

IDAHO DEPARTMENT OF FISH AND GAME

Steven M. Huffaker, Director

Project W-160-R-33

Subproject 53

Completion Report



SAGE-GROUSE ECOLOGY

Study I: Greater Sage-grouse Habitat and Population Trends in Southern Idaho

Study II: Mortality Patterns of Juvenile Greater Sage-grouse

July 1, 2005 to June 30, 2006

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September 2006
Boise, Idaho



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ACKNOWLEDGMENTS

We sincerely appreciate the support provided by Idaho Department of Fish and Game and U.S. Bureau of Land Management personnel. In particular, A. Ogden, J. Rachael, N. Johnson, H. Miyasaki, R. Smith, J. Naderman, C. Anderson, D. Meints, and T. Hemker; S. Sather-Blair, and J. Lowe provided insight and encouragement. Many volunteers also spent countless cold spring nights helping to trap sage-grouse. We are grateful for their generous donation of time and good cheer. Numerous biological aides and wildlife technicians were employed on these studies. In particular, we thank J. R. Hickey, B. Lowe, T. Sachtleben, A. Lewis, D. Wiser, and J. Orton for field assistance. C. E. Braun provided a helpful review of a portion of an earlier draft of this report.

**PROGRESS REPORT
STATEWIDE WILDLIFE RESEARCH**

STATE:	<u>Idaho</u>	JOB TITLE:	<u>Sage-Grouse Ecology</u>
PROJECT:	<u>W-160-R-33</u>		
SUBPROJECT:	<u>53</u>	STUDY NAME:	<u>Greater Sage-grouse Habitat and Population Trends in Southern Idaho</u>
STUDY:	<u>I</u>		
JOB:	<u>1</u>		
PERIOD COVERED:	<u>July 1, 2005 to June 30, 2006</u>		

**GREATER SAGE-GROUSE (*CENTROCERCUS UROPHASIANUS*) HABITAT AND
POPULATION TRENDS IN SOUTHERN IDAHO**

Abstract

Funding provided by the Bureau of Land Management (BLM) and the U.S. Geological Survey (USGS) allowed the Department to expand work from an initial assessment of greater sage-grouse (*Centrocercus urophasianus*) populations and sagebrush (*Artemisia* spp.) rangeland on and near the Curlew National Grasslands (CNG) and the eastern portion of Owyhee County to include most sage-grouse habitat in Idaho. In the Curlew and Owyhee areas, initial assessment indicated that breeding populations showed distinct declines in the early 1980s with more severe declines during the early 1990s. Statewide monitoring data (males/lek) indicated that lek size significantly decreased ($r^2 = 0.50$, $P = 0.00$) from 1965-2003. Annual rates of change suggest a long-term decline for sage-grouse and support the trend information obtained from lek attendance. Sage-grouse populations declined at an overall rate of 1.47% per year from 1965-2003. From 1965-1984, the population declined at an average rate of 3.04% and fluctuated around a level that was approximately 1.1 times higher than the 2003 population. From 1985-2003, the population fluctuated around a level that was approximately 7% below the 2003 population and had an average change of 0.12% per year. Twenty-three percent of the CNG and 32% of BLM land in the Curlew Valley area remain in 11-25% sagebrush canopy cover and, thus, may provide suitable nesting and early brood-rearing habitat for sage-grouse. However, there may be an overestimate of quality nesting and brood cover available to grouse because the herbaceous understory was not considered in habitat classification. Moreover, habitat in both areas is highly fragmented. Understory forbs and grasses in sagebrush-dominated areas vary from sparse to relatively dense native stands. Because of increased funding, initial efforts began in FY 2001 to map sage-grouse distribution across southern Idaho. Maps were developed at the 1:100,000 scale. The maps have 6 basic layers. Sage-grouse stronghold habitats are areas with sufficient breeding habitat and stable to increasing population trends. Isolated habitats are those areas where breeding habitat remains but grouse within these areas are isolated from other sage-grouse populations. Key areas are those areas where sagebrush occurs with relatively intact understory, and sage-grouse use all or a portion of these areas sometime throughout the year. The other 3 layers are those areas surrounding sage-grouse use areas that have potential for rehabilitation (juniper [*Juniperus* spp.] invasion areas, crested wheatgrass [*Agropyron cristatum*] seedings, and sagebrush with annual grass understory). The maps are being used to help

biologists and land managers with landscape level management decisions. Updates and maintenance will continue into the future as cover changes due to development, rehabilitation, and wildfires.

Introduction

Sage-grouse populations throughout the west are closely tied to sagebrush habitats (Patterson 1952, Braun et al. 1977, Braun 1987). The dependence of sage-grouse on sagebrush for winter habitat has been well documented (Eng and Schladweiler 1972; Beck 1975, 1977; Robertson 1991). Similarly, the relationship between sagebrush and sage-grouse nest success has been thoroughly described (Klebenow 1969, Wallestad and Pyrah 1974, Wakkinen 1990, Connelly et al. 1991). Despite the well-known importance of this habitat to sage-grouse and other sagebrush obligates (Braun et al. 1976), the quality and quantity of sagebrush habitats continue to decline (Braun 1987, Swenson et al. 1987, Connelly et al. 2004). Schneegas (1967) reported that 2-2.5 million ha of sagebrush grassland had been treated from 1937-1967, and Braun et al. (1976) stated that an additional 3.9-8.4 million ha had been altered since 1967. Patterson (1952) indicated that sage-grouse have not adjusted, and doubtlessly will not adjust, their life processes to fit a pattern of land use that eliminates or seriously disturbs large tracts of sagebrush habitats.

Braun et al. (1977) previously described guidelines for maintenance of sage-grouse habitats. Since the publication of those guidelines, much more information has been obtained on the relative size of sagebrush habitats used by these grouse (Connelly 1982, Connelly et al. 1988, Wakkinen et al. 1992), the seasonal importance of sagebrush habitats (Benson et al. 1991, Connelly et al. 1991), the effects of pesticides on this species (Blus et al. 1989), and the effects of fire on sage-grouse (Benson et al. 1991, Robertson 1991, Fischer 1994, Connelly et al. 2000*b*). The new information was incorporated into revised guidelines for managing sage-grouse populations and habitats (Connelly et al. 2000*c*). Unfortunately, high-quality baseline data on current sage-grouse habitat are still lacking. Much of these data are available from files of various state and federal agencies. Collecting and compiling this information is a relatively simple, although time-consuming, task. This sort of assessment was completed for part of southeastern Idaho (Crowley and Connelly 1996, 1997) and it provides a solid basis for more intensive habitat assessment using GIS and satellite imagery (Homer et al. 1993). The purpose of this work is to assess long-term trends in populations throughout southern Idaho and associated changes in quantity and quality of sage-grouse habitats.

Study Area and Methods

Additional funding was obtained in FY 2000 from BLM and USGS. This funding allowed a biologist to be assigned to work on this project full-time. Therefore, data on sage-grouse populations (lek counts) and sagebrush habitats (mapping prescribed burns and wildfires, mapping other land-use changes, and detailed mapping of sage-grouse range) have been collated for all of southern Idaho.

Populations

Breeding populations have been monitored throughout most of southern Idaho for the last 25-50 years, and the more recent data were collected using standard lek censusing procedures (Jenni and Hartzler 1978, Connelly et al. 2003b). Lek surveys were used to detect leks (Connelly et al. 2003b) and lek counts were used to assess sage-grouse population trends in many areas of the state. The mean number of males per lek was determined by year, and data from satellite leks were not included (Gardner et al. 1997). During the mid-1980s through the late 1990s, many lek routes were established across the state. A lek route is a series of leks counted in one breeding area. Maximum number of males per route is recorded each year and general trends are obtained from these counts. Numerous lek routes occur throughout southern Idaho. Data from all lek routes have been collected since the mid-1990s to assess statewide population trends.

We calculated annual rates of change based on leks counted in consecutive years. We used annual rates of change applied to all known active leks in 2003 for a given state or province and standardized these values to reflect a percentage of the 2003 population. This approach provided a population index value that allowed an assessment of change over time. We then used these data to evaluate trends, variation, and density dependence in rates of population change from 1965-2003 and during early (mid-1960s to mid-1980s; a time of active sagebrush eradication programs) and late (mid-1980s to 2003; generally a time of reduced sagebrush control programs) periods. This approach treated the overall population with a density-independent model that provided an unbiased assessment of trend over the entire assessment period. The density-independent approach assumes normally distributed variation in the annual instantaneous growth rate (Dennis et al. 1991). Additionally, we applied a density-dependent model (Dennis and Taper 1994) to each time series (overall, early, and late) and assessed the likelihood of density dependence and approximate equilibrium population size as a proportion of the 2003 population. We used linear regression to estimate the parameters of the density-dependent model and bootstrapped the estimate to determine significance.

Habitats

In FY 1998, the statewide sage-grouse habitat assessment considered the Greater Curlew Valley area containing 212,083 ha in Oneida County. In FY 1999, this work was expanded to include approximately 1,300 km² of the eastern portion of Owyhee County. Thus, both eastern and western sage-grouse habitats within Idaho were sampled. In the Curlew Valley, mean annual precipitation ranges from 33 cm in the valleys to 46 cm in the mountains, half of which falls during winter as snow. Precipitation patterns are similar, but the amount is slightly greater in Owyhee County. The Curlew Valley area contains farmland, Conservation Reserve Program (CRP) fields, and rangeland classified as a sagebrush/bluebunch wheatgrass (*Artemisia tridentata*/*Agropyron spicatum*) habitat type. The eastern portion of Owyhee County consists of sagebrush-dominated areas fragmented by crested wheatgrass seedings and large burns, often dominated by cheatgrass (*Bromus tectorum*). Other areas in Owyhee County are dominated by low sage (*A. arbuscula*) and a mixture of mountain (*A. vaseyana*) and Wyoming (*A. wyomingensis*) big sagebrush with bluebunch wheatgrass and Idaho fescue (*Festuca idahoensis*) understory.

Disturbance to native stands of vegetation has been widespread in both areas (Gardner et al. 1997; J. W. Connelly, personal observation). Most of the remaining sagebrush habitat is now found on public lands administered by the U.S. Forest Service (USFS) and BLM. Sagebrush stands on these lands have been periodically subjected to prescribed fire, wildfire, herbicide treatments, and other sagebrush eradication techniques.

Results

Population Trends

Statewide

Recent analysis of lek data indicated that the existing database contained incomplete counts along lek routes as well as data from counts made during unfavorable weather. To improve the quality of these data, original data sheets were reviewed and unreliable counts were deleted from analysis of population trends. Nineteen lek routes distributed across southern Idaho had sufficient data to assess population trends since 1994. Most populations showed a slight decline during 1994-1996. Following a relatively wet year in 1996, populations generally increased until 2000 and began to decrease again during 2001 and 2002. During 2004-2005, lek counts across the state were stable to increasing with a few exceptions in the Southwest Region (Cow Creek), Magic Valley Region (Grassy Hills, Brown's Bench, Black Pine), Upper Snake Region (Stibal), and Southeast Region (Curlew). The overall 5-year average across the state appears to be stable.

A summary of the statewide population trends was reported by Connelly et al. (2004). Those data indicated that the proportion of active leks decreased from 1975-2003, averaging between 90% and 94% from 1965-1975 but decreasing to 73-77% from 1990-2003. Similarly, population trends indicated by average and median males per lek also decreased from 1975-2003 by 53% and 59%, respectively. Monitoring data (males/lek) indicated that lek size significantly decreased ($r^2 = 0.50$, $P = 0.00$) from 1965-2003 (Figure 1).

Annual rates of change suggest a long-term decline for sage-grouse in Idaho (Figure 2) and support the trend information obtained from lek attendance (males/lek). Sage-grouse populations declined at an overall rate of 1.47% per year from 1965-2003. From 1965-1984, the population declined at an average rate of 3.04% and fluctuated around a level that was approximately 1.1 times higher than the 2003 population. From 1985-2003, the population fluctuated around a level that was approximately 7% below the 2003 population and had an average change of 0.12% per year. Our analysis suggested a reasonably high likelihood of density dependence for the overall assessment period (likelihood = 0.84) and late period (likelihood = 0.88). However, we did not find substantial evidence for density dependence in the early period (likelihood = 0.47). Populations in the late 1960s and early 1970s were approximately 2 to 3 times higher than current populations (Figure 2). The population reached a low in the mid-1990s and has increased since that time. However, previous population recoveries did not reach levels attained in the late 1960s and early 1970s.

Curlew Valley Area Twenty-one leks (not including satellite leks) were documented within this study area between 1966 and 1998. Seven leks (33%) were on BLM land, 9 (43%) on USFS

land, and 5 (24%) on private land. For these leks, male attendance averaged 15 birds/lek from 1966-1997, approximately half of the statewide average for the same period. During spring 1999, 11 new leks were located in this study area. Of these, none were on BLM land, 8 occurred on USFS land, and 3 were on private land. Maximum male counts on the new leks ranged from 2 to 34 birds and the average size of the new leks was 12 males. Two routes have been established from these leks in the Curlew area, the Curlew lek route and the Rockland lek route. The Rockland lek route has increased substantially since 1999. The 2003 lek count was 118, more than double the previous 2 years' counts of 58 and 50 in 2002 and 2001, respectively. However, the Curlew lek route declined from 21 in 2000 to 5 in 2003. This could be related to a wildfire during the mid-1990s that burned much of the habitat within the Curlew Route. Some birds from the original Curlew Route may have shifted to the Rockland Route.

Breeding populations showed distinct declines in the early 1980s, with more severe declines during the early 1990s (Figure 3). Sage-grouse lek attendance appeared to reach an all-time low in this study area during the mid-1990s. From 1996-1999, only 2 of 7 (29%) known leks on BLM land and 3 of 9 (33%) known leks on USFS lands were active.

Owyhee County

During 1999, 7 new leks were identified near Grasmere in the southeastern portion of Owyhee County. Of these, 6 occurred on dry lakebeds and one was in a crested wheatgrass seeding. The new leks ranged from 1-19 males and the average size was <12 males. One new route (Sheep Creek) was established as a result of these new leks. Early data were infrequently collected and lek counts may not have been conducted using standard protocols. Thus, these data should be viewed with caution. More recent counts of males along the route are relatively static with about 50 males counted each spring since 1999 (Figure 4). Some birds attending these leks move south to summer range in the alfalfa fields near Riddle and into Nevada.

Habitat Trends

Statewide

ArcGIS® shapefiles of prescribed burns and wildfire occurring from 1990-2004 were obtained from BLM. Personnel from BLM and IDFG developed a detailed map of sagebrush distribution and sage-grouse range in Idaho. This map identifies areas where sage-grouse populations appear to be healthy or stable (source habitats, stronghold areas, isolated habitats) and areas where sage-grouse populations appear to be declining or threatened due to major habitat loss and fragmentation (conifer invasion, crested wheatgrass seedings, sagebrush with annual grass understory). The purpose of this mapping effort was to provide wildlife and habitat managers with information to prioritize sage-grouse populations for protection from wildfire and other land-use changes, and to identify areas for improvement of existing degraded habitat to increase or stabilize the range of sage-grouse in Idaho. It can also be used as a visual tool to identify changes in habitat, sage-grouse range, and land-use change from the 1950s to present. Shapefiles for the 2004 version of the habitat planning maps can be obtained through BLM or IDFG (Figure 5).

Curlew Valley Area

Privately-owned land comprises 41% of this study area; the BLM administers 40% of the area, and the USFS manages 17% of the study area. Nine percent (47,896 acres) of the USFS land is a separate administrative unit called the Curlew National Grasslands (CNG). About 67% of the study area could be considered historic sagebrush habitat and about 51% (177,540 acres) remains sagebrush-dominated rangeland. Fifty-seven percent of historic sagebrush habitat on the CNG and 49% of BLM land is now either classified as grass/forb or <10% sagebrush canopy cover and thus considered poor breeding and winter sage-grouse habitat. Twenty-three percent of the CNG and 32% of BLM remain in the 11-25% sagebrush canopy cover class and, thus, may provide suitable nesting and early brood-rearing habitat for sage-grouse. Overall, about 17% of the historic sagebrush habitat within the study area contains sagebrush cover suitable for nesting and early brood rearing.

Owyhee County

No quantitative assessments were made of habitat within this study area. Generally, higher-elevation breeding habitat on the southern portion of the study area appears in better ecological condition with a healthy herbaceous understory compared to the more xeric northern portion of the study area. The eastern portion of this study area is highly fragmented by wildfire and crested wheatgrass seedings.

Discussion

Populations

Sage-grouse populations have declined throughout the species' range (Connelly and Braun 1997, Connelly et al. 2004); the Greater Curlew Valley study area and eastern Owyhee County, as well as the remainder of the state, were no exceptions. However, the declines within both study areas appeared more severe than those in the remainder of Idaho. Due to the continued decline of active sage-grouse leks and numbers of males/lek, the hunting season in and around the Curlew Valley was closed during fall 2002. The season will remain closed until sage-grouse populations in the area begin to stabilize.

Autenrieth (1981) provided data that suggested Idaho had a relatively stable sage-grouse population from 1960-1979. In a more recent study, Connelly and Braun (1997) indicated that sage-grouse breeding populations had declined by 40% when they compared the long-term average of males/lek to the average obtained from 1985-1994 data. Our analysis generally supports the findings of previous research efforts. However, the estimated decline provided by Connelly and Braun (1997) was lower than that indicated by the current data. This may be due to use of a larger, more complete data set as well as the addition of 9 more years of data.

Habitat

Fire and drought may have major impacts on sage-grouse populations (Connelly and Braun 1997, Connelly et al. 1994, Connelly et al. 2000*b*). Both study areas, along with much of the

Intermountain West, suffered from drought in the late 1980s and early 1990s. Moreover, the CNG had a routine prescribed burning program to control sagebrush, and wildfires on both USFS and BLM lands were relatively frequent from 1961-1996 (Gardner et al. 1997). Moreover, during summer 2006, a wildfire burned >20,000 ha in the Curlew Valley affecting a large portion of the available sage-grouse winter range. Wildfires were also relatively frequent in the Owyhee County study area during the 1970s, 1980s, and 1990s.

Less than 35% of federally-managed rangelands within the Curlew study area currently support acceptable sagebrush cover for sage-grouse nesting and early brood-rearing habitat. However, this may be an overestimate of quality nesting and brood cover available to grouse because the herbaceous understory was not considered in habitat classification. Some of the sagebrush understory in the study area is degraded because of land management practices and the presence of bulbous bluegrass (*Poa bubosa*), a highly competitive exotic (Gardner et al. 1997, Apa 1998). Sage-grouse hens select habitat with healthy herbaceous understories for nesting and early brood rearing (Klebenow 1969, Connelly et al. 1991, Gregg 1991, Holloran et al. 2005). Remaining sagebrush rangelands within the study area are now being assessed to determine how much of the remaining habitat provides quality nesting and brood-rearing conditions for sage-grouse (Eddingsaas et al. 2005).

The 2004 version of the map showing sage-grouse stronghold areas, isolated habitats, key sage-grouse use areas, crested wheatgrass seedings, annual grass understory, and conifer invasion has been completed. The map will be updated annually as new fires occur and we obtain additional information on sage-grouse habitat across the state (change from perennial grassland to stronghold, etc.).

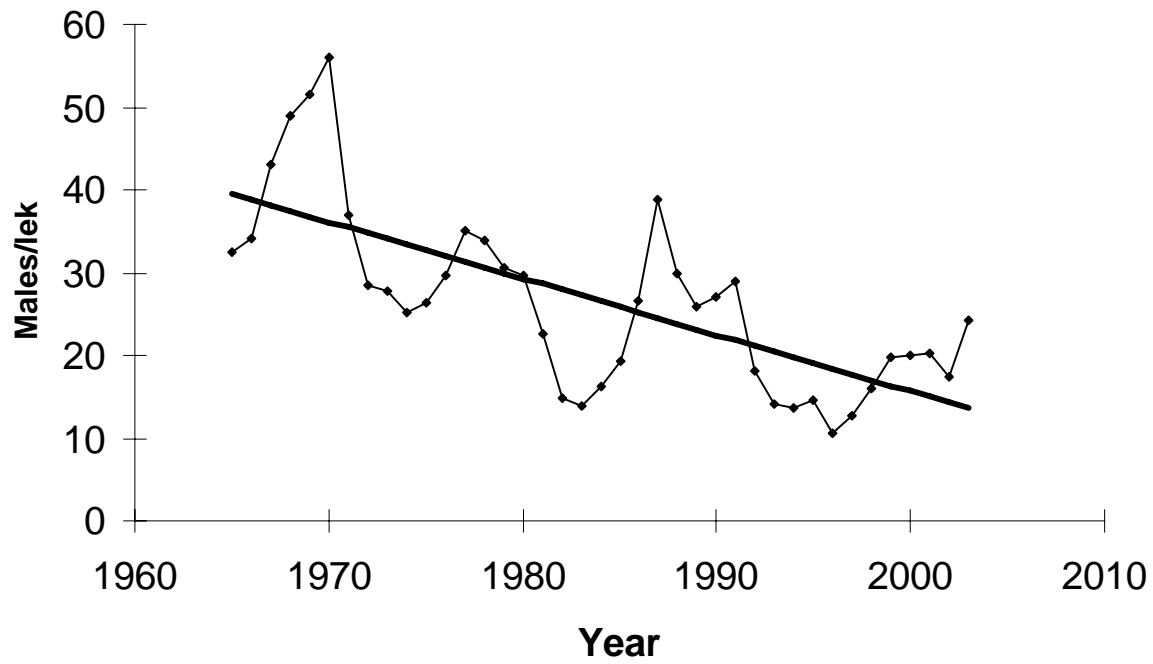


Figure 1. Change in lek size for sage-grouse in Idaho, 1965-2003.

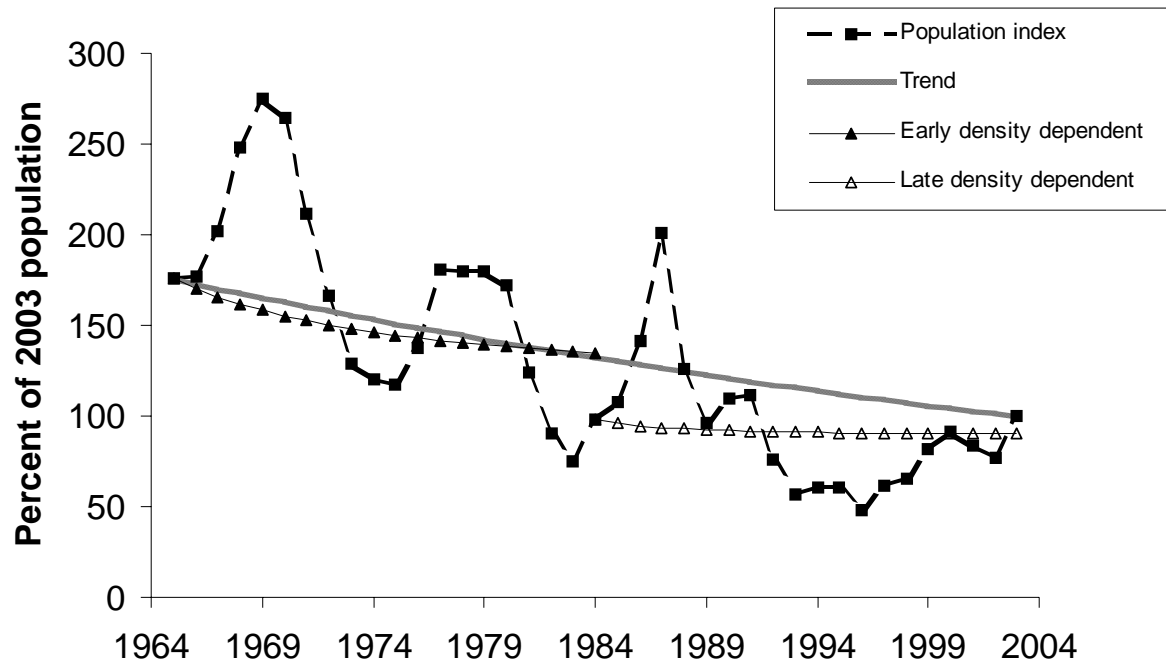


Figure 2. Change in the population index for greater sage-grouse in Idaho, 1965-2003.

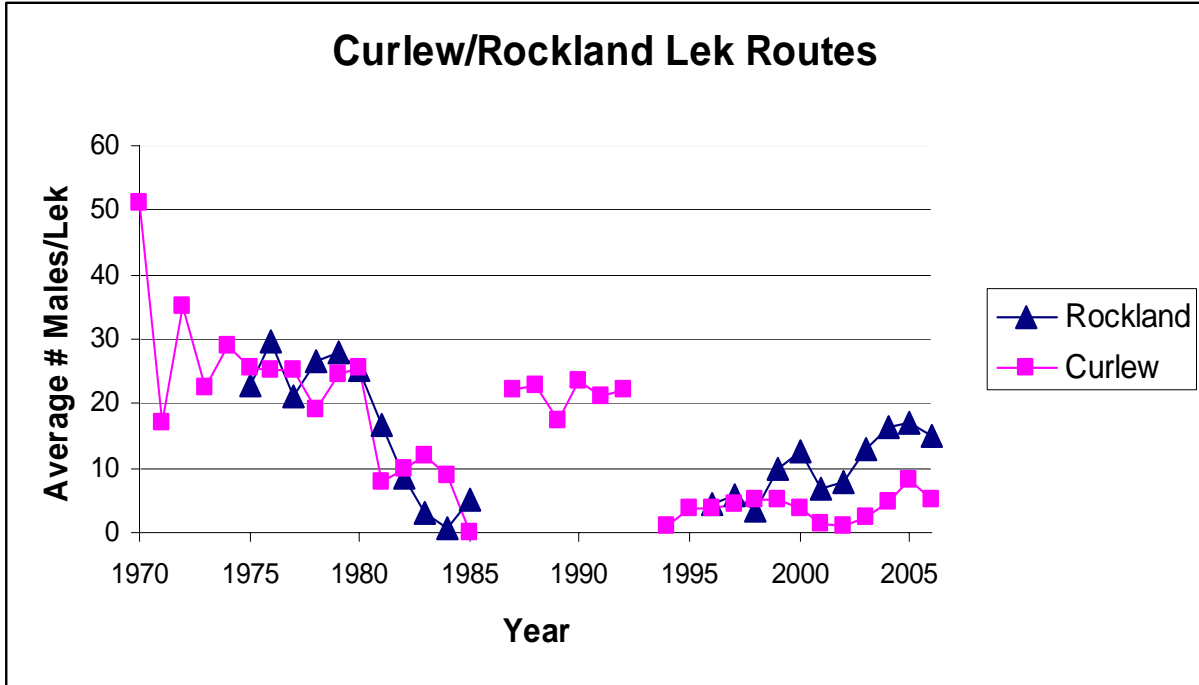


Figure 3. Sage-grouse population trends in the Curlew Valley area, 1970-2005.

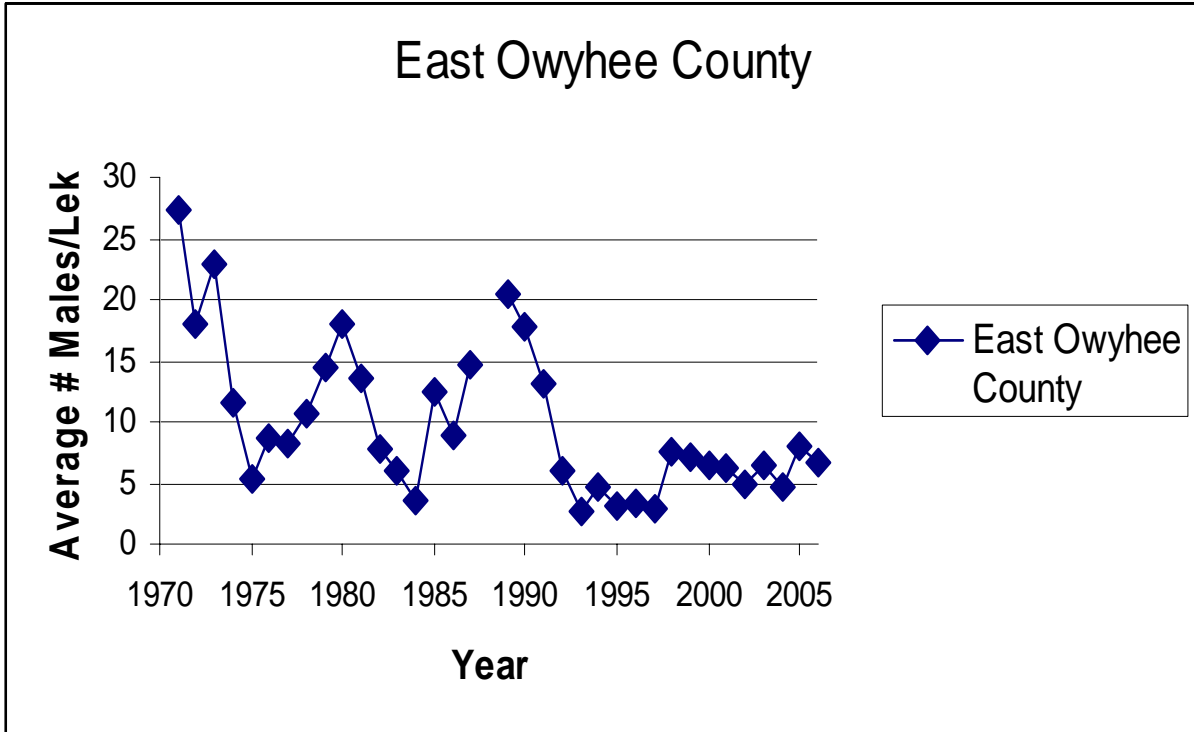


Figure 4. Sage-grouse population trends in eastern Owyhee County, 1970-2005.

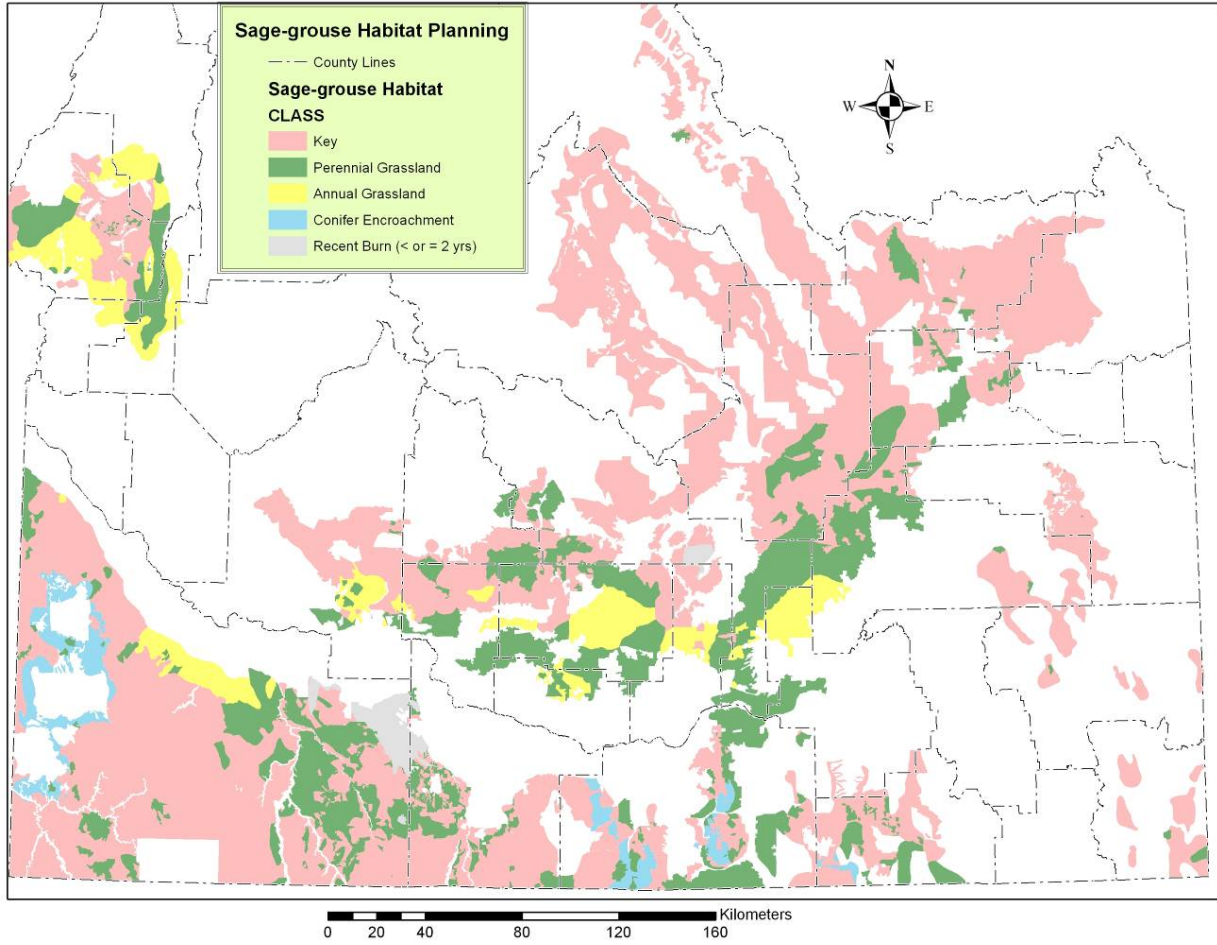


Figure 5. Idaho mid-scale sage-grouse habitat planning map, 2004-2005.

**PROGRESS REPORT
STATEWIDE WILDLIFE RESEARCH**

STATE:	<u>Idaho</u>	JOB TITLE:	<u>Sage-Grouse Ecology</u>
PROJECT:	<u>W-160-R-33</u>		
SUBPROJECT:	<u>53</u>	STUDY NAME:	<u>Mortality Patterns of Juvenile</u>
STUDY:	<u>II</u>		<u>Greater Sage-grouse</u>
JOBS:	<u>1-2</u>		
PERIOD COVERED:	<u>July 1, 2005 to June 30, 2006</u>		

JOB 1. MORTALITY PATTERNS OF JUVENILE GREATER SAGE-GROUSE

Abstract

Low recruitment has been suggested as a primary factor contributing to declines in greater sage-grouse populations. We evaluated movements and survival of 58 radio-marked, juvenile sage-grouse from 1 September (10 weeks of age) to 29 March (40 weeks of age) during 1997-1998 and 1998-1999 in lowland and mountain valley study areas in southeastern Idaho. Juvenile sage-grouse captured in the mountain valley moved further ($\bar{x} = 16.2$ km, range = 12.1-24.2 km, $F_{1,22} = 9.64$, $P = 0.005$) from summer to winter range than juvenile grouse captured in the lowland area ($\bar{x} = 12.8$ km, range = 7.3-19.1 km). Fifty-percent of deaths in the lowland population were attributable to human-related mortality including power line collisions and legal harvest. All deaths in the mountain valley population were attributed to avian or mammalian predators. Survival was relatively high for birds from both populations, but survival was higher across years in the lowland ($\bar{x} = 0.86$, SE = 0.06, $n = 43$) than in the mountain valley population ($\bar{x} = 0.64$, SE = 0.13, $n = 14$). Our findings indicate that juvenile sage-grouse from populations that move farther distances to access seasonal ranges may experience lower survival than juveniles from more sedentary populations. Moreover, high juvenile survival in our study suggests that if low recruitment occurs in sage-grouse populations, it is likely due to other factors, especially low early chick survival.

Introduction

Greater sage-grouse historically occupied sagebrush rangelands in at least 13 states and 3 Canadian provinces, and now occur in 11 states and 2 provinces (Schroeder et al. 2004). Range-wide, populations declined 3.5% per year from 1965-1985 and 0.4% per year from 1986-2003 (Connelly et al. 2004). These declines are attributed to loss, degradation, and fragmentation of sagebrush steppe habitat resulting from long-term impacts including agricultural expansion (Swenson et al. 1987), drought (Connelly and Braun 1997), fire (Connelly et al. 2000b, Connelly et al. 2004), invasive species (Connelly et al. 2004), and livestock-related activities (Beck and Mitchell 2000, Crawford et al. 2004). Continuing changes to sage-grouse habitats include communication towers, mining and energy developments, roads, power lines, fences, reservoirs, and urbanization (Braun 1987, Braun 1998, Connelly et al. 2004). These changes have affected

brood-rearing habitats, potentially driving population declines through low survival of juveniles (Connelly and Braun 1997, Beck et al. 2003, Crawford et al. 2004).

Sage-grouse are long-lived birds, but adult males typically have shorter life spans than adult females (June 1963, Connelly et al. 1994, Zablan et al. 2003). Lower survival in adult males is likely related to rapid weight loss and increased vulnerability of males on leks during the breeding season (Beck and Braun 1978, Connelly et al. 1994). Average annual survival rates for sage-grouse banded on leks in Colorado and primarily recovered by hunters were 59% and 37% for adult (>1 year of age) females and males, respectively; and 77% and 63% for sub-adult (<1 year of age) females and males, respectively (Zablan et al. 2003). Annual survival rates for radio-marked adult sage-grouse in southeastern Idaho over 8 years ranged from 60-78% (Connelly et al. 1994). In southwestern Idaho, annual survival rates were 54-87% for adult males, 42-80% for adult females, and 22-55% for sub-adult (10 weeks to 15 months of age) females (Wik 2002). In northwestern Colorado, survival rates pooled over 2 years were 57% for adult females and 75% for yearling females (Hausleitner 2003).

Estimates of chick (0-10 weeks of age) and juvenile (10-40 weeks of age) survival are limited and have not been based on standardized time periods, making comparisons difficult. Crawford et al. (2004) averaged partial estimates from 3 studies to compute a mean survival rate of 10% for juvenile sage-grouse from hatching to the first potential breeding season. June (1963) reported that survival of juveniles from hatching to autumn was 38% in Wyoming. Chick survival between hatching date and 50 days after hatching (7 weeks of age) was estimated to be 33% in Washington (Schroeder 1997) and 18% in Alberta (Aldridge and Brigham 2001). In contrast, mortality rates for chicks from all North American grouse species range from 40-50% from hatching to autumn (Bergerud 1988).

We investigated movements and survival rates of juvenile sage-grouse occupying different habitats (Connelly et al. 1988, Connelly et al. 2003a) to better understand survival of different age classes of greater sage-grouse in southeastern Idaho. We defined juveniles as birds from 10 weeks of age until entering their first breeding season in March (approximately 40 weeks of age). We based our definition on the fact that young males outweigh young and adult females by 10-12 weeks post hatching and weights of young female and adult female sage-grouse are nearly equal by October (Patterson 1952, Dalke et al. 1963). Our objectives were to: 1) assess space use and seasonal movements of juvenile greater sage-grouse in mountain valley and lowland populations; 2) estimate survival rates of juvenile greater sage-grouse in mountain valley and lowland populations; 3) document mortality patterns for juvenile greater sage-grouse in mountain valley and lowland populations; and 4) evaluate relationships between seasonal movements and survival rates of juvenile sage-grouse.

Study Areas

Medicine Lodge, the mountain valley study area (Figure 6), consisted of 157-km² in Clark County, Idaho (44° 18' N, 112° 27' W) and was administered by private landowners (50%), BLM (46%), and the state of Idaho (4%). Elevations range from 1,664-2,282 m above mean sea level with topography of moderate to high relief. Main topographical features include creek drainages, basalt outcroppings, mountain ridges, and peaks. Livestock ponds, wet meadows,

springs, seeps, and creeks were common. Vegetation was dominated by mountain big sagebrush at higher elevations in the north, xeric sagebrush composed of Wyoming big sagebrush and basin big sagebrush (*Artemisia tridentata tridentata*) on deeper soils in the south, and low sagebrush on ridgetops with underlying shallow soils throughout Medicine Lodge (Table 1). Douglas-fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*) stands occurred at higher elevations. Portions of the area were previously strip-sprayed to remove sagebrush and planted with crested wheatgrass. Predominant land use was livestock grazing.

Table Butte, the lowland study area (Figure 6), consisted of 451-km² in Clark (77%) and Jefferson (23%) counties, Idaho (44° 06' N, 112° 24' W) with lands administered by BLM (57%), private landowners (39%), and the state of Idaho (4%). Elevations range from 1,463-1,812 m, and topography is of low relief with outcrops of basalt scattered throughout the landscape. Free water was scarce. The surrounding private land was predominately crop agriculture dominated by alfalfa and potato production. A xeric sagebrush community composed of Wyoming big sagebrush, basin big sagebrush, and some three-tip sagebrush (*A. tripartita*) covered most of the unfragmented rangelands (Table 1). A portion of the area burned in the early 1990s and was dominated by seeded crested wheatgrass. Conservation reserve program lands bordered alfalfa fields in the eastern portion of Table Butte. Livestock grazing and cropland agriculture were the dominant land uses.

The climate of both study areas is continental, characterized by cold winters and hot summers. We obtained climatic data from a weather station at the U.S. Sheep Experiment Station in Dubois, Idaho (1,664 m; 44° 15' N, 112° 12' W; Figure 6; Western Regional Climate Center 2005). Average monthly temperatures from September through March were 1.3° C in 1997-1998 and 1998-1999, similar to the 30-year (1971-2000) average of 0.1° C. September through March cumulative precipitation was 13 cm in 1997-1998 and 14 cm in 1997-1998, slightly drier than the 16 cm, 30-year average (Western Regional Climate Center 2005).

Coyotes (*Canis latrans*), red fox (*Vulpes vulpes*), common ravens (*Corvus corvax*), golden eagles (*Aquila chrysaetos*), soaring hawks (*Buteo* spp.), and weasels (*Mustela* spp.) were common predators of sage-grouse in both study areas. There was much less cropland, no low-lying power lines, and relatively few pasture fences in Medicine Lodge compared to Table Butte. Grouse in Table Butte were exposed to agricultural hazards such as agrochemicals (Blus et al. 1989), farm machinery, fences, power lines, and vehicles, as well as non-native predators including dogs, domestic cats, and red fox.

Methods

Trapping and Marking

We trapped yearling and adult female sage-grouse in March and April on 7 leks in and adjacent to both study areas to facilitate trapping of juveniles during summers 1997 and 1998. Females breeding on these leks commingled, but separated following nesting to rear broods. We trapped and marked juveniles from the first week of August through the first week of October, but we did not trap during full moons or the 1-week mid-September hunting season. While trapping and handling birds, we followed animal welfare protocols of Gaunt and Oring (1997) and the

University of Idaho Animal Care and Use Committee. We used a spotlighting technique (Giesen et al. 1982, Wakkinen et al. 1992, Connelly et al. 2003b) to trap sage-grouse. We used roosting locations of radio-marked yearling and adult females as well as observations of sage-grouse broods in evening hours to locate juveniles during the trapping period. We restrained all captured grouse in burlap sacks to reduce stress. To reduce hen-brood separation, we held all captured birds in partitioned cardboard boxes or paper sacks and released birds at the point of capture.

We assigned captured sage-grouse to age and gender categories based on mass (Eng 1955a, Pyrah 1961, Dalke et al. 1963), plumage characteristics (Bihrlé 1993), and length of primary feathers (Beck et al. 1975, Idaho Department of Fish and Game 1989). We weighed each juvenile and, depending on mass, we fitted individuals with 15 or 18 g radio transmitters with built-in mortality sensors (Advanced Telemetry Systems, Inc., Isanti, Minnesota) and a numbered aluminum leg band. Radio transmitters were <3% of the body mass of each juvenile grouse.

Monitoring

We detected locations of radio-marked grouse with radio telemetry from the ground by visual observations of the birds or by circling the estimated location using the loudest signal strength (Springer 1979). Relocations were made from a fixed-wing aircraft twice each year, when several marked birds could not be located from the ground. We relocated birds on the ground that we initially located from the air. We recorded the Universal Transverse Mercator (UTM) coordinates (datum, NAD27; projection, UTM Zone 12) at each location with a GPS unit or by examining 7.5-minute, USGS topographical maps. We documented fate (alive or dead) for each bird based on pulse signals. When pulse signals indicated mortality, we collected forensic evidence to identify cause of death (Thirgood et al. 1998).

Space Use and Movements

We conducted home range analyses in ArcView 3.3 (Environmental Systems Research Institute, Inc., Redlands, California, USA, 1992-2002) to delineate study area boundaries. We used the Home Range extension for ArcView (Rodgers and Carr 2002) to select 90% of all sage-grouse diurnal locations from 1 September through 29 March, 1997-1998 and 1998-1999 in each study area with the harmonic mean method (Dixon and Chapman 1980) and then placed a minimum convex polygon (Mohr 1947) around these locations using the Animal Movements Program extension for ArcView (Hooge and Eichenlaub 1997). We used a 100% minimum convex polygon to delineate the area all grouse used from 1 September through 29 March, 1997-1998 and 1998-1999.

We clipped 30-m resolution vegetation coverage grids from Idaho GAP (Scott et al. 2002) to the 90% minimum convex polygon for each study area. We reclassified the vegetation in each study area as agriculture, forest, grassland, low intensity urban, low sagebrush, mountain big sagebrush, riparian, other shrubs, and xeric big sagebrush (basin and Wyoming) cover types. We used Frag Stats 3.3 (McGarigal and Marks 1995) to evaluate fragmentation metrics at the cover type scale including patch density, mean patch area, and perimeter to area ratio of patches for

agriculture, grassland, low sagebrush, mountain big sagebrush, and xeric big sagebrush. The subset of cover types we selected was important for sage-grouse relative to space use in the study areas.

We designated seasons as summer (Jun-Aug), fall (Sep-Nov), winter (Dec-Feb), and spring (March-May; Leonard et al. 2000). We evaluated linear distances juvenile sage-grouse moved from fall to winter range using the Pythagorean theorem to compute distance moved by each bird from the UTM coordinates at the earliest location in fall following capture (Sep or Oct) to the UTM coordinates at the latest location in winter, excluding the location of death.

We used a 3-way ANOVA to evaluate differences in gender, year, and study area, and interactions, for distances moved from fall range to winter range (PROC GLM; SAS Institute 2001) and pooled non-significant interactions into sampling error. We assessed normality and equal variance in movement distances with appropriate plots (Proc UNIVARIATE; SAS Institute 2001). Because of its effect on normality and equal variance, we removed 1 female captured in Table Butte in 1997 that moved 32.8 km from fall to winter range. This bird also made long-distance movements the following year, which did not correspond with movement patterns of other birds. Retaining this bird in our analysis affected our ability to detect differences among variables. We normalized and homogenized variances of the remaining set of response data through a log₁₀ transformation. We report statistical differences based on the transformed data, but report raw estimates of movement distances to improve interpretability of results. We conducted post hoc multiple comparisons with the Tukey-Kramer HSD test.

Survival

We evaluated juvenile sage-grouse survival for the 30-week period extending from 1 September through 29 March in 1997-1998 and 1998-1999. Grouse were censored if their radio transmitters were lost or quit functioning, and were right-censored if they survived past 29 March. Each year, survival of right-censored birds was confirmed with aerial flights conducted shortly after 29 March.

We evaluated survival by year (1997 and 1998), gender (male and female), and study area. We estimated survival with the Kaplan-Meier product limit estimator (Kaplan and Meier 1958) modified for staggered entry (Pollock et al. 1989). We computed the variance for survival estimates following Greenwood (1926) and compared survival rates between groups with a log-rank test (Cox and Oakes 1984:105). We did not have a sufficient sample of birds to test for differences in survival between years at Medicine Lodge; however, we found no difference in survival between years at Table Butte ($\chi^2 = 0.03$, $P = 0.862$); we used this evidence to pool data within study areas across years.

Results

Trapping and Marking

Twenty-six juveniles were radio-marked in 1997 and 32 in 1998. Female to male ratios for radio-marked juvenile sage-grouse were 0.9:1 during 1997 and 1:1 during 1998. Of the radio-

marked juveniles, 15 (26%) were captured in Medicine Lodge (3 in 1997 and 12 in 1998) and 43 (74%) were captured in Table Butte (23 in 1997 and 20 in 1998).

Space Use and Movements

Xeric big sagebrush was the dominant cover type in each study area (Table 1). Agriculture covered 28% of Table Butte and only 6% of Medicine Lodge, and patches of agricultural cover were nearly 8 times larger on average in Table Butte than in Medicine Lodge (Table 1). Patch density was highest for low sagebrush in Medicine Lodge and for grassland cover in Table Butte. Xeric big sagebrush provided patches of cover with more complex or elongated boundary shapes than other cover types in both study areas based on largest perimeter to area ratios (Table 1).

We delineated a 100% minimum convex polygon for the area used by all sage-grouse from 1 September through 31 March, 1997-1998 and 1998-1999, based on 317 diurnal locations of grouse following capture and located through aerial and ground monitoring (Figure 6). Of these locations, 50 were from 13 birds in Medicine Lodge and 267 were from 40 birds in Table Butte. After removing 1 outlier location from consideration, we delineated the Medicine Lodge study area boundaries from 44 of 50 locations from 13 birds (Figure 6). We delineated the Table Butte study area with 241 of 267 locations from 40 birds (Figure 6). Movement analyses were based on 234 locations in fall and 74 locations in winter, which corresponds to 97% of all locations from August through March. We evaluated distances moved from fall to winter ranges for 5 grouse (2 females, 3 males) captured in Medicine Lodge and 22 grouse (9 females, 14 males) captured in Table Butte.

There were no differences in fall to winter movements for year or gender main effects or for the gender x year, study x year, or the gender x study x year interactions. Juvenile sage-grouse captured in Medicine Lodge moved further ($\bar{x} = 16.2$ km, range = 12.1–24.2 km, $F_{1,22} = 9.64$, $P = 0.005$) from summer to winter range than juvenile grouse captured in Table Butte ($\bar{x} = 12.8$ km, range = 7.3–19.1 km). There was a difference in movement distances for the gender x study area interaction ($F_{1,22} = 8.14$, $P = 0.009$). We found no difference (Tukey-Kramer HSD test $P = 0.094$) in movements between females ($\bar{x} = 20.6$ km, range = 17.0–24.2 km) and males ($\bar{x} = 13.3$ km, range = 12.1–14.1 km) captured in Medicine Lodge. Females captured in Medicine Lodge moved further (Tukey-Kramer HSD test $P < 0.05$) from summer to winter habitat than females ($\bar{x} = 12.0$ km, range = 7.3–19.1 km) and males ($\bar{x} = 13.4$ km, range = 9.6–18.4 km) captured in Table Butte. Three grouse (2 females, 1 male) crossed Interstate 15 to access habitat in Fremont and eastern Clark counties. We located these birds 11 times (4% of all Table Butte locations) from 1 November to 22 December in 1997 and 1998 (Figure 6).

One female from Medicine Lodge died within 1 day of capture in 1997; following a necropsy we determined this bird died from capture-related stress, and was thus not considered in survival analyses. One male trapped in Table Butte in 1998 lost his radio collar 6 weeks after he entered the study on 1 September and was censored. Of the remaining 56 birds, 11 (20%) died from 1 September through 31 March, 1997-1998 and 1998-1999 (Figure 7). The remaining 45 birds (Medicine Lodge = 9, Table Butte = 36) survived and became sub-adult sage-grouse. Mortality by study area was 5 of 14 (36%) in Medicine Lodge and 6 of 43 (14%) in Table Butte. Two

deaths occurred in September (18%), 5 in October (46%), 1 in November (9%), 2 in December (18%), and 1 in March (9%; Figure 7). All mortalities in Medicine Lodge were attributed to predators (avian = 80%, mammal = 20%), while mortality associated with human activities (legal harvest = 17%, power line collisions = 33%) accounted for 50% of mortalities in Table Butte. All mortalities associated with human activities in Table Butte occurred during September and October (Figure 7). Of total mortalities, avian predation was the cause of death for 36% of grouse, followed by mammal predation (27%), power line collisions (18%), legal harvest (9%), and unknown cause (9%; Figure 7). We found no difference ($\chi^2 = 0.15$, $P = 0.699$) in survival between female ($\bar{x} = 0.78$, $SE = 0.08$, $n = 27$) and male ($\bar{x} = 0.82$, $SE = 0.07$, $n = 30$) juvenile sage-grouse. Survival was lower ($\chi^2 = 3.12$, $P = 0.077$) at Medicine Lodge ($\bar{x} = 0.64$, $SE = 0.13$, $n = 14$) than at Table Butte ($\bar{x} = 0.86$, $SE = 0.06$, $n = 43$; Figure 8). Once young sage-grouse reached 10 weeks of age, they experienced low-to-moderate mortality (14-36%) through March. Mortality in both study areas was concentrated in fall with only 3 deaths occurring from December through March.

Discussion

Our estimates of juvenile sage-grouse survival are higher than estimates of survival for chicks from hatching to 7 weeks (Schroeder 1997, Aldridge and Brigham 2001), hatching through autumn (June 1963), and hatching until birds enter the breeding season (Crawford et al. 2004). A comparison of our results with previous estimates suggests relatively high mortality of sage-grouse chicks (0-10 weeks of age), probably most influenced previous estimates of juvenile survival. We did not investigate survival of chick sage-grouse (see Job 2) and it is difficult to know whether recruitment was higher or lower for sage-grouse inhabiting the 2 study areas. Greater concentrations of predators, use of agrochemicals, and other human-related activities in and near agricultural areas may have reduced survival of chicks in Table Butte compared to Medicine Lodge, even though estimates of juvenile survival were lower in Medicine Lodge.

Low recruitment in prairie grouse reflects low juvenile survival rates, low reproductive potential for adult females or both phenomena. Clutch sizes for sage-grouse average 6.6–9.1 eggs (Schroeder et al. 1999), reflecting a relationship between low adult mortality rates and low clutch size among North American grouse (Bergerud 1988). Average nest success (nests hatching >1 egg) for sage-grouse ranges from 15-86% (Schroeder et al. 1999). In southeastern Idaho, percentage of females known to initiate nesting was 55% for yearlings and 78% for adults, nest success for both age classes averaged 52%, and renesting rate for unsuccessful first nesters was 15% (Connelly et al. 1993). Renesting rates in areas with smaller populations were 36% in Alberta (Aldridge and Brigham 2001), and 82% for yearling females and 88% for adult females in Washington (Schroeder 1997). These findings suggest reproductive success among female sage-grouse may be highly variable. Our study suggests that survival of chick sage-grouse may be the factor most limiting recruitment in sage-grouse populations and needs further study.

Population viability analysis for sage-grouse in North Park, Colorado, incorporating sensitivity and elasticity analyses of vital rates indicated that adult and juvenile survival followed by adult and juvenile fecundity most limited population growth (Johnson and Braun 1999). Reproductive success, measured through mean juvenile-to-adult ratios in summer, of Attwater's prairie-chicken (*Tympanuchus cupido attwateri*) in Texas was less than that for greater prairie-chickens

(*T. c. pinnatus*) in summer and fall across its range of distribution (Peterson and Silvy 1996). In addition, average nest success and chicks per brood prior to brood breakup were also lower for Attwater's compared to greater prairie-chickens (Peterson and Silvy 1996). These results indicate that declines in prairie grouse populations are likely related to low juvenile survival or poor reproductive success among females.

Adult sage-grouse have low over-winter natural mortality, and most mortality occurs in spring and summer (Connelly et al. 2000a). We likewise found low over-winter mortality of juvenile sage-grouse. Therefore, specific causes of mortality during spring and summer could potentially be influencing population declines of sage-grouse, and identification of these factors may provide managers with information to develop recommendations and strategies for increasing numbers of sage-grouse. Exposure to wet and cold weather after hatching can limit survival of sage-grouse chicks (Patterson 1952), linking yearly survival to annual weather patterns. Predation is the largest direct cause of prairie grouse mortality, through affecting nest success, juvenile survival, and adult survival (Schroeder and Baydack 2001); other factors responsible for juvenile mortality include accidents, hunting, disease, and parasites. Half of the deaths in the lowland population were attributable to human activities during September and October. In contrast, all deaths in the mountain valley population were related to predators from October through December when birds were moving to winter habitats.

Sage-grouse in Medicine Lodge moved farther from fall ranges to winter ranges than birds in Table Butte. Although our sample was limited, females from the mountain valley population moved farther than males and females from the lowland population. Female sage-grouse disperse greater distances than males (Dunn and Braun 1985), and juvenile prairie grouse may move further during autumn than adults, leading to higher mortality (Bowman and Robel 1977). Our results support the concept that mortality of juvenile sage-grouse in fall may increase as distances moved between seasonal ranges increases.

Management Implications

Previous studies suggest recruitment is very important in maintaining sage-grouse populations (Connelly and Braun 1997, Crawford et al. 2004). Understanding survival and mortality patterns of juvenile sage-grouse is critical because recruitment has the greatest effect on growth of sage-grouse populations. Managers and researchers should focus efforts on factors that influence sage-grouse production, and chick and juvenile survival. A common way production is indexed in sage-grouse populations is through ratios of juveniles to adult (including yearling) hens obtained from the wings of hunter-harvested birds in autumn (Connelly and Braun 1997, Connelly et al. 2000c, Beck et al. 2003). These ratios have, at times, indicated stable to increasing populations when populations were declining, likely reflecting disproportionate harvest of adult females and juveniles near moist areas (Beck et al. 2003). Additional work on evaluating production should compliment our understanding of recruitment, which appears to be low in sage-grouse populations (Dunn and Braun 1985). Particular importance should be placed on studies evaluating chick and juvenile survival.

Both sage-grouse populations we studied were migratory, moving >10 km from fall to winter ranges (Connelly et al. 2000c). We found that juveniles migrating long distances to winter

ranges may have higher mortality, increasing the need to conserve large continuous areas of sage-grouse habitat to reduce exposure to predators and other hazards. Conservation and enhancement of movement corridors and large unfragmented habitat patches appears critical to promoting high survival among juvenile sage-grouse from migratory populations.

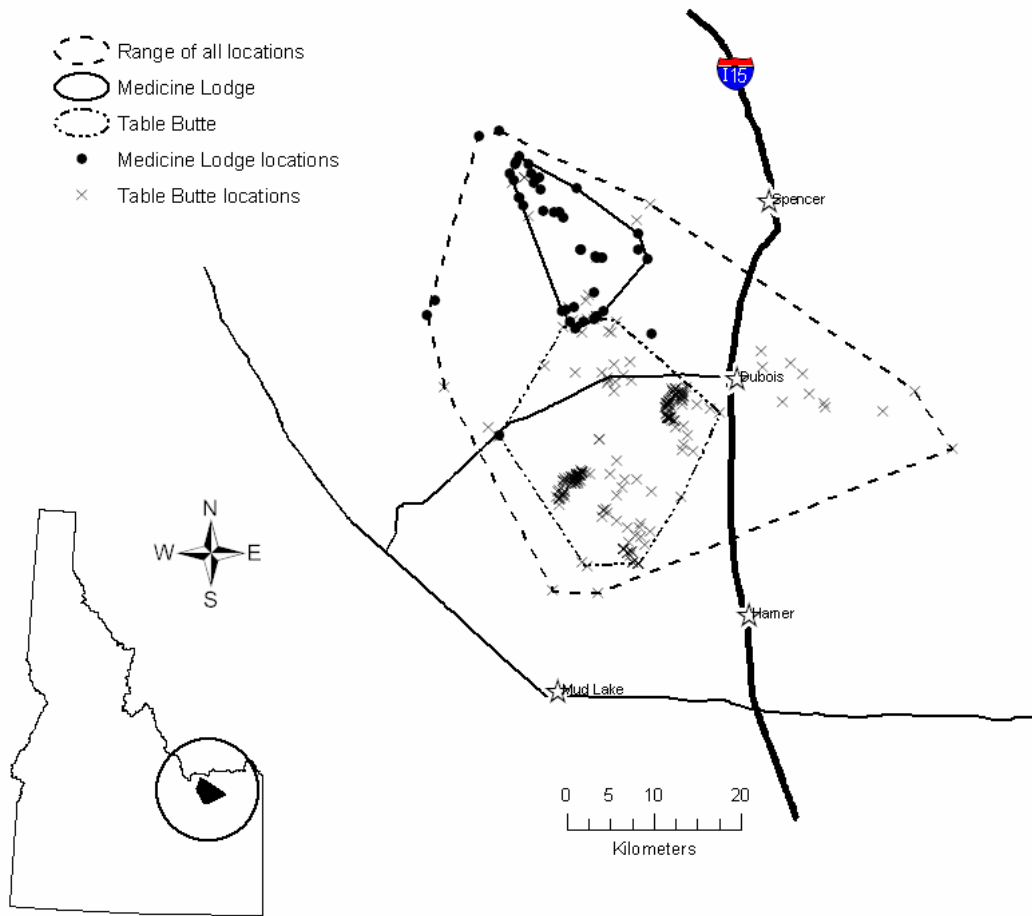


Figure 6. Juvenile greater sage-grouse study areas and range of all locations, southeastern Idaho, 1997-1999. Medicine Lodge and Table Butte study area boundaries based on 90% minimum convex polygons around all juvenile sage-grouse locations in these areas from 1 September through 29 March, 1997-1998 and 1998-1999. Range of all locations was delineated with a 100% minimum convex polygon around all juvenile sage-grouse locations from 1 September through 29 March, 1997-1998 and 1998-1999.

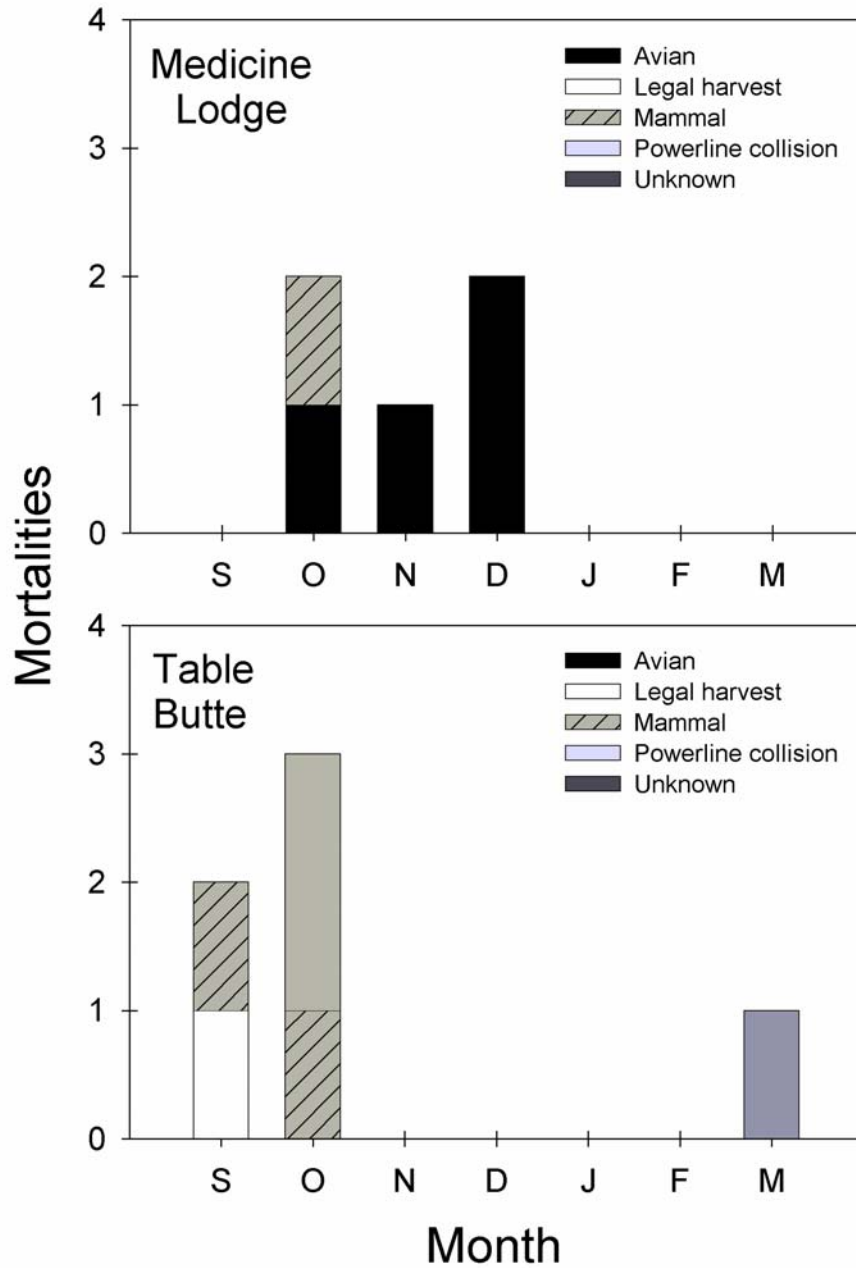


Figure 7. Mortality by cause and month for juvenile greater sage-grouse, Medicine Lodge and Table Butte, Idaho. Mortalities are monthly totals from September through March, 1997-1998 and 1998-1999.

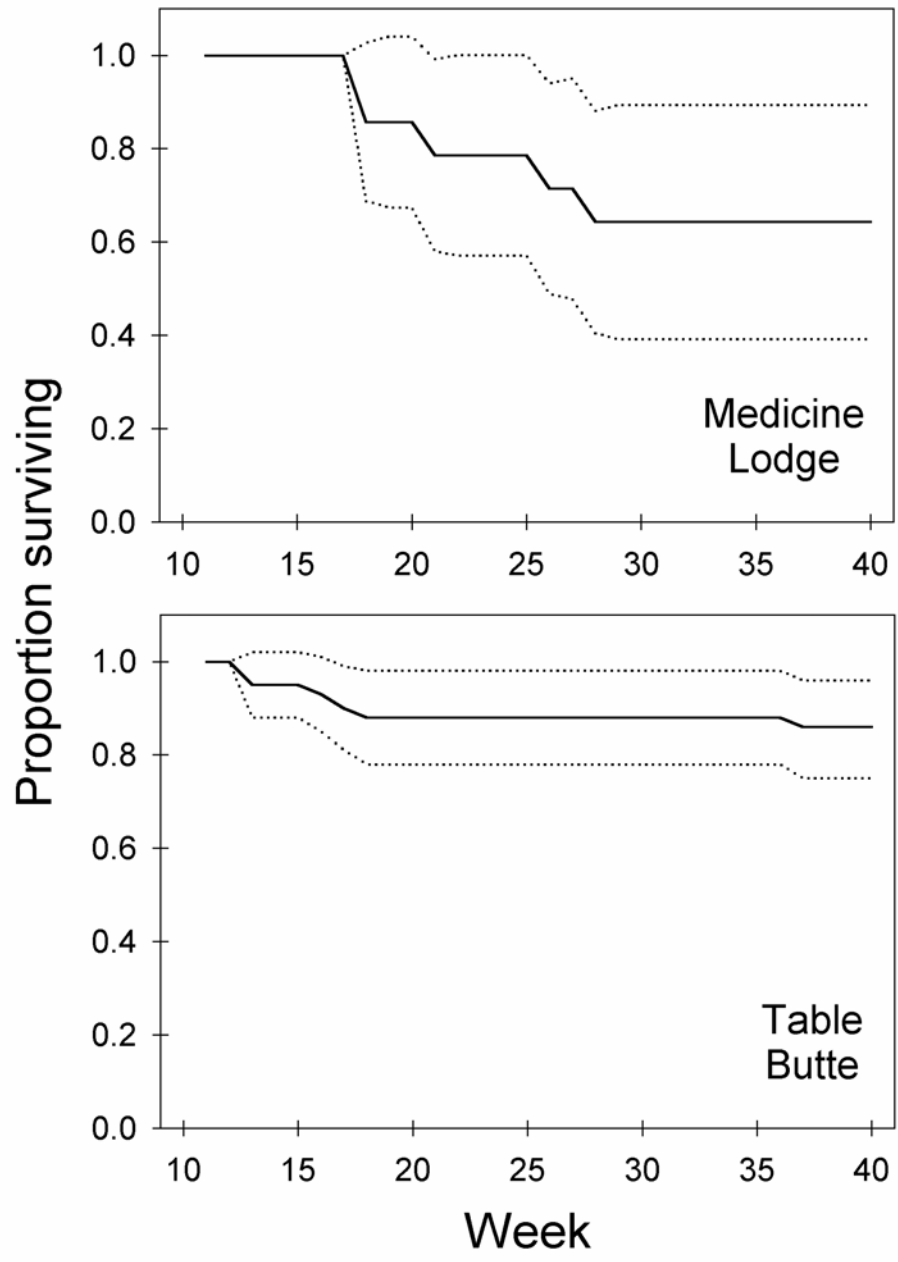


Figure 8. Kaplan-Meier product limit survival curves with 95% confidence limits (dashed lines) for juvenile greater sage-grouse, Medicine Lodge and Table Butte, Idaho. Survival rates are from 1 September (week 10) through 29 March (week 40), 1997-1998 and 1998-1999.

Table 1. Area and patch metrics for cover types important to greater sage-grouse, Medicine Lodge and Table Butte, southeastern Idaho, 1997-1999.

Location Cover type	Area (%)	Patch metrics		
		Mean area (km ²)	Density (No./km ²)	Perimeter: area ratio
Medicine Lodge				
Agriculture	6	1.78	3	100
Grassland	1	0.05	22	448
Low sagebrush	15	0.18	84	418
Mountain big sagebrush	33	0.92	36	424
Xeric big sagebrush ^a	43	1.28	34	476
Total (%)	98 ^b			
Table Butte				
Agriculture	28	14.05	2	58
Grassland	23	0.39	6	378
Xeric big sagebrush	48	1.81	27	448
Total (%)	99 ^c			

^a Basin and Wyoming big sagebrush.

^b Remaining cover (2%) composed of forest, riparian, and other shrubs.

^c Remaining cover (1%) composed of low intensity urban, riparian, and other shrubs.

JOB 2. SURVIVAL CAUSE SPECIFIC MORTALITY AND INTER-BROOD MOVEMENTS OF GREATER SAGE-GROUSE CHICKS

Introduction

Information on age and cause-specific mortality in greater sage-grouse chicks is lacking. Predation frequently may be the proximate cause of mortality, and other factors, such as habitat quality, may influence predation rates. Quality of sage-grouse brood-rearing habitat may differ among sagebrush species and subspecies, which vary in understory herbaceous composition and structure according to elevation, soil conditions, weather conditions, geographic features, and historical land management practices. Brood-rearing habitat characteristics and resources (invertebrate and forb abundance) associated with these sagebrush habitats may limit sage-grouse populations through decreased survival of chicks (Klebenow 1969, Blake 1970, Wallestad 1975, Autenrieth 1981). Along with habitat quality, the age of the hen and her previous experience at rearing broods may also influence chick survival through increased ability to locate areas with high invertebrate and forb abundance and adequate escape cover from predators.

In Colorado, sage-grouse brood sizes were reduced 42% by August (Rogers 1964). In Washington, sage-grouse chick survival was estimated to be 20-33% between day of hatch and 50 days of age (Schroeder 1997, Sveum et al. 1998). In Wyoming, sage-grouse chick survival between hatching and autumn was estimated at 38% (June 1963). However, information on brood size may be biased if brood mixing occurs very frequently. Current information suggests chick survival rates in sage-grouse are lower than those reported for other grouse species. Survival of greater prairie-chickens in Kansas was estimated at 58% during the first 10 weeks after hatch (Bowman 1971). Spruce grouse (*Canachites canadensis*) brood size was reduced by 35% from time of hatching to independence (Boag et al. 1979).

Inter-brood movements may result in erroneous interpretation of brood counts and survival. Inter-brood movements of North American grouse chicks are poorly understood due to their cryptic coloration and secretive nature (Keppie 1977). Several studies have reported enlarged broods suggesting that inter-brood movements occur in most grouse species (Wing et al. 1944, Bendell 1955, Chambers and Sharp 1958, Zwickel 1967, Maxson 1978). However, these observations involved unmarked individuals. Observations of inter-brood movements of marked hens and chicks have been observed in spruce grouse (Keppie 1977) and ruffed grouse (*Bonasa umbellus*; Larson et al. 2001); only the former study indicated the timing and frequency of inter-brood movements.

No study has documented inter-brood movements in greater sage-grouse. Nevertheless, both Patterson (1952) and Dalke et al. (1963) observed enlarged broods and broods with chicks of different ages, indicating that inter-brood movements do occur in sage-grouse populations. During the breeding seasons of 1999-2002, inter-brood movements were documented and frequency of occurrence was calculated.

The purpose of this work was to assess survival rates, document cause-specific mortality factors and assess inter-brood movements for sage-grouse chicks from hatching until 10 weeks of age.

Study Area

This study was conducted on a 2,700-km² area in the Upper Snake River Plain of southeastern Idaho, near the Montana border. The boundaries were formed by the Centennial Mountains to the north, Interstate 15 to the east, State Highway 33 to the south, and the Lemhi Mountain range to the west. Parts of Jefferson, Clark, and Butte counties were included in this study area. The topography is generally low relief with outcrops of Pleistocene basalt and elevations ranging from 1300-2500 m (Blaisdell 1958). The outcrops consist of pressure ridges formed by cooling lava, mounds located at points of extrusion, and an occasional crater (Blaisdell 1958). The soil is of basaltic origin and sandy loam in texture (Blaisdell 1958). Soil depths vary from no soil to 1 m in swales (Blaisdell 1958). Precipitation varies and averages 17.5-30.0 cm at lower elevations and 30.5-45.5 cm at higher elevations. Yearly temperatures range from 35 to -10° C (Blaisdell 1958). Land ownership is a mix of private and public lands. Lower elevation areas produce potatoes, wheat, and alfalfa, and the dominant use of sagebrush-grasslands in this area is primarily cattle and sheep grazing.

The area was largely sagebrush-grassland. Sagebrush habitats ranged from xeric regions dominated by Wyoming big sagebrush to higher elevation regions characterized by a mix of Wyoming big sagebrush and mountain big sagebrush (Hironaka et al. 1983). Other common shrubs included basin big sagebrush, three-tipped sagebrush, black sagebrush (*Artemisia nova*), bitterbrush (*Purshia tridentata*), rabbitbrush (*Chrysothamnus* spp.), and snowberry (*Symphoricarpos* spp; Hironaka et al. 1983). The understory was a mix of forbs and perennial grasses such as lupine (*Lupinus* spp.), gilia (*Gilia* spp.), common dandelion (*Taraxacum officinale*), goatsbeard (*Tragopogon dubius*), western yarrow (*Achillea millefolium*), Idaho fescue, plains reedgrass (*Calamagrostis montanensis*), Columbia needlegrass (*Stipa columbiana*), crested wheatgrass, bluebunch wheatgrass, Indian rice grass (*Oryzopsis hymenoides*), and thickspike wheatgrass (*Agropyron dasystachyum*; Klebenow 1969).

The study area was divided into 4 study sites (Table Butte, Lidy Flats, Crooked Creek, Birch Creek) based on lek complexes, nesting and brood-rearing range, and geographic barriers.

Table Butte

Table Butte is a 26,000 ha lowland with elevations ranging from 1300-1800 m. This area is located between 3 major highways (State Route 26 on the western end, State Route 22 on the northern end, and Interstate 15 on the eastern end) and Mud Lake Wildlife Management Area and Camas National Wildlife Refuge bordering the southern portion. The topography is characterized by flat to gently undulating terrain interspersed with exposed silicate and basaltic volcanic outcrops (Ertter and Moseley 1992). Soils are light colored semiarid aridisols and entisols (DeLucia 1981). Annual precipitation averages 17.5-30 cm (DeLucia 1981). This area was dominated by Wyoming big sagebrush, and patches of basin big sagebrush occurred around the Medicine Lodge sinks. Because this area was surrounded by agriculture, sage-grouse chicks may have been influenced by predator communities associated with agriculture and may have been exposed to agricultural chemicals (Blus et al. 1989).

Lidy Flats

Lidy Flats is a lowland area bordering the foothills of the Centennial Mountains to the north, Interstate 15 to the east, State Route 22 to the south and Crooked Creek to the west. Elevations range from 1,600-2,500m. Topography consists of a gentle south-facing slope interspersed with ravines. This area contained >30,000 ha of sagebrush rangelands and was fragmented by agricultural fields and the town of Small between Medicine Lodge drainage and Interstate 15. Soils range from slightly dark-colored to dark-colored semiarid mollisols (DeLucia 1981). Annual precipitation ranges from 30.5-45.5 cm (DeLucia 1981). Dominant vegetation was Wyoming big sagebrush adjacent to patches of low sagebrush at lower elevations and mountain big sagebrush at higher elevations near the foothills of the Centennial Mountains. A stand of three-tipped sagebrush occurred on the southeastern section of this area where there is a history of frequent burning (Naderman, pers. comm.). Sage-grouse chick survival may have been influenced by predator communities associated with agriculture and by agricultural chemicals (Blus et al. 1989).

Crooked Creek

Crooked Creek is a 10,000 ha mountain-valley region surrounded by mountainous terrain on 3 sides and agricultural fields on the southern end. Elevations range from 1,700-2,500 m. The terrain is characterized by deep canyons and steep hills on the northern portion of the study site forming alluvial fans on the southern portion of the study area. Soils are dark-colored semiarid mollisols (DeLucia 1981). Annual precipitation ranges from 30.5-45.5 cm (DeLucia 1981). Wyoming big sagebrush and low sagebrush occurred at lower elevations and mountain big sagebrush occurred in foothills of the surrounding mountains and at higher elevations.

Birch Creek

Birch Creek is a 12,000 ha mountain-valley region with the Lemhi Mountain range forming the western border and the Bitterroot Mountains forming the eastern border. State Route 22 forms the southern border and the northern border is about 20 km north of the intersection of State Route 22 and State Highway 33. The southern part of the study site was on Idaho National Laboratory's (INL) land. Soils range from very dark-colored semiarid mollisols at the foothills to light-colored semiarid aridisols and entisols in the valley region (DeLucia 1981). Annual precipitation ranges from 30.5-45.5 cm (DeLucia 1981). Wyoming big sagebrush and low sagebrush dominated lower elevations and the valley floor. Mountain big sagebrush became dominant as elevation increased.

Methods

Greater sage-grouse hens were captured at night with spotlights (Giesen et al. 1982, Wakkinen et al. 1992) on or near leks during early spring (Mar-Apr) and in late-brood rearing habitat in August. Age, sex, and weight were recorded for each greater sage-grouse captured, and all birds were fitted with a uniquely-numbered leg band. Age was classified as yearling or adult using wing characteristics (Eng 1955b, Crunden 1963, Gill 1967). Females were fitted with a battery-powered radio-transmitter (ATS, Inc.) with built-in mortality sensor. Radios weighed <18 g

(<3% of mean hen weight) and were attached with a necklace harness. Birds were released at point of capture.

Chick Mortality

Beginning in mid-April, radio-marked greater sage-grouse hens were monitored regularly to determine breeding status. Nests were located and monitored 2-3 times a week until the nest was destroyed or approached hatching. As hatching neared, nests were monitored daily until chicks hatched. After eggs hatched, micro-transmitters were attached to 1-2 day old chicks using sutures (Burkepile et al. 2002); all captured chicks were weighed (see Appendix A) and micro-transmitters were placed on 2-3 chicks per brood. Radio-marked hens and chicks were located daily, but to minimize human disturbance, hens with broods were only approached to within about 40 m. When a radio-marked chick was missing from the brood, the area between the previous observation and the observation where the chick disappeared was systematically searched to locate the radio and determine fate of the chick.

Mortalities were assigned to “predation” when evidence was found of consumed body parts, tooth marks, or feather plucking or when scat, predator footprints, or dens were present. Mortalities were assigned to “exposure” when death was associated with rainy days and cold temperatures. All other mortalities were assigned to “other” or “unknown.” Mortalities in the “other” category were known mortality causes that were not related to predation or exposure, such as trampling or drowning.

Vegetation Sampling

Brood-rearing habitat characteristics were measured approximately once every 4 days until the brood reached 9 weeks of age or the brood was lost. A brood’s location was determined by walking a half-circle around the hen and brood, marking at least 3 points with surveyor’s tape, and recording the compass direction to the point where the brood is located. The intersection of the 3 recorded directions was the assumed brood location. Vegetation was sampled at each brood site within 72 hours of locating the brood during the early-brood-rearing period and within 5 days during the late brood-rearing period.

At each brood site, the following habitat characteristics were recorded: percent shrub canopy cover, shrub height, grass height, percent grass cover, percent bare ground, percent litter cover, percent lesser forb cover, and percent cover of each greater forb. Forbs were categorized as greater and lesser forbs. Greater forbs represented important food sources (common dandelion, yellow salsify, prairie pepperweed, clover, knotweed, yarrow, sweet clover, vetch, milkvetch, prickly lettuce, harkness gilia, and sego lily) for sage-grouse (Klebenow and Gray 1968, Peterson 1970, Wallestad et al. 1975, Drut et al. 1994). Lesser forbs included those plants not known to be important food sources. Percent canopy coverage of shrubs was determined using line-intercept (Canfield 1941) along a 15 m transect in each of the cardinal directions from the center of the brood location. At 1 m intervals, height of the shrub and grass nearest to the transect line was measured to determine average grass and shrub height. Percent coverage of bare ground, grasses, forbs, and litter was estimated using a 20 x 50-cm quadrat (Daubenmire 1959). Quadrats were positioned along each transect every 2 m.

Inter-brood Movements

Inter-brood movements were divided into 2 categories, adoption and brood switching. Adoption occurred when a hen accepted orphaned chicks into their own brood after the maternal hen died. Brood switching occurred when the maternal hen was still alive yet ≥ 1 of her chicks moved to another brood.

Statistical Analysis

Nest success was estimated from percent of radio-marked nesting females that successfully hatched ≥ 1 egg. Nest success was compared among years and age classes using χ^2 analyses. Chick survival was divided into 2 periods. The chick period was from day of hatch to 21 days post-hatch. During this period, chick diets contain primarily invertebrates, chicks are poor flyers, and still require brooding by the hen. The second stage is the fledgling period from 22 days post-hatch to 63 days post-hatch. During the fledgling stage, young greater sage-grouse diets consist primarily of forbs; chicks are good flyers and do not require as much brooding by the hen.

Chick and fledgling survival was calculated using the Kaplan-Meier (1958) method as described by Pollock et al. (1989), and variance of the chick survival rate was estimated as a proportion in a cluster sample with individual broods as clusters (Flint et al. 1995). Cox's Proportional Hazard (Hosmer and Lemeshow 1999) models were used to determine influence of precipitation, hen characteristics, food abundance, and habitat on chick survival. Lack of independence was adjusted by using a covariance sandwich matrix (Lin and Wei 1989). For each chick survival period, 2 sets of models were developed. The first set of models included winter precipitation, May precipitation, June precipitation, hen age, week of hatch, and study site. Both May and June are times of significant rainfall for eastern Idaho. The second set of models included habitat characteristics: shrub height, grass height, grass cover, litter cover, lesser forbs, and greater forbs. The second set of models only included data from 2000-2002 because no vegetation data were collected in 1999. Precipitation data were collected at a National Oceanographic and Atmospheric Administration weather station on the U.S. Department of Agriculture Sheep Experiment Station outside of Dubois, Idaho. Vegetation measurements were averaged over the first 3 weeks for each brood. During the late brood-rearing period, vegetative characteristics were averaged over 3 2-week periods.

The Kaplan-Meier (1958) product limit estimator was used to determine brood-switching rates, and the log-rank test was used to test for differences among years. Due to the low number of hens with broods dying, differences in adoption rates among years were not evaluated. Differences in frequency of brood switching between brood-rearing periods were evaluated using a chi-squared analysis. Years were pooled to determine if the frequency of brood switching differed between yearlings and adults.

Results

Nesting

During 4 breeding seasons, 152 nests were monitored (Table 2). Nest success of adult greater sage-grouse hens ranged from 40-55% and did not differ ($\chi^2 = 0.81$, $P = 0.84$) among years (Table 2). Nest success of adult hens ranged between 40-55% and did not differ ($\chi^2 = 1.27$, $P = 0.74$) among years. Due to low sample sizes, annual variation of nest success of yearling hens could not be assessed; years were pooled to compare differences in nest success between adult and yearling hens. There was no difference ($\chi^2 = 0.05$, $P = 0.82$) in nest success between adults ($\bar{x} = 47\%$, $n = 110$) and yearlings ($\bar{x} = 45\%$, $n = 27$).

Chick Survival

From 1999-2002, 179 chicks from 64 broods were radio-marked (Table 3). Chick survival ranged from 31-55%. The average age at mortality was 8 (range 1-21) days post-hatch. The main cause of mortality was predation (Table 4). Chicks were preyed upon by coyotes, foxes, rattlesnakes (*Crotalus viridis*), and various species of avian predators. Due to lack of evidence found at depredation sites, it was not possible to determine which predators accounted for the majority of chick mortalities. Additionally, 3 chicks died from exposure after the hen was killed and 1 chick drowned in an irrigation ditch in the Birch Creek study area.

Using data from 1999-2002, 10 models were developed using precipitation, hen age, and hatch week (Table 5). The model with the lowest AIC value was the null model which carried 25% of the weight; however, 5 univariate models including winter precipitation, study site, week of hatch, age, and June precipitation had a delta AIC of <2 and carried 9-13% of the weight (Table 5). Because all 5 of these models have weak support, they likely have little influence on chick survival.

Using data from 2000-2002, 18 different habitat models were developed from characteristics measured during the 2000-2002 breeding seasons. The 2 top models combined carried 62% of the weight (Table 6). These 2 models included greater forbs, grass height, and grass cover. All other models had delta AIC values >2. Parameter estimates indicate that increasing grass cover and greater forbs result in increased survival and decreasing grass height results in decreased survival (Table 7). Hazard ratios indicate that grass height and grass cover have the strongest influence on chick survival (Table 7). This would explain higher survival in 2002, where average grass cover and greater forbs were slightly higher than 2000 and 2001 (Table 8).

Fledgling Survival

During the fledgling stage, 72 chicks from 38 broods were monitored (Table 9). Survival was relatively high and ranged from 73-94% (Table 9). Fledgling survival did not differ among years ($\chi^2 = 1.539$, $P = 0.215$). Predation was the major source of mortality accounting for 88% ($n = 8$) of known mortalities (Table 10). One death was recorded in a 4-week post-hatch chick; this mortality was due to exposure when a snow storm occurred in the middle of June. Observations

of the roost site suggested all chicks could not be brooded by the hen and the chick on the outside edge died from exposure.

Due to low numbers of mortalities occurring during the fledgling period, 6 univariate models were used to evaluate influence of vegetative characteristics on fledgling survival (Table 11). No vegetation characteristics (Table 12) had a strong influence on survival of fledgling greater sage-grouse.

Inter-brood Movements

From 1999-2002, 3 adoptions and 11 brood-switching events were documented. Four hens with broods died while rearing chicks. Of the brood hens that died, 75% of the broods were adopted by another hen. The 3 chicks that were not adopted were 5 days old and were found dead near the dead hen. The chicks that were successfully adopted were 5 ($n = 3$), 25 ($n = 2$) and 32 days old ($n = 3$).

Brood-switching rates ranged from 15-51% from 1999-2002 (Table 13); however, there was no difference ($\chi^2 = 1.5551$, $P = 0.6696$) in rates among years. Most brood switching occurred during the late brood-rearing period. Similarly, there appeared to be no difference ($\chi^2 = 5.36$, $P = 0.52$) in the percentages of times that brood-rearing hens were observed with other hens among years (Table 14). During the late brood-rearing period, brood hens were observed in contact with other hens a higher ($\chi^2 = 2.29$, $P = 0.32$) proportion of the time than during the early brood-rearing period (Table 14). There was no difference ($\chi^2 = 0.5164$, $P < 0.47$) between the proportion of chicks switching broods between adults ($\bar{x} = 14\%$, $n = 52$) and yearlings ($\bar{x} = 23\%$, $n = 15$).

Discussion

Chick Mortality

Hatching to 3 weeks of age appeared to be the critical period for survival of greater sage-grouse during their first year. Both nest success and fledgling survival showed little annual variation indicating that both of these parameters are less variable than chick survival.

Survival rates documented in the Upper Snake River Plain of eastern Idaho were similar to the survival rates reported for Alberta (Aldridge 2005) and similar to the survival rates found in ruffed grouse (Larson et al.2001) and sharp-tailed grouse (Manzer 2004). During all of these studies, the majority of mortalities occurred during the first 2 weeks post-hatch. During this time period, greater sage-grouse chicks are weak flyers and depend on hiding in vegetation for protection from predators. This lack of mobility may increase chick vulnerability to predators and may vary depending on quality of the herbaceous understory.

This is the first study to estimate survival of greater sage-grouse fledglings. Very little is known about survival of greater sage-grouse chicks after 3 weeks post-hatch and data on brood size may be biased if brood mixing occurs very frequently. Results from this study indicate that survival after the first 3 weeks post-hatch is relatively high. Survival rates during the fledgling stage are

similar to juvenile (Beck et al. 2006) and adult (Schroeder et al. 1999) survival rates. No vegetative characteristics were identified as having a strong influence on survival. This may be due to the low number of individuals that died during this time period; however, high survival rates indicate that habitat was not limiting fledgling survival.

Predation was the leading cause of mortality of greater sage-grouse chicks during both brood-rearing periods in the Upper Snake River. Other studies of radio-marked ruffed grouse (Larson et al. 2001) and sharp-tailed grouse (Manzer 2004) also determined the leading cause of mortality in chicks was predation. Unfortunately, the rate of predation by individual predator species could not be determined due to lack of evidence at kill sites. Red fox and coyote predation could be identified because radio-transmitters were found in the feces of both coyotes and foxes.

Although exposure has been suggested as a leading cause of mortality in grouse species (Patterson 1952), exposure accounted for <12% of the known mortalities in this study. Similarly, Manzer (2004) reported that exposure accounted for <10% of known mortalities in his study of sharp-tailed grouse. These results are not unexpected. Zwickel (1967) found that during cold, rainy days, chicks spent more time brooding, thus reducing the need to thermoregulate and conserving energy. If food is readily available, grouse chicks only need to forage for short periods of time throughout the day and can spend the rest of the time brooding. Research also indicates that during bad weather, grouse chicks avoid dense vegetation to avoid becoming wet and increasing energy demands (Erikstad and Spidso 1982).

Although vegetation measurements were averaged over several weeks, some habitat characteristics influencing sage-grouse chick survival were identified. Models indicate that increased grass and major forb cover increases chick survival. Top models in both this study and Aldridge (2005) included forb and grass cover as the most important habitat characteristics influencing chick survival. Although both studies found weak support for these models, similar results from both studies provide stronger support for this conclusion.

Inter-brood Movements

Adoption of orphaned chicks. This research indicates that greater sage-grouse hens readily adopt orphaned chicks. Adoption of orphaned chicks occurred during both the early and late brood-rearing periods; however, adoption rates appeared to be higher during the late brood-rearing period. A somewhat similar pattern was also observed in blue grouse (*Dendragapus obscurus*) where chicks <11 days post-hatch were never observed after the hen died, yet all the chicks >11 days post-hatch were observed with other hens after the maternal hen died (Keppie 1977).

The low adoption rate during the early brood-rearing period may be due to the solitary nature of hens with broods during this period (Dalke et al. 1963). During the early brood-rearing period, the locations of hens with broods are usually mutually exclusive whereas during the late brood-rearing period, hens with broods shared locations (Dalke et al. 1963). The one adoption that was observed during the early brood-rearing period occurred in an area where unmarked hens with broods were observed on numerous occasions.

Lower adoption rates during the early brood-rearing period may also be due to the physiology of sage-grouse chicks. At an early age, greater sage-grouse chicks may not be able to thermoregulate well; therefore, if they cannot find a hen to brood, they are susceptible to exposure (Patterson 1952), whereas chicks during the late brood-rearing period can thermoregulate well and may survive several days without a hen before being adopted.

Brood switching. Rates of brood switching in greater sage-grouse are higher than those reported for blue grouse. However, the rates documented in this study are similar to those reported for other precocial species (Williams 1994, Bustnes and Erikstad 1991). Most brood switching occurred during the late brood-rearing period when hen ranges were not mutually exclusive. This pattern was also reported in blue grouse (Keppie 1977) and least sandpipers (*Calidris minutilla*; Cooper and Miller 1992). In waterfowl, the switching of broods appears to occur shortly after hatching (Williams 1994, Eadie et al. 1988). The one inter-brood movement that occurred during the early brood-rearing period involved a 6-day-old chick. This movement occurred after a predator killed 2 of the 3 radio-marked chicks. The third chick was located with an unmarked hen near the area where the radio-marked hen and her brood were observed the previous day. It is likely that the brood was scattered during the predators' attack and then the unmarked hen responded to the distress calls of the radio-marked chick before the radio-marked hen returned.

Bendell (1955) suggested that weather may influence the frequency of inter-brood movements of blue grouse. Keppie (1977) did not observe this pattern in blue grouse, and this does not appear to be the case in greater sage-grouse. There were no apparent differences in frequencies of inter-brood movements during wet years (2000 and 2001) compared to dry years (1999 and 2002). However, the number of birds switching broods each year was low which may have masked effects of weather on brood-switching rates.

Results from this study indicate that inter-brood movements may be due to multiple factors. Most of the inter-brood movements occurred during the late brood-rearing period when broods are at high densities. Thus, most brood switching may occur due to accidental mixing in late brood-rearing habitats and switching may occur at higher frequencies in areas where broods come in contact with each other.

Management Implications

High mortality during the first 3 weeks post hatch appears to be a major factor affecting greater sage-grouse populations. Efforts to increase greater sage-grouse populations should focus on increasing chick survival. Since greater sage-grouse chick survival is linked to cover of grasses and major forbs, efforts should focus on increasing cover of native grasses and forbs. Exotic grasses such as cheatgrass and crested wheatgrass may not provide the protective cover needed by chicks to hide from predators. Loss of native bunchgrass communities may be detrimental to the survival of greater sage-grouse chicks, and protection of these communities should enhance greater sage-grouse populations.

Although the best models in this study had weak support, results are similar to those reported by Aldridge (2005). There is a need to conduct more experimental studies to better determine the

influence of habitat characteristics on greater sage-grouse survival. These studies should focus on habitat manipulations in early brood-rearing areas. Experimental studies may provide stronger support for both this and Aldridge's (2005) models.

Table 2. Nest success of yearling and adult greater sage-grouse, Upper Snake River Plain, eastern Idaho, 1999-2002 breeding seasons.

Year	Adult		Yearling	
	Successful (%)	Failed (%)	Successful (%)	Failed (%)
1999	55 (<i>n</i> = 11)	45 (<i>n</i> = 9)	30 (<i>n</i> = 3)	70 (<i>n</i> = 7)
2000	48 (<i>n</i> = 12)	52 (<i>n</i> = 13)	60 (<i>n</i> = 3)	40 (<i>n</i> = 2)
2001	40 (<i>n</i> = 14)	60 (<i>n</i> = 21)	33 (<i>n</i> = 1)	67 (<i>n</i> = 2)
2002	49 (<i>n</i> = 21)	51 (<i>n</i> = 22)	50 (<i>n</i> = 5)	50 (<i>n</i> = 5)
Total	47 (<i>n</i> = 58)	53 (<i>n</i> = 65)	45 (<i>n</i> = 13)	55 (<i>n</i> = 16)

Table 3. Kaplan- Meir survival rates and standard errors of greater sage-grouse chicks during first 3 weeks post-hatch, Upper Snake River Plain, eastern Idaho, 1999-2002 breeding seasons.

Year	Number chicks	# Broods	K-M Survival (%)
1999	28	13	31 (0.09)
2000	41	15	31 (0.07)
2001	39	14	41 (0.08)
2002	71	22	55 (0.06)
Total	179	64	42 (0.06)

Table 4. Causes of greater sage-grouse chick mortalities, Upper Snake River Plain, eastern Idaho, 1999-2002 breeding seasons.

Year	Predation (%)	Exposure (%)	Other (%)
1999	100 (<i>n</i> = 5)	0 (<i>n</i> = 0)	0 (<i>n</i> = 0)
2000	100 (<i>n</i> = 19)	0 (<i>n</i> = 0)	0 (<i>n</i> = 0)
2001	94 (<i>n</i> = 14)	0 (<i>n</i> = 0)	6 (<i>n</i> = 1)
2002	78 (<i>n</i> = 14)	17 (<i>n</i> = 3)	5 (<i>n</i> = 1)
Total	85 (<i>n</i> = 52)	11 (<i>n</i> = 7)	4 (<i>n</i> = 2)

Table 5. Proportional hazard models determining the influence of weather and hen characteristics on greater sage-grouse chick survival, Upper Snake River Plain, eastern Idaho, 1999-2002 breeding seasons.

Model ^a	AICc	deltaAICc	AICcweight
W/O	137.2820	0.000000	0.254400
WP	138.6096	1.327599	0.130988
SS	138.7586	1.476599	0.121584
HW	138.8126	1.530599	0.118345
JP	139.2796	1.997599	0.093701
MP	139.2956	2.013599	0.092954
HA	139.2966	2.014599	0.092908
HA, HW	140.7772	3.495182	0.044315
JP, MP	141.3102	4.028182	0.033947
JP, MP, WP	142.7101	5.428143	0.016858

^a W/O = null model, WP = winter precipitation, SS = study site, HW = week of hatch, JP = June precipitation, MP = May precipitation, and HA = hen age.

Table 6. Proportional hazard models determining the influence of habitat and food abundance on greater sage-grouse chick survival, Upper Snake River Plain, eastern Idaho, 2000-2002 breeding seasons.

Model ^a	AICc	deltaAICc	AICcweight
GF, GH	453.5295	0.000000	0.333372
GH, G, GF	453.7041	0.174621	0.305500
GH, G, GF, LF	455.7627	2.233262	0.109140
GH, G, GF, L	455.9717	2.442262	0.098310
GH, G	458.0225	4.493000	0.035260
GH, G, L, LF, GF	458.0880	4.558524	0.034124
GH, G, L	458.9411	5.411621	0.022275
GF	459.2645	5.735024	0.018949
GH, G, LF	460.1001	6.570621	0.012478
G, GF	460.8465	7.317000	0.008591
GH, G, L, LF	461.2047	7.675262	0.007182
G, GF, BIO	462.3191	8.789621	0.004114
GH	462.6545	9.125024	0.003479
GH	463.7745	10.245020	0.001987
BG	464.1415	10.612020	0.001654
LF	464.7055	11.176020	0.001248
W/O	465.1780	11.648520	0.000985

^a GF = greater forbs, GH = grass height, G = grass cover, LF = lesser forbs, L = litter cover, BG = bare ground, and W/O = null model.

Table 7. Model parameter estimates and hazard ratios of the top 2 models selected for greater sage-grouse chick survival, Upper Snake River Plain, eastern Idaho, 2000-2002 breeding seasons.

Model	Parameters ^a	Parameter estimate	Hazard ratio
1	GH	0.094 (0.031)	1.099 (0.927)
	GF	-7.054 (2.296)	0.001 (1.018)
2	GH	0.105 (0.032)	1.111 (0.940)
	G	-1.440 (1.003)	0.237 (0.977)
	GF	-5.913 (2.500)	0.003 (1.023)

^a GH = grass height, GF = greater forbs, and G = grass cover.

Table 8. Mean vegetative characteristics at greater sage-grouse brood-rearing sites during the chick stage, Upper Snake River Plain, eastern Idaho, 2000-2002 breeding seasons.

Year	<i>n</i>	SH ^a	GH ^a	G ^a	L ^a	LF ^a	GF ^a
2000	12	34 (2.6)	22 (0.9)	40 (3.5)	34 (3.6)	33 (3.5)	14 (3.2)
2001	10	33 (3.8)	19 (1.1)	46 (3.7)	43 (2.8)	40 (4.1)	10 (2.2)
2002	18	32 (2.2)	17 (0.8)	47 (3.7)	63 (2.3)	35 (2.2)	17 (2.3)

^a SH = shrub height, GH = grass height, G = grass cover, L = litter cover, LF = lesser forbs, and GF = greater forbs.

Table 9. Kaplan-Meier survival rates and standard errors of greater sage-grouse fledglings from 3 weeks to 9 weeks post-hatch, Upper Snake River Plain, eastern Idaho, 1999-2002 breeding seasons.

Year	Number chicks	# Broods	K-M Survival (%)
1999	9	5	75 (0.22)
2000	12	8	73 (0.13)
2001	19	10	73 (0.15)
2002	32	15	95 (0.04)
Total	72	38	83 (0.06)

Table 10. Causes of greater sage-grouse fledgling mortalities, Upper Snake River Plain, eastern Idaho, 1999-2002 breeding seasons.

Year	Predation (%)	Exposure (%)	Other (%)
1999	100 (<i>n</i> = 1)	0 (<i>n</i> = 0)	0 (<i>n</i> = 0)
2000	100 (<i>n</i> = 3)	0 (<i>n</i> = 0)	0 (<i>n</i> = 0)
2001	67 (<i>n</i> = 2)	33 (<i>n</i> = 1)	0 (<i>n</i> = 0)
2002	100 (<i>n</i> = 1)	0 (<i>n</i> = 0)	0 (<i>n</i> = 0)
Total	88 (<i>n</i> = 7)	12 (<i>n</i> = 1)	0 (<i>n</i> = 0)

Table 11. Proportional hazard models determining the influence of habitat and food abundance on greater sage-grouse fledgling survival, Upper Snake River Plain, eastern Idaho, 2000-2002 breeding seasons.

Model ^a	AICc	deltaAICc	AICcweight
W/O	51.00600	0.000000	0.318153
GF	52.11567	1.109667	0.182673
SH	52.94267	1.936667	0.120808
GH	52.94967	1.943667	0.120386
BG	53.60267	2.596667	0.086851
L	53.60867	2.602667	0.086591
G	53.65667	2.650667	0.084538

^a W/O = null model, GF = greater forbs, SH = shrub height, GH = grass height, BG = bare ground, L = litter cover, and G = grass cover.

Table 12. Mean vegetative characteristics at brood sites during the fledgling stage, Upper Snake River Plain, eastern Idaho, 2000-2002 breeding seasons.

Year	<i>n</i>	SH ^a	GH ^a	G ^a	L ^a	LF ^a	GF ^a
2000	7	46 (4.1)	25 (3.9)	49 (4.0)	49 (4.0)	18 (4.1)	6 (1.4)
2001	10	46 (2.9)	21 (1.3)	58 (2.5)	56 (2.7)	16 (2.6)	11 (1.6)
2002	13	44 (2.5)	21 (0.8)	57 (4.2)	51 (2.9)	18 (2.0)	9 (1.7)

^a SH = shrub height, GH = grass height, G = grass cover, L = litter cover, LF = lesser forbs, and GF = greater forbs.

Table 13. Number of radio-marked greater sage-grouse chicks and rates of brood switching Upper Snake River Plain, eastern Idaho, 1999-2002 breeding seasons.

Year	Radio-marked chicks (<i>n</i>)	Chicks switched (<i>n</i>)	K-M rates of brood switching (SE)
1999	29	1	0.25 (0.21)
2000	43	4	0.51 (0.22)
2001	42	2	0.18 (0.10)
2002	71	1	0.15 (0.07)

Table 14. Frequency of observations of greater sage-grouse-hens with other hens Upper Snake River Plain, eastern Idaho.

Year	Early brood-rearing		Late brood-rearing	
	% with other brood hens	<i>n</i>	% with other brood hens	<i>n</i>
1999	0	12	25	32
2000	0	6	33	58
2001	6	17	17	47
2002	0	31	29	52

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APPENDIX A

Variation in the Hatch Weights of Greater Sage-Grouse Chicks

Abstract

Little is known about the hatch weights of greater sage-grouse chicks. Previous research indicated that hatch weights varied between years and age class. However, this research did not allow for lack of independence within each brood; therefore, results may be biased. During the 1999-2002 breeding seasons, hatch weights of 332 1-day-old chicks from 61 broods were recorded. Hatch weight did not differ among years and between hen age classes. Moreover, hatch weights of chicks did not differ between years within the same hen. Most of the variation in hatch weights of chicks was due to variation among hens. Linear regression indicated that hen pre-laying weight was not related to hatch weight and hatch weight was positively but weakly related to clutch size. Lack of differences in chick weights suggests that hen condition and environmental parameters have little influence on the hatch weight of greater sage-grouse chicks. Because hen condition and environmental factors do not influence hatch weights of chicks, hatch weights may be an inherited trait.

Introduction

Hatch weight of precocial chicks may be ecologically important. Chicks that hatch at a larger weight tend to have higher survival probabilities (Moss et al. 1981, Blomqvist et al. 1997) and higher growth rates (Redfield 1978). Larger precocial chicks may have greater energy reserves that may reduce risk of starvation during periods of inclement weather (Ankney 1980). Moreover, larger-bodied individuals may be able to withstand colder periods better because of the lower surface area (Ricklefs 1983, Rhymer 1988) and may be better able to obtain food resources and escape predators (Swennen 1989, Anderson and Alisauskas 2001). Hatch weights of precocial chicks may be influenced by egg size, hen condition, environmental factors, genetics, or contaminants. The influence of hatch weights on grouse chicks is not well understood. Moss et al. (1981) determined that survival of red grouse (*Lagopus lagopus scoticus*) chicks was related to hatch weight but research on willow grouse (*Lagopus lagopus lagopus*; Erikstad 1985) and greater sage-grouse found that chick survival was not related to hatch weights of chicks. In blue grouse, hatch weight was related to growth rates (Redfield 1978); however, in willow grouse, there was no correlation between hatch weight and chick growth (Erikstad 1985). Factors influencing hatch weights of grouse chicks are not well understood. Few studies have attempted to determine if hatch weights of chicks vary among years, or with hen age and/or hen condition. Laboratory studies with red grouse (Moss et al. 1993) and capercaillie (*Tetrao urogallus*; Marcstrom 1960) found little variation in chick hatch weights. In blue grouse, the hatch weights of chicks varied among broods but not within broods until chicks were >7 days post-hatch when chick weights differed within a brood (Redfield 1978). In red grouse, hatch weights appear to be related to egg size and are an inherited trait (Moss and Watson 1982).

There is little information on hatch weights of greater sage-grouse chicks. Reported hatch weights ranged between 30-31 g (Patterson 1952, Petersen 1980); however, sample sizes were

low in both studies. Petersen (1980) found that chick weights varied between years and age class. However, he did not take into account the lack of independence among brood mates. During the 1999-2002 breeding seasons, hatch weights of greater sage-grouse chicks were recorded to determine if chick weights varied within broods, among broods, and among years. The influence of clutch size, hen pre-laying weight, and hen age on hatch weights of greater sage-grouse chicks was also assessed.

Methods

This study was conducted on a 2,700-km² area in the Upper Snake River Plain of southeastern Idaho, near the Montana border. Study area boundaries were formed by the Centennial Mountains to the north, Interstate 15 to the east, State Highway 33 to the south, and the Lemhi Mountain range to the west. Parts of Jefferson, Clark, and Butte counties were included in this study area. The topography is generally low relief with outcrops of Pleistocene basalt with elevations ranging from 1300-2500 m (Blaisdell 1958). The outcrops consist of pressure ridges formed by cooling lava, mounds located at points of extrusion, and an occasional crater (Blaisdell 1958). The soil is basaltic origin and sandy loam in texture (Blaisdell 1958). Soil depths vary from no soil to 1 m in swales (Blaisdell 1958). Precipitation varies from an average annual rainfall of 17.5-30.0 cm at lower elevations and 30.5-45.5 cm at higher elevations. Yearly temperatures range from 35 to -10° C (Blaisdell 1958). The area is largely sagebrush-grassland. Sagebrush habitats range from xeric regions dominated by Wyoming big sagebrush to higher elevation regions characterized by a mix of Wyoming big sagebrush and mountain big sagebrush (Hironaka et al. 1983). Other common shrubs include basin big sagebrush, three-tipped sagebrush, black sagebrush, bitterbrush, rabbitbrush, and snowberry (Hironaka et al. 1983).

Sage-grouse hens were captured by spotlighting (Giesen et al. 1982, Wakkinen et al. 1992) on or near leks during March-April 1999 and 2002 in southeastern Idaho. We fitted females with battery-powered radio transmitters (ATS, Inc.) weighing <18 g (<2% of mean hen weight) and attached with a necklace harness (Connelly et al. 2003b). Beginning in mid-April, radio-marked hens were regularly monitored to determine breeding status. Each nest was located and monitored 2-3 times a week. When hatch time neared, nests were monitored daily until hatch. Broods were captured within 36 hours of hatching, by locating the radio-marked hen, visually locating the chicks, and catching them by hand. After capture, chicks were placed in a cotton holding bag to prevent escape and reduce injury. All chicks were weighed to the nearest 0.5 g. Although all chicks were weighed within 36 hours of hatching, earlier work with blue grouse and capercaillie indicated that chicks do not gain weight within the first 3-4 days post-hatch (Marcstrom 1960, Redfield 1978).

A mixed-effects model was used with individual chick weights nested within hens to test for differences in chick weights among years and between age classes of hens. Linear regression was used to determine the relationship between average chick weights with hen weight and clutch size. SAS and Sigma Plot was used to analyze all data.

Results

During the 4 breeding seasons, 332 chicks were weighed from 61 different broods (Table A-1). The weights of chicks hatched by adult hens did not vary ($F = 1.10$, $P = 0.3595$) among years. Covariance parameter estimates indicated that the greatest source of variation was among individual hens (Table A-2). Since there was no difference between years and sample size of yearlings was low, years were pooled to determine if weights of chicks hatched from adult and yearling hens varied. There was no difference ($F = 0.67$, $P = 0.4183$) in hatch weights of chicks from different age classes of hens. Hatch weights also were compared for individual hens monitored over 2 years with consecutive clutches to determine if hatch weights vary between years within the same hen. No difference ($F = 0.25$, $P = 0.6232$) was detected in hatch weights of chicks in different years from the same hen.

Because age did not explain variation of chick weights among hens, linear regression was used to determine if chick weights were related to clutch size or pre-laying hen weight. Variation within a brood was low, so chick weights were averaged within each brood and average chick weight was used as a dependent variable. There was no relationship ($n = 26$, $F = 2.4599$, $P = 0.1294$, adj. $r^2 = 0.05317$) between hen weight and average chick weight (Figure A-1). However, there was a slightly positive ($n = 56$, $F = 8.1887$, $P = 0.006$, adj. $r^2 = 0.11377$) trend with average chick weight and clutch size (Figure A-2). Although, this trend was significant, the r^2 value was low and only explained 11% of the variation.

Discussion

This study documented greater variation in chick weights than previously reported in greater sage-grouse. Chick weights recorded in the Upper Snake River study area ranged from 23.5-35.5 g, whereas previous studies reported chick weights ranging between 30-31 g (Patterson 1952, Peterson 1980). Sample sizes were low in these previous studies and may not have captured the true variation of chick weights in greater sage-grouse. Patterson (1952) recorded the hatch weight of 8 chicks and Petersen (1980) reported the hatch weight of 65 chicks from 12 broods. Moss et al. (1981) reported similar ranges of variation in red grouse; however, Redfield (1978) reported greater variation in the hatch weight of blue grouse.

Results from this study do not agree with those of Petersen (1980), who found that chick weights differed between years and age classes. However, his results should be approached with caution because he did not allow for lack of independence among chicks of the same brood. Low variation among years documented in this study supports past research on hatch weights of other precocial species. In studies of incubator-hatched red grouse chicks, there was no difference in hatch weights of chicks among years (Moss and Watson 1982). In wild populations of whimbrels (*Numenius phaeopus*; Grant 1991), canvasbacks (*Aythya valisineria*), and redheads (*Aythya americana*; Austin and Serie 1994), hatch weights did not differ among years despite variations in environmental conditions. Both 2000 and 2001 were extremely dry years (NOAA); nevertheless, these dry years did not appear to influence chick weights the proceeding years suggesting that environmental factors have little to no influence on chick hatch weights.

Variation in hatch weights was greater among hens than within broods. Greater variation of hatch weights among broods than within broods also has been documented in waterfowl (Austin and Serie 1994), shorebirds (Blomqvist et al. 1997, Grant 1991), and galliformes (Redfield 1978, Moss et al. 1993).

The lack of differences among years and between 2 successive clutches of the same hen suggests that hatch weight is probably not influenced by variations in hen condition and environmental conditions. Hausleitner (2003) found that blood chemistry levels did not differ between years suggesting that there was little variation in hen condition between years. Also, Robb et al. (1992) found low variation in hen condition between years in willow ptarmigan. This low variation in hen condition may explain the low variation in hatch weights of greater sage-grouse chicks among years. Because weights of adult and yearling greater sage-grouse chicks did not differ and weights of chicks from successive clutches from same hen did not differ between years, it is unlikely that variation in chick weights among hens is due to differences in age. Austin and Serie (1994) found that hatch weights were not influenced by the age of the hen in canvasbacks and redheads. Moss et al. (1981) and Redfield (1978) did not test for differences between age classes.

No other study has addressed the influence of clutch size on chick weights. Increasing clutch size might result in decreasing chick weights because of allocation of resources needed for egg laying. However, a weak trend in the opposite direction was identified in this study. This relationship explained only 11% of the variation among individuals and may be explained if hens that lay larger clutches are also predisposed to hatching heavier chicks.

High variation among hens suggests that other factors besides environmental factors, hen age, and hen condition influence chick weights. Petersen (1980) found that hatch weights of greater sage-grouse chicks were correlated with egg size. This pattern was also observed in red grouse (Moss and Watson 1982). Moreover, egg size and chick weights in domestic chickens are heritable traits (Tullett and Burton 1982, Koerhuis et al. 1997, Suarez et al. 1997), suggesting that chick weights in greater sage-grouse may also be heritable traits. Heritability of hatch weights may explain the variation of chick weights among broods.

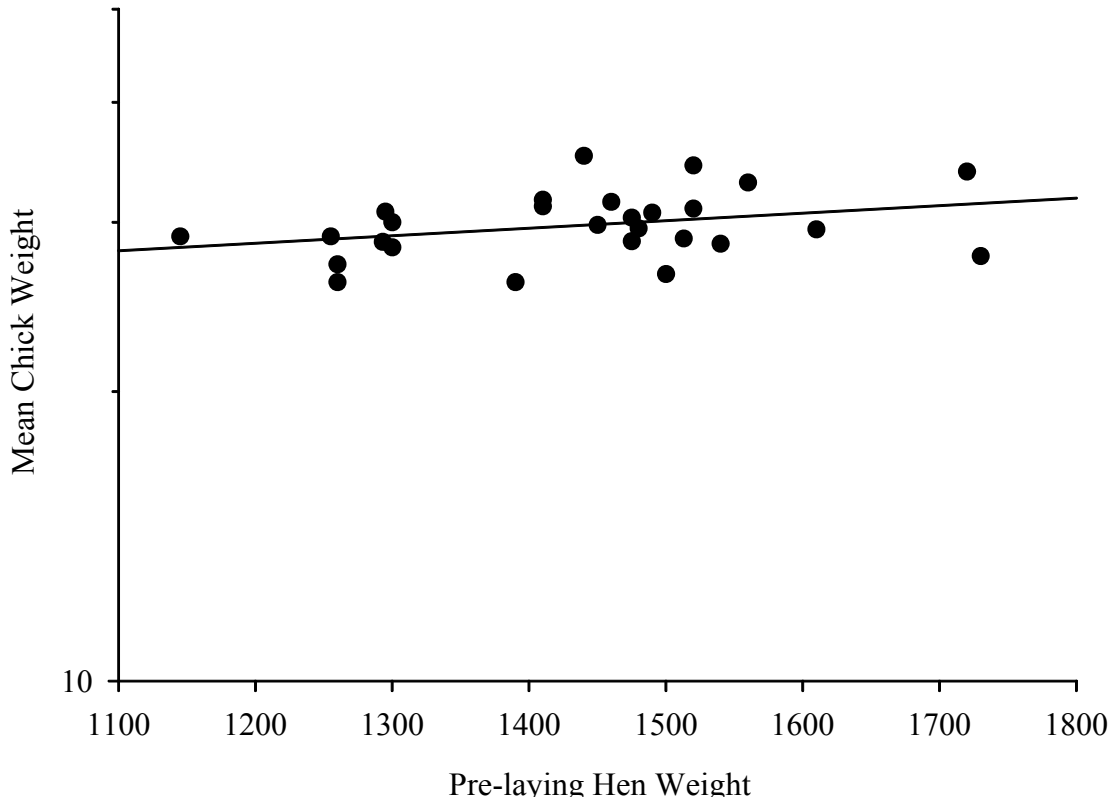


Figure A-1. Relationship of average chick weight in each brood pre-laying weight of greater sage-grouse hens in southeastern Idaho.

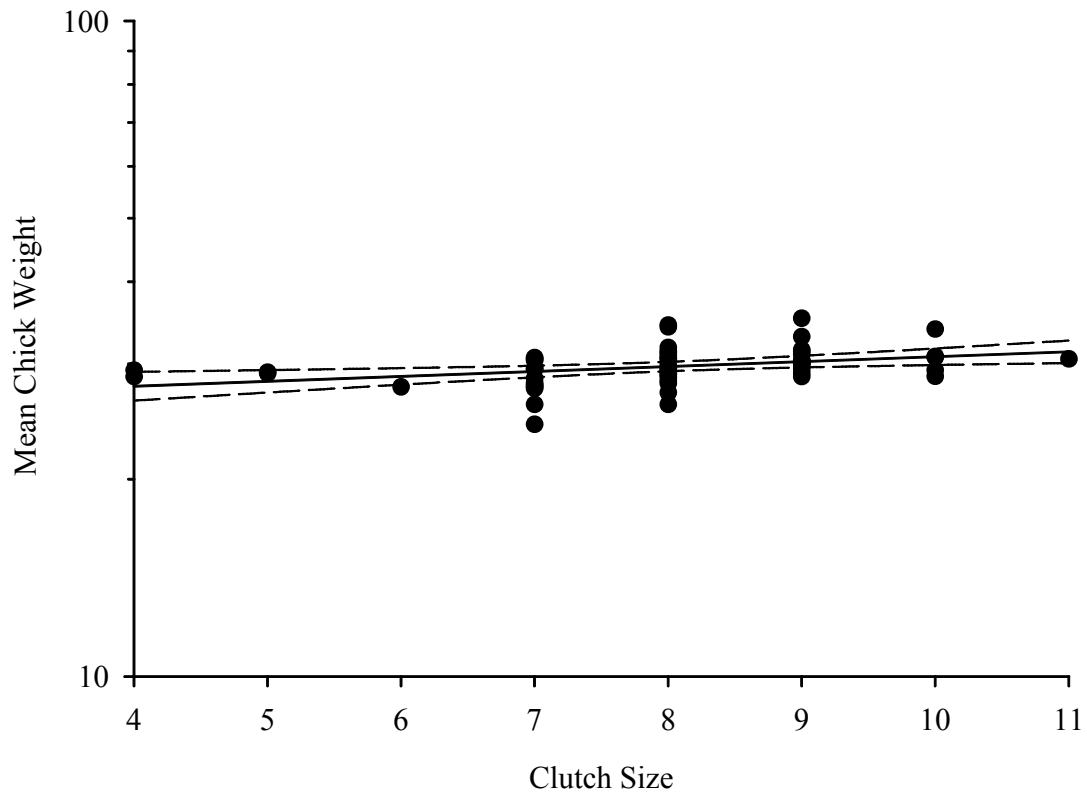


Figure A-2. Relationship of average chick weight in each brood to clutch size of greater sage-grouse hens in southeastern Idaho.

Table A-1. Average hatch weights of sage-grouse chicks in southeast Idaho separated by year and hen age class.

Year	Yearling				Adult			
	# hens	# chicks	(SE)	Range	# hens	# chicks	(SE)	Range
1999	3	16	30.0 (0.41)	25.5-32	8	37	30.7 (0.48)	26.5-35.5
2000	1	4	29.1 (0.96)	28-32	11	55	29.9 (0.34)	23.5-35.5
2001	1	8	28.6 (0.65)	25-31	13	76	30.2 (0.29)	25-37
2002	5	32	31.1 (0.43)	27-36	19	104	30.0 (0.24)	25-35

Table A-2. Covariance parameter estimates of greater sage-grouse chick weights between years, hens, and chicks.

Variables	Covariance estimates
Years	0.13
Hens	4.06
Individual chicks	2.33

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FEDERAL AID IN WILDLIFE RESTORATION

The Federal Aid in Wildlife Restoration Program consists of funds from a 10% to 11% manufacturer's excise tax collected from the sale of handguns, sporting rifles, shotguns, ammunition, and archery equipment. The Federal Aid program then allots the funds back to states through a formula based on each state's geographic area and the number of paid hunting license holders in the state. The Idaho Department of Fish and Game uses the funds to help restore, conserve, manage, and enhance wild birds and mammals for the public benefit. These funds are also used to educate hunters to develop the skills, knowledge, and attitudes necessary to be responsible, ethical hunters. Seventy-five percent of the funds for this project are from Federal Aid. The other 25% comes from license-generated funds.

