leq 0.001$), mountain shrub ($H_{0.05,\,9,\,30} = 3.81$, $P = 0.051$), and the Bald Mountain burn ($H_{0.05,\,12,\,20} = 10.96$; $P = 0.001$) brood locations than at random sites (Table 3.10). Chick forb cover was greater at Wyoming big sagebrush ($H_{0.05,\,5,\,30} = 12.53$, $P \leq 0.001$), mountain shrub ($H_{0.05,\,9,\,30} = 9.22$, $P = 0.002$), and the Bald Mountain burn ($H_{0.05,\,12,\,20} = 4.26$, $P = 0.039$) brood locations than at random sites (Table 3.10). Conversely, low sagebrush cover types had lower hen ($H_{0.05,\,51,\,30} = 17.81$, $P \leq 0.001$) and chick ($H_{0.05,\,51,\,30} = 6.47$, $P = 0.011$) forb cover at brood locations than at random sites (Table 3.10). Measurements of total shrub cover indicated that broods used areas having greater percent crown cover in mountain big sagebrush ($H_{0.05,\,18,\,30} = 15.94$, $P \leq 0.001$) and lower total shrub cover in the Bald Mountain burn ($H_{0.05,\,12,\,20} = 14.85$, $P \leq 0.001$) cover type than at random sites (Table 3.10). No differences were detected between habitat comparisons of early and late brood-rearing locations (Table 3.11).

Table 3.10. Habitat characteristics of sage-grouse brood and random locations by cover type, Sheldon National Wildlife Refuge, Nevada, 1998-2000.

	Mountain big sagebrush		Wyoming big sagebrush		Low sagebrush	
	Brood ($n = 18$)	Random ($n = 30$)	Brood ($n = 5$)	Random ($n = 30$)	Brood ($n = 51$)	Random ($n = 30$)
Variable	$\bar{x}$ (SD)	$\bar{x}$ (SD)	$\bar{x}$ (SD)	$\bar{x}$ (SD)	$\bar{x}$ (SD)	$\bar{x}$ (SD)
Key hen forbs	3.53 (2.39)[a]	2.13 (2.04)	9.40 (1.04)[a]	1.21 (1.20)	5.65 (3.78)[a]	10.20 (5.32)
Key chick forbs	3.48 (2.42)	2.32 (1.84)	16.38 (9.09)[a]	1.95 (1.70)	5.46 (3.62)[a]	8.17 (4.45)
Total forbs	18.13 (6.43)[a]	9.38 (6.46)	20.62 (9.25)[a]	6.44 (5.47)	17.54 (8.58)	16.29 (5.74)
Short grass	13.66 (6.77)[a]	5.84 (5.62)	6.74 (4.78)[a]	2.08 (2.69)	9.01 (4.53)	9.82 (3.94)
Tall grass	10.78 (7.05)	10.17 (7.48)	3.68 (4.88)	3.09 (4.05)	4.43 (4.08)[a]	1.39 (1.73)
Short shrub	22.79 (14.54)[a]	12.41 (9.07)	11.88 (8.09)	14.84 (8.03)	26.44 (10.18)	22.75 (9.16)
Medium shrub	10.75 (7.05)	11.47 (9.54)	7.45 (7.20)	9.92 (9.18)	0.00	0.00
Tall shrub	10.24 (11.88)	3.80 (5.97)	3.21 (7.18)	1.92 (4.21)	0.00	0.00
Total shrub	43.77 (10.77)[a]	27.68 (12.17)	22.54 (16.47)	26.67 (10.18)	26.44 (10.18)	22.75 (9.16)

	Mountain shrub		Bald Mountain burn		Catnip Mountain burn	
	Brood ($n = 9$)	Random ($n = 30$)	Brood ($n = 12$)	Random ($n = 20$)	Brood ($n = 8$)	Random ($n = 20$)
Variable	$\bar{x}$ (SD)	$\bar{x}$ (SD)	$\bar{x}$ (SD)	$\bar{x}$ (SD)	$\bar{x}$ (SD)	$\bar{x}$ (SD)
Key hen forbs	4.02 (3.12)[a]	2.36 (2.44)	6.74 (4.77)[a]	2.26 (2.28)	5.40 (6.78)	4.29 (4.52)
Key chick forbs	5.76 (3.31)[a]	2.48 (2.11)	5.18 (3.19)[a]	3.36 (3.95)	8.50 (6.90)	8.76 (8.41)
Total forbs	16.72 (7.75)	14.77 (7.40)	16.65 (4.12)	17.24 (9.42)	23.18 (10.55)	27.49 (20.45)
Short grass	7.52 (4.81)	9.81 (9.67)	11.62 (9.30)	8.52 (9.26)	9.41 (8.02)	7.61 (6.22)
Tall grass	9.70 (8.80)	13.04 (11.15)	18.28 (11.39)	26.24 (12.91)	9.60 (5.86)	13.32 (10.59)
Short shrub	31.48 (16.15)[a]	20.26 (12.64)	7.23 (3.83)[a]	17.78 (5.32)	12.73 (6.07)	8.44 (6.50)
Medium shrub	7.35 (10.35)	13.46 (9.08)	2.98 (3.68)	3.49 (5.29)	4.81 (8.92)	2.44 (6.310
Tall shrub	1.36 (2.82)[a]	6.35 (7.19)	0.00	0.00	0.00	0.00
Total shrub	40.18 (13.13)	40.06 (12.51)	10.21 (4.42)[a]	21.27 (7.99)	17.54 (9.80)	10.89 (8.21)

[a] Means within cover types differ ($P \leq 0.05$).

Table 3.11. Habitat characteristics (% cover) of sage-grouse brood locations during early and late brood-rearing periods at Sheldon National Wildlife Refuge, 1998-2000.

	Early brood-rearing (n = 115)		Late brood-rearing (n = 13)		
Habitat characteristic	$\bar{x}$	SD	$\bar{x}$	SD	P-value
Hen forbs	5.28	3.93	3.31	2.77	0.061
Chick forbs	6.02	4.70	4.38	3.50	0.200
Total forbs	17.93	8.32	18.15	12.62	0.512
Short grass	9.67	6.00	7.65	3.67	0.224
Tall grass	8.32	8.37	15.40	15.16	0.051
Short shrub	22.26	12.67	19.00	12.19	0.421
Medium shrub	3.68	9.68	2.03	5.20	0.382
Tall shrub	1.95	6.13	5.89	12.71	0.084
Total shrub	28.00	14.41	26.92	19.43	0.559

DISCUSSION

Nesting success of radio-marked hens in this study (36%) was similar to findings in other states, which ranged from 25% in Wyoming (Patterson 1952:104) to 64% in Montana (Wallestad and Pyrah 1974). Renesting rates from this study (29%) were higher than reported by Patterson (1952: 103) and Eng (1963) who suggested renesting rates of sage-grouse was 10%. Renesting accounted for approximately 18% of all broods recruited to 1 August and was likely an important factor in sage-grouse recruitment on SNWR.

Cover type was important in selection of nest sites at SNWR. Mountain big sagebrush cover types contained 41% (29/70) of all nests and 37% (10/27) of all successful nests. Mountain shrub was also important to nesting hens, containing 30% (21/70) of the nests, of which 30% (8/27) were successful. These results are similar to those reported by Hanf et al. (1994) in central Oregon. Other studies found that > 90% of nests found were under sagebrush (Patterson 1952:114, Gill 1965, Wallestad and Pyrah

1974, Braun et al. 1977, Gates 1983). In southeastern Idaho, nesting success for hens that selected non-sagebrush plants for nest sites was lower than for females using sagebrush for nest sites (Connelly et al. 1991). In contrast, results from SNWR indicated nest cover did not affect nesting success. However, results from SNWR were similar to Connelly et al.'s (1991) findings that nest-site selection was not related to experience. There was no difference between the proportion of yearling hens nesting in sagebrush and non-sagebrush nest cover compared to adults, indicating sage-grouse may select structural characteristics (e.g., residual herbaceous cover associated with shrub species used for nesting) during nest-site selection (Connelly et al. 1991).

Vegetative characteristics at successful nest sites were similar to unsuccessful nest sites but all nest sites had greater amounts of tall residual grass ($\geq$ 18 cm) than nest areas and random sites, and greater amounts of medium height shrub cover (40-80 cm) than at random sites. Gregg et al. (1994) also found that nesting sage-grouse selected cover types with a medium height shrub component and areas with greater cover of tall residual grass for nesting. Further, studies in southeastern Oregon demonstrated that habitat characteristics at nest areas could not be differentiated from those measured at random locations (Gregg 1991).

Habitat conditions that provide adequate residual herbaceous cover might mask the importance of vegetative structural characteristics that are selected by nesting sage-grouse occupying degraded rangelands (Fischer 1994). If a minimum cover or height value of habitat components is needed by females to nest successfully, and all available nesting habitats provides this minimum value, then selection may not be demonstrated for that vegetative component. Tall grass cover on SNWR was similar for successful and unsuccessful nest sites, regardless of cover type. When grass is tall and uniformly distributed throughout the study area, selection for this particular habitat component may be difficult to demonstrate.

Nest sites on SNWR were ≤ 16.5 km from the lek sites that hens were captured on. Consecutive year nesting data may indicate possible nest-site fidelity by female sage-grouse on SNWR. Distances moved from lek sites to initial nest locations may be an important consideration in sage-grouse management, but nest-site fidelity may be of even greater importance, particularly to evaluate impacts of land use changes on sage-grouse habitats (Berry and Eng 1985).

Additional results from this study indicated that hens with broods used areas with greater forb cover within cover types than at random sites, indicating use was influenced by availability of forbs. These findings are consistent with Drut et al. (1994), who noted that sage-grouse broods selected sites with greater frequency of forbs than at random sites.

An abundance and diversity of forbs were critical components of sage-grouse brood-rearing habitat in Montana (Peterson 1970). Klebenow (1969) noted that broods in Idaho used areas where forb availability was greatest. Previous studies on habitat use by sage-grouse hens with broods demonstrated that sage-grouse distribution and habitat selection were associated with plant phenology and desiccation of forbs (Klebenow and Gray 1968, Klebenow 1969, Oakleaf 1971, Wallestad 1971, Pyle 1992). In Idaho, broods were generally found in higher elevation bitterbrush stands as summer progressed, presumably because of the greater availability of succulent vegetation than in lower elevation sagebrush habitats (Klebenow 1969). On SNWR, sage-grouse hens initially used low sagebrush cover types during the early brood-rearing period and shifted to big sagebrush and mountain shrub cover types as the season progressed.

Other studies have reported changes in cover types, sagebrush height, and canopy cover used by broods throughout the summer. In Idaho, broods were observed in open stands of sagebrush with a canopy cover of < 30% (Klebenow 1969). Sagebrush height and canopy cover in Montana were greater at brood sites in late summer than in early summer (Peterson 1970, Wallestad 1971). On SNWR, sage-grouse hens with broods used areas having greater amounts of shrub cover within mountain big sagebrush cover types and less shrub canopy cover in the Bald Mountain burn sites than to random sites, but canopy cover of shrubs did not appear to be a factor in habitat use.

Home range size varied among broods. Sample size was too low to make comparisons of home range estimates of sage-grouse broods between years; however, in 1998, above average precipitation may have resulted in greater forb availability and may have influenced brood movements and home range size on SNWR. Increased quantity and quality of forbs during years of high precipitation results in increased chick growth and survival, which may be reflected in recruitment rates (Patterson 1952). Predation risks for chicks may increase when cover and forage availability are limited by precipitation.

MANAGEMENT IMPLICATIONS

Sage-grouse are sagebrush obligates, yet the importance of a balance of sagebrush, native grasses, and forbs for fulfilling their life history requirements has been well documented (Connelly et al. 2000*b*). Despite their dependence on sagebrush, virtually no undisturbed tracts of sagebrush-steppe habitat exist within the current distribution of sage-grouse (Schneegas 1967, Braun 1998). The primary factors that affect sagebrush ecosystems are habitat deterioration, loss, and fragmentation through sagebrush control programs for agricultural production (Yocum 1956, Swensen et al. 1987), increased livestock forage (Schneegas 1967), urban development (Call 1979, Braun 1998), and mining activities (Call and Maser 1985, Braun 1987). Additionally, historic overgrazing and altered fire regimes have resulted in shrub dominance at the expense of the herbaceous understory (Blaisdell et al. 1982, West and Hassan 1985, Laycock 1991, Winward 1991, Miller and Rose 1995). Observations from Patterson (1952:192) suggest that sage-grouse have not, and likely will not, acclimate their life history to fit land use practices that disturb large tracts of sagebrush rangelands, upon which sage-grouse are dependent.

Sage-grouse require vast expanses of suitable habitat (Eng and Schladweiler 1972, Berry and Eng 1985), which necessitates management on a landscape scale to ensure that life history needs of sage-grouse are met. To make certain that critical sage-grouse habitat is not lost, seasonal use areas for nesting, brood-rearing, and migration routes must be identified and managed appropriately to ensure that these habitats are available during the breeding season. Although trends of traditional habitat use by sage-grouse have been observed (Eng and Schladweiler 1972, Berry and Eng 1985, Connelly et al. 1988), site fidelity in sage-grouse remains poorly understood, necessitating the need for long-term telemetry studies, which follow individually marked birds over consecutive years. Information on the timing and distance of seasonal movements is necessary for: defining sage-grouse populations; identifying breeding, nesting, brood-rearing, and winter habitats; and evaluating impacts of land use practices on sage-grouse (Connelly et al. 1988).

Causes for declines in sage-grouse populations are varied, but ultimately are habitat based. Land-management practices that reduce herbaceous cover in sagebrush communities, in favor of shrub dominance, will not afford recovery of sage-grouse populations. Management practices (e.g., prescribed fire) that achieve a mosaic of food and cover suitable for sage-grouse and which recast the balance of native herbaceous species in degraded sagebrush communities may be necessary for restoration of sagebrush-steppe ecosystems, and ultimately, the restoration of sage-grouse populations and other species dependent upon sagebrush habitats.

CHAPTER 4. SHORT-TERM RESPONSE OF SAGE-GROUSE HABITATS TO WILDFIRE ON SHELDON NATIONAL WILDLIFE REFUGE, NEVADA

INTRODUCTION

Sagebrush-steppe communities, characterized by an overstory of sagebrush (*Artemisia* L. spp.) and an understory of perennial bunchgrasses and forbs, comprise the largest semi-arid ecosystem in the western United States, occupying approximately $45x10^6$ ha (West and Young 1998). The herbaceous understory is a particularly important component of the sagebrush-steppe ecosystem, providing food and cover for sage-grouse, and thus is an important indicator of sagebrush community health (Miller and Eddleman 2000).

Before Euro-American settlement of the West, fire was a common occurrence in some sagebrush-steppe cover types and increased the abundance of herbaceous species while reducing shrub overstories (Daubenmire 1968, Burkhardt and Tisdale 1976, Wright et al. 1979, Gruell 1985). Historically, the frequency of fire in sagebrush-steppe communities occurred every 100-200 years in low sagebrush (*A. arbuscula* Nutt.; Young and Evans 1981, Miller and Rose 1999), 50-100 years in Wyoming big sagebrush (*A. tridentata* Nutt. ssp. *wyomingensis* Beetle & Young; Wright and Baily 1982), and 12-25 years in more mesic mountain big sagebrush [*A. t.* Nutt. ssp. *vaseyana* (Rydb.) Beetle] cover types (Houston 1973, Burkhardt and Tisdale 1976, Gruell et al. 1994, Miller and Rose 1999).

The introduction of domestic livestock grazing in the late 19th century, and the subsequent history of overgrazing, dramatically changed sagebrush-steppe community structure (Miller et al. 1994). Associated understory species were not able to withstand the grazing pressure (Young et al. 1979), resulting in shrub dominance (Blaisdell et al. 1982, West and Hassan 1985, Laycock 1991, Winward 1991, Miller and Rose 1995). The loss of herbaceous vegetation, combined with the removal of fine fuels, and human-induced fire suppression efforts altered natural fire regimes in sagebrush-steppe ecosystems (Winward 1991, West 1999). Sagebrush-steppe communities evolved with periodic low-intensity wildfires (Gruell 1996) and were dependent on this intermittent removal or thinning of sagebrush cover to maintain balanced understories (Winward 1991).

Practices that reduce herbaceous cover in sagebrush communities may adversely affect sage-grouse nesting and brood-rearing habitat. Forbs constituted 20-50% of pre-laying sage-grouse hen diets in Oregon and were higher in nutrient content (crude protein, phosphorous, calcium) than sagebrush (Barnett and Crawford 1994). Studies by Gregg et al. (1994) and DeLong et al. (1995) identified relationships between vegetative cover and successful nesting by sage-grouse. Greater amounts of tall residual grass (≥ 18 cm) and medium height shrub cover (40-80 cm) at nest sites decreased the risk of nest depredation (Gregg et al. 1994, DeLong et al. 1995). Habitat structural components and the availability of insects and succulent forbs are also important factors associated with habitat selection by hens with broods (Klebenow 1969, Peterson 1970, Wallestad 1971, Autenrieth 1981). Previous studies of habitat use by sage-grouse broods revealed that distribution and habitat selection by sage-grouse were associated with plant phenology and desiccation of forbs (Klebenow and Gray 1968, Klebenow 1969, Oakleaf 1971, Wallestad 1971, Pyle 1992). In southeastern Oregon, lower consumption of forbs and insects and increased reliance on sagebrush appeared to negatively affect chick survival (Drut et al. 1994).

Prolonged livestock grazing of upland meadows in northern Nevada made them less suitable for sage-grouse and reduced rangeland forbs (Neel 1980). The reduction or removal of livestock, and management practices (e.g., prescribed burning), may enhance recovery of degraded sagebrush communities. However, livestock removal alone may not increase forbs if shrub dominance inhibits the development of native herbaceous understories (Young and Evans 1978). Prescribed fire may increase the availability of forbs in some sagebrush habitats characterized by shrub dominance (Pyle and Crawford 1996).

Prescribed fire is controversial in sage-grouse management (Dalke et al. 1963, Braun et al. 1977, Connelly et al. 1981). Sagebrush is temporarily eliminated following burning and, therefore, results in short-term losses of cover for sage-grouse (Young and Evans 1978). However, burning in small areas may achieve a mosaic of food and cover suitable for sage-grouse (Klebenow 1972). Fischer et al. (1996) found that the short-term effects of prescribed fire did not enhance brood-rearing habitat, and may have been detrimental to Formicidae, insects important in sage-grouse chick diets. However, spring and fall prescribed burns did not adversely affect most insects and increased total forb cover and diversity in sagebrush-bitterbrush [*Purshia tridentata* (Pursh) DC.] stands (Pyle and Crawford 1996).

The goal of this study was to measure the short-term effects of wildfire on habitat characteristics necessary for fulfilling some of the life-history needs of sage-grouse. Specifically the objectives were to: 1) Determine the response of native grasses, forbs, shrubs, and ground-dwelling arthropods to wildfire, and 2) Compare these changes to associated unburned control sites.

METHODS

Habitat Characteristics

Plant response following wildfire was evaluated within mountain big sagebrush communities on the 1988 Bald Mountain and 1996 Catnip Mountain wildfire sites on SNWR. Frequency of occurrence and percent canopy cover of shrubs was measured with the line intercept method (Canfield 1941) at wildfire and control sites with randomly placed 20-m transects. Habitat sampling was conducted for 2 brood-rearing periods: early (hatching through 6 weeks) and late (7 to 12 weeks after hatching). Early and late brood-rearing periods were determined from observations on habitat use by hens with 6 week old broods (Martin 1970) and information from Peterson (1970) who found a dietary change in juvenile sage-grouse approximately 6 weeks after hatching.

The height of each intercepted shrub was measured from the ground to the top of the canopy and classified as: short (< 40 cm), medium (40-80 cm), or tall (> 80 cm). Shrub canopy cover was recorded separately for each height class and identified to species. Species composition, cover (i.e., ocular estimates to the nearest percentage point), and frequency of grasses and forbs were estimated at 10 (20- x 50-cm) rectangular plots spaced equidistantly along the transect (Daubenmire 1959). Tallest droop heights of grasses (excluding flower stalks) were measured in each plot and classified as short (< 18 cm) or tall (≥ 18 cm). Forbs were identified to genus (species where possible) and phenological phase was recorded within each 20- x 50-cm plot. Plant nomenclature followed Hitchcock and Cronquist (1991).

Plant phenology was divided into 1 of 5 stages: vegetation stage, bud stage, flowering stage, post-flowering stage, and senesced. Plants were identified as succulent if > 50% of the leaves had not senesced. Forb species were classified as a particular phenological stage when > 50% of individual plants, within each 20- x 50-cm rectangular plot, reflected the same vegetative state (Baruan and Ramakrishnan 1989). Senescent forbs were not considered as available sage-grouse foods.

Data from Bald Mountain were collected on the wildfire site and an adjacent unburned control. On Catnip Mountain, a road separated the burned and unburned treatments. For Bald Mountain and Catnip Mountain elevation, soil, topography, and cover types were similar for burned and unburned control sites; therefore, any structural and compositional differences in vegetation between burn and unburned sites were assumed to be due to the fire disturbance. Samples were collected in wildfire sites from randomly located plots on burned and unburned areas. The position of each transect was determined from a randomly selected compass bearing and placed > 50 m from the road system or edge of burn. Starting point and distance traveled were determined from a random numbers table.

Differences in habitat characteristics between burned and unburned sites were conducted on 3 variables known to be important in sage-grouse nesting and brood-rearing habitats (Dalke et al. 1963, Peterson 1970, Wallestad 1971): total shrub cover, tall grass cover ($\geq$ 18 cm), and total forb cover. When necessary, variables were transformed to approximately normal distribution before statistical analysis; however, transformations could not normalize all the data. Therefore, Kruskal-Wallace single-factor analysis of variance (ANOVA) was used to examine if characteristics differed between treatments (Zar 1999:197). The level of significance was defined as $P \leq 0.05$ for all comparisons.

Arthropod Abundance

Arthropod abundance was measured with pitfall traps (Morrill 1975) in burned and unburned sites. Fifty traps, filled with a 1:1 saline solution, were placed in the ground, equidistantly along a randomly placed 200-m line transect at site. Insects were collected for 7 days during the early brood-rearing period and counts were made of total insects per sample for each taxonomic group. Only those Families known to be important in juvenile sage-grouse diets [Acrididae (grasshoppers), Formicidae (ants), Scarabaeidae (june beetles), and Tenebrionidae (darkling beetles)] were used to compare insect abundance between burned and unburned locations (Klebenow and Gray 1968, Peterson, 1970, Pyle and Crawford 1996).

Differences in arthropod abundance between burned and unburned sage-grouse habitat were assessed with a two-factor ANOVA (Zar 1999:231). The factors included TREATMENT, YEAR, and a TREATMENT*YEAR interaction. All variables were examined for normality, kurtosis, and skewness and a log transformation was used to approximate the normal distribution before statistical tests. Means and standard deviations were computed from non-transformed data. Analyses in which

TREATMENT*YEAR interactions were significant underwent a TREATMENT*YEAR mean separation applying Tukey's multiple comparison test (Zar 1999:260). The level of significance for statistical tests was defined as $P \leq 0.05$.

RESULTS

Habitat Characteristics

Bald Mountain

The frequency of occurrence and canopy cover estimates of forb, grass, and shrub species measured at the Bald Mountain wildfire and control areas for early and late brood-rearing periods are summarized in Appendices B and C. Collectively, 10 genera of grasses were recorded at Bald Mountain. The most common grass on the burn and controls sites was cheatgrass (*Bromus tectorum* L.), an exotic annual, which occurred at 48% of the burn and control sites with mean percent cover of 7.53 and 7.42, respectively. The next most common grass was needlegrass (*Stipa* L. spp.), occurring on 27% of the burn sites and 28% of the control sites with percent cover of 6.66 and 5.85, respectively. During the early brood-rearing period, 9 genera of grass contributed to 33% of total grass cover on burned and 27% on the control areas. Percent cover of tall grass ($H_{0.05,25,20} = 0.66$, $P = 0.417$) was not different between burned and unburned sites (Tables 4.1). Similarly, for the late brood-rearing period 10 genera of grass contributed to 26% total grass cover on the burn and 34% on the control areas. Cheatgrass composed 3% of the tall grass cover during the early brood-rearing period and 8% for the late brood-rearing period in Bald Mountain wildfire site. On Bald Mountain control sites, cheatgrass

Table 4.1. Percent cover for habitat characteristics on random wildfire and control sites during the early and late brood-rearing period, Sheldon National Wildlife Refuge, Nevada, 1998-2000.

		Burn			Control		
Location	Habitat characteristic	$\bar{x}$	SD	*n*	$\bar{x}$	SD	*n*
Bald Mountain early brood-rearing	Total forbs	17.48[a]	6.92	20	26.52	10.10	25
	Tall grass	18.96	8.17	20	18.78	11.50	25
	Total shrub	19.56[a]	13.38	20	40.79	15.06	25
Bald Mountain late brood-rearing	Total forbs	9.81	5.09	20	14.84	9.19	20
	Tall grass	26.24	12.91	20	27.44	15.07	20
	Total shrub	21.27[a]	7.99	20	41.04	8.31	20
Catnip Mountain early brood-rearing	Total forbs	28.45[a]	15.18	27	13.38	8.49	28
	Tall grass	8.84	7.82	27	9.85	7.22	28
	Total shrub	10.88[a]	76.78	27	33.28	9.49	28
Catnip Mountain late brood-rearing	Total forbs	23.62	19.99	19	12.52	11.74	20
	Tall grass	13.32	10.59	19	12.82	9.49	20
	Total shrub	10.89[a]	8.21	19	43.40	9.20	20

[a] Means within rows differ ($P \leq 0.05$).

composed 12% of total tall grass cover during the early brood-rearing period and 20% for the late brood-rearing period (Table 4.2)

Table 4.2. Percent cover of tall cheatgrass and total tall grass cover on random wildfire and control sites, Sheldon National Wildlife Refuge, Nevada, 1998-2000.

Location	Habitat characteristic	Early brood-rearing		Late brood-rearing	
		$\bar{x}$	SD	$\bar{x}$	SD
Bald Mountain burn	Tall cheatgrass	0.52	1.22	2.76	5.86
	Tall grass	18.96	8.17	34.76	14.16
	Total grass	32.64	10.28	26.24	12.91
Bald Mountain control	Tall cheatgrass	2.18	4.05	5.53	7.66
	Tall grass	18.78	11.50	27.44	15.07
	Total grass	29.96	10.96	33.84	12.65
Catnip Mountain burn	Tall cheatgrass	0.02	7.82	0.00	0.00
	Tall grass	8.84	7.82	13.32	10.59
	Total grass	16.68	10.58	20.26	9.39
Catnip Mountain control	Tall cheatgrass	1.29	5.89	1.34	3.38
	Tall grass	9.85	7.22	12.82	9.49
	Total grass	17.86	9.69	19.47	10.54

Sixty species of forbs were recorded in the burn and control locations for the early and late brood-rearing periods. Of 43 forb genera identified on the wildfire and control sites, 34 were on wildfire sites and 31 on control sites during the early brood-rearing season (Appendix B). Control sites had more total forbs ($H_{0.05,25,20} = 8.28$, $P = 0.004$) than burned sites (Table 4.1). Comparatively, 29 forb genera were identified on wildfire sites and 27 on control sites during the late brood-rearing season. (Appendix C). Dominant forbs included: mountain dandelion (*Agoseris/Microseris* spp.), littleflower collinsia (*Collinsia parviflora* Lindl.), lupine (*Lupinus* L. spp.), and pink microsteris [*Microsteris gracilis* (Hook.) Greene] during the early brood-rearing period and collomia (*Collomia* Nutt. spp.) during the late brood-rearing period. All other forbs were recorded in frequencies of < 25%. Frequency data from Bald Mountain suggested collomia, hawksbeard, lupine, and long-leaf phlox were more common on unburned control areas.

During the early brood-rearing period, mean shrub cover was 20% with mountain big sagebrush contributing 7% of the total, in the burn (Appendix B). Unburned controls had an average of 41% total shrub cover with mountain big sagebrush contributing 23% of the total. Control sites had more total shrub cover than unburned sites during the early ($H_{0.05, 25, 20} = 16.25$, $P \leq 0.001$) and late ($H_{0.05, 20, 20} = 28.71$, $P \leq 0.001$) brood-rearing period (Table 4.1).

Percent cover of total forbs and tall grass was similar between burned and unburned areas during the early brood-rearing period in all 3 years (Table 4.3). Total shrub cover was greater in control sites in 1998 ($H_{0.05, 22, 24} = 6.16$, $P = 0.008$) than in 1999 and 2000 (Table 4.3). During the late brood-rearing period, total forb cover was greater at burned and unburned sites in 1998 than in 1999 ($H_{0.05, 10, 10} = 5.85$, $P = 0.016$; $H_{0.05, 10, 10} = 10.57$, $P = 0.001$ burn and control, respectively). Comparisons of total forb cover in late brood-rearing burn and controls sites indicated the control had greater total forb cover ($H_{0.05, 10, 10} = 7.00$, $P = 0.008$) in 1998 compared to the burn (Table 4.4).

Table 4.3. Cover (%), by year, for habitat characteristics on random wildfire and control sites during the early brood-rearing period, Sheldon National Wildlife Refuge, Nevada, 1998-2000.

		Year					
		1998		1999		2000	
Location	Habitat characteristic	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Bald Mountain burn	Total forbs	20.23	8.07	14.73	4.39	--	--
	Tall grass	20.36	5.87	17.55	10.10	--	--
	Total shrub	16.67	13.33	22.49	13.46	--	--
Bald Mountain control	Total forbs	32.29	6.94	22.62	9.80	22.80	12.21
	Tall grass	21.88	14.49	16.88	9.72	16.36	8.30
	Total shrub	51.23A[a]	15.21	32.71B	9.36	36.06B	13.39
Catnip Mountain burn	Total forbs	21.14	10.85	26.71	9.47	17.86	8.01
	Tall grass	7.48	4.11	10.83	10.86	7.74	6.68
	Total shrub	11.91	5.98	8.89	8.58	12.21	11.86
Catnip Mountain control	Total forbs	15.29	10.82	13.36	7.49	10.41	5.36
	Tall grass	12.85	9.74	7.37	4.57	8.33	3.40
	Total shrub	27.50A	9.06	37.36B	8.89	36.55B	6.98

[a] Means followed by the same letter within a row do not differ ($P > 0.05$).

Table 4.4. Cover (%), by year, for habitat characteristics on random wildfire and control sites during the late brood-rearing period, Sheldon National Wildlife Refuge, Nevada, 1998-1999.

		Year			
		1998		1999	
Location	Habitat characteristic	$\bar{x}$	SD	$\bar{x}$	SD
Bald Mountain burn	Total forbs	12.68[a]	4.51	6.93	3.99
	Tall grass	30.21	12.97	22.26	12.18
	Total shrub	21.07	7.69	21.46	8.69
Bald Mountain control	Total forbs	21.69[a]	6.68	7.99	5.23
	Tall grass	31.83	18.88	23.04	8.95
	Total shrub	40.62	7.82	41.46	9.18
Catnip Mountain burn	Total forbs	37.69[a]	18.74	9.54	7.24
	Tall grass	13.42	8.43	13.20	13.13
	Total shrub	9.63	9.76	12.15	6.60
Catnip Mountain control	Total forbs	18.72[a]	12.56	6.31	6.91
	Tall grass	13.63	8.71	12.01	10.63
	Total shrub	43.92	11.17	40.69	6.95

[a] Means within rows differ ($P \leq 0.05$).

Catnip Mountain

The frequency of occurrence and canopy cover estimates of forb, grass, and shrub species measured at the Catnip Mountain wildfire and control areas for early and late brood-rearing periods are summarized in Appendices D and E. Collectively, 11 genera of grasses were recorded at Catnip Mountain. The most common grass on wildfire and control sites was squirreltail [*Sitanion hystrix* (Nutt.) J.G. Sm.], occurring at 46% of the burn sites and 30% of the control sites with mean percent cover of 6.59 and 3.46, respectively. Cheatgrass occurred on 16% of burn sites and 18% of control sites with a mean percent cover of 1.20 and 3.30, respectively. During the early brood-rearing period 12 genera of grass contributed to 17% total grass cover on wildfire sites and 19% on unburned sites. Tall grass cover was similar for burned and unburned sites ($H_{0.05,27,26} = 0.69$, $P = 0.408$; Table 4.1). Similarly, for the late brood-rearing period 11 genera of grass contributed to 20% total grass cover on wildfire sites and 29% on unburned sites during the late brood-rearing period. Cheatgrass composed < 1% of tall grass cover during the early and late brood-rearing period on Catnip Mountain wildfire sites. On Catnip Mountain control sites, cheatgrass composed 13% of the total tall grass cover during the early brood-rearing period and 5% for the late brood-rearing period (Table 4.2).

Sixty species of forbs were recorded in the control sites for the early and late brood-rearing periods. Thirty-five forb genera were found on wildfire sites compared to 34 on unburned controls during the early brood-rearing period (Appendix D). Catnip Mountain had greater total forb cover ($H_{0.05,28,27} = 18.00$, $P \leq 0.001$) on burn compared to unburned sites (Table 4.1). During the late brood-rearing period, 28 forb genera were identified in the wildfire sites and 24 in the control areas (Appendix E). Although treatment effects were not detected between burn and control sites, during the late brood-rearing period ($H_{0.05,\,38,39} = 2.20$, $P = 0.146$), total forb cover was greater on burned (28%) compared to unburned (13%) sites (Table 4.1). Dominant forb species included: mountain dandelion, littleflower collinsia, desert parsley, pink microsteris, and lupine. All other forbs were recorded in frequencies of < 25%. Frequency data from Catnip Mountain suggested mountain dandelion, hawksbeard, lupine and groundsmoke (*Gayophytum* A. Juss. spp.) were more abundant, while buckwheat was less common on wildfire sites.

During the early brood-rearing period mean cover of shrubs was 11%, with mountain big sagebrush contributing 1% of the total, in the wildfire site. Comparatively, in the unburned control total shrub cover was 33% with mountain big sagebrush contributing 21% of the total. Total shrub cover was less on burn plots for both early ($H_{0.05,\,28,\,27} = 32.29$, $P \leq 0.001$) and late ($H_{0.05,\,20,\,20} = 28.98$, $P \leq 0.001$) brood-rearing (Table 4.1).

Percent cover of total forbs and tall grass was similar between burned and unburned areas during the early brood-rearing period in all 3 years (Table 4.3). There was greater total shrub cover ($H_{0.05,25,27} = 4.45$, $P = 0.022$) on the control site during 1999 and 2000 than in 1998 (Table 4.3). During the late brood-rearing period, total forb cover was greater on burned and unburned sites in 1998 than in 1999 ($H_{0.05,\,10,\,10} = 7.82$, $P =$ 0.005; $H_{0.05,\,10,\,10} = 7.21$, $P = 0.007$ burn and control, respectively). Total forb ($H_{0.05,\,10,\,10}$

= 4.32, $P = 0.038$) cover during 1998 was greater in wildfire sites than the control during the late brood-rearing period (Table 4.4).

Arthropod Abundance

Collections of ground dwelling arthropods in burned and unburned sites demonstrated that the same 4 taxa occurred in both Bald Mountain and Catnip Mountain wildfire and control sites. On Bald Mountain, more ants ($F_{1,293} = 56.93$, $P \leq 0.001$) were collected on wildfire sites compared to the unburned control (Table 4.5). Ant (Formicidae) abundance varied by year ($F_{2,293} = 26.80$, $P \leq 0.001$), likely due to the many ants collected on wildfire sites in 1999 (Table 4.6). However, there was no interaction between TREATMENT and YEAR ($F_{2,293} = 1.51$, $P = 0.224$) indicating any difference in ant abundance between burn and control sites was similar between years (Table 4.5). The abundance of darkling beetles (Tenebrionidae) on burned and unburned sites did not differ ($F_{1,292} = 0.85$, $P = 0.358$) although the TREATMENT*YEAR interaction was significant ($F_{2,292} = 9.61$, $P \leq 0.001$; Table 4.5). This suggests abundance of Tenebrionids was depressed in 1998 but were numerically greater in wildfire sites during 1999 and 2000 (Table 4.6). No differences were detected between other taxonomic groups (Table 4.5).

Table 4.5. *P*-values from two-factor ANOVA of pitfall trap samples at random burned and unburned locations, Sheldon National Wildlife Refuge, Nevada, 1998-2000.

Location	Taxa	TREATMENT	YEAR	TREATMENT x YEAR
Bald Mountain	Acrididae	0.839	0.660	0.469
	Formicidae	≤ 0.001	≤ 0.001	0.224
	Scarabaeidae	0.484	0.393	0.799
	Tenebrionidae	0.358	≤ 0.001	≤ 0.001
Catnip Mountain	Acrididae	0.053	0.655	0.100
	Formicidae	0.501	0.827	0.009
	Scarabaeidae	0.172	0.005	0.171
	Tenebrionidae	0.001	≤ 0.001	0.229

Table 4.6. Arthropod abundance (total insects captured/transect) from Bald Mountain pitfall trap samples at burned and unburned locations, Sheldon National Wildlife Refuge, Nevada, 1998-2000.

	Year					
	1998		1999		2000	
Taxa	Burn	Control	Burn	Control	Burn	Control
Acrididae	5	3	2	3	2	4
Formicidae	2,533	1,276	22,700	3,282	4,096	2,044
Scarabaeidae	2	5	7	5	1	3
Tenebrionidae	77	157	500	411	260	150

On Catnip Mountain, burned areas had a greater abundance of darkling beetles ($F_{1,292} = 10.92$, $P = 0.001$). The abundance of grasshoppers (Acrididae) was similar on burned and unburned sites ($F_{1,293} = 3.77$, $P = 0.053$); however, sample size may have been too small for the treatment effect to be detected (Table 4.7). The abundance of ants on burned and unburned sites did not differ ($F_{1,293} = 0.46$, $P = 0.500$) although the TREATMENT*YEAR interaction was significant ($F_{2,293} = 4.80$, $P = 0.009$; Table 4.5). This suggests ant abundance was numerical greater in control sites during 1998 and 2000.

Abundance of june beetles (Scarabaeidae) was similar on burned and unburned controls ($F_{1,293} = 1.87$, $P = 0.172$).

Table 4.7. Arthropod abundance (total insects captured/transect) from Catnip Mountain pitfall trap samples at burned and unburned locations, Sheldon National Wildlife Refuge, Nevada, 1998-2000.

	Year					
	1998		1999		2000	
Taxa	Burn	Control	Burn	Control	Burn	Control
Acrididae	3	1	3	1	2	0
Formicidae	1,800	2,155	1,362	503	651	702
Scarabaeidae	1	15	12	10	40	9
Tenebrionidae	25	45	41	34	71	40

DISCUSSION

The results indicated plant communities in the wildfire and associated control sites did not differ appreciably in species composition. The 1988 Bald Mountain wildfire site contained adequate grass height, percent tall grass cover, and total shrub canopy cover required for nesting (see Connelly et al. 2000*b*). Burning on the Bald Mountain site had little stimulatory effect on total forb cover 10 to 12 years post-burn. However, alteration of the sagebrush community did not limit sage-grouse use for successful nesting and brood-rearing (Chapter 3).

Wildfires did not increase frequency of exotic plant species (e.g., cheatgrass), nor did wildfire appear to have a detrimental effect on native perennial grasses (*Agropyron, Festuca, Elymus, Stipa, Poa, Sitanion,* and *Oryzopsis*). Other authors have noted that cover of perennial bunchgrasses gradually increased following burning (Harniss and Murray 1973, Young and Evans 1978, Wamboldt and Payne 1986), particularly if there was a high density of native grasses present before the fire (West and Hassan 1985). Results from this study indicate perennial bunchgrass had cover levels similar to those on unburned controls. Native bunchgrasses comprised 68% of total grass cover on the Bald Mountain wildfire site. This compares to cheatgrass, which composed 26% of total grass cover on the Bald Mountain burn. On Bald Mountain control sites, cheatgrass composed 23% of the total grass cover; nearly as much as in the burn site. On Catnip Mountain, 89% of the total grass cover was due to perennial grass species. Cheatgrass made up < 1% of the total grass cover on both Catnip Mountain wildfire and control sites, suggesting cheatgrass was not a major component of the pre-burn community. Although cheatgrass occurred in Bald Mountain and Catnip Mountain mountain big sagebrush communities, cheatgrass typically will not dominate in more mesic sagebrush cover types (e.g., mountain big sagebrush) above 1,500 m in elevation (Miller and Eddleman 2000).

The 1996 Catnip Mountain burn was effective at changing the mountain big sagebrush community structure to one dominated by native grasses and forbs. Burning increased frequency of squirreltail and forbs, particularly the Cichorieae (e.g., milky-juiced composites) and the annual *Microsteris gracilis.* Results were similar to other studies, which noted an increase in Cichorieae following burning in mountain big sagebrush communities (Blaisdell 1953, Mangan and Autenrieth 1985, Martin 1990, Pyle and Crawford 1996). In addition, McDowell (2000) noted higher frequencies of *Agoseris* spp. and *Microsteris gracilis* 1 and 2 years post-burn in mountain big sagebrush communities in southeastern Oregon. Total forb cover was greater on Catnip Mountain burn sites during the early and late brood-rearing period. These results are consistent with previous studies of prescribed fire effects in big sagebrush cover types (Blaisdell 1953, Muegler and Blaisdell 1958, Cook et al. 1994, McDowell 2000). The increase in total forb cover in 1998 during the late brood-rearing period was likely associated with above normal precipitation and favorable growing conditions during that year.

Past research has suggested that fire may benefit sage-grouse brood habitat if the burn produces a mosaic of successionally variable sagebrush habitat interspersed with open patches that have increased forb production (Klebenow 1972). Wildfire reduced total shrub cover at both Bald Mountain and Catnip Mountain, which is the primary factor that influences competitive interactions between the herbaceous understory and shrub component (Sneva et al. 1984, Winward 1991). Percent cover of rabbitbrush (*Chrysothamnus* Nutt. spp.) and horsebrush (*Tetradymia* DC. spp.) was slightly higher on the wildfire sites. These results are consistent with previous studies, which reported increased yields of these species on burned plots (Chadwick and Dalke 1965, Harniss and Murray 1973).

Post-fire reestablishment of big sagebrush depends on the species involved (Bunting 1985). Mountain big sagebrush establishes readily from seed (Winward 1970) and typically the community reestablishes rapidly following fire (Tisdale 1994). However, Nelle et al. (2000) found burning resulted in a long-term negative impact on sage-grouse nesting habitat because mountain big sagebrush communities required > 20 years for canopy cover to reestablish at levels sufficient for nesting. Preliminary results of shrub reestablishment following the Catnip Mountain wildfire suggested conditions prior to and following the burn allowed shrubs to reestablish to nearly fully stocked levels (i.e., 0.7 to 1.4 plants/m^2), although cover was only 12.5% of pre-burn levels (Ziegenhagen et al. 2000; R.F. Miller, Oregon State University, personal communication). In mountain big sagebrush communities, across 8 burn sites in eastern Oregon, northwestern Nevada, and northeastern California, full shrub canopy cover was achieved 14-27 years post-burn (Ziegenhagen et al. 2000).

The importance of insects in juvenile sage-grouse diets during early brood-rearing is well documented (Patterson 1952, Klebenow and Gray 1968, Peterson 1970, Drut et al. 1994). Further, consumption of invertebrates by juvenile sage-grouse was correlated with chick survival and growth (Johnson and Boyce 1990). In southeastern Idaho, prescribed fire negatively impacted arthropod abundance in 1 of 3 insect Orders important in sage-grouse chick diets and did not enhance sage-grouse brood-rearing habitat (Fischer et al. 1996). Results from this study indicated that fire did not negatively impact arthropod abundance .

Grasshopper abundance was low in both wildfire and unburned control sites, but appeared to be greater in wildfire sites. The small sample size may be due to the sampling procedure, which may not have produced an accurate assessment of Acrididae response to wildfire. However, fire has been shown to result in increased densities of grasshoppers in tall grass prairie habitats (Nagel 1973, Evans 1984). The increase in Tenebrionidae in both wildfire sites was consistent with results from Parmenter and MacMahon (1984), who found that removal of shrubs from a shrub-steppe community in Wyoming did not adversely affect abundance of darkling beetles. Further, Rickard

(1970) concluded that occurrence of shrubs was not necessary for the persistence of ground-dwelling beetles in big sagebrush-bitterbrush communities in southeastern Washington. In Illinois, Rice (1932) collected more ants on burned prairie sites than on nearby controls. Other studies have reported either abundance of ants was greater on burned areas compared to unburned controls (Hurst 1970, Anderson et al. 1989, Andersen 1991) or that ants were not negatively impacted by fire (Warren et al. 1987, Zimmer and Parmenter 1998). Results from this study are consistent with the literature: Bald Mountain wildfire sites had greater abundance of ants compared to adjacent unburned control sites; on Catnip Mountain, abundance of ants was similar between burned and unburned sites.

The ultimate evaluation of the effects of wildfire is use by sage-grouse for fulfilling all of their life history needs. Gates (1983) reported greater use of burned sagebrush-steppe habitat by sage-grouse; however, Bensen et al. (1991) found sage-grouse use of burn sites was limited to areas with remnant patches of sagebrush. Although small sample sizes did not warrant statistical comparisons of use versus availability of burned and unburned sites, wildfire sites may be important for use as sage-grouse brood-rearing habitats (Chapter 3). Of 390 locations of 20 radio-marked hens with broods, 19% (76/390) were in the 1988 Bald Mountain wildfire site. Only the low sagebrush cover type had a higher proportion of use by sage-grouse broods (40%). However, only 3% (13/390) of the brood locations were observed in the 1996 Catnip Mountain wildfire site. Additionally, of the 22 radio-marked hens within the Bald

Mountain vicinity, 17% (3/18) nested within the wildfire site. Of those, 67% (2/3) nested successfully.

Data from SNWR indicated fire may increase the abundance of forbs and insects available to sage-grouse in mountain big sagebrush habitats used for brood-rearing, particularly in areas where dense shrub cover excludes the herbaceous vegetation. The short-term habitat response to wildfire in this study indicates prescribed fire may be a useful land management tool to achieve management objectives to manipulate vegetation and improve wildlife habitat in mountain big sagebrush communities on SNWR.

MANAGEMENT IMPLICATIONS

Fire is a natural part of the sagebrush-steppe ecosystem and is both an inexpensive and effective means of controlling sagebrush in shrub dominated communities (Ralphs and Busby 1979). However, several considerations must be made to predict the outcome and potential benefits of fire in the sagebrush-steppe ecosystem. Fire may be an effective management tool in mountain big sagebrush communities where sagebrush is abundant, an understory of native grasses and forbs are present, and aggressive exotic plant species (e.g., cheatgrass) are limited (Miller and Eddleman 2000). However, in Wyoming big sagebrush communities, where forb abundance and biotic potential is typically lower compared to other sagebrush habitats, fire may not be as effective in maintaining or rehabilitating herbaceous understories (Bunting et al. 1987, Byrne 2002) and does not appear to enhance sage-grouse habitat (Fischer et al. 1996). Further, burning sagebrush-steppe communities, which are characterized by a predominately cheatgrass understory, is likely to promote more cheatgrass, increase fire frequency, decrease occurrence of native shrubs, grasses, and forbs, and thus result in a loss of sage-grouse habitat (West and Hassan 1985, Miller and Eddleman 2000).

The sagebrush-steppe arthropod fauna is strongly associated with the plant community and forb diversity and abundance. The response of prairie insects to prescribed fire has been well documented (Cancelado and Yonke 1970, Nagel 1973, Panzer and Schwartz 2000); however, the effect of fire on sagebrush-steppe arthropod communities is poorly known. Invertebrate populations naturally fluctuate, both temporally and spatially; therefore, treatment effects may be difficult to determine if analyses are conducted at a broad level of identification. Fire effects on individual arthropod species, which may be negatively impacted by fire, may not be apparent at the Order or Family level (Friend 1996). Thus, collection of pre-treatment baseline information, replicated sampling of adjacent unburned controls and pre- and post-burned sites, and long-term monitoring is necessary to assess the effects of land management practices on the overall composition of sagebrush-steppe arthropod assemblages.

When considering fire as a tool to manage sagebrush habitat, land managers must also account for the habitat needs of sage-grouse during all stages of their life cycle. Sagebrush-steppe communities must provide forbs for pre-laying hens and chicks (Barnett and Crawford 1994, Drut et al. 1994), grass and shrub cover for secure nesting (Gregg et al. 1994, DeLong 1995), insects during brood-rearing (Patterson 1952, Klebenow and Gray 1968, Peterson 1970), and sagebrush for late summer and winter foods. Prescribed fire may produce higher yields of forbs important for pre-laying hens and brood-rearing, but may negatively impact essential sagebrush-steppe habitat that provide food and cover on sage-grouse winter ranges (Call and Maser 1985, Connelly et al. 2000*a*). Thus, no decisions on habitat manipulations in sagebrush-steppe ecosystems should be made without documenting winter habitat needs for sage-grouse.

Although results from this study indicate vegetative and structural components needed for successful sage-grouse nesting and brood-rearing were found in wildfire sites and fire did not negatively impact arthropod abundance, land managers should be cautious in the use of prescribed fire as a management tool for sage-grouse habitats. Land managers and wildlife biologists must develop long-term responses of plants and insects that may provide critical foods to hens and chicks (specifically, species composition, quantity, nutrient content, and differential phenology). Further, long-term breeding season data, in conjunction with detailed fire histories, to ascertain temporal and spatial effects of sage-grouse habitat use and selection are not available. Thus, wildlife biologists and managers must ascertain the use of burned and unburned areas by sage-grouse for fulfilling all of their life history needs.

CHAPTER 5. PHYSIOLOGY AND REPRODUCTIVE ECOLOGY OF GREATER SAGE-GROUSE FEMALES ON SHELDON NATIONAL WILDLIFE REFUGE, NEVADA AND HART MOUNTAIN NATIONAL ANTELOPE REFUGE, OREGON

INTRODUCTION

Formerly one of the most abundant game birds in the western United States and southwestern Canada, Greater Sage-Grouse (*Centrocercus urophasianus*) have declined throughout much of their range (Johnsgard 1983, Connelly and Braun 1997, Braun 1998). Current sage-grouse distribution extends from central Washington to southern Alberta and Saskatchewan, east to western North and South Dakota, and south to northeastern California, Colorado, Montana, Nevada, Oregon, Utah, and Wyoming (Johngard 1983, Drut 1994), closely paralleling the distribution of sagebrush-steppe ecosystems (Autenrieth 1981). Since Euro-American settlement of the West, sage-grouse have been extirpated from 5 states and 1 Canadian province (Braun 1998).

The decline in sage-grouse populations has been attributed to alteration of sage-grouse habitats by expanding agriculture and urban development, sagebrush (*Artemisia* L. spp.) control programs, altered fire regimes, and prolonged drought throughout the western rangelands in the 1930s and again in the late 1980s and early 1990s (Patterson 1952:15, Dalke et al. 1963, Johnsgard 1983, Fischer 1994, Hanf et al. 1994). Klebenow (1972) noted the decline in sage-grouse numbers coincided with the period of maximum use of native rangelands by domestic livestock from 1900 to 1915. Historic overgrazing was associated with alteration of sagebrush habitats that resulted in shrub dominance at the expense of the herbaceous understory (Blaisdell et al. 1982, West and Hassan 1985, Laycock 1991, Winward 1991, Miller and Rose 1995).

The current sage-grouse breeding population in Nevada is estimated at < 15,000 individuals (Braun 1998). Sage-grouse in northwestern Nevada declined in abundance and distribution during the mid-1960s. Although analysis of numerical trend data indicated significant declines in sage-grouse productivity (chicks/hen) from 1965-1975 (Zunino 1984), sage-grouse production on Sheldon National Wildlife Refuge (SNWR) was greater than on areas surrounding the Refuge (Klebenow 1985). Present spring sage-grouse populations on SNWR have been estimated at approximately 1,569 individuals (J.K. Barnett, U.S. Fish and Wildlife Service, personal communication).

In Oregon, sage-grouse declined in abundance and distribution in the early 1900s and occupied approximately 50% of their original range by 1940 (Crawford and Lutz 1985). Numerical trend data collected by the Oregon Department of Fish and Wildlife since 1940 indicated that populations had declined approximately 60% and productivity measures (chicks/adult and percentage of adults with broods) had decreased nearly 80% (Crawford and Lutz 1985).

Declines in sage-grouse abundance in Nevada and Oregon were attributed to low productivity (Crawford and Lutz 1985, Klebenow 1985). Factors influencing declines in productivity include: lowered reproductive success, possibly associated with reduced availability of forbs for pre-laying hens (Barnett and Crawford 1994); reduced nest success associated with inadequate residual herbaceous cover (Gregg et al. 1994, DeLong et al. 1995, Sveum et al. 1998); and lowered chick survival associated with reduction of forbs used for food (Drut et al. 1994).

Traditionally, wildlife studies have involved measuring habitat components and have often not considered physiological data, which may be important in learning what is regulating a population. Several studies have indicated nutritional variation in wild breeding bird populations as affecting reproductive success (Lack 1966, 1968; Ryder 1970; Moss and Watson 1974; Moss et al. 1975; Newton 1979). Information on hematological values and serum blood chemistries is available for domestic birds, but little has been published for wild avian species (Zinkl 1986, Kaneko et al. 1997), and information for sage-grouse is not available. Reference values for hematology and serum chemistry may be useful in determining the health of wildlife species (Cambell 1994) and may provide both insight into differences in habitat components and a means for quantitative assessment of the "nutritional adequacy" of the habitat (Seal 1978).

In 1995, the U.S. Fish and Wildlife Service (USFWS) implemented the first limited entry sage-grouse hunt on SNWR to obtain wings from harvested grouse to better estimate sage-grouse recruitment rates on the Refuge. Before 1995, the 10 year average for the recruitment index on SNWR was 1.84 chicks/hen (Refuge Files, 1994, USFWS, Lakeview, Oregon, USA). From 1995-1997, sage-grouse production on SNWR ($\bar{x}$ = 64% immatures in fall harvest, 2.47 chicks/hen, $n = 446$ wings; USFWS 1997, Sage-grouse Production Report, Lakeview, Oregon, USA) was greater compared to the long-term average in Oregon during the past 15 years ($\bar{x}$ = 43% immatures in the fall harvest, $n = 6{,}438$ wings; Crawford and Torland 2000) and Hart Mountain National Antelope Refuge (HMNAR), Oregon ($\bar{x}_{1989\text{-}1997} = 0.21$ chicks/hen). On HMNAR, sage-grouse populations fluctuated between the 1940s and 1980s; however, overall numbers of sage-grouse declined from an estimated 8,750 birds in the 1940s to approximately 2,000 in the 1980s (Pyle et al. 1990). Because recruitment of chicks was higher on SNWR than areas adjacent to the Refuge, elements of this study were directed toward features that related to higher chick survival (e.g., physiology of hens and availability and nutrient content of forbs) and, ultimately, recruitment into the fall population. The objectives of this study included: 1) Evaluation of reproductive parameters to discern differences between SNWR and areas surrounding the Refuge; 2) Comparison of habitat characteristics in cover types used by hens radio-marked on SNWR during the breeding season with other populations; 3) Measurement of nutrient content of forbs in the diet of juvenile sage-grouse in comparison to adjacent locations in southeastern Oregon; and 4) Establishment of hematological and serum chemistry reference ranges for sage-grouse hens to assess physiological condition. Hart Mountain National Antelope Refuge served as a comparison site for measures of reproductive parameters, habitat components (forbs, tall residual grass, and shrub cover) that were potentially related to reproductive success, chemical composition of forbs, and physiology of sage-grouse hens.

METHODS

Trapping and Radio-Marking

Sage-grouse were captured from mid-March to mid-April, 1998-2000 using spotlighting techniques (Giesen et al. 1982, Wakkinen et al. 1992). Sage-grouse hens were fitted with a serially-numbered aluminum leg band and a 20-g necklace-mounted ATS radio transmitter (Advanced Telonics Systems, Inc., Insanti, MN, USA). Sex and age of radio-marked birds were assigned on the basis of plumage characteristics and wing molt (Crunden 1963, Dalke et al. 1963).

Sage-grouse were monitored 2 times/wk with a hand-held antenna and portable receiver throughout the breeding season to ascertain nest initiation rate and estimate nesting success. When monitoring revealed that a hen had initiated a nest, the hen was approached until observed on the nest. Nesting hens were then monitored remotely (> 25 m) to avoid disturbance. Once monitoring revealed a hen had moved away from the nest and incubation had likely ceased, the nest was examined to determine fate. Nests were classified as successful if ≥ 1 egg hatched. Depredated nests were distinguished from successful nests by the presence of a firmly attached shell membrane in broken eggs (Wallestad and Pyrah 1974).

Home range estimates were obtained using the Animal Movement Analysis extension in ArcView GIS 3.2a (Environmental Systems Research Institute, Inc., Redlands, CA, USA). Home ranges for each brood were delineated using the 100% minimum convex polygon method (Mohr 1947) and included all locations from the time of hatch through 1 August (Wallestad 1971). Sample size (i.e., minimum observations per brood < 50) precluded the use of other home range estimators (e.g., kernel estimates; Seaman et al. 1999).

Reproductive Success

Nest initiation rates, nest success, renesting rate, renest success, mean clutch size, brood success, and chicks/hen were ascertained from following radio-collared hens. Nest initiation rates were defined as the number of hens known to initiate a nest divided by the total number of radio-marked females alive at the onset of the breeding season. Nesting success was calculated by dividing the number of successful nests by the total number of nesting hens. Clutch size was estimated after hatching by examination of the eggshell fragments. Brood success was calculated by dividing the number of hens that recruited ≥1 chick to 1 August by the total number of successful nests. Recruitment (chicks/hen) was calculated as the number of chicks that survived to 1 August divided by the total number of radio-marked hens still alive at the onset of nesting.

To examine if sage-grouse productivity parameters differed by site or year, a factorial analysis of variance (ANOVA) was conducted on data from SNWR and HMNAR (Zar 1999:283). The factors included: SITE, YEAR, REPRODUCTIVE PARAMETER, SITE*REPRODUCTIVE PARAMETER, and YEAR*REPRODUCTIVE PARAMETER. The level of significance for statistical test was defined as $P \leq 0.05$.

Habitat Characteristics

Four cover types used by sage-grouse for nesting and brood-rearing were compared between study areas during 2 periods (spring and summer): Wyoming big sagebrush (*A. tridentata* Nutt. ssp. *wyomingensis* Beetle & Young), mountain big sagebrush [*A. t.* Nutt. ssp. *vaseyana* (Rydb.) Beetle], low sagebrush (*A. arbuscula* Nutt.), and mountain shrub. Canopy cover of shrubs were measured at random locations using the line intercept method (Canfield 1941) along 2 (10-m) perpendicular transects. The height of each intercepted shrub was measured from the ground to the top of the canopy and classified into 1 of 3 classes: short (< 40 cm), medium (40-80 cm), or tall (> 80 cm).

Shrub canopy cover was recorded separately for each height class and identified to species. Species composition, cover (i.e., ocular estimates to the nearest percentage point), and frequency of grasses and forbs were estimated at 5 (20- x 50-cm) rectangular plots spaced equidistantly along each transect (Daubenmire 1959). Tallest droop heights of grasses (excluding flower stalks) were measured in each plot. Grass height was classified as short (< 18 cm) or tall (≥ 18 cm).

Grasses and forbs were identified to genus (species where possible). Forbs were categorized as those known to be important in sage-grouse hen and chick diets and total forbs. Hen forbs were identified as those that composed > 1% of the diet by weight (Barnett and Crawford 1994) and included: Desert parsley (*Lomatium* Raf. spp.), hawksbeard (*Crepis* L. spp.), long-leaf phlox (*Phlox longifolia* Nutt.), pussytoes (*Antennaria* Gaertn. spp.), mountain dandelion (*Agoseris* Raf. spp.), clover (*Trifolium* L. spp.), milkvetch (*Astragalus* L. spp.) and buckwheat (*Eriogonum* Michx. 0spp.). Chick forbs were identified from crop contents and were defined by aggregate mass of ≥ 1 % or frequency of occurrence ≥ 10% (Drut et al. 1994; Table 3.1). Plant nomenclature followed Hitchcock and Cronquist (1991).

Random sites were selected from cover type maps of the study areas. The position of the first transect was determined from a randomly selected compass bearing and placed > 50 m from the road system or edge of cover type. Percent cover of forb, grass, and shrub species measured at random locations were compared among cover types between SNWR and HMNAR. Kruskal-Wallis single-factor ANOVA was used for all comparisons. If a significant ANOVA was found, nonparametric multiple comparisons ($\alpha = 0.05$) were used to identify which habitat components contributed to the difference (Zar 1999:223). Nonparametric tests were used because assumptions of parametric tests (e.g., normality and homoscedasticity) were not met (Zar 1999:197). Significance was defined as $P \leq 0.05$.

Nutrient Analysis

In 1999, long-leaf phlox was collected during the flowering stage from 4 randomly-selected low sagebrush locations on SNWR and HMNAR. All other forbs were collected from randomly-selected locations in 2000 during the post-flowering stage. Forbs were selected after an extensive literature review of food habits of juvenile sage-grouse (Klebenow and Gray 1968, Martin 1970, Peterson 1970, Oakleaf 1971, Wallestad 1971, Evans 1986, Pyle 1992, Drut et al. 1994, Johnson and Boyce 1990, Pyle and Crawford 1996) and included: pursh's milkvetch (*A. purshii* Dougl. Ex Hook.), obscure milkvetch (*A. obscurus* S. Wats.), long-leaf phlox, pussytoes [*A. dimorpha* (Nutt.) Torr. & Gray], and large-headed clover [*Trifolium macrocephalum* (Pursh) Poir.].

Plant samples were analyzed for nutrient content (calcium, magnesium, phosphorous, potassium, sodium, sulfur, crude protein, and gross energy). Because plant parts vary by chemical composition (Nagy and Haufler 1980), nutritional analysis was conducted only on the plant parts consumed by sage-grouse. Clipping forb species for the collection of plant parts simulated the feeding activities of juvenile sage-grouse (Nagy and Haufler1980). Since nutrient content differs with phenology (Oakleaf 1971), nutritional analysis of leaves was separated into 1 of 4 classifications: vegetation stage, bud stage, flowering stage, and post-flowering stage. Samples were placed in paper sacks and air dried. The Wildlife Habitat Laboratory at Washington State University, Pullman, conducted laboratory analyses.

Two-factor ANOVA was used to test for site effects on nutrient concentrations (Zar 1999:231). If differences were found between sites a separate single-factor ANOVA was used to evaluate concentrations of calcium, magnesium, phosphorous, potassium, sodium, sulfur, crude protein, and gross energy (Zar 1999:178). Significance was defined as $P \leq 0.05$.

Collection of Blood Samples

Blood samples were collected from sage-grouse hens on SNWR and HMNAR from mid-March through April, 1999-2000 by venipuncture of the cutaneous ulnar vein. Blood collection was done upon capture, following attachment of a radio-collar and leg band. Birds were released after ensuring adequate clotting of the venipuncture site. Approximately 1 ml of blood was taken from each hen and collected in Microtainer ® serum separator tubes (Becton Dickinson and Company, Franklin Lakes, NJ, USA) for serum samples and Microcontainer ® EDTA tubes for whole blood and plasma. The EDTA tubes were agitated gently approximately 15 seconds after collection of the blood sample to ensure adequate mixing of blood and the anticoagulant. Samples for serum chemistry were allowed to clot for 1-6 hours. The serum clot tubes were then centrifuged at 3,000-3,500 rpm for 10 minutes before the serum was removed.

Serum samples were used to determine glucose, creatine phosphokinase, aspartate aminotransferase, calcium (Ca), phosphorous (P), uric acid (UA), and albumin values. Whole blood was used to determine red blood cell counts, hemoglobin, and packed cell volume (PCV); plasma was used to determine total plasma protein (TPP) values. Blood smears were prepared from the whole blood to determine white blood cell (WBC) differential counts.

Refrigerated blood samples were sent within 24-48 hours to the Veterinary Diagnostic Laboratory at Oregon State University, Corvallis, for analysis. Serum biochemistries were performed on an automated chemistry analyzer (Hitachi 717 Biochemical Analyzer, Roche/Boehringer Manheim, Indianapolis, IN, USA) using standard reagents and methods (S.J. Tornquist, Oregon State University, personal communication). Packed cell volumes were measured by the standard capillary tube method after centrifugation of a microhematocrit tube. Plasma proteins were determined by refractometer. Total WBC counts were performed by use of either an eosinophil unopette chamber (Unopette 5877, Becton-Dickinson, Cockeyville, MD, USA) or estimated from a blood smear using 40X magnification (S.J. Tornquist, Oregon State University, personal communication).

Hematology and blood chemistry means, standard deviations, and ranges were calculated. To examine if hematological and serum chemical data differed by site or age, a factorial ANOVA was conducted on the data from sage-grouse hens (Zar 1999:283). The factors included AGE, SITE, BLOOD PARAMETER, an AGE*SITE interaction, and SITE*BLOOD PARAMETER interaction. Of the15 blood parameters available, those, which were identified as reliable indicators of sage-grouse condition (M.R. Dunbar, U.S. Fish and Wildlife Service, personal communication) and considered to limit reproductive performance in galliforms (Hinkson 1970, Beckerton and Middleton 1982, Cain et al. 1982), were used in analysis. These included: WBC, TPP, Ca, P, UA, and albumin.

If main effects and interactions were significant, the model was simplified and a single-factor ANOVA was conducted to examine which hematological values and blood chemistries varied (Zar 1999:178). A two-factor ANOVA was conducted to investigate the relationship between physiological condition of hens and their ability to nest successfully (Zar 1999:231). The factors included: NEST FATE, BLOOD PARAMETER, and a NEST FATE*BLOOD PARAMETER interaction. A two-factor ANOVA was also conducted within each study area to assess the relationship between physiological condition of hens and their ability to successfully recruit chicks to 1 August. The factors included: BROOD FATE, BLOOD PARAMETER, and a BROOD FATE*BLOOD PARAMETER interaction. All variables were examined for normality, kurtosis, and skewness. Assumptions of normality were met and transformations of the data were not required. Significance was defined as $P \leq 0.05$.

RESULTS

Trapping and Radio-Marking

Eighty and 56 females were captured on SNWR and HMNAR, respectively. The age ratio was 43 yearling female: 37 adult female on SNWR and 31 yearling female: 25 adult female on HMNAR. Of the 80 females captured on SNWR blood samples were drawn from 34 hens. On HMNAR, blood samples were obtained from 36 sage-grouse hens; however, due to missing observations only 34 were used in statistical analysis.

Location data were collected for 14 broods at SNWR and 11 broods at HMNAR (Table 5.1). Mean number of observations per brood was 23.14 ± 2.56 (SE; range = 8-38 observations per brood) and 13.83 ± 0.97 (SE; range = 8-17 observations per brood) for SNWR and HMNAR, respectively. Sample size did not warrant separate analyses of early and late brood-rearing home ranges; therefore, locations for early and late brood-rearing periods were analyzed collectively. At SNWR mean brood home range size was 19.63 km^2 ± 6.90 (SE), whereas on HMNAR mean home range size was 8.56 km^2 ± 3.23 (SE).

Table 5.1. Comparison of home range estimates for sage-grouse broods from Sheldon National Wildlife Refuge, Nevada, and Hart Mountain National Antelope Refuge, Oregon, 1998-2000.

Location	Brood ID	Year	Number of locations	Home range (km^2)
SNWR	0.040	1998	12	0.80
	0.303	1998	8	0.33
	0.170	1999	15	3.13
	9.302	1999	19	1.54
	9.411	1999	25	10.03
	9.813	1999	15	46.46
	9.979	1999	30	12.04
	0.220	1999	19	50.50
	0.280	1999	21	71.86
	9.282	2000	33	62.01
	9.429	2000	19	0.40
	9.572	2000	34	4.29
	9.661	2000	36	7.46
	9.782	2000	38	4.00
HMNAR	262	1998	8	8.44
	271	1999	13	1.15
	274	1999	17	2.61
	276	1999	15	0.47
	278	1999	17	3.10
	283	1999	15	9.37
	299	2000	15	27.22
	300	2000	8	5.61
	301	2000	14	1.75
	307	2000	13	31.44
	308	2000	17	2.97

Reproductive Success

On SNWR, observations of the same hens, in consecutive years, were considered to be independent samples for measures of nest initiation rates, nest success, renesting rate, renest success, brood success, and chicks/hen. Therefore, the total sample size on SNWR was 103 hens. Of hens radio-marked on SNWR, 13 were lost to predation prior to nesting, 61 initiated nests and 29 were unaccounted for or were monitored remotely.

On HMNAR, 7 were lost to predation prior to nesting, 43 initiated nests, and 2 left the study area. Hens depredated before the onset of the breeding season, unaccounted for hens, and females monitored remotely were not included in calculations of nest initiation. Thirty-three of the initial 61 nests on SNWR were depredated, 5 were abandoned, and 22 clutches hatched. Nine hens renested; 4 renests were depredated and 5 were successful. Comparatively, 23 of the initial 43 nests were depredated, 4 were abandoned, and 20 clutches hatched on HMNAR. Eight hens renested; 4 renests were depredated and 4 were successful. On SNWR, 17 of 27 successful females recruited broods to 1 August (53 chicks). Sixteen hens recruited broods at HMNAR (51 chicks).

No differences in sage-grouse reproductive parameters were observed between SNWR and HMNAR ($F_{1,47} = 0.02$, $P = 0.903$), and YEAR had insignificant effects on reproductive parameters ($F_{2,47} = 0.18$, $P = 0.835$). There was no interaction between SITE and REPRODUCTIVE PARAMETERS ($F_{7,47} = 0.09$, $P = 0.998$) or SITE and YEAR suggesting differences in productivity measures were independent of site and year differences. Mean renesting rates and chicks/hen declined from 1998-2000 on SNWR (Table 5.2). Although SITE differences were not detected in reproduction parameters, chick/hen ratios doubled on HMNAR in 1999 and 2000 (Table 5.2). A similar increase (based on age ratio indices from harvest data) was observed on SNWR during 1999 and 2000 (chicks/hen = 2.12, $n = 93$ wings and 2.07, $n = 165$ wings, respectively); however, this increase in production was not reflected in the radio-marked sample (chicks/hen = 0.84 and 0.76, respectively).

Table 5.2. Comparison of sage-grouse reproduction parameters from Sheldon National Wildlife Refuge, Nevada and Hart Mountain National Antelope Refuge, Oregon, 1998-2000.

	SNWR				HMNAR			
Reproduction parameter	1998	1999	2000	$\bar{x}$	1998	1999	2000	$\bar{x}$
Nest initiation (%)	100	84	100	93.8	67	100	100	89.5
Nest success (%)	36	33	38	36.0	36	41	60	46.5
Renesting rate (%)	50	33	12	25.05	14	55	17	33.3
Renest success (%)	43	50	100	55.5	100	50	0	50.0
Mean clutch size[a]	8	8	7	7.67	7	7	7	7
Brood success (%)	50	88	62	68.0	75	80	56	69.5
Total chicks recruited	10	21	22	17.67	9	21	21	17
Mean brood size	5	3	2.75	3.58	3	2.6	2.3	2.63
Chicks/hen from radio-marked sample	0.91	0.84	0.76	0.84	0.6	1.24	1.31	1.05
Chicks/hen from harvest data	1.1	2.12	2.07	1.76	--[b]	--	--	--

[a] Mean clutch size determined from initial successful nests.

[b] Wing data for HMNAR were not available for comparison.

Habitat Characteristics

From 1998 through 2000, 121 random sites were sampled during spring and 120 during summer at SNWR. Concurrently, 115 total random sites were sampled during spring and 115 during the summer at HMNAR. In low sagebrush communities, HMNAR had greater total forb cover ($H_{0.05,30,30} = 10.68$, $P = 0.001$), short grass cover ($H_{0.05,30,30} = 27.32$, $P \leq 0.001$), and tall grass cover ($H_{0.05,30,30} = 4.05$, $P = 0.044$) during spring than at SNWR (Table 5.3). Greater amounts of hen forbs were observed in Wyoming big sagebrush ($H_{0.05,31,29} = 6.19$, $P = 0.013$) and mountain big sagebrush ($H_{0.05,31,28} = 4.30$, $P = 0.038$) cover types on HMNAR than at SNWR (Table 5.3). Cover of short grass in Wyoming big sagebrush, mountain big sagebrush, and mountain shrub cover types ($H_{0.05,31,30} = 33.69$, $P \leq 0.001$; $H_{0.05,30,28} = 32.44$, $P \leq 0.001$; $H_{0.05,30,28} = 29.19$, $P = 0.023$, respectively) and medium height shrubs ($H_{0.05,25,30} = 21.11$, $P \leq 0.001$; $H_{0.05,25,28} = 0.028$

$H_{0.05, 26, 27} = 17.19$, $P \leq 0.001$, respectively) was greater at HMNAR (Table 5.3). Greater canopy cover of short shrubs was observed in Wyoming big sagebrush ($H_{0.05, 25, 30} = 27.64$, $P \leq 0.001$) and mountain shrub ($H_{0.05, 26, 27} = 5.03$, $P = 0.025$) communities and less canopy cover in mountain big sagebrush cover types ($H_{0.05, 25, 28} = 24.54$, $P \leq 0.001$) on SNWR than at HMNAR (Table 5.3). Mountain shrub communities had greater amounts of tall grass cover ($H_{0.05, 29, 27} = 11.86$, $P = 0.001$) on SNWR than at HMNAR (Table 5.3).

During summer, low sagebrush cover types had greater total forb cover ($H_{0.05, 30, 29} = 11.74$, $P = 0.001$) and less short and medium height shrub cover ($H_{0.05, 30, 29} = 9.90$, $P = 0.002$; $H_{0.05, 30, 29} = 4.07$, $P = 0.044$, respectively) on HMNAR than at SNWR (Table 5.4). Short grass cover was greater on HMNAR for all cover types (low sagebrush: $H_{0.05, 30, 29} = 27.84$, $P \leq 0.001$; Wyoming big sagebrush: $H_{0.05, 30, 30} = 33.28$, $P \leq 0.001$; mountain big sagebrush: $H_{0.05, 29, 30} = 34.17$, $P \leq 0.001$; mountain shrub: $H_{0.05, 30, 26} = 24.21$, $P \leq 0.001$). Medium height shrub cover was greater in Wyoming big sagebrush ($H_{0.05, 30, 30} = 17.84$, $P \leq 0.001$), mountain big sagebrush ($H_{0.05, 30, 30} = 22.347$, $P \leq 0.001$), and mountain shrub ($H_{0.05, 30, 26} = 26.01$, $P \leq 0.001$) communities on HMNAR compared to SNWR (Table 5.4). Mountain big sagebrush and mountain shrub cover types on HMNAR had greater hen ($H_{0.05, 29, 30} = 16.04$, $P \leq 0.001$; $H_{0.05, 30, 26} = 7.72$, $P = 0.006$, respectively) and chick ($H_{0.05, 30, 30} = 20.41$, $P \leq 0.001$; $H_{0.05, 30, 26} = 13.61$, $P \leq 0.001$, respectively) forb cover and less tall grass cover ($H_{0.05, 30, 30} = 20.41$, $P \leq 0.001$; $H_{0.05, 30, 26} = 17.28$, $P \leq 0.001$, respectively) than SNWR (Table 5.4).

Table 5.3. Habitat characteristics at random spring locations, by cover type, on Sheldon National Wildlife Refuge, Nevada and Hart Mountain National Antelope Refuge, Oregon, 1998-2000.

		Canopy cover (%)			
		SNWR		HMNAR	
Cover type	Habitat characteristic	$\bar{x}$	SD	$\bar{x}$	SD
Low sagebrush	Hen forbs	10.20	5.32	13.15	10.66
	Chick forbs	8.17	4.45	12.09	9.50
	Total forbs	16.29[a]	5.74	26.57	12.81
	Short grass	9.82[a]	3.94	16.32	4.04
	Tall grass	1.39[a]	1.73	2.17	1.84
	Short shrubs	22.75	9.16	21.79	6.82
	Medium shrubs	0.00	0.00	0.00	0.00
	Tall shrubs	0.00	0.00	0.00	0.00
Wyoming big sagebrush	Hen forbs	1.97[a]	1.65	2.83	2.61
	Chick forbs	3.06	2.74	3.93	4.04
	Total forbs	9.82	5.77	9.96	5.73
	Short grass	1.90[a]	2.85	9.47	5.25
	Tall grass	3.32	3.36	1.75	1.99
	Short shrubs	22.84[a]	8.00	8.54	6.35
	Medium shrubs	3.92[a]	5.77	12.80	6.92
	Tall shrubs	1.67	4.73	1.83	3.30
Mountain big sagebrush	Hen forbs	4.16[a]	2.00	6.88	9.33
	Chick forbs	6.27	3.45	6.04	3.02
	Total forbs	15.55[a]	7.35	24.72	10.22
	Short grass	7.99[a]	6.80	21.76	6.65
	Tall grass	7.22	4.85	5.78	5.19
	Short shrubs	6.13[a]	4.90	18.19	8.93
	Medium shrubs	11.70[a]	8.54	20.33	13.58
	Tall shrubs	3.83[a]	6.28	0.82	2.64
Mountain shrub	Hen forbs	5.09	3.72	5.49	3.20
	Chick forbs	6.46	3.53	7.36	2.81
	Total forbs	20.21	9.94	23.44	8.54
	Short grass	9.47[a]	5.25	25.13	10.51
	Tall grass	13.90[a]	8.54	6.95	5.32
	Short shrubs	10.98[a]	7.74	7.33	6.97
	Medium shrubs	12.78[a]	9.87	32.11	17.17
	Tall shrubs	5.82	7.94	7.95	13.09

[a] Means within rows differ ($P \leq 0.05$).

Table 5.4. Habitat characteristics at random summer locations, by cover type, on Sheldon National Wildlife Refuge, Nevada and Hart Mountain National Antelope Refuge, Oregon, 1998-2000.

		Canopy cover (%)			
		SNWR		HMNAR	
Cover type	Habitat characteristic	$\bar{x}$	SD	$\bar{x}$	SD
Low sagebrush	Hen forbs	4.46	3.13	5.82	3.59
	Chick forbs	4.62	3.37	5.46	3.52
	Total forbs	11.60[a]	7.28	18.80	7.41
	Short grass	8.07[a]	4.73	17.41	5.37
	Tall grass	2.48	3.22	1.22	1.46
	Short shrubs	25.52[a]	9.49	15.86	11.43
	Medium shrubs	0.27[a]	0.82	0.00	0.00
	Tall shrubs	0.00	0.00	0.00	0.00
Wyoming big sagebrush	Hen forbs	1.21	1.20	3.30	3.19
	Chick forbs	1.95	1.70	2.37	2.18
	Total forbs	6.44	5.47	8.73	6.91
	Short grass	2.08[a]	2.69	11.77	7.23
	Tall grass	3.09	4.05	1.85	1.80
	Short shrubs	14.84[a]	8.03	7.40	4.33
	Medium shrubs	9.93[a]	9.18	22.40	9.45
	Tall shrubs	1.92	4.21	2.75	6.75
Mountain big sagebrush	Hen forbs	2.13[a]	2.04	6.88	6.26
	Chick forbs	2.32[a]	1.84	3.18	1.91
	Total forbs	9.38[a]	6.46	22.76	9.33
	Short grass	5.84[a]	5.62	22.09	9.08
	Tall grass	10.17[a]	7.48	3.46	3.30
	Short shrubs	12.41	9.07	13.38	10.74
	Medium shrubs	11.47[a]	9.54	30.37	13.97
	Tall shrubs	3.80	5.97	2.49	6.93
Mountain shrub	Hen forbs	2.36[a]	2.44	7.37	5.05
	Chick forbs	2.48[a]	2.11	3.18	1.91
	Total forbs	14.77	7.40	17.70	8.34
	Short grass	9.81[a]	9.67	22.09	9.08
	Tall grass	13.04[a]	11.15	3.46	3.30
	Short shrubs	20.26[a]	12.64	13.38	10.74
	Medium shrubs	13.46[a]	9.08	30.37	13.97
	Tall shrubs	5.35	7.19	2.49	6.93

[a] Means within rows differ ($P \leq 0.05$).

Nutrient Analysis

The mean concentration of 6 minerals, crude protein, and gross energy values from 5 plant species collected on SNWR and HMNAR varied (Table 5.5). Samples of *Phlox longifolia* had higher potassium ($F_{1,7}$ = 23.77, P = 0.002) and crude protein ($F_{1,7}$ = 12.20, P = 0.010), and *Trifolium marcrocephalum* had higher magnesium concentrations ($F_{1,4}$ = 7.22, P = 0.046) on HMNAR than at SNWR (Table 5.5). Although SITE differences were not detected in the analysis of *Antennaria dimorpha* nutrient concentration levels ($F_{1,32}$ = 1.06, P = 0.310), samples from SNWR had higher crude protein (18.65%) and magnesium concentrations (5,400 ug/g) than samples from HMNAR (5.47% crude protein and 2,167 ug/g magnesium, respectively; Table 5.5). No differences were detected between other plant species (Table 5.5).

Table 5.5. Chemical composition of forbs collected at SNWR, Nevada and HMNAR, Oregon during the brood-rearing period, 1999-2000.

	Nutrient concentration			
	SNWR		HMNAR	
Variable	$\bar{x}$	SE	$\bar{x}$	SE
Antennaria dimorpha leaves				
Calcium (ug/g)	7,000	378.59	7,600	152.75
Magnesium (ug/g)	5,400	115.47	2,167	328.30
Phosphorous (ug/g)	1,400	0.00	1,333	88.19
Potassium (ug/g)	9,767	788.11	8,367	841.30
Sodium (ug/g)	250	20.82	193	34.80
Sulfur (ug/g)	773	49.78	730	25.17
Crude protein (%)	18.65	0.12	5.47	0.34
Gross energy (cals/gm)	3,904	104.88	3,858	254.08
Astragalus obscurus leaves				
Calcium (ug/g)	6,400	776.75	6,267	1,217
Magnesium (ug/g)	1,867	371.18	1,667	218.58
Phosphorous (ug/g)	1,100	57.741	1,057	43.33
Potassium (ug/g)	12,677	1,201.90	13,333	333.33
Sodium (ug/g)	99.67	40.92	89.00	20.95
Sulfur (ug/g)	1,300	0.00	1,233	88.19
Crude protein (%)	12.64	0.31	11.84	0.38
Gross energy (cals/gm)	4,447	48.12	4,631	41.28
Astragalus purshii leaves				
Calcium (ug/g)	9,633	33.33	9,133	66.67
Magnesium (ug/g)	1,933	66.67	2,467	120.19
Phosphorous (ug/g)	960	78.10	970	30.00
Potassium (ug/g)	12,000	0.00	12,000	577.35
Sodium (ug/g)	104	8.33	260	115.04
Sulfur (ug/g)	1,300	115.47	1,267	120.19
Crude protein (%)	11.65	0.79	11.21	0.11
Gross energy (cals/gm)	3,961	29.55	4,243	125.37
Phlox longifolia flowers & leaves				
Calcium (ug/g)	8,350	272.34	8,020	287.05
Magnesium (ug/g)	2,950	150	3,100	122.47
Phosphorous (ug/g)	2,400	129	2,940	282.13
Potassium (ug/g)	14,250[a]	629	18,800	663.32
Sodium (ug/g)	109	18.97	72.80	12.63
Sulfur (ug/g)	2,150	64.55	2,040	40.00
Crude protein (%)	12.19[a]	0.13	14.23	0.51
Gross energy (cals/gm)	4,204	50.42	4,250	46.64
Trifolium macrocephalum leaves				
Calcium (ug/g)	26,667	881.92	30,333	1,763.80
Magnesium (ug/g)	3,033[a]	392.99	4,500	378.59
Phosphorous (ug/g)	1,167	66.67	1,133	88.19
Potassium (ug/g)	12,000	577.35	15,667	2185.80
Sodium (ug/g)	603	399.18	237	100.06
Sulfur (ug/g)	1,467	33.33	1,600	57.74
Crude protein (%)	15.84	0.42	16.09	0.50
Gross energy (cals/gm)	4,203	9.02	4,057	118.52

[a] Means within rows differ ($P \leq 0.05$).

Hematology and Serum Chemistry Data

Means, standard deviations, and reference ranges for all sage-grouse hens, without regard to site and age, varied (Table 5.6). AGE had insignificant effects on hematological or serum chemistry parameters between yearlings and adults ($F_{1,285} = 0.02$, $P = 0.882$). Both SITE ($F_{1,285} = 3.96$, $P = 0.048$) and BLOOD PARAMETER ($F_{1,285} = 407.34$, $P \leq 0.001$) effects were significant for sage-grouse hens on SNWR and HMNAR and the SITE*BLOOD PARAMETER interaction was significant ($F_{4,285} = 3.79$, $P = 0.005$) suggesting the 6 blood parameters examined were dependent upon site differences.

Table 5.6. Hematology and serum chemistry values for sage-grouse females, without regard to site and age, Sheldon National Wildlife Refuge, Nevada and Hart Mountain National Antelope Refuge, Oregon, mid-March-April 1999-2000.

Measure	Mean ± SD	Range (minimum-maximum)	*n*
Hematology			
Packed cell volume (%)	55.78 ± 5.09	43.00-67.00	37
White blood cells ($10^3\mu$l)	5.65 ± 2.37	2.00-14.00	64
Heterophils ($10^3\mu$l)	2.16 ± 1.37	0.24-6.26	64
Lymphocytes ($10^3\mu$l)	3.31 ± 1.53	0.96-8.05	64
Monocytes ($10^3\mu$l)	0.89 ± 1.71	0-1.09	49
Basophils ($10^3\mu$l)	0.10 ± 1.93	0-1.22	54
Eosinophils ($10^3\mu$l)	0.053 ± 0.070	0-1.76	17
Serum Chemistry			
Plasma protein (g/dl)	6.03 ± 1.22	3.00-8.50	55
Glucose (mg/dl)	333 ± 34.08	280-475	60
Creatine phosphokinase (IU/L)	2585 ± 976.18	1022-5900	60
Aspartate aminotransferase (IU/L)	448 ± 75.25	324-787	60
Calcium (mg/dl)	25.13 ± 6.28	42.30-1458	58
Phosphorous (mg/dl)	8.03 ± 2.31	15.80-482	60
Uric acid (mg/dl)	6.19 ± 1.88	11.80-371	60
Albumin (g/dl)	2.06 ± 0.24	2.50-124	60

Hens had higher serum Ca values ($F_{1,56} = 4.60$, $P = 0.036$) on HMNAR (26.63 mg/dl) than at SNWR (23.17 mg/dl; Table 5.7). Uric acid concentration was greater ($F_{1,58} = 5.09$, $P = 0.028$) in birds captured at HMNAR (6.67 mg/dl) than hens captured on SNWR (5.60 mg/dl; Table 5.7). No differences were detected between other blood parameters (Table 5.7). Physiological condition (i.e., the state of blood parameters controlled by nutrition and which, in turn, influence sage-grouse fitness) did not affect a hen's ability to nest successfully ($F_{2,296} = 0.11$, $P = 0.897$), nor was condition related to a hen's ability to successfully recruit chicks to 1 August for either SNWR ($F_{1,44} = 2.04$, $P = 0.162$) or HMNAR ($F_{1,78} = 3.51$, $P = 0.065$; Table 5.8).

Table 5.7. Hematology and serum chemistry values for sage-grouse females on Sheldon National Wildlife Refuge, Nevada and Hart Mountain National Antelope Refuge, Oregon, mid-March-April 1999-2000.

	SNWR				HMNAR			
Measure	$\bar{x}$	SD	Range (minimum-maximum)	*n*	$\bar{x}$	SD	Range (minimum-maximum)	*n*
White blood cells ($10^3\mu l$)	6.16	2.53	3.40-14.00	34	5.08	2.07	2.00-10.00	30
Plasma protein (g/dl)	6.16	1.05	4.20-8.00	23	5.95	1.34	3.00-8.50	32
Calcium (mg/dl)	23.17[a]	5.30	12.30-31.80	25	26.63	6.62	14.70-42.30	33
Phosphorous (mg/dl)	7.89	1.85	4.40-12.00	27	8.14	2.65	4.20-15.80	33
Uric acid (mg/dl)	5.60[a]	1.82	2.60-9.30	27	6.67	1.82	3.80-11.80	33
Albumin (g/dl)	2.05	0.24	1.50-2.50	27	2.07	0.25	1.50-2.50	33

[a] Means within rows differ ($P \leq 0.05$).

Table 5.8. Hematology and serum chemistry values for nesting sage-grouse females and those females which recruited chicks to 1 August, without regard to site or age, Sheldon National Wildlife Refuge, Nevada and Hart Mountain National Antelope Refuge, Oregon, mid-March-April 1999-2000.

	Nest fate						Survival of $\geq$1 chick to 1 August					
	Successful			Unsuccessful			Successful			Unsuccessful		
Measure	$\bar{x}$	SD	*n*	$\bar{x}$	SD	*n*	$\bar{x}$	SD	*n*	$\bar{x}$	SD	*n*
White blood cells ($10^3\mu$l)	5813	2559	22	5491	1893	26	5786	1758	18	5550	3575	8
Plasma protein (g/dl)	5.63	1.31	20	6.26	1.16	22	6.39	1.16	16	5.64	1.84	8
Calcium (mg/dl)	25.50	6.28	21	25.26	5.14	23	24.33	6.62	16	25.26	2.74	8
Uric acid (mg/dl)	6.45	2.12	22	6.23	1.83	23	5.88	1.96	17	7.39	2.46	8
Albumin (g/dl)	2.07	0.27	22	2.10	0.23	23	2.06	0.31	17	2.06	0.07	8

DISCUSSION

From 1995-1997, sage-grouse production on SNWR ($\bar{x} = 64\%$ immatures in fall harvest, 2.47 chicks/hen, $n = 446$ wings; USFWS 1997, Sage-grouse Production Report, Lakeview, Oregon, USA) was greater compared to the long-term average in Oregon during the past 15 years ($\bar{x} = 43\%$ immatures in the fall harvest, $n = 6{,}438$ wings; Crawford and Torland 2000) and HMNAR ($\bar{x}_{1989\text{-}1997} = 0.21$ chicks/hen). Although sage-grouse production appeared higher on SNWR than HMNAR, ultimate and proximate causes for the difference are unknown. In 1998, sage-grouse production on SNWR was lower ($\bar{x} = 48\%$ immatures in the fall harvest, 1.10 chicks/hen, $n = 96$ wings) compared with the previous 3 years. The chick/hen ratio doubled during 1999 and 2000 (chicks/hen = 2.12, $n = 93$ wings and 2.07, $n = 165$ wings, respectively); however, this increase in production was not reflected in the radio-marked sample from SNWR (chicks/hen = 0.84 and 0.76, respectively). Although site differences were not detected in reproduction parameters, the number of chicks recruited on HMNAR during 1998-2000 represented the highest percentage of immatures in the population since 1989 (M.W. Byrne, Oregon State University, personal communication). Wing data for HMNAR were not available for long-term comparison. Recruitment necessary for a sustainable sage-grouse population is considered 2.25 chicks/hen into the fall population (Connelly and Braun 1997, Connelly et al 2000*b*). Although not statistically significant, chick/hen ratios at HMNAR were numerically greater than SNWR, which may have biological relevance in the evaluation of sage-grouse recruitment rates.

An accurate estimate of chick survival is essential for determining recruitment of sage-grouse chicks into the fall population; however, direct measures of sage-grouse chick production are not available. Knowledge of reproductive performance in sage-grouse populations have been limited by employing traditional age ratio indices and flush count methodologies. Estimates of survival from wing harvest data are complicated by the potential bias that juvenile birds are more vulnerable to hunter harvest than adult birds, particularly early in the season (Dobkin 1995). Brood flush counts are inherently biased due to the probability of sighting and accurately counting chicks (Riley et al. 1998), the density of vegetation, the ability of hens to avoid observers, and the age of chicks, all of which influence how widely broods range from the hen and the likelihood of a chick flushing (Healy et al. 1980). Brood adoption and brood mixing may also bias brood size estimates based on flush counts (Larson et al. 2001). Although sage-grouse chick survival directly affects recruitment and, ultimately, our understanding of the long-term declines in sage-grouse populations, information on factors influencing survival are unknown.

Although no differences in sage-grouse reproductive parameters were observed between SNWR and HMNAR, trends in reduced abundance and productivity observed at HMNAR before 1998 suggest habitat-related influences may be responsible for the differences in sage-grouse production between the 2 study areas. Nest success of radio-marked hens observed in this study (SNWR = 36%; HMNAR = 47%) was similar to other states where nesting success ranged from 25% in Wyoming (Patterson 1952:104) to 64% in Montana (Wallestad and Pyrah 1974). Nest success on HMNAR (47%) was higher than previously reported in earlier studies from Hart Mountain (Coggins 1998) in 1989-1991 (22%) and 1995-1997 (37%). Brood success was also greater on HMNAR (70%) compared to earlier studies at Hart Mountain (Coggins 1998) in 1989-1991 (36%) and 1995-1997 (39%). Coggins (1998) suggested the corresponding increases in nest success and residual grass cover on HMNAR between 1989-1991 and 1995-1997 likely resulted from a higher probability of hens nesting in cover, which provided improved nest concealment. Further, brood success and summer forb availability were greater at HMNAR during 1995-1997 compared to 1989-1991 suggesting that hens with broods remained in upland brood-rearing habitats longer, reducing their movements, and thereby increasing chick survival (Coggins 1998).

Results from SNWR indicated that hens with broods used areas characterized by greater hen, chick, and total forb cover than at random sites, suggesting use was influenced by availability of forbs (Chapter 3). These findings are consistent with studies in Oregon, which noted that sage-grouse broods selected sites characterized by greater frequency of forbs than at random sites (Drut et al. 1994). Peterson (1970) reported that abundance and diversity of forbs were critical components of sage-grouse brood-rearing habitat in Montana. In Idaho, broods were found where forb availability was greatest (Klebenow 1969).

Studies that dealt with habitat use by sage-grouse hens with broods revealed changes in sage-grouse distribution and habitat selection were associated with plant phenology and desiccation of forbs (Wallestad 1971, Pyle 1992). In Idaho, broods were increasingly found in higher elevation bitterbrush [*Purshia tridentata* (Pursh) Nutt.]

habitats as summer progressed, presumably because of greater availability of succulent vegetation than in lower elevation sagebrush habitats (Klebenow 1969). Results from SNWR are consistent with the literature; sage-grouse hens initially selected low sagebrush cover types during the early brood-rearing period and shifted to big sagebrush and mountain shrub cover types as the season progressed (Chapter 3). On HMNAR, Crawford and Coggins (1998) noted that brood use was primarily in low sagebrush and mountain big sagebrush cover types during 1989-1990. Conversely, greater forb availability in 1995-1996 may have enabled hens with broods to find sufficient forbs to meet their physiological requirements within the cover type in which they nested, resulting in more uniformly distributed use among cover types (Coggins 1998). No differences in forb cover were detected between brood sites and random locations within cover types on HMNAR during 1998-2000 (M.W. Byrne, Oregon State University, personal communication). Differences in habitat use between SNWR and HMNAR may be attributed to differences in forb availability. Forb cover was consistently greater on HMNAR than at SNWR during 1998-2000 for all cover types.

Lower sage-grouse recruitment rates on SNWR during 1998-2000 may be related to differences in forb availability. Home range size for sage-grouse broods was greater on SNWR compared to HMNAR. On SNWR, where forb availability was lower, hens with broods may have had to travel farther to locate habitats with greater availability of succulent forbs. Although sample size was too low to make comparisons of home range estimates of sage-grouse broods, above average precipitation on SNWR in 1998 may have reduced brood movements due to increased availability of forbs ($\bar{x}_{\text{home range}} = 0.56$

$km^2 \pm 0.23$ (SE); $n = 2$). Drought conditions may be responsible for the large movements observed in 1999 ($\bar{x}_{\text{home range}} = 27.94\ km^2 \pm 10.54$ (SE); $n = 7$) and 2000 ($\bar{x}_{\text{home range}} = 15.63\ km^2 \pm 11.65$ (SE); $n = 5$), presumably because forbs were more limiting (Chapter 3). Patterson (1952) found that increased quantity and quality of forbs during years of high precipitation resulted in increased chick growth and survival, which may be reflected in recruitment rates. However, it is important to note the method used to estimate brood home range size may have influenced the results. Differences in brood home range size between SNWR and HMNAR may have been confounded by sample size and the statistical properties of the minimum convex polygon (MCP) estimator. The disadvantage of 100% MCP is the size of the home range estimate increases as sample size increases (Boulanger and White 1990). The number of observations per brood was greater on SNWR ($\bar{x} = 23.14 \pm 2.56$ (SE)) than HMNAR ($\bar{x} = 13.83 \pm 0.97$ (SE)), which may have resulted in the inclusion of areas not utilized by sage-grouse on SNWR, producing an overestimate of home range size. Thus, MCP home range estimates may be of limited use for drawing meaningful comparisons between sage-grouse populations on SNWR and HMNAR unless the number of observations per brood used to calculate home range size is approximately equal for both study sites (Halloran and Bekoff 2000).

Nutrient analysis of forbs collected from HMNAR during the brood-rearing period indicated higher crude protein, magnesium, and potassium levels than at SNWR. The nutrient content of food is determined by the chemical composition of food and the animal's ability to digest and utilize the nutrients (Haufler and Servello 1996). Greater precipitation at HMNAR than SNWR in 1999-2000, may account for the increased nutrient content by facilitating earlier growth and delaying phenology in sage-grouse food forbs (Cook et al. 1994).

Potassium is acquired, in part, by bacterial synthesis in the gastrointestinal tract. Thus, diets of free-ranging wildlife are seldom deficient in potassium (Robbins 1993). Magnesium is the chelated metal in chlorophyll (Robbins 1993) and, therefore, is not likely to be deficient in most sage-grouse diets. However, domestic poultry chicks deficient in magnesium exhibited lethargy and poor growth (Roudybush 1997). In laying hens, magnesium deficiency is characterized by poor egg production and hatching success (Roudybush 1997). Dietary protein is also important in avian reproduction. Beckerton and Middleton (1982) noted that increases in dietary protein levels in captive ruffed grouse (*Bonasa umbellus*) were associated with increases in clutch size, hatching success, chick weight at hatching, and chick survival. Although results from previous studies of wild tetraonid populations (Miller et al. 1970, Moss et al. 1975, Watson and Moss 1972, Lance 1978) and domestic poultry (Clark et al. 1942, Reid et al. 1951, Harms and Waldroup 1963, Krueger et al. 1974, Menge et al. 1979) support Beckerton and Middleton's (1982) observations, little is known about the basic nutritional requirements of free-ranging sage-grouse.

Pre-laying nutrition may have a significant effect on breeding success of several upland game bird species (Beckerton and Middleton 1982, 1983; Barnett and Crawford 1994). Quality of eggs in red grouse (*Lagopus lagopus scoticus*) is affected by spring diets, with more nutritious diets resulting in larger clutches and larger, more viable chicks than those of hens on less nutritious diets (Moss et al. 1975). Consumption of forbs by pre-laying sage-grouse hens increased nutrient content of the composite diet, suggesting that consumption of forbs may affect reproductive success by improving physiological condition of hens and potentially influencing both nest initiation rates and renest rates (Barnett and Crawford 1994). Increases in dietary protein levels in captive ruffed grouse were associated with linear increases in duration of laying, rate of laying, clutch size, weight of the first egg, mean egg weight, clutch weight, hatching success, chick weight at hatching, and chick survival (Beckerton and Middleton 1982). Likewise, clutch size and chick viability of captive willow ptarmigan (*L. l. lagopus*) were higher when diets of hens contained 20% crude protein compared with 15% (Hanssen et al. 1982).

Results from this study indicate blood Ca and UA levels were greater in sage-grouse hens on HMNAR than at SNWR. Although reference values for hematology and serum chemistry are useful in determining the physiological condition of wildlife species (Cambell 1994), interpretation of blood chemistry and hematological values is more complex than evaluating a single parameter. Thus, the entire biochemistry profile should be used to evaluate the condition of the organism (Seal 1978, Schulz et al. 2000).

Reference serum Ca values for avian species average 8-15 mg/dl (Harris 1991), but sage-grouse were much higher, averaging 25.13 mg/dl ± 6.28 (SD). Marked increases in plasma Ca concentrations may occur in some avian species prior to egg laying (Lewandowski et al. 1986); therefore, timing of capture may be responsible for greater serum Ca concentrations in hens at HMNAR. On SNWR, 53% (18/34) of hens were captured prior to 1 April (range = 22 March-15 April, 1999 and 14 March-7 April, 2000), whereas only 12% (4/34) of hens on HMNAR were captured before 1 April (range = 19 March-21 April, 1999 and 31 March-11 April, 2000).

Total protein may also be influenced by reproductive condition (Tell and Citino 1992). Blood urea nitrogen (BUN) is present in low concentrations in avian plasma (Sykes 1971); therefore, UA measurements are the most sensitive indicators of nitrogen, a measure of crude protein, in birds. Amand (1986) reported UA values of avian species ranged from 3-10 mg/dl. Harris (1991) noted UA reference values for avian species ranged from 2-14 mg/dl. Results from this study indicate sage-grouse hen UA concentrations are consistent with the literature. However, measurements of adequate dietary intake of protein must consider not only the blood UA level but also the TPP. In cases of malnutrition or starvation, the blood UA level increases in contrast to decreasing TPP concentrations (Sturkie 1965).

Previous studies have reported TPP values for a number of avian species. Zinkl (1986) noted TPP in domestic chickens ranged from 4.00-5.50 g/dl. Balash et al. (1973) found mean TPP values in several species of galliforms ranged from 3.50-4.90 g/dl. However, past research on the influence of reproductive status on the level of serum protein in the domestic fowl has been inconsistent. Sturkie and Newman (1951) found no significant difference in the TPP levels between laying and non-laying hens. However, Greenberg et al. (1936) found serum protein values for the pullet increased from 3.8%, 0.5-2.0 months before laying, to 5.0%, 1-2 days before laying. A similar increase was observed by Vanstone et al. (1955) in pullets beginning to lay for the first time and by Bell and McIndoe (1962) in the plasma of 2 year old hens during the pre-laying period.

Sage-grouse hen TPP in this study ranged from 3.00-8.50 g/dl and is consistent with the literature.

The function of blood cells in birds generally corresponds to that of other species (Zinkl 1986). The number of WBC is affected by several factors including: stress, disease, trauma (Jarrett 1972, Seal et al. 1972, Sturkie 1976), and diet (Cook 1937). The total WBC count in this study was 5.56 10^3 μl ± 2.37 (SD). The PCV, or hematocrit, is the most useful method of evaluating the red cell mass of avian species (Dein 1986). A number of variables have been shown to affect the PCV value including: age, molt, reproductive cycle, air temperature (Rehder et al. 1982) and egg laying (Bell et al. 1964). The mean PCV value for sage-grouse females in this study was 55.78% ± 5.09 (SD), which is higher than reported in the literature. Dein (1986) reported PCV values for avian species typically fall between 37% and 53%. Concordantly, Balasch et al. (1973) reported means ranging from 36.15% ± 3.98 (SE) and 43% ± 4.02 (SE) for 6 species of galliformes including: chukar (*Alectoris graeca*), pheasants, Guinea fowl (*Numida meleagris*), peacocks (*Pavo cristatus*), chickens (*Gallus gallus gallus*), and guans (*Penelope waglierii*). Gee *et al.* (1981) found a mean PCV of 35% in masked bobwhite (*Colinus virginianus ridwayi*).

Previous authors have indicated hematological values vary among species and may be influenced by other factors such as sex (Gee et al. 1981, Kocan and Pitts 1976), age (Kocan and Pitts 1976), molt (Driver 1991), time of year (Kocan and Pitts 1976, Perry et al. 1986), nutritional status (Newberne 1975), and physiological condition (Altman and Dittmer 1964). Based on the data presented in this study, hematology and serum chemistry reference ranges of sage-grouse hens fall within or above reference values of blood parameters described in the literature for other gallinaceous species. This suggests sage-grouse hens on SNWR and HMNAR were not nutritionally stressed. Further, physiological condition did not limit their ability to nest successfully or successfully recruit chicks to 1 August. Although no previous information on reference values for hematology and serum biochemistries are available for sage-grouse, the reference ranges presented in this study may provide a reasonable guide for assessing the physiological condition of sage-grouse hens in other populations. However, further information is needed under different physiological, geographic, and environmental conditions to develop standardized hematological and serum chemistry value ranges for free-ranging sage-grouse populations. Long-term studies are necessary to evaluate physiological indices over the entire range and distribution of sage-grouse to augment the reliability of physiological data as an indicator of the health of sage-grouse populations and to expand its application in sage-grouse management.

MANAGEMENT IMPLICATIONS

Sage-grouse depend on sagebrush for fulfilling most of their life history requirements. They feed, nest, raise their broods, and winter in sagebrush, making them a sagebrush obligate (Braun et al. 1977). As a sagebrush obligate, sage-grouse may potentially serve as an indicator of a healthy, balanced sagebrush ecosystem. Despite their dependence on sagebrush, virtually no undisturbed tracts of sagebrush-steppe habitat exist within the current range of sage-grouse (Schneegas 1967, Braun 1998). Factors that affect sagebrush ecosystems include: habitat deterioration, loss, and fragmentation through sagebrush control programs for agricultural production (Yocum 1956, Swensen et al. 1987), increased livestock forage (Schneegas 1967), urban development (Call 1979, Braun 1998), and mining activities (Call and Maser 1985, Braun 1987). In addition, historic overgrazing and altered fire regimes have been associated with alteration of sagebrush habitats, which have resulted in an increase in shrub density leading to a decline in native grasses and forbs (Blaisdell et al. 1982, West and Hassan 1985, Laycock 1991, Winward 1991, Miller and Rose 1985). Land management practices that reduce herbaceous cover, in favor of shrub dominance, may have adverse effects on sage-grouse nesting and brood-rearing.

Implementation of land management practices, which result in increased forb production and arthropod abundance, may influence reproductive success of pre-laying sage-grouse by improving their physiological condition and potentially influencing nesting and renesting, as well as enhancing brood survival and recruitment of chicks. On HMNAR sage-grouse productivity increased when nesting and brood-rearing habitats contained: 15-20% forb cover with at least 2-6% comprised of hen and chick forbs during the early brood-rearing period; 5-17% tall grass cover; 8-16% forb cover with at least 2-3% comprised of hen and chick forbs during the late brood-rearing period; and 10-20% low (< 40 cm) and medium (40-80 cm) shrub canopy cover in nesting and brood-rearing habitats (Coggins 1998).

Although sagebrush removal may have short-term negative impacts on sage-grouse nesting habitats (Connelly et al. 1991), land management practices (e.g., prescribed fire) can be used in areas where suitable nesting habitat exists nearby, creating a mosaic of successionally variable sagebrush habitat interspersed with open patches characterized by increased forb production (Klebenow 1972). Previous studies have reported an increase in herbaceous vegetation following burning (Harniss and Murray 1973, Young and Evans 1978, Uresk et al. 1980, Young and Miller 1985, Cook et al. 1994) and increased biomass production and basal area of perennial bunchgrasses and forbs following fire (Harniss and Murray 1973, Uresk et al. 1980, Young and Miller 1985, Akinsoji 1988, Cook et al. 1994, Pyle and Crawford 1996). In the long-term, as sagebrush reestablishes, the balance of native grasses, forbs, and medium height shrub cover may enhance sage-grouse nesting habitat.

Lower sage-grouse recruitment rates observed on SNWR were attributed, in part, to differences in forb availability and home range size. Lower forb abundance at SNWR may have affected the physiological condition of chicks and corresponding larger home range size at SNWR may have predisposed juvenile sage-grouse to greater vulnerability to predation, weather, and other mortality factors. Although the importance of providing a balance of sagebrush, native grasses, and forbs for fulfilling all of sage-grouse life history needs has been well documented (Connelly et al. 2000*b*), factors influencing chick survival remain unknown and represent the largest gap of knowledge in sage-grouse reproductive ecology. Although sage-grouse chick survival directly affects recruitment into the fall population and, ultimately, our understanding of the long-term declines in sage-grouse populations, factors influencing survival are not available.

Analysis of numerical trend data and habitat evaluation combined with physiological data may provide insight into habitat differences between study areas not previously recognized by wildlife biologists and land managers (Seal 1978). Although physiological condition of sage-grouse hens did not appear to affect a female's ability to nest successfully or successfully recruit chicks into the fall population, it does not negate the use of physiological parameters (e.g., hematological and serum chemistry values) as an important diagnostic tool when evaluating free-ranging sage-grouse health and condition. Estimates of condition were assessed from only 2 years of data collected during March through April, while estimates of nesting and brood success were made in May through June and August, respectively. Factors unrelated to hen condition (e.g., shrub canopy cover, residual tall grass cover, predation, insect and forb availability for chicks, and hen movements) may influence nest fate and the number of chicks that survive to 1 August. Concurrently, nest fate and brood success may be related to physiological parameters not considered in this model. Thus a long-term data set is needed before relationships between condition and nesting and brood success may be identified. Physiological indices may provide important information relating to the effects of existing land management practices (e.g., prescribed fire) and other habitat manipulations on physiological condition. Further, such practices may promote evaluation of habitat manipulation more efficiently than traditional cause and effect studies and conventional measures of habitat components, which are necessary for fulfilling the life history needs of sage-grouse.

CHAPTER 6. SYNTHESIS AND REVIEW

Greater Sage-Grouse (*Centrocercus urophasianus*) have experienced declines throughout their range over the last 50 years (Johnsgard 1983, Crawford and Lutz 1985, Drut 1994). The decline in sage-grouse numbers has been associated with reduced productivity attributed to alteration and loss of sagebrush-steppe habitats by expanding agriculture and urban development, sagebrush (*Artemisia* L. spp.) control programs, historic overgrazing by domestic livestock, and altered fire regimes (Dalke et al. 1963, Call 1979, Johnsgard 1983, Klebenow 1985). The decline in sage-grouse abundance and distribution has prompted some environmental coalitions to consider petitioning for the protection of sage-grouse under the Endangered Species Act.

Sage-grouse are sagebrush obligates (Braun et al. 1977). However, the importance of providing a balance of sagebrush, native grasses, and key rangeland forbs for fulfilling all of their life history requirements has been well documented (Connelly et al. 2000*b*). Several studies have described sage-grouse nesting habitat, selection of habitat components by hens, and relation of nest sites characteristics to available habitat (Patterson 1952, Gray 1967, Klebenow 1969, Wallestad and Pyrah 1974, Hulet et al. 1986). Previous authors have also reported habitat and structural characteristics and availability of insects and succulent forbs as primary determinants of habitat selection by hens with broods (Klebenow 1969, Peterson 1970, Wallestad 1971, Autenrieth 1981). Differences in sage-grouse recruitment rates between SNWR and HMNAR were attributed, in part, to differences in forb abundance and home range size. Lower forb availability at SNWR may have affected the physiological condition of chicks. Further, larger home range size at SNWR may have predisposed sage-grouse chicks to greater vulnerability to predation, weather, and other mortality factors.

Despite their dependence on sagebrush, virtually no undisturbed tracts of sagebrush-steppe habitat exist within the current distribution of sage-grouse (Schneegas 1967). Sage-grouse need vast expanses of suitable habitat (Eng and Schladweiler 1972, Berry and Eng 1985), which necessitates management on a landscape scale to ensure that life history requirements are met. To ensure that critical sage-grouse habitat is not lost, seasonal use areas for nesting, brood-rearing, and wintering must be identified and managed accordingly. Although trends of traditional habitat use by sage-grouse have been observed (Eng and Schladweiler 1972, Berry and Eng 1985, Connelly et al. 1988), the role of site fidelity in sage-grouse remains poorly understood. Information on the timing and distance of seasonal movements is necessary for defining sage-grouse populations; identifying breeding, nesting, brood-rearing, and winter habitats; and evaluating impacts of land use (Connelly et al. 1988).

Before Euro-American settlement of the West, fire was a frequent occurrence in some sagebrush-steppe cover types, increasing the dominance of many herbaceous species while reducing the shrub overstory (Daubenmire 1968, Burkhardt and Tisdale 1976, Wright et al. 1979, Gruell 1985). With the introduction of domestic livestock in the 19th century, the herbaceous understory was unable to support increased grazing pressures causing rapid deterioration of understory species and movement toward sagebrush dominance (Laycock 1991). Practices that reduce herbaceous cover in sagebrush communities may have negative impacts on sage-grouse nesting and brood-rearing habitat. The reduction or removal of livestock grazing and management practices (e.g., prescribed burning) may promote recovery of degraded sagebrush communities.

Prescribed fire is controversial in sage-grouse management (Dalke et al. 1963, Braun et al. 1977, Connelly et al. 1981). Big sagebrush is temporarily eliminated from the community following burning and, therefore, results in short term losses of cover and nesting habitat for sage-grouse (Young and Evans 1978); however, burning in small areas may achieve a mosaic of food and cover suitable for sage-grouse (Klebenow 1972). When considering fire as a management tool to enhance sagebrush habitat, managers must take into account the habitat needs of sage-grouse during all stages of their life cycle. Sagebrush-steppe communities must provide forbs for pre-laying hens and chicks (Barnett and Crawford 1994, Drut et al. 1994), grasses and shrub cover for secure nesting (Gregg et al. 1994, DeLong et al. 1995), insects during brood-rearing (Patterson 1952, Klebenow and Gray 1968, Peterson 1970), and sagebrush for late summer and winter foods. Prescribed fire may produce higher yields of forbs important for pre-laying hens and brood-rearing; however, fire is not desirable in winter habitats because sagebrush is essential for food and cover (Call and Maser 1985, Connelly et al. 2000*a*).

Although results from this study indicated vegetative and structural components implicated in successful sage-grouse nesting and brood-rearing were found in wildfire sites and that fire did not negatively impact arthropod abundance, land managers should be cautious in the use of prescribed fire as a management tool for sage-grouse habitats. Land managers and wildlife biologists must develop long-term responses of plants and insects that may provide critical foods to hens and chicks (specifically, species composition, quantity, nutrient content, and differential phenology). Further, long-term breeding season data, in conjunction with detailed fire histories, to ascertain temporal and spatial effect of sage-grouse habitat use and selection are not available. Thus, wildlife biologists and managers must ascertain the use of burned and unburned areas by sage-grouse for fulfilling all of their life history needs.

Traditionally, wildlife studies have involved measuring parameters of habitat and have often not considered physiological data, which may be extremely important in determining what is regulating a population. Several studies have identified that nutritional variation in wild breeding bird populations can greatly effect breeding success (Lack 1966, 1968, Ryder 1970, Moss et al. 1974, Newton 1979). Analysis of numerical trend data and habitat evaluation combined with sage-grouse physiological data may provide insight into habitat differences not previously recognized by wildlife biologists and land managers (Seal 1978). Further, such practices may promote evaluation of habitat manipulation more efficiently than traditional cause and effect studies. Reference ranges of sage-grouse blood parameters presented in this study may provide a reasonable guide for assessing the physiological condition of other pre-laying sage-grouse hen populations; however, further information is needed under different physiological, geographic and environmental conditions to develop standardized hematological and serum chemistry value ranges for free-ranging sage-grouse populations.

Causes of sage-grouse decline are varied, but ultimately they are habitat based. Current land-management practices that reduce herbaceous cover in sagebrush communities, in favor of shrub dominance, may not afford recovery of sage-grouse populations. Management practices, (e.g., prescribed fire) that achieve a mosaic of food and cover suitable for sage-grouse and which recast the balance of native herbaceous species in degraded sagebrush communities may be necessary in the restoration of sagebrush-steppe ecosystems, and ultimately, the recovery of sage-grouse populations and other species dependent upon sagebrush habitats.

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APPENDICES

Appendix A. Description of vegetation zones at Sheldon National Wildlife Refuge, Nevada (adapted from Rogers and Tiehm 1979, Klebenow and Burkhardt 1982, and Gregg 1991).

Vegetation zone	Description	Associated species
Desert shrub	Occurs in the lowest elevations between 1,400 m and 1,600 m.	
Greasewood	Greasewood (*Sarcobatus vermiculatus*) occurs on poorly undrained bottomlands where salts accumulate and a relatively high water table is present. On the more saline soils greasewood may be less common and species such as saltgrass (*Distichlis spicata* var. *stricta*) and sea-blite (*Suadeda torreyana* var. *torreyana*) are more common.	*Agropyron smithii* *Chrysothamnus nauseosus* *Elymus cinereus* *Grayia spinosa* *Tetradymia spinosa*
Budsage	Budsage (*Artemisia spinescens*) occurs on better-drained, rocky soils of hillsides. Big sagebrush (*A. tridentata*) and green rabbitbrush (*Chrysothamnus viscidiflorus puberulus*) are frequent associates.	*Astragalus newberryi* *A. purshii* *Camissonia boothii* *C. claviformis* *Cryptantha pterocarya* *Cymopterus corrugatus* *C. purpurascens* *Gilia micromeria* *G. sinuata* *Halogeton glomeratus* *Malacothrix torreyi* *Mentzelia albicaulis* *M. congesta* *Orobanche corymbosa* *O. fasciculate* *Pediocactus simpsonii* *Phacelia glandulifera* *Salvia dorrii* *Stephanomeria exigua*

Shrub-steppe		
Mountain big sagebrush	Mountain big sagebrush (*A. t. vaseyana*) is the dominant component. Occurs on tablelands, ridgetops, and basin terraces. A clay pan or impermeable rock layer at a depth of 30 to 46 cm characterizes sites. Precipitation is from 25 to 38 cm. Elevation is from 1,700 to 2,100 m. Shrub cover ranges from 10-25%. Grass cover ranges from 20-40% Forb cover ranges from 5-10%.	*Elymus cinereus* *Chrysothamnus viscidiflorous* *Purshia tridentata* *Tetradymia canescens* *Poa sandbergii* *Sitanion hystrix* *Festuca idahoensis* *Crepis acuminata* *Phlox longifolia* *Balsamorhiza sagittata* *Symphoricarpos orbiculatus* *Achillea lanulosa* *Lupinus* spp.
Wyoming big sagebrush	Wyoming big sagebrush (*A. t. wyomingensis*) is the dominant shrub component. Occurs in mountainous terrain with slope gradients form 25-70% Mean annual precipitation is 23 to 38 cm. Elevation ranges from 1,400 to 2,100 m. Shrub cover ranges from 10-30%. Grass cover ranges from 25- 80%. Forb cover ranges from 10-15%.	*Stipa thurberiana* *Chrysothamnus viscididflorus* *Tetradymia canescens* *Poa sanbergii* *Bromus tectorum* *Sitanion hystrix* *Crepis acuminata* *Lupinus* spp. *Astragalus* spp.
Basin big sagebrush	Occurs on low terraces associated with drainages and lake basins. Primary plant species are basin big sagebrush (*A. t. tridentata*) and basin wild rye (*Elymus cinereus*).	*Elymus cinereus* *Bromus tectorum* *Poa* spp.
Low sagebrush	Low sagebrush (*A. arbuscula*) is the dominant shrub component. Green	*Allium anceps* *A. parvum* *Arenaria congesta*

Appendix A (Continued).

	rabbitbrush or bitterbrush (*Purshia tridentata*) may be present. Sandberg bluegrass (*Poa sandbergii*), Thurber needlegrass (*Stipa thurberiana*) and squirreltail (*Sitanion hystrix*) are common associates. Mean annual precipitation ranges from 20 to 28 cm. Elevation ranges from 1,300 to 1,800 m. Shrub cover ranges from 10-20%. Grass cover ranges from 30- 35%. Forb cover ranges from 5-10%.	*Aster scopulorum* *Balsamorhiza serrata* *Draba douglasii* *Erigeron bloomeri* *E. chrysopsidis* *Eriogonum caespitosum* *E. ovalifolium* *Haplopappus acaulis* *Lesquerella kingii* *Lomatium canbyi* *L. nevadense* *Phlox diffusa* *P. longifolia* *Penstemon humilis* *Tetradymia canescens* *Trifolium macrocephalum* *Crepis modocensis*
Mountain shrub	Common elevations between 1,800 and 2,300 m. Primary plant species are mountain big sagebrush, bitterbrush, bluegrass (*Poa* spp.), and needlegrass (*Stipa* spp.).	*Ribes aureum* *Rosa woodsia* *Symphoricarpus oreophilus*

Appendix A (Continued).

Mountain mahogany	Mountain mahogany (*Cercocarpus ledifolius* var. *ledifolius*) occurs on rocky soils and ridge tops often with late enduring snow banks at elevations above 1,829 m. Big sagebrush, needlegrass, and bluegrass are common associates.	*Fritillaria atropurpurea* *Gayophytum racemosum* *Penstemon gracilentus* *Phacelia hastata* *P. ramosissima*
Western Juniper	Common above 1,829 m. Frequently intergraded with big sagebrush communities being more common on relatively moist sites. Thurber needlegrass, Sandberg bluegrass, prairie junegrass (*Koeleria nitida*) and lupines are common associates.	*Allium platycaule* *Antennaria dimorpha* *A. rosea* *Arabis puberula* *A. sparsiflora* *Eriogonum strictum* *E. umbellatum* *Gilia capillares* *Lupinus caudatus* *L. saxosus*
Wetland vegetation		
Willow community	Willow (*Salix* spp.) and associated species usually line the stream banks in dense thickets. Occurs in the relatively dry and warm eastern portion of the Refuge.	*Ribes aureum* *R. divaricatum* *Rosa woodsii* *Salix lasiandra* *S. melanopsis* *S. scouleriana* *Scirpus acutus* *Triglochin concinna*
Aspen community	Aspen (*Populus tremuloides*) is dominant along stream banks in the higher elevations. Wild rose (*Rosa woodsii* var. *ultramontana*), snowberry (*Symphoricarpus oreophilus* var. *utahensis*), and chokecherry (*Prunus virginiana* var. *melanocarpo*) are common associates.	*Agastache urticifolia* *Bromus carinatus* *Paeonia brownii* *Phacelia ramosissima* *Urtica holosericea* *Vernica americana*

Appendix A (Continued).

Sedge meadow	Common where broad flat areas are subjected to frequent inundations and a high water table. The most conspicuous species are sedges (*Carex* spp.), rushes (*Juncus* spp.), and various grasses.	*Agrostis stolonifera* *Artemisia biennis* *Atriplex truncata* *Beckmannia syzigachne* *Boisduvalia glabell* *Castilleja exilis* *Carex lanuginosa* *C. simulata* *C. nebrascensis* *Crepis runcinata* *Deschampsia danthonioides* *Epilobium adenocaulon* *Haploppappus lanceolatus* *Hordeum jubatum* *Juncus balticus* *J. nevadensis* *Plagiobothrys leptocladus* *Psilocarpus brevissimus* *Puccinellia nuttalliana* *Rumex cripus* *Scirpus americanus* *S. pungens* *Senecio hydrophyllus* *Sidalcea oregana* *S. americanus* *Solidago spectabilis* *Trifolium variegatum* *T. wormskioldii* *Triglochin concinna*

Appendix B. Cover (%, $\bar{x}$ ± SE) and frequency of occurrence (%) of shrubs, grasses, and forbs from randomly sampled locations during the early brood-rearing period at Bald Mountain wildfire and control sites, Sheldon National Wildlife Refuge, Nevada, 1998-2000.

	Bald Mountain Burn ($n = 20$)		Bald Mountain Control ($n = 25$)	
Habitat characteristic	Cover	Frequency	Cover	Frequency
Shrubs				
Artemisia arbuscula	0.81 ± 0.81	2	1.47 ± 0.71	4
A. tridentata vaseyana	7.07 ± 1.87	16	22.52 ± 1.94	53
Chrysothamnus nauseosus	0.00	0	0.24 ± 0.14	2
C. viscidiflorus	5.90 ± 1.12	19	4.06 ± 0.69	18
Leptodactylon pungens	0.08 ± 0.08	<1	0.00	0
Purshia tridentata	0.00	0	0.29 ± 0.21	<1
Rosa woodsii	0.21 ± 0.16	1	0.00	0
Symphoricarpos spp.	1.98 ± 1.25	6	2.10 ± 1.00	6
Tetradymia canescens	2.36 ± 0.69	9	1.58 ± 0.57	5
Grasses				
Agropyron spicatum	1.25 ± 0.66	7	2.64 ± 0.98	11
Bromus tectorum	6.79 ± 1.61	46	6.91 ± 1.48	47
Carex spp.	0.35 ± 0.27	4	0.14 ± 0.06	2
Elymus cinereus	3.77 ± 1.46	11	2.21 ± 0.80	6
Festuca spp.	6.49 ± 2.25	23	3.65 ± 1.38	13
Juncus spp.	0.02 ± 0.02	1	0.07 ± 0.07	1
Poa sandbergii	4.92 ± 0.75	37	1.80 ± 0.37	17
Sitanion hystrix	1.64 ± 0.45	13	2.06 ± 0.50	20
Stipa spp.	7.97 ± 1.83	32	8.62 ± 2.24	36
Forbs				
Agoseris/Microseris spp.	2.26 ± 0.49	33	1.93 ± 0.28	46
Allium spp.	<0.01 ± 0.005	1	0.16 ± 0.10	4
Arabis spp.	0.02 ± 0.02	1	0.12 ± 0.04	5
Arenaria spp.	0.02 ± 0.02	1	0.00	0
Astragalus spp.	0.04 ± 0.03	1	0.05 ± 0.05	<1
A. filipes	0.00	0	0.44 ± 0.22	5
Balsmarhiza sagittata	0.15 ± 0.08	3	1.11 ± 0.38	6
Castilleja spp.	0.01 ± 0.01	1	0.00	0
Collinsia parviflora	7.09 ± 0.92	88	8.59 ± 1.10	91
Collomia spp.	0.17 ± 0.08	7	0.00	24
Crepis spp.	0.68 ± 0.50	5	1.08 ± 0.43	12
C. acuminata	0.16 ± 0.12	4	1.18 ± 0.38	15
C. modocensis	0.06 ± 0.04	1	0.00	0
Cryptantha spp.	0.09 ± 0.04	8	0.01 ± 0.01	1
Delphinium spp.	0.06 ± 0.03	2	0.62 ± 1.56	15
Descurainia spp.	0.01 ± 0.01	1	0.00	0
Epilobium spp.	0.13 ± 0.06	1	0.08 ± 0.04	4
Eriastrum wilcoxii	<0.01 ± 0.005	1	0.00	0
Erigeron spp.	0.09 ± 0.09	1	0.00	0
Eriogonum spp.	0.52 ± 0.38	3	0.34 ± 0.22	2
Eriophylum lanatum	0.03 ± 0.03	1	0.00	0
Frasera albicaulis	0.12 ± 0.07	5	0.02 ± 0.02	<1
Fritellaria atropurpurea	0.03 ± 0.03	1	0.00	0

Appendix B (Continued).

Gayophytum spp.	0.00	0	0.03 ± 0.03	2
Iris missouriensis	0.12 ± 0.12	1	0.05 ± 0.05	<1
Lithophragma spp.	0.03 ± 0.03	1	0.04 ± 0.03	2
Lithospermum ruderale	0.00	0	0.12 ± 0.08	2
Lomatium spp.	0.49 ± 0.18	11	0.99 ± 0.22	19
Lupinus spp.	1.92 ± 0.36	38	4.28 ± 0.58	64
Mentha arvensis	0.00	0	1.58 ± 1.09	5
Mentzelia spp.	0.03 ± 0.03	1	0.00	0
Mertensia spp.	0.67 ± 0.24	10	0.67 ± 0.23	14
Microsteris gracilis	1.08 ± 0.25	42	1.01 ± 0.22	33
Montia spp.	0.63 ± 0.63	3	0.04 ± 0.04	2
Myosotis micrantha	0.00	0	0.17 ± 0.15	2
Paeonia brownii	0.00	0	0.05 ± 0.05	<1
Penstemon spp.	0.00	0	0.01 ± 0.01	<1
Phacelia spp.	0.01 ± 0.01	1	0.00	0
P. linearis	0.00	0	0.03 ± 0.03	1
Phoenicaulis cheiranthoides	0.00	0	0.02 ± 0.02	<1
Phlox spp.	0.09 ± 0.09	1	0.00	0
P. hoodii	0.25 ± 0.19	3	0.01 ± 0.01	<1
P. longifolia	0.00	0	0.42 ± 0.14	11
Ranunculus glaberrimus	0.16 ± 0.07	5	0.04 ± 0.03	1
R. testiculatus	0.00	0	0.03 ± 0.03	2
Senecio spp.	0.00	0	0.46 ± 0.21	5
S. canus	0.00	0	0.01 ± 0.01	<1
S. integerrimus	0.00	0	0.02 ± 0.02	<1
Tragopogon dubius	0.03 ± 0.03	1	0.00	0
Viola spp.	0.08 ± 0.08	2	0.04 ± 0.02	2
Unknown	0.06 ± 0.03	3	0.00	2

Appendix C. Cover (%. $\bar{x}$ ± SE) and frequency of occurrence (%) of shrubs, grasses, and forbs from randomly sampled locations during the late brood-rearing period at Bald Mountain wildfire and control sites, Sheldon National Wildlife Refuge, Nevada, 1998-2000.

	Bald Mountain Burn (n = 20)		Bald Mountain Control (n = 20)	
Habitat characteristic	Cover	Frequency	Cover	Frequency
Shrubs				
Artemisia tridentata vaseyana	7.76 ± 1.60	21	25.65 ± 2.16	63
Chrysothamnus viscidiflorus	7.98 ± 1.41	25	4.30 ± 0.86	22
Leptodactylon pungens	0.41 ± 0.21	3	0.00	0
Purshia tridentata	0.08 ± 0.08	<1	0.27 ± 0.19	<1
Symphoricarpos spp.	2.32 ± 1.01	7	1.65 ± 0.61	13
Tetradymia canescens	1.96 ± 0.55	8	0.98 ± 0.34	5
Grasses				
Agropyron spicatum	2.31 ± 0.96	6	0.00	0
Bromus tectorum	8.27 ± 2.02	49	7.87 ± 1.52	48
Carex spp.	0.19 ± 0.13	2	0.61 ± 0.28	6
Elymus cinereus	7.25 ± 3.04	8	6.13 ± 1.93	15
Festuca spp.	5.54 ± 1.40	19	10.34 ± 2.21	28
Juncus spp.	0.17 ± 0.10	3	0.00	0
Koeleria cristata	0.06 ± 0.06	1	0.06 ± 0.04	4
Poa sandbergii	1.31 ± 0.28	17	1.55 ± 0.49	12
Sitanion hystrix	7.59 ± 1.53	35	4.36 ± 0.77	30
Stipa spp.	5.35 ± 1.20	21	3.08 ± 0.66	19
Forbs				
Agoseris/Microseris spp.	0.38 ± 0.19	8	0.13 ± 0.05	4
Allium spp.	0.02 ± 0.02	1	0.10 ± 0.07	2
Antennaria spp.	0.06 ± 0.04	1	0.00	0
Arabis spp.	0.00	0	0.03 ± 0.03	1
Astragalus spp.	0.13 ± 0.13	1	0.09 ± 0.07	1
A. filipes	0.06 ± 0.06	2	0.54 ± 0.24	6
Balsmarhiza sagittata	0.06 ± 0.06	1	0.78 ± 0.35	4
Castilleja spp.	0.13 ± 0.13	1	0.00	0
Collinsia parviflora	0.10 ± 0.07	2	0.22 ± 0.12	6
Collomia spp.	0.61 ± 0.27	17	0.78 ± 0.17	34
Crepis spp.	0.52 ± 0.24	5	1.38 ± 0.60	12
C. acuminata	0.44 ± 0.23	6	0.52 ± 0.26	6
Cryptantha spp.	0.22 ± 0.09	11	0.10 ± 0.06	3
Delphinium spp.	0.00	0	0.03 ± 0.03	1
Epilobium spp.	0.01 ± 0.01	1	<0.01 ± 0.005	<1
Eriastrum wilcoxii	0.04 ± 0.02	3	<0.01 ± 0.005	1
Eriogonum spp.	0.34 ± 0.25	2	0.28 ± 0.19	2
Eriophylum lanatum	0.03 ± 0.03	1	0.00	0
Frasera albicaulis	0.16 ± 0.13	1	0.19 ± 0.19	1
Gayophytum spp.	0.46 ± 0.18	10	0.20 ± 0.09	4
Iris missouriensis	0.13 ± 0.13	1	0.00	0
Lithospermum ruderale	0.34 ± 0.34	1	0.00	0
Lomatium spp.	0.24 ± 0.12	4	0.07 ± 0.04	2

Appendix C (Continued).

Lupinus spp.	4.03 ± 0.77	36	7.61 ± 1.41	63
Mentha arvensis	0.00	0	0.47 ± 0.47	2
Mentzelia spp.	0.02 ± 0.02	1	0.00	0
Mertensia spp.	0.13 ± 0.07	3	0.13 ± 0.05	3
Microsteris gracilis	0.26 ± 0.14	5	0.03 ± 0.02	2
Montia spp.	0.50 ± 0.50	3	0.03 ± 0.03	1
Phacelia spp.	0.07 ± 0.06	2	0.07 ± 0.06	1
Phlox spp.	0.13 ± 0.13	1	0.00	0
P. hoodii	0.07 ± 0.07	2	0.00	0
P. longifolia	0.00	0	0.7 ± 0.23	13
Polygonum	0.03 ± 0.03	1	0.00	0
Senecio spp.	0.04 ± 0.03	1	0.28 ± 0.14	3
Tragopogon dubius	0.00	0	0.03 ± 0.03	1
Viola spp.	0.00	0	0.06 ± 0.04	2
Unknown	0.19 ± 0.09	2	0.07 ± 0.05	2

Appendix D. Cover (%, $\bar{x} \pm$ SE) and frequency of occurrence (%) of shrubs, grasses, and forbs from randomly sampled locations during the early brood-rearing period at Catnip Mountain wildfire and control sites, Sheldon National Wildlife Refuge, Nevada, 1998-2000.

	Catnip Mountain Burn (n = 27)		Catnip Mountain Control (n = 28)	
Habitat characteristic	Cover	Frequency	Cover	Frequency
Shrubs				
Artemisia arbuscula	0.14 ± 0.14	1	0.22 ± 0.22	<1
A. tridentata vaseyana	1.13 ± 0.53	4	20.51 ± 1.57	63
Chrysothamnus nauseosus	0.08 ± 0.08	<1	0.01 ± 0.01	<1
C. viscidiflorus	6.41 ± 1.62	23	2.83 ± 0.42	16
Leptodactylon pungens	0.15 ± 0.08	1	0.49 ± 0.18	5
Purshia tridentata	0.49 ± 0.25	1	2.73 ± 0.99	7
Ribes spp.	0.00	0	0.02 ± 0.02	<1
Symphoricarpos spp.	0.14 ± 0.10	1	0.03 ± 0.03	<1
Tetradymia canescens	0.74 ± 0.42	4	0.49 ± 0.18	3
Grasses				
Agropyron spicatum	0.34 ± 0.18	2	0.59 ± 0.29	5
Bromus tectorum	0.98 ± 0.46	18	4.09 ± 1.67	23
Carex spp.	0.76 ± 0.29	5	1.19 ± 0.22	6
Elymus cinereus	0.76 ± 0.58	1	0.92 ± 0.44	2
Festuca spp.	1.34 ± 0.47	8	2.63 ± 0.80	17
Juncus spp.	0.15 ± 0.14	1	0.25 ± 0.16	2
Koeleria cristatum	0.32 ± 0.14	3	0.24 ± 0.11	3
Oryzopsis hymenoides	0.46 ± 0.23	1	0.13 ± 0.13	1
Poa sandbergii	3.22 ± 0.93	19	2.85 ± 0.69	28
Sitanion hystrix	5.22 ± 0.95	41	2.66 ± 0.48	24
Stipa spp.	3.24 ± 0.99	18	2.53 ± 1.02	13
Unknown	0.22 ± 0.22	2	0.49 ± 0.49	3
Forbs				
Agoseris/Microseris spp.	4.77 ± 0.75	53	1.67 ± 0.34	33
Allium spp.	<0.01 ± 0.003	1	0.04 ± 0.04	2
Antennaria dimorpha	<0.01 ± 0.007	<1	0.03 ± 0.03	1
Arabis spp.	0.06 ± 0.05	1	0.29 ± 0.10	6
Aster spp.	0.00	0	0.01 ± 0.01	<1
Astragalus spp.	0.01 ± 0.01	<1	0.01 ± 0.01	<1
A. filipes	0.01 ± 0.01	<1	0.00	0
A. obscurus	0.00	0	0.02 ± 0.02	<1
A. purshii	0.01 ± 0.01	2	<0.01 ± 0.007	<1
Balsmarhiza sagittata	0.94 ± 0.44	6	0.30 ± 0.20	3
Castilleja spp.	0.34 ± 0.23	5	0.17 ± 0.09	4
Collinsia parviflora	4.39 ± 0.68	67	3.73 ± 0.83	68
Crepis spp.	0.14 ± 0.09	2	0.21 ± 0.09	4
C. acuminata	0.81 ± 0.25	10	0.31 ± 0.16	4
C. modocensis	0.04 ± 0.04	<1	0.00	0
Cryptantha spp.	0.35 ± 0.24	8	0.15 ± 0.15	8
Delphinium spp.	0.12 ± 0.12	2	0.03 ± 0.03	1
Descurainia spp.	0.03 ± 0.02	1	<0.01 ± 0.003	<1
Epilobium spp.	0.00	0	<0.01 ± 0.003	<1
Eriastrum wilcoxii	0.04 ± 0.02	3	0.00	0

Appendix D (Continued).

Erigeron spp.	0.00	0	0.02 ± 0.02	<1
Eriogonum spp.	0.36 ± 0.23	2	0.90 ± 0.35	8
Eriophylum lanatum	0.02 ± 0.02	<1	0.00	0
Frasera albicaulis	0.06 ± 0.06	1	0.03 ± 0.02	<1
Fritillaria atropurpurea	0.08 ± 0.04	1	0.03 ± 0.03	1
Geum spp.	0.00	0	0.02 ± 0.02	1
Gayophytum spp.	0.24 ± 0.08	12	0.07 ± 0.03	<1
Iris missouriensis	0.00	0	0.18 ± 0.18	<1
Lithophragma spp.	0.10 ± 0.05	4	0.07 ± 0.04	<1
Lithospermum ruderale	0.48 ± 0.29	2	0.02 ± 0.02	2
Lomatium spp.	0.74 ± 0.21	19	1.07 ± 0.29	28
Lupinus spp.	2.38 ± 0.49	31	1.80 ± 0.88	15
Mentzelia spp.	<0.01 ± 0.007	<1	0.00	0
Mertensia spp.	0.49 ± 0.20	9	0.06 ± 0.03	1
Microsteris gracilis	2.59 ± 0.53	61	1.0 ± 0.20	44
Penstemon spp.	0.00	0	0.03 ± 0.03	<1
Phacelia spp.	0.50 ± 0.24	7	0.21 ± 0.10	4
P. linearis	0.07 ± 0.07	1	0.00	0
Phlox spp.	0.09 ± 0.02	<1	0.00	0
P. longifolia	0.17 ± 0.09	5	0.02 ± 0.02	<1
Phoenicaulis cheiranthoides	0.00	0	0.18 ± 0.13	2
Polygonum spp.	0.03 ± 0.02	2	0.00	0
Ranunculus glaberrimus	0.04 ± 0.03	1	0.12 ± 0.04	4
Senecio spp.	0.91 ± 0.39	13	0.88 ± 0.25	14
S. canus	0.07 ± 0.05	2	0.02 ± 0.02	<1
S. integerrimus	0.36 ± 0.29	6	0.01 ± 0.01	<1
Tragopogon dubius	0.04 ± 0.04	<1	0.00	0
Viola spp.	0.42 ± 0.19	10	0.17 ± 0.14	4
Zygadenus spp.	0.06 ± 0.06	<1	0.00	0
Unknown	0.07 ± 0.06	1	0.51 ± 0.31	8

Appendix E. Cover (%, $\bar{x} \pm$ SE) and frequency of occurrence (%) of shrubs, grasses, and forbs from randomly sampled locations during the late brood-rearing period at Catnip Mountain wildfire and control sites, Sheldon National Wildlife Refuge, Nevada, 1998-2000.

	Catnip Mountain Burn (n = 19)		Catnip Mountain Control (n = 20)	
Habitat characteristic	Cover	Frequency	Cover	Frequency
Shrubs				
Artemisia arbuscula	0.00	0	0.32 ± 0.24	2
A. tridentata vaseyana	2.69 ± 1.28	9	23.34 ± 1.86	59
Chrysothamnus viscidiflorus	4.80 ± 0.86	21	4.58 ± 1.02	21
Leptodactylon pungens	0.00	0	0.27 ± 0.13	3
Purshia tridentata	0.14 ± 0.10	1	1.74 ± 0.85	6
Symphoricarpos spp.	0.16 ± 0.14	1	0.35 ± 0.35	1
Tetradymia canescens	0.58 ± 0.27	4	0.58 ± 0.28	3
Unknown	0.03 ± 0.03	<1	0.00	0
Grasses				
Agropyron spicatum	0.34 ± 0.19	2	1.02 ± 0.70	5
Bromus tectorum	1.41 ± 0.76	13	1.96 ± 0.93	12
Carex spp.	0.50 ± 0.50	1	0.53 ± 0.28	3
Elymus cinereus	0.44 ± 0.28	2	0.50 ± 0.39	1
Festuca spp.	2.24 ± 0.97	14	2.56 ± 0.87	16
Juncus spp.	0.38 ± 0.22	4	0.41 ± 0.22	4
Koeleria cristata	0.08 ± 0.08	2	0.56 ± 0.38	4
Oryzopsis hymenoides	0.13 ± 0.13	1	0.00	0
Poa sandbergii	2.14 ± 0.58	24	3.29 ± 0.81	24
Sitanion hystrix	7.95 ± 1.02	50	4.25 ± 0.88	35
Stipa spp.	5.13 ± 1.30	26	4.48 ± 1.72	20
Forbs				
Agoseris/Microseris spp.	2.06 ± 0.62	23	1.15 ± 0.41	17
Allium spp.	0.00	0	0.03 ± 0.03	1
Antennaria spp.	0.06 ± 0.06	1	0.00	0
Arabis spp.	0.00	1	0.23 ± 0.09	4
Aster spp.	0.03 ± 0.02	1	0.00	0
Astragalus spp.	0.00	0	0.19 ± 0.13	2
A. filipes	0.13 ± 0.13	1	0.00	0
A. obscurus	0.03 ± 0.03	1	0.00	0
Balsmarhiza sagittata	2.31 ± 1.24	6	1.63 ± 1.17	5
Castilleja spp.	0.87 ± 0.52	5	0.43 ± 0.25	4
Chaenactis spp.	0.00	0	0.06 ± 0.06	1
Collinsia parviflora	0.72 ± 0.30	9	0.91 ± 0.34	13
Collomia spp.	0.13 ± 0.06	6	0.005 ± 0.005	7
Crepis spp.	0.75 ± 0.36	7	0.24 ± 0.13	3
C. acuminata	0.19 ± 0.10	3	0.38 ± 0.26	4
Cryptantha spp.	0.55 ± 0.20	15	0.09 ± 0.05	4
Epilobium spp.	0.03 ± 0.03	1	0.00	0
Eriastrum wilcoxii	0.00	0	0.01 ± 0.01	1
Erigeron spp.	0.01 ± 0.01	1	0.03 ± 0.03	1
Eriogonum spp.	0.32 ± 0.14	4	1.38 ± 0.52	11
Frasera albicaulis	0.06 ± 0.06	1	0.06 ± 0.06	1

Appendix E (Continued).

Fritellaria atropurpurea	0.01 ± 0.01	1	0.00	0
Gayophytum spp.	3.67 ± 1.50	26	0.65 ± 0.19	19
Lithophragma spp.	0.00	0	0.01 ± 0.01	1
Lithospermum ruderale	0.88 ± 0.52	3	0.00	0
Lomatium spp.	0.34 ± 0.17	6	0.41 ± 0.15	11
Lupinus spp.	5.11 ± 1.27	42	2.79 ± 0.94	21
Mertensia spp.	0.22 ± 0.13	5	0.06 ± 0.05	2
Microsteris gracilis	2.79 ± 0.97	23	1.30 ± 0.39	21
Phacelia spp.	1.29 ± 0.65	9	0.03 ± 0.03	1
Phlox spp.	0.03 ± 0.03	1	0.00	0
P. longifolia	0.09 ± 0.04	3	0.02 ± 0.01	1
Polygonum spp.	0.03 ± 0.02	1	0.00	0
Senecio spp.	0.68 ± 0.41	8	0.39 ± 0.13	7
Tragopogon dubius	0.15 ± 0.07	2	0.00	0
Viola spp.	0.02 ± 0.01	2	0.00	0
Unknown	0.02 ± 0.01	2	0.11 ± 0.11	2