FACTORS AFFECTING GREATER SAGE-GROUSE (*CENTROCERCUS*

UROPHASIANUS) SURVIVAL AND MOVEMENT

IN SOUTH-CENTRAL UTAH

by

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ABSTRACT

Factors Affecting Greater Sage-grouse (*Centrocercus urophasianus)* Survival and

Movement in South-central Utah

by

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Greater sage-grouse (*Centrocercus urophasianus*) adult and juvenile survival

have been identified as critical demographic parameters. However, little is known

regarding the dynamics of juvenile sage-grouse. From 2008-2010, I used radio-telemetry

and 2 transmitter types to monitor 91 juvenile sage-grouse. Program MARK was used to

analyze survival data. Over-winter survival was 0.802 - 0.982 and 0.687 - 0.969 for

females and males, respectively. Fall survival rates were 0.522 - 0.623 for females and

0.332 - 0.449 for males. Survival from fall through winter was 0.418 - 0.616 for females

and 0.228 - 0.435 for males. For both years combined, the probability predation caused

death was 0.705, and probability harvest caused death was 0.159. The probability

unreported harvest caused death was 0.091. Sex ($p = 0.103$) and transmitter type ($p =$

0.09) affected survival. Back-mounted transmitters negatively affected survival and their

use should be avoided to minimize experimental bias.

Sage-grouse age and breeding status may affect susceptibility to harvest. Radio-telemetry data collected from 1998-2009, maximum likelihoods, and profile likelihood confidence intervals ($\alpha = 0.1$) were used to assess hen harvest risk by breeding status. The probability of harvest was 0.087 (0.035-0.171) and 0.011 (0.001-0.039) for brood hens and non-brood hens, respectively. More research is needed to determine the acceptable harvest rates for juvenile and adult hen sage-grouse. Future harvest management actions should attempt to shift harvest away from juveniles and the hens associated with them.

Sage-grouse are dependent on sagebrush (*Artemisia* spp.) during winter months. Impacts to wintering areas could have a disproportionate effect on population size. On Parker Mountain, sage-grouse used winter habitats characterized by 0-5% slopes regardless of aspect and slopes 5-15% south to west in aspect. The timing of movements to wintering areas varied between years. In 2008 movements occurred rapidly during November, whereas in 2009 movements were slow and meandering beginning in late September and continuing through November. A vast majority of significant winter use (areas with kernel density estimates of $>.94$ locations per km^2) was on a small percentage, 3%, of the available habitat. Some critical wintering areas may not be readily identifiable in typical years.

(157 pages)

PUBLIC ABSTRACT

Greater sage-grouse are the largest North American grouse species and are dependent on sagebrush for survival. Sage-grouse populations have declined throughout the west. Habitat fragmentation and degradation are likely the main causes of declining populations, and concern has lead to the petitioning for the sage-grouse to be listed under the Endangered Species Act. Survival of adult and juvenile sage-grouse is thought to be limiting population growth. However, survival of juvenile sage-grouse is poorly understood. I aimed to improve the knowledge gap regarding juvenile sage-grouse survival. With improved knowledge of juvenile survival, management actions can be employed to benefit sage-grouse populations.

With declining populations some groups articulated concerns regarding the possible impacts of harvest on sage-grouse populations. Adult hen and juvenile sage-grouse could be more susceptible to hunting than males. The differential susceptibility is likely due to the clumped distribution of females in moist areas with juveniles during the fall. I aimed to quantify the impacts of hunting on adult hen and juvenile sage-grouse. With a better understanding of the role of adult hens and juveniles in harvest, management strategies can be used to ensure effects of hunting on sage-grouse are not negatively impacting populations.

Sage-grouse are dependent during winter months on sagebrush for food. Winter habitat of sage-grouse is likely based on many physical land attribute factors and historic use. Snow can limit the availability of sagebrush. There have been several descriptions of greater sage-grouse winter habitat, as well as another species of sage-grouse the

Gunnison's sage grouse. Winter habitat has been largely described as based on slope and aspect. I aimed to determine which of the previously described winter habitats (greater vs. Gunnison) best described sage-grouse use on Parker Mountain, Utah. Knowledge of the type of winter habitat used on Parker Mountain will allow for management and protection of winter habitat. Protection of winter habitat is important, because degradation of winter habitats can cause adverse impacts to overall populations.

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"In certain matters, I too will stand corrected by those who come after" - Lovett Williams

Danny Caudill

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

POPULATION STATUS

Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) populations have declined range-wide (Braun 1998). The historic range of the sage-grouse has declined in area by more than 55% (Connelly et al. 2004, Schroeder et al. 2004). However, the true rate and magnitude of the decline since pre-settlement times is uncertain (U.S. Fish and Wildlife Service [USFWS] 2010). Sage-grouse may have once occupied 12 states and 3 Canadian provinces. They have been extirpated from Nebraska and British Columbia (Connelly et al. 2004, Schroeder et al. 2004). Current range includes 11 states and 2 Canadian provinces (Connelly et al. 2004, Schroeder et al. 2004).

In Utah up to 60% of sage-grouse habitat has been lost and 49% of known leks were reported inactive (Beck et al. 2003). The current distribution of sage-grouse in Utah is clumped except for the northern portion of the state. The pattern of sage-grouse habitat in "discontinuous blocks" excluding the northern part of the state was noted as early as the 1970's by Jarvis (1973).

Braun (1998) identified agriculture, mining and energy development, farm sites, reservoirs, urbanization, and roads as factors contributing to habitat loss. Additionally, he cited fragmentation in the form of fences, power lines, and roads as other causes in the decline. Crawford and Lutz (1985) and Crawford (1982) determined lowered survival, through hunting, was not the cause of long-term population declines in Oregon. Connelly et al. (2004) concluded no studies have shown hunting is a primary cause in the decline of sage-grouse numbers.

EVOLUTIONARY RELATIONSHIPS

AND LIFE HISTORY

Evolutionary relationships of the genus *Centrocercus* have been debated (Johnsgard 1983). Hudson and Lanzillotti (1964) through anatomical comparison found the genus *Centrocercus* was closest to *Dendragapus* and suggested the relations of *Centrocercus* to other genera needed re-examination. Short (1967) also concluded the genus *Centrocercus* is most closely related to the genus *Dendragapus*. The proximal relationship of *Centrocercus* and *Dendragapus* to each other and their association to *Tympanuchus* has been shown through genetic work (Gutiérrez et al. 2000, Lucchini et al. 2001, Dimcheff et al. 2002, Drovetski 2002).

Zammuto (1986) reported longevity and clutch size are directly linked for North American game birds. Species with large clutch sizes live shorter lives as compared to species with smaller clutches. For a review of sage-grouse general life history, and other tetraonids see Table 1-1.

JUVENILE SURVIVAL

Johnson and Braun (1999) concluded adult and juvenile survival were the demographic parameters most limiting to population growth. Although a substantial amount of information is available concerning population dynamics of adult birds (Crawford et al. 2004), a gap exists range-wide regarding the dynamics of juvenile sage-grouse (e.g. survival, dispersal, predation, recruitment) (Utah Division of Wildlife Resources [UDWR] 2002, Crawford et al. 2004, Beck et al. 2006).

Swenson (1985) reported male juvenile sage-grouse had higher mortality than juvenile females during unfavorable years and in poorer habitats in Montana. In southeastern Idaho, Beck et al. (2006) reported juvenile sage-grouse (10+ weeks old to 29 March) experienced mortality ranging from 14-36% and found no difference in survival between genders. Most mortality was concentrated in fall. In south-central Idaho, Wik (2002) reported juvenile female survival rates of 0.40 - 0.69 and 0.87 - 1.00 for fall (September - November) and winter (December - February) respectively. Swanson (2009) reported juvenile survival rates (both sexes) in the Dakotas of 0.316 - 0.667 and 0.778 - 1.00 for late brood rearing (16 July - 31 October) and winter (1 November - 28 February), respectively. Legal harvest accounted for 17% of juvenile mortality on one study site and none on the other area Beck et al. (2006) examined. Wik (2002) reported harvest rates for juvenile females of 16.7%, 0%, and 37.5% for 1999, 2000, and 2001 respectively. Connelly et al. (2000) reported females were more susceptible to hunting than males. He attributed the differential susceptibility to the clumped distribution of females in mesic areas with juveniles. Wik (2002) provided evidence in support of Connelly et al. (2000). No adult males were harvested, while 5.9% of adult and 18.1% of juvenile hens were harvested. Sika (2006) concluded female survival (during the hunting season 1 September to 1 November in Montana) was higher for individuals that spent little or no time brood rearing vs. individuals raising broods to 30 days. No mortality in the study was directly attributed to harvest (including crippling).

Few fall and winter survival estimates for sage-grouse are available (Anthony and Willis 2009). In southeastern Oregon, October through February survival for adult female sage-grouse was 45.6% (Anthony and Willis 2009). The authors also noted a high

mortality rate during fall (October). Swanson (2009) also reported high mortality during 16 July - 31 October, and attributed the high mortality rates to west nile virus outbreaks and predation. Sika (2006) reported winter female survival of 90.5% and 74.3% for 1 November 2004 to 14 April 2005 and 1 November 2005 to 8 April 2006 respectively. Wik (2002) reported winter (December - February) survival rates of 85-90%, 88-100%, and 87-100% for all males (juveniles and adults), adult females, and juvenile females, respectively. Battazzo (2007) reported winter (1 November - 1 March) survival rates of 0.91-0.92, 0.86-0.87, and 0.88-0.89 for juvenile, yearling, and adult female sage-grouse, respectively. Swanson (2009) reported late brood rearing (16 July - 31 October) survival rates in North and South Dakota of 0.5-0.842, 0.556-0.875, 0.222-0.5, and 0.0-0.667 for adult females, yearling females, adult males, and yearling males, respectively. He also reported winter (1 November - 28 February) survival rates of 0.929-1.00, 0.889-1.00, 1.00, and 0.80 for adult females, yearling females, adult males, and yearling males, respectively. Zablan et al. (2003) found no evidence winter precipitation or temperature affected survival of sage-grouse. Conversely, Moynahan et al. (2006) reported severe winter weather negatively impacted sage-grouse in north-central Montana. However, their conclusions were based on one severe winter.

Pitman et al. (2006) reported 70% survival of juvenile lesser prairie-chickens (*Tympanuchus pallidicinctus*) in Kansas from 1 August to 31 March. Most of the mortality, 73.7%, occurred prior to 1 November (but after 1 August) and 68.4% of mortality was attributed to mammalian causes. Bowman and Robel (1977) noted high mortality for juvenile greater prairie chickens (*T. cupido*) during brood break up (late August through mid September). Survival from 1 December-31 May in willow

ptarmigan (*Lagopus lagopus*) was 69% and 81% on a hunted and unhunted area respectively (Smith and Willebrand 1999). Juvenile white-tailed ptarmigan (*L. leucura*) in Montana experience 31% and 43% over-winter survival for males and females respectively (Choate 1963). Spruce grouse (*Falcipennis canadensis*) in Alberta exhibited 87% over-winter survival (defined as the period of permanent snow cover ~ 1 Dec.-31 March) (Keppie 1979). Keppie (1979) concluded fall and winter were not critical survival periods for spruce grouse, and high survival rates during winter may be more frequent in tetraonids than was previously assumed. Keppie (1987) reported the rate at which juvenile spruce grouse were recruited was the most important factor affecting population change. Similarly, Steen and Erikstad (1996) showed apparent winter survival of juvenile willow ptarmigan had the largest potential impact on λ.

Wolfe et al. (2007) reported for lesser prairie-chickens 52.9% and 55.7% of predation were attributed to raptors in Oklahoma and New Mexico, respectively. Additionally, young birds were more susceptible to mammalian predation (66.7%) than adults (15.1%). Hagen et al. (2007) noted raptor predation on lesser prairie-chickens occurred more frequently from November-April than during summer. However, most mortality (59%) was attributed to mammalian predation.

HARVEST DYNAMICS AND EFFECTS

Some stakeholders have articulated concerns regarding the possible impacts of harvest on sage-grouse populations (Connelly et al. 2004). Harvest of sage-grouse occurs in 9 of the 11 states in which they occur. To date Washington and North Dakota do not have open seasons for sage-grouse. Washington and North Dakota closed their sage-

grouse seasons in 1988 and 2008, respectively. Neither Canadian province in which

sage-grouse occur allows harvest to date. Few studies have examined the effects of

hunting on sage-grouse populations (Connelly et al. 2004, USFWS 2005, 2010, Reese

and Connelly 2011). The Idaho Sage-grouse Advisory Committee ranked hunting 17th

out of 19 threats (Idaho Sage-grouse Advisory Committee 2006). Further studies are

needed to determine the effects of harvest on game birds (Baines and Linden 1991).

Historic sage-grouse hunting seasons, opening dates as early as 1 July (1901 in

Nevada), produced a highly selective kill (Patterson 1952). Colorado's sage-grouse

season in 1907 was 1 September to 1 October: bag and possession limits were 25 and 50

respectively (Rogers 1964). As the opening date of the season was postponed from 18

August, 27 August (Wyoming) to 15 September (Utah) the percentage of females

harvested was 63%, 60%, and 56% respectively (Patterson 1952). He recommended

sage-grouse seasons start no earlier than 20 September allowing birds to begin fall

dispersal before harvest. Girard (1937) suggested Wyoming move the sage-grouse

season from 3 August to 1 September. Ellison (1991) recommended early seasons to

increase the possibilities for compensatory harvest. However, he warned if the season is

too early young could be highly vulnerable to harvest.

Hunting season dynamics (e.g. length, bag/possession limits, timing, etc.) have

long been debated. Braun (1981) found longer hunting seasons increased number of hunt

days and hunters, but did not affect total number of birds harvested. On the contrary,

Crawford (1982) reported season length was directly linked to harvest. Hoffman (1985)

concluded season length had no effect on number of hunters, harvest, hunter success,

subsequent spring densities, or distribution of harvest of blue grouse (*Dendragapus*

obscurus). Additionally, production (juveniles/female in the harvest sample) and number of hunters accounted for 85% of the variation in harvest (Hoffman 1985). Increasing season length and bag limits did not increase hunters afield or sage-grouse harvested in Jackson County, Colorado (Braun and Beck 1985). Brøseth and Pedersen (2010) reported willow ptarmigan on hunted areas increased the use of cover habitats, and that both habitat of the hunt unit and population density affect catch per unit effort. They argued, given a fixed number of hunter days, areas with little or no escape cover will have a higher catch per unit effort and consequently a higher percentage harvest of the population when compared to areas with more escape cover.

"Opening day phenomenon" has been a topic of interest when setting seasons for many game species. Opening day phenomenon is the idea that most of the harvest and effort for a species occurs on the opening day(s) of the season. Braun and Beck (1985) reported an average of 67.2% of sage-grouse wings were received on opening weekends from 1977-1982 in North Park, Colorado. In Middle Park, Colorado from 1975-1982 an average of 43.8% of blue grouse wings were collected on opening weekends (Hoffman 1985). Giesen (1999) reported from 1980-1997, 55.7% of Columbian sharp-tailed (*T. phasianellus columbianus*) grouse wings were collected on opening weekends in Colorado. In addition, 79% and 21% of wings were collected on weekends and weekdays respectively. Sisson (1976) reported 83% of effort and 78% of sharp-tailed grouse (*T. phasianellus*) harvest occurred on weekends. Additionally, 52% of effort and 51% of harvest occurred during the first week of the season. During the first 2 weeks of the season 73% of effort and 71% of harvest occurred. Seasons ranged in length from 4 to 7 weeks.

Dynamics of the hunters afield have been debated; however, few studies have examined them directly. To assess the dynamics of hunters in Moffat County, Colorado, over the course of three years Braun (1981) conducted a survey. He reported 69.1-75.9% of hunters normally hunt sage-grouse on the area, while 6.8-11.1% of hunters normally hunt sage-grouse elsewhere. He reported 18.3-22.4% of hunters were first-time sage-grouse hunters. Sisson (1976) reported 15.1% of sharp-tailed grouse hunter effort on 3 study areas in the Sand Hills of Nebraska was from non-residents.

Historically, a harvest rate below 30% was thought to have little impact on sage-grouse populations (Autenrieth 1981, Braun 1981). Braun and Beck (1985) concluded harvest rates up to 20-25% would not be additive in Jackson County, Colorado. Hoffman (1985) concluded in his study site in Colorado a 25% harvest rate would have no measurable impact on blue grouse populations. Sedinger et al. (2010) concluded harvest was unlikely to influence local population dynamics as long as harvest rates are <11%. Bendell and Elliott (1967) using 2 separate calculations derived acceptable harvest rates for blue grouse of 20% and 30%.

Legal harvest accounted for 17% of juvenile mortality on one study area and none on the other area Beck et al. (2006) examined. Wik (2002) reported differential age and sex harvest rates. He reported 0% for adult males, 5.9% for adult females, and 18.1% for juvenile females across study years (1999 - 2001). Many studies have reported harvest rates for sage-grouse populations, but did not consider different age or gender vulnerability: 25% in Wyoming (Patterson 1952); 6.8% in Idaho (Dalke et al. 1963); 12% and 11% in 1962 and 1961 respectively in Wyoming (June 1963); 24% on Parker Mountain, Utah (Jarvis 1973); 12% in North Park, Colorado (Schoenberg 1981); 23% in

Owyhee County, Idaho (Autenrieth 1981); 7-10.9% in Moffat County, Colorado (Braun 1981); 7-11% in Jackson County, Colorado (Braun and Beck 1985); 14-18.7% in Jackson County, Colorado (Zablan et al. 2003). Autenrieth (1981) concluded the high harvest rate, in relation to other studies, was likely caused by the study site being located in a low precipitation area. He hypothesized, "sage-grouse in habitat where forbs are available throughout the range remain dispersed and therefore less vulnerable to harvest."

Studies on blue grouse have reported low harvest rates relative to those experienced by sage-grouse. In Montana 7% and 12% harvest rates of blue grouse occurred in 1957 and 1958 respectively (Mussehl 1960). The difference in harvest rate was attributed to differences in the stage of the altitudinal migration between years. Other authors reported: Zwickel et al. (1968) 4.2% harvest in Washington; Hoffman (1981, 1985) ≤3.9% harvest in Colorado; Bendell and Elliott (1967) annual harvest of 0.7% of adult males and 5% of hens and chicks on Vancouver Island, British Columbia; Braun (1981) 3.9% harvest rate in Colorado. Zwickel and Bendell (2005) reported an average harvest rate of 6.9% on Vancouver Island from 1969-1977. Harvest rates for each demographic were: 1% adult males, 2% yearling males, 14% adult females, 8% yearling females, 13% juveniles (banded), 3% juveniles (wing-tagged).

Fischer and Keith (1974) reported a 5% harvest return for ruffed grouse (*Bonasa umbellus*). Fischer and Keith (1974) reported harvests of 7% and 4% for juvenile ruffed grouse banded <805 or ≥805m from a road, respectively. They also reported territorial adult males banded within ≤100, 101-200, 201-301, and ≥302 meters of a road were shot at rates of 48%, 13%, 5%, and 1% respectively. Brøseth and Pedersen (2000) reported that the spatial distribution of willow ptarmigan hunting pressure was dependent upon the

starting location of the hunters. Areas closer to the base cabin received most of the hunting pressure, and survival probability was best predicted by distance from the base cabin. Harvested birds were closer to the base camp and their home ranges experience twice the hunting pressure.

Sisson (1976) noted sharp-tailed grouse residing on publicly owned land may be susceptible to over-harvest and special regulations may be required to prevent over-harvest. Gregg (1990) found the least accessible and least noted study area for sharp-tail hunting had the lowest kill rate. Small et al. (1991) reported harvest mortality, for ruffed grouse, on public hunting areas (73% adults and 56% juveniles) was higher than on private lands (13% adults and 9% juveniles).

Few studies have addressed crippling losses. Those that have reported crippling losses have used varying methods making comparison and accuracy difficult to assess. Additionally, studies may have varying definitions of "crippling" (see Haines et al. 2006). In many instances crippling estimates were based on guesswork (Gregg 1990). Braun and Beck (1985) estimated sage-grouse crippling loss ranging from 5.5-7%. Hoffman (1985) estimated a 5% crippling loss for blue grouse, measured through check stations. An 11% crippling rate for sharp-tailed grouse in Nebraska was determined through extensive hunter surveys (Sisson 1976). Small et al. (1991) reported 5% of ruffed grouse mortality was due to crippling by hunters. Haines et al. (2006) provided a review of reported crippling loss for northern bobwhite (*Colinus virginianus*) ranging from 5-31% of recorded harvest and 5-24% of total harvest.

Connelly et al. (2000) reported females were more susceptible to hunting than males. They attributed the differential susceptibility to the clumped distribution of

females in mesic areas with juveniles. Fifteen percent of adult male mortality and 42% of

adult female mortality was due to harvest, and harvest loss was likely additive to winter

mortality (Connelly et al. 2000). Harvest accounted for 50% of annual sage-grouse

mortality on Parker Mountain, Utah (Jarvis 1973). Braun (1981) stated juvenile sage-

grouse are more susceptible to harvest than adults and yearlings. Mussehl (1960)

reported harvest rates of 7.7% and 12.6% for juvenile blue grouse in 1957 and 1958

respectively. Bendell and Elliott (1967) reported higher harvest rates for hen and chick

blue grouse than for adult males, 5% and 0.7% respectively. Hoffman (1985) reported

juveniles accounted for 55% of harvest of blue grouse in Middle Park, Colorado.

Juveniles comprised 56.3% of the Columbian sharp-tailed grouse harvest in Colorado;

only 10.1% were ≤10 weeks of age and 3.1% were ≤9 weeks of age (Giesen 1999).

Bergerud (1970) proposed there may be a differential vulnerability to harvest of early- vs.

late-hatched willow ptarmigan chicks. A higher percentage of juvenile greater prairie

chickens were harvested in an early season (September -October) vs. a late season

(November -January) (Durbain et al. 1999). Baines and Linden (1991) argued that due to

their lower reproductive potential and higher mortality rates, the selection of juveniles

over adults is preferable.

Redfield (1975) noted successful female blue grouse with broods may be more

susceptible to harvest than unsuccessful females. In Colorado from 1953-1961 an

average 41% of sage-grouse harvest was male and 59% of harvest was female (Rogers

1964). In Wyoming 60% and 63% of the total sage-grouse kill was female in 1950 (27

August opening date) and 1951 (18 August opening date), respectively (Patterson 1952).

In Utah (1951: 15-16 September hunting season) 44% of the sage-grouse harvest was

male and 56% female (Patterson 1952). The ratio of adult to yearling male and female blue grouse was 49% and 51% respectively (Hoffman 1985). Giesen (1999) reported a 1:1 sex ratio of harvested adult and juvenile Columbian sharp-tailed grouse. In Washington a 1:1 sex ratio for harvested adult and juvenile spruce grouse was observed (Zwickel and Brigham 1970). Lumsden and Weeden (1963) found a ratio of 1.24:1 adult and 0.93:1 juvenile male to female of spruce grouse in Ontario. Hudson (1985) reported adult red grouse (*L. l. scoticus*), particularly cocks, were selectively shot, though not intentionally in Northern England.

Sedinger et al. (2010) suggested there was no support for an additive effect of harvest on sage-grouse survival on 2 study areas in Colorado and Nevada. Connelly et al. (2000) concluded sage-grouse harvest loss was likely additive to winter mortality. Additionally, Gibson et al. (2011) concluded harvest mortality for sage-grouse in Mono county, California was additive. Small et al. (1991) advised ruffed grouse harvest mortality was partially, possibly completely, additive to natural mortality. Smith and Willebrand (1999) concluded harvest mortality was mostly, and possibly completely, additive for willow ptarmigan in Sweden. Hudson (1985) reported there was some degree of evidence for harvest being compensatory on red grouse in Northern England. Evidence suggests mortality may be totally compensatory at harvest rates of 30% for red grouse and 5% for blue grouse (hens only) (Ellison 1991).

MOVEMENTS

Swanson (2009) reported brood breakup was the 4 October (median range was 17 July - 8 November) at a median age of 134 days (range was 38 - 173). He reported

breakup was usually initiated by the adult female and juveniles dispersed within days. Dunn and Braun (1986) noted juvenile sage-grouse moved to winter areas in November, and movement was tied to snowfall. Connelly et al. (1988) reported sage-grouse (of all sex and age classes) moved to winter areas beginning in Late August and continuing into December. Movements were slow and meandering. Likewise Swanson (2009) reported movements (of all sex and age classes) to wintering areas occurred over several months. Connelly et al. (1988) reported that juvenile sage-grouse moved an average of 14.9 km between summer and winter ranges. They also found that leks were in close proximity to wintering areas. Fall movements and directional movements to wintering areas of adult and juvenile sage-grouse were similar (Connelly et al. 1988). Schoenberg (1981) reported winter ranges of 5,000-25,000 ha and 6,400- 11,900 ha for males and females respectively. Sage-grouse congregate in large flocks during the winter (Girard 1937, Rasmussen and Griner 1938, Dalke et al. 1963, Ihli et al. 1973). In Colorado, winter flocks break-up during the first 2 weeks of April (Schoenberg 1981).

WINTER DIET

The majority of the sage-grouse winter diet is comprised of sagebrush (*Artemisia spp*.) (Wallestad et al. 1975). The winter (Nov.-March) diet in Wyoming was 99.7% sagebrush (Patterson 1952). Griner (1939) reported nearly 100% of the winter diet of sage-grouse was sagebrush. Black sage (*A. nova*) was preferred in Idaho, but snow can limit availability (Dalke et al. 1963).

WINTER HABITAT

In Wyoming vegetation distribution in a mountain big sagebrush (*A. tridentata vaseyana*) steppe was dependent on wind exposure and topography (Burke et al. 1989). During winter, sage-grouse typically use south to west aspects (Beck 1977) with slopes less than 5% (Eng and Schladweiler 1972, Beck 1977, Bruce 2008). Sage-grouse are reported to rarely use slopes greater than 5-10% (Eng and Schladweiler 1972, Beck 1977). Hupp and Braun (1989) reported Gunnison sage-grouse (*C. minimus*) used drainages ("Narrow [<100m] flood plains of permanent and intermittent streams, shallow eroded gulches on slopes) and slopes (>5°) with south or west aspects. Doherty et al. (2008) reported slope was an important topographic predictor of sage-grouse use. Snow cover is an important parameter determining use areas (Beck 1977, Hupp and Braun 1989). Sagebrush cover has been identified as an important parameter for winter habitat (Eng and Schlaweiler 1972, Woodward 2006, Battazzo 2007, Doherty et al. 2008, Swanson 2009).

Beck (1977) found nearly 80% of use occurred on areas comprising less than 7% of the total area. Carpenter et al. (2010) reported 72% of model validation location occurred in the highest quality wintering areas (2 highest Resource Selection Functions [RSF] bins), which accounted for only 13% of the study area. Swenson et al. (1987) reported lekking male sage-grouse declined by 73% as the proportion of ploughed wintering areas increased from 10% (1975) to 30% (1984). Woodward (2006) reported after 827 acres of winter habitat was chisel-plowed, sage-grouse returned to the plowed area despite seemingly good habitat elsewhere. Sage-grouse may exhibit site fidelity to wintering areas (Eng and Schladweiler 1972, Berry and Eng 1985, Connelly et al. 1988,

Woodward 2006). Eng and Schladweiler (1972) concluded the carrying capacity of

wintering areas would be severely hampered if sagebrush was removed. Doherty et al.

(2008) concluded impacts to wintering habitats could disproportionately affect population

size. Braun et al. (1977) recommended no manipulation of sagebrush take place in any

important winter areas known (within 10 years) to support sage-grouse.

RADIO-TELEMETRY

Radio-telemetry is commonly used to study wildlife population biology, ecology,

and behavior (Mech 1983, Fuller et al. 2005) and provides for opportunities to gather data

that are impossible or impractical using other methods (Fuller et al. 2005). Radio

transmitter style and attachment method is a critical component of any radio-telemetry

study (Fuller et al. 2005). The avian neck mounted attachment method for radio

packages first was modified by Amstrup (1980) from marker designs of Pyrah (1970) and

others. Necklaces are the most commonly used method for attaching of radio transmitters

(Mech 1983). Several back mounted (backpack) transmitters have been developed:

Brander (1968) developed a harness style backpack for ruffed grouse, Dwyer (1972)

described a harness style backpack for ducks (*A*. spp.), and Perry et al. (1981) developed

a glue on backpack for mourning doves (*Zenaida macroura*). Necklaces are widely used

for studying sage-grouse (Connelly et al. 1993, Connelly et al. 2000, Wik 2002,

Schroeder and Robb 2003, Beck et al. 2006, Doherty et al. 2008, Swanson 2009).

Harness style backpack transmitters also have been used for sage-grouse (Eng and

Schladweiler 1972, Connelly et al. 1988, Swanson 2009). A suture-on method for

attaching backpack transmitters has been used for waterfowl (Rotella et al. 1993). Davis

et al. (1999) reported a 1.6 gram prong and suture method had no adverse effects on wood duck (*Aix sponsa*) ducklings. Burkepile et al. (2002) concluded small (<2g) suture-on backpack transmitter to monitor sage-grouse chicks was effective. The suture-on method for attachment (Burkepile et al. 2002) has not been tested using larger packages (>4g) on sage-grouse. Fleskes (2003) noted poor retention of a spear-suture radio package (8-9 gram weight) on northern pintails (*Anas acuta*). Pietz et al. (1995) described an "anchor" radio package (4 gram weight) and concluded the method was effective. However, Paquette et al. (1997) reported the "anchor" method may have negatively affected survival and reproduction. Additionally, Zimmer (1997) reported poor retention for the method using an 8 gram transmitter.

The idea of so called "radio-handicapping" has long been argued. Boag (1972) found decreased food consumption and activity levels of harness style radio-equipped vs. control captive red grouse. He noted the greatest differences within the first week of instrumentation. The transmitters' percent of body weight was relatively high (3.5-4.5%). Several authors have concluded radio-tags can cause adverse effects to individuals: in gray partridge (*Perdix perdix*) (Bro et al. 1999), in (*Tetrao tetrix*) (Caizergues and Ellison 1998) and Columbian sharp-tailed grouse (Marks and Marks 1987). Color of radio units may play a role in causation of adverse effects (Erikstad 1979). Small and Rusch (1985) reported some individual ruffed grouse fitted with harness style backpack transmitters would not accept the package and other individuals had longer (vs. poncho) acclimation periods. However, they found no difference in flight abilities after acclimatization. They detected a slightly higher survival rate for individuals fitted with ponchos, but attributed the lighter package weight of the poncho as

the cause for the differential. Rotella et al. (1993) found evidence that harnessed backpack transmitters affected nesting behavior and sutured backpacks had poor retention in Mallards. Numerous authors have reported adverse effects of backpack style transmitters on waterfowl in: wild mallards (Pietz et al. 1993, Dzus and Clark 1996), captive blue-winged teal (*A. discors*) and mallards (Greenwood and Sargeant (1973), Barrow's goldeneye (*Bucephala islandica*) (Robert et al. 2006), northern pintails (Fleskes 2003), canvasbacks (*Aythya valisineria*) (Perry 1981), brant (*Branta bernicla nigricans*) (Ward and Flint 1995). Marcström et al. (1989) concluded necklace radio packages are more suitable for studies of ring-necked pheasant survival than are backpack radio packages.

Other authors have shown radio packages have no measurable effect on survival. Hagen et al. (2006) found no difference in survival of lesser prairie-chickens (*Tympanuchus pallidicinctus*) fitted with a necklace style radio and leg band vs. only fitted with a leg band. Boag et al. (1973) reported no difference in survival for harness style radio-equipped red grouse vs. red grouse fitted with back-tabs. Additionally, no difference was detected in back-tabbed vs. leg-banded birds. Hines and Zwickel (1985) reported radio packages had little measurable effect on young blue grouse. Additionally, they concluded, through a review of the literature, that there is limited support for the view that radio packages adversely influence survival or reproduction of galliforms. In Georgia the effect of radio transmitters on northern bobwhites was examined extensively and it was found the effect of radio transmitters was negligible (Sisson et al. 2006, Terhune et al. 2007). Johnson and Berner (1980) concluded radio packages had no adverse effect on ring-necked pheasants (*Phasianus colchicus*) so long as the individual's

mass was enough to carry the package. Thirgood et al. (1995) found no measurable effect of necklace radios vs. wing tags on red grouse.

Capture alone may cause adverse effects to avian species. Capture myopathy (see Abbott et al. 2005) could have variable effects on individuals, and vary by temperature, humidity, and handling time (Nicholson et al. 20000). Capture method also effects capture myopathy in mallards (Bollinger et al. 1989, Dabbert and Powell 1993). Capture myopathy has been documented in mallards (Bollinger et al. 1989, Dabbert and Powell 1993), and several gallinaceous species including wild turkeys (*Meleagris gallapavo*) (Spraker et al. 1987, Nicholson et al. 2000, Conner et al. 2006), red-legged partridge (*Alectoris rufa*) (Höfle et al. 2004), and northern bobwhites (Abbott et al. 2005). Based on their results some researchers have embraced the use of an adjustment or acclimatization period (Höfle et al. 2004, Conner et al. 2006).

Technological advances have lead to the development and miniaturization of satellite (platform transmitter terminals [PTT]) and global positioning system (GPS) telemetry packages available for use on avian species. When compared to PTTs, GPS transmitters are more accurate (Fuller et al. 2005). However, PTTs are currently available in lighter weight packages. Satellite (PTTs) telemetry has been used to study several species including: greater snow geese (*Chen caerulescens atlantica*) (Blouin et al. 1999), Greenland white-fronted geese (*Anser albifrons flavirostris*) (Fox et al. 2003), northern pintails (Miller et al. 2005), grey teal (*A. gracilis*) (Roshier and Asmus 2009), and magpie geese (*Anseranas semipalmata*) (Traill et al. 2010). Global Positioning System (GPS) transmitters have been used on gallinaceous species including wild turkeys (Guthrie et al. 2011) and capercaillies (*T. urogallus*) (Wegge et al. 2007). A glued on

backpack (Perry et al. 1981) GPS transmitter has been used for sage-grouse (Stringham 2010).

Newer GPS transmitters may have several advantages over traditional very high frequency (VHF) transmitters. They can collect multiple locations per day at pre-programmed times, reduce problems with on-the-ground access, and eliminate observer disturbance of the bird. They also can provide real time data on survival, movements, habitat use, and timing of nest initiation. Solar-powered GPS transmitters must be mounted dorsally with exposure to the sun to ensure adequate battery recharge. However, the VHF choice of methodology has been largely preferred because of the higher costs associated with newer GPS satellite telemetry technology, and concerns about the possible effects on survival of increased transmitter weights and the location of the package on the back of the birds (Utah Wildlife-in-Need 2011).

STUDY PURPOSE

The purpose of this study was to provide new information regarding the role and contribution of juvenile survival in sage-grouse population dynamics for application to management. The specific objectives of this research were to determine: 1) juvenile survival rates and the factors affecting them, 2) the effects of transmitter type (necklace vs. backpack) on juvenile survival, 3) harvest risk by breeding status of female sage-grouse, and 4) winter habitat use vs. availability on Parker Mountain in south-central Utah.

STYLE GUIDE

This thesis was written according to the guidelines of the Journal of Wildlife Management (Chamberlain and Johnson 2008).

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Table 1-1 Comparison of general life history traits of several Tetraonids. See Bergerud (1988) for further discussion on the population ecology of grouse.

	Adult Male Survival	Adult Female Survival	Clutch Size	Nest Success	Juvenile Survival (a)	Mean Longevity after first fall	Maximum Longevity Records
Blue Grouse	75% [1] 69% [2] 74% [3]	72% [1] 44% [6]	4-9 [1] 6.0 [8]	40% [1] 73.3% [7 adult] 57.1% [7 yearling]	46% - 60% [1] At Least 40% [5]	3.1 yrs [male] 2.09 yrs [female] See 23	14 yrs [4]
Spruce Grouse	50 % [9]	45% [9]	7.5 [10]	81% [10]	87% both sexes [11] (b)		5.3 yrs [25]
Sage Grouse	49.7% [12] 37% [29]	58.5% [12] 59% [29] 42-80% [28]	7-8 [13] 4-8 [14] 6.3-9.1 [30]	36% [12 adult] 53.7% [12 yearling] 52.4% [16] 38.4% [16] 45% [28] 52% [31]	86% [15] 64% [15] 34.8 - 69% [females only 28]	Adult Female 2.02 yrs [average 24] 1.04-3.47 yrs [range 24]	9 yrs [29]
Ruffed Grouse	34% [32]		11.4 (6-15) [17] 9.86 [26]	62% [18] 66% [26]	39% [Sept.-March 27] 26.4% [Sept.- Feb. 26]	1.25 yrs [13]	7.6 yrs [25]
Sharp-tailed Grouse	20.5% [20] 29.4% [20]	20.5% [20] 29.4% [20]	5-17 [13] 11.6 [19]	55% [19]		1.10 yrs [13]	6.3 yrs [25]
Red Grouse	35% [22]	35% [22]	6.1 - 8.1 [21]	82.5% [21,22]		2.92 yrs (+1 yrs old) ~ 4yrs. [22]	
Greater prairie chicken	47% [13]	44% [13]	11.8 [19]	50% [19]		1.2yrs [13]	

a = survival from Sept. - March unless noted otherwise

b = survival period defined as permanent snow cover (~1 December average across years) to 31 March

1 Zwickel and Bendell 1967; 2 Bendell 1955; 3 Bendell and Elliot 1967; 4 Zwickel et al. 1989; 5 Zwickel 1983; 6 Boag 1966; 7 Hoffman 1985; 8 Hoffman 1981; 9 Robinson 1980; 10 Ellison 1974; 11 Keppie 1979; 12 Braun 1981; 13 Johnsgard 1983; 14 Rasmussen and Griner 1938; 15 Beck et al. 2006; 16 Patterson 1952; 17 Edminster 1947; 18 Bergerud 1988; 19 Sisson 1976; 20 Robel et al. 1972; 21 Jenkins et al. 1963; 22 Jenkins et al. 1967; 23 Lewis and Zwickel 1982; 24 Sika 2006; 25 Clapp et al. 1982; 26 Devers et al. 2007; 27 Larson et al. 2001; 28 Wik 2002; 29 Zablen et al. 2003; 30 Connelly et al. 2004; 31 Connelly et al. 1993; 32 Fischer and Keith 1974

CHAPTER 2

FACTORS AFFECTING GREATER SAGE-GROUSE JUVENILE SURVIVAL AND ADULT HEN HARVEST RISK: IMPLICATIONS FOR RESEARCH AND MANAGEMENT

ABSTRACT: Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) adult and juvenile survival are the population parameters frequently identified as most critical to population growth. Juvenile survival is one of the least documented demographic parameters of sage-grouse. Sage-grouse brood hens and broods may be more susceptible to harvest than males and hens without broods. This potentially higher susceptibility to harvest may reflect the clumped distribution of hens and their broods in good brood-rearing habitat during hunting seasons. Sage-grouse telemetry studies typically use necklace type radio transmitters. However, given the increased interest in deployment of back and rear mounted global positioning system collars, there has been concern birds fitted with back-mounted collars may experience higher mortality rates. From 2008-2010, I studied the survival patterns of 91 juvenile sage-grouse that were radio collared on Parker Mountain, in south-central Utah. Two transmitter types were used (avian necklace and suture-on backpack) to determine if transmitter type affected survival. Nesting and survival radio-telemetry data collected from 1998-2009 on Parker Mountain was used to assess hen harvest risk. The nest survival model within Program MARK was used to analyze juvenile survival data. Maximum likelihoods and profile likelihood confidence intervals ($\alpha = 0.1$) were used to assess hen harvest risk by breeding status. The juvenile sage-grouse studied exhibited high over-winter survival (females:

0.802 - 0.982 and males: 0.687 - 0.969). Fall survival rates were 0.522 - 0.623 for

females and 0.332 - 0.449 for males. Survival from fall through winter was 0.418 - 0.616

for females and 0.228 - 0.435 for males. The main source of mortality was predation

(probability predation caused death was 0.705 for both years combined). Harvest was a

significant source of mortality (the probability harvest caused death was 0.159 for both

years combined). Unreported harvest played a role in the general harvest dynamic; the

probability unreported harvest caused death was 0.091. Sex (p= 0.103) and transmitter

type (p = 0.09) affected survival. Back-mounted transmitters negatively affected

survival. The probability of harvest was 0.087 (0.035-0.171) and 0.011 (0.001-0.039) for

brood hens and non-brood hens, respectively. There was evidence that brooding hens are

more susceptible to harvest. However, the evidence from this study was inconclusive at

$\alpha = 0.1$. High accessibility coupled with public landownership could have influenced

harvest. No evidence was found to warrant including an "acclimatization period" in the

analyses. Future research is needed to determine the acceptable harvest rate for juvenile

female and adult hen sage-grouse. Future survival studies on sage-grouse should avoid

the use of back-mounted transmitters to minimize experimental bias. Future harvest

management actions should attempt to shift harvest away from juveniles and the hens

associated with them.

INTRODUCTION

Johnson and Braun (1999) concluded adult and juvenile survival were the

demographic parameters most limiting to population growth for greater sage-grouse

(*Centrocercus urophasianus*; hereafter sage-grouse). Although a substantial amount of

information is available concerning population dynamics of adult birds (Crawford et al. 2004), a gap exists range-wide regarding the dynamics of juvenile sage-grouse (e.g. survival, dispersal, predation, recruitment) (Utah Division of Wildlife Resources [UDWR] 2002, Crawford et al. 2004, Beck et al. 2006). Swenson (1985) reported male juvenile sage-grouse had higher mortality than juvenile females during unfavorable years and in poorer habitats in Montana. Beck et al. (2006) reported juvenile sage-grouse (10+ weeks old to 29 March) experienced survival ranging from 0.64-0.86 and found no difference in survival between genders in southeastern Idaho. Most mortality was concentrated in fall. Wik (2002) reported fall (September - November) survival rates for juvenile female sage-grouse of 0.40 and 0.69 for 1999 and 2000, respectively, in south-central Idaho. He also reported winter (December - February) survival rates for juvenile female sage-grouse of 0.87 (1999-2000) and 1.00 (2000-2001). Swanson (2009) reported juvenile survival rates (both sexes) in the Dakotas of 0.316 - 0.667 and 0.778 - 1.00 for late brood rearing (16 July - 31 October) and winter (1 November - 28 February), respectively.

Few fall and winter survival estimates for sage-grouse are available (Anthony and Willis 2009). In southeastern Oregon, October through February survival for adult female sage-grouse was 45.6% (Anthony and Willis 2009). The authors also noted a high mortality rate during fall (October). Sika (2006) reported winter female survival rates of 90.5% and 74.3% for 1 November 2004 to 14 April 2005 and 1 November 2005 to 8 April 2006 respectively. Wik (2002) reported winter (December - February) survival rates of 0.85-0.90 (adult and juvenile males), 0.88-1.00 (adult female), and 0.87-1.00 (juvenile female). Battazzo (2007) reported winter (1 November - 1 March) survival

rates for female age classes of 0.91-0.92 (juvenile), 0.86-0.87 (yearling), and 0.88-0.87 (adult). Swanson (2009) reported late brood rearing (16 July - 31 October) survival rates in North and South Dakota of 0.5-0.842, 0.556-0.875, 0.222-0.5, and 0.0-0.667 for adult females, yearling females, adult males, and yearling males, respectively. He also reported winter (1 November - 28 February) survival rates of 0.929-1.00, 0.889-1.00, 1.00, and 0.80 for adult females, yearling females, adult males, and yearling males, respectively. Zablan et al. (2003) found no evidence winter precipitation or temperature affected survival of sage-grouse. Conversely, Moynahan et al. (2006) reported severe winter weather negatively impacted sage-grouse in north-central Montana. However, their conclusions were based on one severe winter.

Some stakeholders have articulated concerns regarding the possible impacts of harvest on sage-grouse populations (Connelly et al. 2004). Harvest of sage-grouse occurs in 9 of the 11 states in which they occur. Washington and North Dakota do not have open seasons for sage-grouse. Washington closed the sage-grouse season in 1988, and North Dakota closed the sage-grouse season in 2008. Neither Canadian province where sage-grouse occur allows harvest. However, few studies have examined the effects of hunting on sage-grouse populations (Connelly et al. 2000, 2003, 2004, USFWS 2005, 2010, Reese and Connelly 2011). The Idaho Sage-grouse Advisory Committee ranked hunting 17th out of 19 threats (Idaho Sage-grouse Advisory Committee 2006). Further studies to determine the effects of harvest on game birds are needed (Baines and Linden 1991).

Many studies have reported harvest rates for sage-grouse populations, but did not consider differential age or gender vulnerability: 25% in Wyoming (Patterson 1952);

6.8% in Idaho (Dalke et al. 1963); 12% and 11% in 1962 and 1961 respectively in Wyoming (June 1963); 24% on Parker Mountain, Utah (Jarvis 1973); 12% in North Park, Colorado (Schoenberg 1981); 23% in Owyhee County, Idaho (Autenrieth 1981); 7-10.9% in Moffat County, Colorado (Braun 1981); 7-11% in Jackson County, Colorado (Braun and Beck 1985); and 14-18.7% in Jackson County, Colorado (Zablan et al. 2003). Autenrieth (1981) concluded the higher harvest rate on his study area, in relation to other studies, was likely caused by the study site being located in a low precipitation area. He hypothesized, "sage-grouse in habitat where forbs are available throughout the range remain dispersed and therefore less vulnerable to harvest."

Connelly et al. (2000) reported females were more susceptible to hunting than males. He attributed the differential susceptibility to the clumped distribution of females with juveniles in mesic areas. Redfield (1975) noted female blue grouse (*Dendragapus obscurus*) with broods may be more susceptible to harvest than females without broods. Sika (2006) concluded survival during the hunting season (1 September - 1 November in Montana) was higher for females spending little or no time rearing broods than individuals raising broods to 30 days. No mortality in the study was directly attributed to harvest (including crippling). Legal harvest accounted for 17% of juvenile sage-grouse mortality on one study area and none on the other area Beck et al. (2006) examined. Wik (2002) reported harvest rates of 0% (adult male), 5.9% (adult female), and 18.1% (juvenile female) across years (1999-2001). He concluded harvest mortality was additive. Fifteen percent of adult male mortality and 42% of adult female mortality was due to harvest according to Connelly et al. (2000), who concluded harvest loss was likely additive to winter mortality. Harvest accounted for 50% of annual sage-grouse mortality

on Parker Mountain, Utah (Jarvis 1973). In Mono County, California Gibson et al. (2011) concluded harvest mortality for sage-grouse was likely additive.

Spatial dynamics could affect harvest. Fischer and Keith (1974) reported harvests of 7% and 4% for juvenile ruffed grouse (*Bonasa umbellus*) banded <805 or ≥805m from a road, respectively. They also reported territorial adult males banded within ≤100, 101-200, 201-301, and ≥302 meters of a road were shot at rates of 48%, 13%, 5%, and 1% respectively. Brøseth and Pedersen (2000) reported that the spatial distribution of willow ptarmigan (*Lagopus lagopus*) hunting pressure was dependent upon the starting location of the hunters. Areas closer to the base cabin received most of the hunting pressure, and survival probability was best predicted by distance from the base cabin. Harvested birds were closer to the base camp and their home ranges experience twice the hunting pressure. Brøseth and Pedersen (2010) reported willow ptarmigan on hunted areas increased the use of cover habitats, and that both habitat of the hunt unit and population density affect catch per unit effort. They argued, given a fixed number of hunter days, areas with little or no escape cover will have a higher catch per unit effort and consequently a higher percentage harvest of the population when compared to areas with more escape cover.

Sisson (1976) noted sharp-tailed grouse (*Tympanuchus phasianellus*) residing on publicly owned land may be susceptible to over-harvest and special regulations may be required to prevent over-harvest. Gregg (1990) found the least accessible and least noted study area for sharp-tail hunting had the lowest kill rate. Small et al. (1991) reported harvest mortality, for ruffed grouse, on public hunting areas (73% adults and 56% juveniles) was higher than on private lands (13% adults and 9% juveniles).

Radio-telemetry is commonly used to study wildlife population biology, ecology, and behavior (Mech 1983, Fuller et al. 2005) and provides for opportunities to gather data that are impossible or impractical using other methods (Fuller et al. 2005). Radio transmitter style and attachment method is a critical component of any radio-telemetry study (Fuller et al. 2005). The avian neck mounted attachment method for radio packages first was modified by Amstrup (1980) from marker designs of Pyrah (1970) and others. Necklaces are widely used for studying sage-grouse (Connelly et al. 1993, Connelly et al. 2000, Wik 2002, Schroeder and Robb 2003, Beck et al. 2006, Doherty et al. 2008, Swanson 2009). A suture-on method for attaching backpack transmitters has been used for waterfowl (Rotella et al. 1993). Burkepile et al. (2002) concluded small (<2g) suture-on backpack transmitter to monitor sage-grouse chicks was effective. The suture-on method for attachment (Burkepile et al. 2002) has not been tested using larger packages (>4g) on sage-grouse.

Harness style backpack transmitters also have been used for sage-grouse (Eng and Schladweiler 1972, Connelly et al. 1988, Swanson 2009). Small and Rusch (1985) reported some individual ruffed grouse fitted with harness style backpack transmitters would not accept the package and other individuals had longer (vs. poncho) acclimation periods. However, they found no difference in flight abilities after acclimatization. They detected a slightly higher survival rate for individuals fitted with ponchos, but attributed the lighter package weight of the poncho as the cause for the differential. Rotella et al. (1993) found evidence that harnessed backpack transmitters affected nesting behavior and sutured backpacks had poor retention in Mallards (*Anas platyrhynchos*). Numerous authors have reported adverse effects of backpack style transmitters on waterfowl in: wild

mallards (Pietz et al. 1993, Dzus and Clark 1996), captive blue-winged teal (*A. discors*) and mallards (Greenwood and Sargeant (1973), Barrow's goldeneye (*Bucephala islandica*) (Robert et al. 2006), northern pintails (*Anas acuta*) (Fleskes 2003), canvasbacks (*Aythya valisineria*) (Perry 1981), brant (*Branta bernicla nigricans*) (Ward and Flint 1995). Marcström et al. (1989) concluded necklace radio packages are more suitable for studies of ring-necked pheasant (*Phasianus colchicus*) survival than are backpack radio packages.

Other authors have shown radio packages have no measurable effect on survival. Hagen et al. (2006) found no difference in survival of lesser prairie-chickens (*Tympanuchus pallidicinctus*) fitted with a necklace style radio and leg band vs. only fitted with a leg band. Boag et al. (1973) reported no difference in survival for harness style radio-equipped red grouse (*L. l. scoticus*) vs. red grouse fitted with back-tabs. Additionally, no difference was detected in back-tabbed vs. leg-banded birds. Hines and Zwickel (1985) reported radio packages had little measurable effect on young blue grouse. Additionally, they concluded, through a review of the literature, that there is limited support for the view that radio packages adversely influence survival or reproduction of galliforms. In Georgia the effect of radio transmitters on northern bobwhites (*Colinus virginianus*) was examined extensively and it was found the effect of radio transmitters was negligible (Sisson et al. 2006, Terhune et al. 2007). Johnson and Berner (1980) concluded radio packages had no adverse effect on ring-necked pheasants so long as the individual's mass was enough to carry the package. Thirgood et al. (1995) found no measurable effect of necklace radios vs. wing tags on red grouse.

Capture alone has the potential to cause adverse effects to avian species. Capture myopathy (see Abbott et al. 2005) could have variable effects on individuals, and vary by temperature, humidity, and handling time (Nicholson et al. 2000). Capture method also effects capture myopathy in mallards (Bollinger et al. 1989, Dabbert and Powell 1993). Capture myopathy has been documented in mallards (Bollinger et al. 1989, Dabbert and Powell 1993), and several gallinaceous species including wild turkeys (*Meleagris gallapavo*) (Spraker et al. 1987, Nicholson et al. 2000, Conner et al. 2006), red-legged partridge (*Alectoris rufa*) (Höfle et al. 2004), and northern bobwhites (Abbott et al. 2005). Based on their results some researchers have embraced the use of an adjustment or acclimatization period (Höfle et al. 2004, Conner et al. 2006).

Technological advances have lead to the development and miniaturization of satellite (platform transmitter terminals [PTT]) and global positioning system (GPS) telemetry packages available for use on avian species. When compared to PTTs, GPS transmitters are more accurate (Fuller et al. 2005). However, PTTs are currently available in lighter weight packages. Satellite (PTTs) telemetry has been used to study large scale movements several species including: greater snow geese (*Chen caerulescens atlantica*) (Blouin et al. 1999), Greenland white-fronted geese (*Anser albifrons flavirostris*) (Fox et al. 2003), northern pintails (Miller et al. 2005), grey teal (*A. gracilis*) (Roshier and Asmus 2009), and magpie geese (*Anseranas semipalmata*) (Traill et al. 2010). Global Positioning System (GPS) transmitters have been used to study fine scale movements of gallinaceous species including wild turkeys (Guthrie et al. 2011) and capercaillies (*T. urogallus*) (Wegge et al. 2007). A glued on backpack (Perry et al. 1981) GPS transmitter has been used for sage-grouse (Stringham 2010).

Newer GPS transmitters may have several advantages over traditional very high frequency (VHF) transmitters. They can collect multiple locations per day at pre-programmed times, reduce problems with on-the-ground access, and eliminate observer disturbance of the bird. They also can provide real time data on survival, movements, habitat use, and timing of nest initiation. Solar-powered GPS transmitters must be mounted dorsally with exposure to the sun to ensure adequate battery recharge. However, the VHF choice of methodology has been largely preferred because of the higher costs associated with newer GPS satellite telemetry technology, and concerns about the possible effects on survival of increased transmitter weights and the location of the package on the back of the birds (Utah Wildlife-in-Need 2011).

The objectives of this research were to determine: 1) juvenile survival rates and the factors affecting them, 2) the affects of transmitter type (necklace vs. backpack) on juvenile greater sage-grouse survival, and 3) harvest risk by breeding status of hen sage-grouse.

STUDY AREA

The study was conducted on Parker Mountain in south-central Utah within Wayne, Piute, Sevier, and Garfield Counties. Parker Mountain lies at the southern edge of the greater sage-grouse range (Schroeder et al. 2004). The study site ranged in elevation from 2,200 to 3,000 m and rose in elevation gradually from east to west. The average temperature was 3.8 C. The mean maximum and minimum temperatures for January and July were 1, -13 C and 27, 9 C, respectively. Parker Mountain experienced 65 - 80 frost-free days and receives 40-50 cm of precipitation annually, most of which

occurred during the dormant season as snow (60%), and the remainder fell as rain in the late summer (Jaynes 1982). The vegetation was primarily black sagebrush (*Artemisia nova*) on ridges and mountain big sagebrush (*A. tridentata vaseyana*) in the swales. Quaking aspen (*Populus tremuloides*) clones were present in the higher elevations. Pinyon pine (*Pinus edulis*) and juniper (*Juniperus* spp.) occurred at lower elevations. The study area was mainly located on lands managed by the Utah School and Institutional Trust Lands Administration (SITLA) and the Bureau of Land Management (BLM). Those agencies managed 46% (43,745 ha) and 44% (42,643 ha) respectively. The U.S. Forest Service (USFS) managed 9% (8,327 ha) and private lands accounted for 1% (1,363 ha) of the study area. The primary use of the land was cattle grazing. Sheep grazing, big game hunting, and upland bird hunting, including sage-grouse, were significant uses of the study area.

The Parker Mountain sage-grouse hunt unit designated by the UDWR was 601,997 ha. However, most of the unit was unusable to sage-grouse (Fig. 3-1 Chapter 3). Within the hunt unit, a smaller study area (96,078 ha) was established using sagebrush as a criterion (Fig. 3-2 Chapter 3). In 2008 UDWR issued 370 2 bird permits on a first-come first-serve basis for the Parker Mountain unit. In 2009 UDWR issued 265 2 bird permits on a draw basis. The sage-grouse hunting seasons in 2008 and 2009 were 27 September-12 October and 26 September- 11 October, respectively.

METHODS

Juvenile Survival

Juvenile birds were captured using modifications of night spotlighting (Giesen et al. 1982, Wakkinen et al. 1992, Connelly et al. 2003). Trapping was conducted between 1 August-30 September, annually. Trapping ceased 2 days prior to the sage-grouse hunting season. Trapping effort was based on brood locations of radioed hens known to have broods and by using bird dogs to detect the presence of broods not accompanied by a radioed hen. Upon capture, adults were distinguished from juveniles using characteristics of the first secondary (Beck et al. 1975). Juveniles were sexed using primary length, molt (Beck et al. 1975), and DNA analysis. The study protocols were approved by the Utah State University Institutional Animal Use and Care Committee (IACUCC Number 942R).

Juveniles were fitted with suture-on backpack and necklace-style transmitters were used (American Wildlife Enterprises, Monticello, FL). All transmitters weighed 15 grams and did not exceed 3% of the individual's body weight (Thirgood et al. 1995). The transmitters were battery powered and equipped with mortality switches set to trip after 12 hours of inactivity. The type of transmitter the individual received was selected randomly. Backpack transmitters were fitted using modifications of Burkepile et al. (2002). The sutures (2/0 suture thread) were inserted using 18 gauge x 3.81 cm sterile needles. Two sutures were inserted on the individuals back between the wings. Each side of the suture was threaded through a hole in the anterior and posterior end of the transmitter. Square knots were used to fasten the transmitter, and the knots were secured

using cyanoacrylate. Necklace transmitters were mounted using 27.3 kg.-test black nylon coated steel wire threaded through the transmitter, then threaded through clear soft plastic tubing and crimped to itself using #4 black leader sleeves. Backpack transmitters were 35 mm long by 26 mm wide by 14 mm tall with an antenna length of ~250 mm. Necklace transmitters were 26mm long by 26 mm wide by 15 mm tall with an antenna length of ~300 mm.

Survival status of marked individuals was checked bi-monthly. Status was confirmed remotely using the pulse signal emitted by the transmitter mounted on the marked individual. When a mortality signal was detected the transmitter was located and classified into one of four groups: 1) reported harvest, 2) unreported harvest, 3) predation, and 4) other, using evidence from the site (e.g. marks on transmitter, feather patterns, tracks). A mortality was deemed unreported harvest only if irrefutable evidence existed (e.g. lead shot in carcass, obvious shotgun wounds during necropsy, field dressed carcass).

Locations of marked individuals were acquired monthly. Individuals were located by radio-telemetry following direction of antenna and signal strength until the individual was observed (Mech 1983) or by circling the location of the strongest signal strength (Springer 1979). Upon locating the individual, Universal Transverse Mercator coordinates (datum, North American 1983; projection, UTM Zone 12) were documented. If the individual was not observed, we recorded the UTM coordinates, azimuth (to estimated location), and estimated the radius of the circle. Aerial radio-tracking (Mech 1983) was used, bimonthly from January through March, to locate individuals and check survival status. The airplane was fitted with 2 side-facing H-type antennas.

To assess mortality causes and an "acclimatization period," maximum likelihoods and profile likelihood confidence intervals were calculated. Probability of mortality was calculated for 0-10, 11-20, 21-30 days post-capture to assess the need/validity of an acclimatization period. Probability of death causation was calculated using maximum likelihoods and profile likelihood confidence intervals. Causes of mortality that were assessed were reported harvest, unreported harvest, predation, and other (one fence strike occurred).

Survival rates were evaluated by sex, year (2008-2009 and 2009-2010), transmitter type (backpack vs. necklace), and variation in time from 1 September-31 March each year. For analysis purposes fall = 22 August to 1 December, winter = 2 December to 31 March, and total = 22 August to 31 March. For the *a priori* models see Table A-1. The nest survival model implemented in Program MARK was used to estimate survival. If an individual went missing during the study, it was censored after its last known survival date. The Delta Method (Seber 1982:7-9) was used to combine daily survival rates into longer intervals of survival. To calculate confidence intervals for estimates derived using the delta method, estimates were transformed to the logit scale then back-transformed to the probability scale to ensure estimates were bounded (0,1) (Cooch and White 2009: B17-B18). Likelihood ratio tests were used to differentiate between competing models that were nested. All confidence limits were $\alpha = 0.05$ unless otherwise noted.

Hen Harvest Susceptibility

To compare harvest probability of hens known to have broods vs. broodless hens a secondary analysis (primary analysis was nesting and brood rearing) was performed on radio-telemetry and harvest data collected from 1998-2009. These hens were monitored using radio-telemetry from 1 May through July each year (broods were followed from hatch to 42 days). Using these data hens were classified as one of 2 groups: brood hens or non-brood hens. Hens known to have successfully raised at least one chick to 42 days were defined as brood hens. Non-brood hens included the following qualifications: hens known not to have initiated nesting, hens known to have initiated nesting but failed to hatch the clutch, and hens known to have successfully hatched a clutch but failed to raise at least one chick to 42 days. Maximum likelihoods were calculated for probability of death from harvest of brood hens and non-brood hens. Profile likelihood confidence intervals ($\alpha = 0.1$) were calculated for each probability.

To determine accessibility of the study area for hunters, roads were buffered by 300 and 600 m utilizing the buffer tool in ArcView 9.2 (Environmental Systems Research Institute Inc. Redlands, CA). Access to the area used by the birds in the fall was established by creating a 100 MCP using all locations from August - October and buffering it by 300 meters. Roads included both graded dirt roads and "2-track" roads. No paved roads exist on Parker Mountain.

RESULTS

No evidence was found to warrant including an "acclimatization period" in the analyses. There was no difference in mortality rates for any of the periods evaluated for

"acclimatization" post-capture (Table 2-1). Seventeen mortalities were recorded in 2008-2009, and 27 mortalities in 2009-2010. For 2008-2009, the probability death was caused by reported harvest was 0.353 (0.158-0.589); unreported harvest was 0.059 (0.003-0.234); and predation was 0.588 (0.354-0.797). For 2009-2010, the probability death was caused by reported harvest was 0.037 (0.002-0.153); unreported harvest was 0.111 (0.029-0.263); predation was 0.815 (0.643-0.929); and other was 0.037 (0.002-0.153). For both years combined, the probability death was caused by reported harvest was 0.159 (0.072-0.285); unreported harvest was 0.091 (0.029-0.199); predation was 0.705 (0.561-0.825); and other was 0.023 (0.001-0.096). No mortalities were recorded from 1 December 2009 to 31 March 2010 (n = 27) and 4 January 2009 to 31 March 2009 (n = 7). Harvest rates were 23.08% (reported harvest), 3.85% (unreported harvest - bird was found dressed in the field), and 26.92% (total harvest) in 2008. Harvest rates in 2009 were 2.33% (reported harvest), 6.97% (unreported harvest - all were cripples), and 9.3% (total harvest).

Four models were considered competing models (Δ AICc < 2) (Table 2-3). The models ranked 2-4 are nested within the top model. A likelihood ratio test was used to assess the difference between the top-ranked model and the nested competing models (Table 2-4). From the likelihood ratio test it can be shown that sex (p= 0.103) and transmitter type (p= 0.09) affected survival (Table 2-4). Consequently, the general model (top ranked) was considered statistically significant. The model used a quadratic trend in survival (T2) and had an interaction between time and year, as well as an additive effect of sex and transmitter type. However the model was not selected for assessing survival and model averaging was not used because transmitter type was considered significant.

To attain the best survival estimates birds with backpack were not considered, which simplifies the models S(T2 * year + sex + type) into S(T2 * year + sex) and S(T2 * year + type) into S(T2 * year). Of the 2 competing models S(T2 * year + sex) was selected because the additive effect of sex was considered significant. Male survival rates were lower than females, and backpack radios negatively affected survival (Table 2-5). Survival was lower in 2008 than in 2009. Only season (fall vs. winter) in 2009 caused significant effect on group survival estimates at $\alpha = 0.05$. In 2009 survival was lowest around 22 September, whereas in 2008 survival was lowest around 3 October (Fig. 2-1 and Fig. 2-2).

Using the model S(T2 * year + sex) and only birds fitted with necklaces, the following survival estimates were derived. Females experienced winter survival rates of 0.802 (0.57 - 0.925) and 0.982 (0.919 - 0.996) in 2008 and 2009, respectively. Winter survival rates for males were 0.687 (0.371 - 0.891) and 0.969 (0.861 - 0.994) in 2008 and 2009, respectively. Female fall survival rates were 0.522 (0.299 - 0.736) and 0.623 (0.461 - 0.763) in 2008 and 2009 respectively. Male fall survival rates were 0.332 (0.131 - 0.621) and 0.449 (0.258 - 0.656) in 2008 and 2009, respectively. Total survival for females was 0.418 (0.207 - 0.665) and 0.616 (0.448 - 0.755) in 2008 and 2009, respectively. Male total survival was 0.228 (0.067 - 0.548) and 0.435 (0.245 - 0.656) in 2008 and 2009, respectively.

There were 46 observations of brood hens with 4 harvests and 90 observations of non-brood hens with 1 harvest. For brood hens the probability of harvest was 0.087 (0.035-0.171). For non-brood hens the probability of harvest was 0.011 (0.001-0.039).

The selection of distance to buffer was based upon the findings of Fischer and Keith (1974) who found 48%, 13%, 5%, and 1% of territorial adult male ruffed grouse were shot when banded within <101, 101-200, 201-301, and ≥ 302 meters of a road, respectively. Because sage-grouse inhabit much more open country 2 categories were created to evaluate distance to the closest road (≤300m and ≤600m). Accessibility to the study area was high: 43.1% and 68.5% of the area was within 300 and 600 m of a road respectively (Fig. 2-5). Additionally, 84.3% and 99% of August - October locations were within 300 and 600 m of a road, respectively.

DISCUSSION

Johnson and Braun (1999) concluded adult and juvenile survival were the demographic parameters most limiting to population growth. Additionally, Dahlgren (2009) concluded juvenile (labeled "fledgling") survival was the second most important, behind adult hen survival, vital rate for the Parker Mountain population. However, his conclusions could have been biased. The juvenile survival rates he used in his modeling were higher than reported here (Dahlgren used mean 0.70 range of 0.56 - 0.85 vs. juvenile survival estimates of 0.42 and 0.62 for females only in 2008 and 2009 respectively reported here). He also modeled using higher rates than Wik (2002) reported for juvenile females, and higher rates than reported by Swanson (2009). Dahlgren (2009) based his estimate for juvenile survival on the assumption juvenile survival was equal to yearling survival which would likely lead to the overestimation of survival for the younger age class. However, the assumed juvenile survival rates used by Dahlgren (2009) are close to the estimates provided by Beck et al. (2006).

Survival estimates for juvenile sage-grouse are lacking. Beck et al. (2006) reported survival rates on 2 study areas of 0.64 and 0.86 (from 1 September to 31 March), and found no difference in survival between sexes. Wik (2002) provided survival estimates for juvenile female sage-grouse. He reported fall (September - November) survival rates of 0.40 and 0.69 for 1999 and 2000, respectively. Additionally, he reported winter (December - February) survival rates of 0.87 and 1.00 for 1999-2000 and 2000-2001, respectively. From these data it can be derived that the September through February survival rates were 0.348 and 0.69 for 1999-2000 and 2000-2001, respectively. Swanson (2009) reported juvenile survival rates (both sexes combined) in the Dakotas of 0.316 - 0.667 and 0.778 - 1.0 for late brood rearing (16 July - 31 October) and winter (1 November - 28 February), respectively. Additionally, from the rates he reported, survival from 16 July - 28 February was 0.667, 0.438, 0.3045, and 0.2528 for differing years and study areas. On Parker Mountain sage-grouse experienced lower survival rates than reported by Beck et al. (2006), but similar juvenile female fall, winter, and overall survival rates to those reported by Wik (2002). Additionally, survival rates on Parker Mountain were similar to those reported by Swanson (2009). However, comparison is difficult because he reported survival rates for both sexes combined. In contrast to Beck et al. (2006), there was evidence to support a differential survival between sexes.

Sedinger et al. (2010) also provided estimates for juvenile survival. However, the estimates may not be reliable for several reasons. The Colorado study data used in Sedinger et al. (2010) analysis did not include juvenile birds despite what was reported in their manuscript. Trapping on the Colorado study site was conducted "in spring near leks," making it impossible for there to be any banded juveniles (defined as first fall

birds) in the harvest (where the bands were recovered). Those labeled as "juvenile" in the abstract are most likely yearlings, as this is what they are labeled in figure 1 of the paper. The Nevada study site did include juveniles. However, the methodology used to mark these birds was questionable (juveniles were marked in July and August using adult bands size 14 F and 16 M due to the unknown band retention on such young birds). Additionally, it is unclear what was considered adult vs. juvenile in the Nevada study site. In their methods section three age categories are presented (juvenile, yearling, and adult). However, in their abstract and figure 1 of the manuscript only 2 categories are presented (adult and juvenile). Thus, it is unclear if the yearlings in Nevada were considered adult or juvenile for survival estimates.

On Parker Mountain in 2008, the bottom of the quadratic time trend (T2) in survival was shifted later into the season. This was likely caused by high harvest rates in 2008 vs. 2009 coupled with earlier movements to wintering areas in 2009 vs. 2008. The higher harvest rates in 2008 in conjunction with later movements to wintering areas likely caused the lower overall survival rate. During the study juvenile birds experienced fluctuating survival and harvest yearly, and harvest was a major secondary source of mortality. Studies investigating harvest effects must include juvenile birds to fully assess the impacts. On Parker Mountain a majority of mortality occurred during fall (22 August to 1 December) and was similar to the seasonal patterns reported by Beck et al. (2006), Anthony and Willis (2009), Wik (2002), and Swanson (2009). Juvenile birds on Parker Mountain exhibited high over-winter survival.

Severe winter weather did not affect survival. In 2009, winter snow depth was above average (Fig. 2-3), and survival was high (0.9817 and 0.9691 for males and

females respectively). In 2008 the winter survival was lower (0.8018 and 0.6873 for

males and females respectively), but snow depth was below average (Fig. 2-3). This

study's findings parallel those of Zablan et al. (2003) and contradict the findings of

Moynahan et al. (2006). Reported differences in the impact of winter weather may

reflect differences in availability and quality of wintering habitats. On Parker Mountain

there are lower elevation sites with high quality winter habitat where birds may be able to

escape heavy snowfall (see Chapter 3).

Predation accounted for the majority of mortality (probability death was caused

by predation was 0.705 for both years combined). One mortality not attributed to

predation or harvest was attributed to a fence strike. Probability death was caused by a

fence strike was 0.037 for the year in which it occurred and 0.023 for both years

combined.

Braun (1981) concluded juvenile sage-grouse are more susceptible to harvest than

adults and yearlings. Beck et al. (2006) reported a 17% juvenile harvest rate on one study

area and none on the other. Wik (2002) reported harvest rates of 0%, 16.7%, and 37.5%

for juvenile female sage-grouse in 1999, 2000, and 2001, respectively. Reported and

unreported harvest varied annually on Parker Mountain. In 2009, the reported harvest

was less than in 2008 (2.33% vs. 23.08%), but unreported harvest was higher in 2009

(6.98% vs. 3.85%). In 2009 all unreported harvest mortalities were due to crippling,

while in 2008 the unreported harvest was a dressed bird left in the field. The total harvest

in 2008 (26.92%) was higher than in 2009 (9.3%). In 2008 the probability death was

caused by reported harvest was 0.353, while in 2009 it was 0.037. In both years there

were unreported harvest mortalities. In both years combined, the probability death was due to unreported harvest was 0.091, and reported harvest was 0.159.

Wik (2002) expressed concerns for unreported harvest left in the field, as well as the disappearance of birds during the hunting season. Four birds went missing during this study. Two of the birds went missing during the hunting season. Of the remaining 2, one went missing 2 days prior to the season, and the other went missing nine days prior to the season. The frequencies were searched for from the ground and air extensively for the remainder of the study, and never detected. These birds were censored, and if they were in fact unreported harvests the survival estimates would be biased.

Relatively few studies have addressed crippling losses. Those that have reported crippling losses have used varying methods making comparison and accuracy difficult to assess. Additionally, studies differ in their definitions of "crippling" (see Haines et al. 2006). In many instances crippling estimates were based on guesswork (Gregg 1990). This study defined crippled birds as, birds found dead in the field whole and with obvious shot wounds upon necropsy. The crippling rates were 0% in 2008 and 6.79% in 2009. Braun and Beck (1985) estimated sage-grouse crippling loss ranged from 5.5 to 7%. Hoffman (1985) estimated a 5% crippling loss for blue grouse, measured through check stations. An 11% crippling rate for sharp-tailed grouse in Nebraska was determined through extensive hunter surveys (Sisson 1976). Small et al. (1991) reported 5% of ruffed grouse mortality was due to crippling by hunters. Haines et al. (2006) provided a review of reported crippling loss for northern bobwhite ranging from 5-31% of recorded harvest and 5-24% of total harvest. Crippling loss is a part of the harvest dynamic for

many game birds. My results support the need for incorporating crippling loss when establishing sage-grouse harvest regulations.

Differences in reported and unreported harvest mortalities on Parker Mountain between years could have been caused by yearly differences in the distribution of the grouse during the hunting season (see Chapter 3). The difference in distributions was likely caused by earlier movements of the birds toward wintering areas in 2009, which caused birds to be more dispersed during the hunting season. Dunn and Braun (1986) reported movement of juvenile sage-grouse was tied to snowfall. The earlier movements to the wintering areas in 2009 vs. 2008 could have been a result of earlier snowfall events in 2009 (Fig. 2-3). Mussehl (1960) suggested differing harvest rates between years in blue grouse was due to differing stages of the altitudinal migration during the hunting seasons. Additionally, the difference in mortality rates could be due to differences in hunter behavior between years. In 2008, permits to hunt were sold on a first-come first-serve basis, while in 2009 permits were sold using a draw system. The change in the procedure for allocating permits could have changed hunter characteristics such as experience and familiarity with the area. The number of permits issued decreased from 2008 (370) to 2009 (265). Hunter pressure was 1.27 times higher in 2008 than 2009 (457.9 hunter days in 2008 vs. 360.4 hunter days in 2009). Total harvest was 1.25 times higher in 2008 than 2009 (293 in 2008 vs. 234 in 2009). The percentage of juveniles in the harvest dropped slightly from 38.46% in 2008 to 32.25% in 2009 (UDWR unpublished data).

High harvest rates observed on Parker Mountain could be caused by habitat use patterns. Autenrieth (1981) stated, "sage-grouse in habitat where forbs are available

throughout the range remain dispersed and therefore less vulnerable to harvest." Brøseth and Pedersen (2010) reported willow ptarmigan varied habitat use when hunted. Consequently, they concluded both catch per unit effort and the proportion of population killed could be affected by local habitat characteristics. Parker Mountain is a high elevation plateau with ridges and swales. The higher elevation swales provide the best brood habitat. The easy identification of and access to these areas by hunters could lead to the high harvest rates on Parker Mountain.

Harvest rates on Parker Mountain could be influenced by the notoriety, ownership, and accessibility of the area. Parker Mountain is highly accessible public land, and the high-elevation areas used during August-October are saturated with roads. The saturation of roads is likely due to historic use patterns associated with livestock grazing and herding. It is probable roads were constructed in order to access mesic areas where livestock concentrated, and for construction and maintenance of ponds for livestock. Consequently, a majority of the brood hens and broods are in the mesic areas easily accessible during the hunting season. It must also be noted that although there are many roads on Parker Mountain they are virtually unused, except occasionally by ranchers and hunters. In 2009 birds were more dispersed before and during the hunting season vs. 2008. While studying ruffed grouse Fischer and Keith (1974) reported 96% of reported band harvest occurred along roads. They also reported the closer territorial adult males were to roads, the higher the harvest rate. Brøseth and Pedersen (2000) reported that the spatial distribution of willow ptarmigan hunting pressure was dependent upon the starting location of the hunters. Areas closer to the base cabin received most of the hunting pressure, and survival probability was best predicted by distance from the base

cabin. Harvested birds were closer to the base camp and their home ranges experience twice the hunting pressure.

Parker Mountain is almost entirely publicly owned (private lands only account for 1% of the study area) and 100% of known locations occurred on publicly owned property. Sisson (1976) noted sharp-tailed grouse residing on publicly owned land may be susceptible to over-harvest and special regulations may be required to prevent over-harvest. Gregg (1990) found the least accessible and least noted study area for sharp-tail hunting had the lowest kill rate. Small et al. (1991) reported harvest mortality for ruffed grouse on public hunting areas (73% adults and 56% juveniles) was higher than on private lands (13% adults and 9% juveniles).

Connelly et al. (2000) reported females were more susceptible to hunting than males. They attributed the differential susceptibility to the clumped distribution of females with juveniles in mesic areas. Hunters and predators may be keying on these clumped groups of sage-grouse. On Parker Mountain there was evidence brooding hens were more susceptible to harvest than non-brood hens. The confidence intervals do not encompass one another's mean, and only overlap very slightly (by 0.004). However, the confidence intervals do overlap, so at $\alpha = 0.1$, it could not be concluded there was a difference in susceptibility. Sika (2006) reported female survival (during the hunting season 1 September to 1 November in Montana) was higher for individuals spending little or no time brood rearing vs. individuals raising broods to 30 days. However, no mortality in the study was attributed directly to harvest (including crippling). Redfield (1975) noted successful female blue grouse with broods may be more susceptible to harvest than unsuccessful females. Bendell and Elliot (1967) reported an annual harvest

rate of 0.7% of adult males and 5% of hens and chicks. Zwickel and Bendell (2005) reported harvest rates for each demographic: 1% of adult males, 2% of yearling males, 14% of adult females, 8% of yearling females, and 13% of juveniles (banded). Connelly et al. (2000) reported 15% of adult male and 42% of adult female mortality was due to harvest, and concluded harvest loss was additive to winter mortality. Wik (2002) reported harvest rates of 0%, 5.9%, and 18.1% averaged across years (1999-2001) for adult male, adult female, and juvenile female sage-grouse, respectively. He concluded harvest mortality was additive. Gibson et al. (2011) concluded harvest mortality, in Mono county, California, was additive. Sedinger et al. (2010) concluded there was no support for an additive effect of harvest on sage-grouse survival on 2 study areas in Nevada and Colorado. However, their results were likely biased towards adults. The exclusion of juveniles, which are the demographic most impacted by harvest, could have lead to the formation of inaccurate conclusions regarding the impacts of overall harvest. If harvest is additive then harvest management regimes should shift to compensate. Due to the increased susceptibility of hens and juveniles, a shift away from the use of total population kill rates and towards the use of demographic specific harvest rates is warranted. The method using demographic specific harvest rates is more biologically meaningful. Additionally, focusing management on acceptable harvest rates of demographic parameters important to population growth is preferable.

The debate over so-called "radio handicapping" of birds has led some researchers too question the use of radio transmitters for assessing survival. Trapping alone, through capture myopathy, can affect the survival of several avian species (Spraker et al. 1987, Bollinger et al. 1989, Dabbert and Powell 1993, Nicholson et al. 2000, Höfle et al. 2004,

Abbott et al. 2005, Conner et al. 2006) suggesting that any method of marking has the potential to affect survival and mortality. Sedinger et al. (2010) stated, "Connelly et al. (2000) could not control for the possible effects of radios on risk of harvest or predation mortality, which may have affected their conclusions." Diefenbach et al. (2009) reported leg band retention rates in wild turkeys of 79-96% after 3 months and <15% after 15 months. Having band retentions of <100% violates a key assumption of mark-recapture and causes biased estimates of survival and harvest rates (Diefenbach et al. 2009). Sedinger's et al. (2010) conclusions could have been affected by biased estimates of harvest and survival rates.

Researchers have reported varied effects of radios on galliformes. Parry et al. (1997) reported radio-tagged individuals had a lower harvest rate and markedly higher survival than leg banded individuals. Conversely, Several authors concluded radio-tags can cause adverse effects to individuals (Bro et al. 1999, Caizergues and Ellison 1998, Marks and Marks 1987). Still other authors have reported radio transmitters had no effect on individuals (Johnson and Berner 1980, Hines and Zwickel 1985, Thirgood et al. 1995, Hagen et al. 2006, Sisson et al. 2006, Terhune et al. 2007). Capture myopathy is a variable that could cause differing interpretations as to the effect of radio-tagging. Capture myopathy causes variable effects on individuals, and varies by temperature, humidity, and handling time (Nicholson et al. 20000). Capture method also effects capture myopathy in mallards (Bollinger et al. 1989, Dabbert and Powell 1993). This study did not control for the effect of handling time on backpack vs. necklace birds. Fitting a bird with a backpack transmitter did take a longer period of time than fitting with a necklace, but the actual difference in time was not documented. However,

handling time is not likely to have affected survival as this would most likely cause an acute effect on survival. No significant effect was detected (Table 2-6).

Necklaces are widely used for studying sage-grouse (Connelly et al. 1993, Connelly et al. 2000, Wik 2002, Beck et al. 2006, Doherty et al. 2008, Swanson 2009). A suture-on method for attaching backpack transmitters has been used for waterfowl (Rotella et al. 1993). Harness style backpack transmitters also have been used for sage-grouse (Connelly et al. 1988, Swanson 2009). This study has shown there is differential survival by attachment type for sage-grouse. Birds fitted with backpack type transmitters survived at lower rates when compared with birds fitted with necklace type transmitters. Additionally, the effect on survival of transmitter type is variable by season. Survival during winter was 100% for both transmitter types. No mortalities were recorded from 1 December 2009 to 31 March 2010 (n = 27) and 4 January 2009 to 31 March 2009 (n = 7). The variable effect of transmitter type by season was likely due to increased predation on backpack birds in the fall. Connelly et al. (2003) reported harness style backpack transmitters were known to increase the vulnerability of sage-grouse to harvest. Small and Rusch (1985) reported some individual ruffed grouse fitted with harness style backpack transmitters would not accept the package and other individuals had longer (vs. poncho) acclimation periods. However, they found no difference in flight abilities after acclimatization. They detected a slightly higher survival rate for individuals fitted with ponchos, but attributed the lighter package weight of the poncho as the cause for the differential. Rotella et al. (1993) found evidence that harnessed backpack transmitters affected nesting behavior and sutured backpacks had poor retention in Mallards. Numerous other authors have reported adverse effects of backpack style transmitters on

waterfowl (Greenwood and Sargeant 1973, Perry 1981, Pietz et al. 1993, Ward and Flint 1995, Dzus and Clark 1996, Fleskes 2003, Robert et al. 2006). Marcström et al. (1989) concluded necklace radio packages are more suitable for studies of ring-necked pheasant survival than are backpack radio packages.

Global Positioning System (GPS) transmitters have been used to study gallinaceous species, including sage-grouse (Wegge et al. 2007, Stringham 2010, Guthrie et al. 2011). Solar-powered GPS transmitters must be mounted dorsally with exposure to the sun to ensure adequate battery recharge. Although GPS transmitters may have several advantages over traditional VHF transmitters, the use and interpretation of data collected with back-mounted GPS transmitters should be very cautious. This study has shown back mounted transmitters negatively affect survival of sage-grouse. The use of dorsally mounted transmitters on sage-grouse should be avoided, especially when assessing various survival and mortality parameters.

While comparing radio-tagged and leg banded birds may be useful, banded birds are not controls and bands could have varying effects. Studies comparing survival rates between radio-tagged and leg banded individuals (or any other method of marking) should hold other variables constant (i.e. handling time, capture method, transmitter type, etc.) if the differences are to be properly judged, and design tests to ensure band retention across all age and sex classes is 100%.

Based on their results some researchers have embraced the use of an adjustment or acclimatization period (Höfle et al. 2004, Conner et al. 2006). No evidence was found to warrant an "acclimatization period" (Table 2-1) in this study. Holt et al. (2009)

concluded the best estimates of survival are derived without the use of an

"acclimatization period."

MANAGEMENT IMPLICATIONS

High accessibility, public ownership, and habitat characteristics on Parker

Mountain have implications for harvest management. Because of these factors Parker

Mountain is prone to high harvest rates, and managers should take into account the nature

of the area when establishing harvest regulations. Additionally, differing fall dispersal

timing could be important to harvest dynamics. In years when birds have not dispersed

before or during the hunting season there could be an increased juvenile susceptibility to

harvest along with the associated hens. In years when birds have dispersed prior to or

during the hunting season, juveniles will be more dispersed throughout the mountain

causing a less selective harvest.

Juveniles and the hens associated with them are most likely the demographic

parameters impacted and susceptible to harvest. Juvenile sage-grouse could be more

susceptible to harvest than hens. Future studies on harvest of sage-grouse should include

estimates of age-related survival rates. Past studies that have examined harvest without

juvenile birds in the sample may lead to forming inaccurate conclusions on the impacts of

harvest. Research is needed to determine the acceptable harvest rate for juvenile sage-

grouse. Regulations should attempt to maximize the percentage of male grouse in the

harvest, and minimize the percentage of juvenile and consequently successful hen grouse

in the harvest. Harvest recommendation should focus on achieving acceptable

demographic specific (juvenile and female) harvest rates rather than total population harvest rates.

There are several avenues of implementation through which to lessen the impact of hunting on juveniles and hens on Parker Mountain. A male only hunting season for sage-grouse has been suggested, however this approach is not likely feasible. Williams and Austin (1988) reported high hen harvest rates for wild turkeys even during gobbler only seasons, and noted approximately 40% of the time hunters miss identified wild turkeys as to sex. Because hunters are unable to effectively identify the sex of an extremely sexually dimorphic bird such as the wild turkey, then to expect hunters to differentiate between sexes of sage-grouse on the wing is illogical. However, some hunters have expressed interest in sage-grouse as trophies (Reese and Connelly 2011).

Protection of the mesic areas in which broods congregate could assist in protecting juveniles and hens. There are 2 main ways to protect the mesic areas through regulation: closure areas and timing of the season. Protecting the mesic areas by closing them to hunting would provide protection to juveniles and hens in an early hunting season (e.g. September - October). However, closure areas may be difficult in practice. Defining the closure areas so that they are readily recognizable to hunters could be problematic. Additionally, while identifying mesic areas on Wildlife Management Areas and other public lands may be plausible, the identification and regulation of mesic areas on private lands may be impracticable. Protection of the congregated broods and hens could take place though timing of the hunting season, the season could take place after the broods have left the mesic areas for the wintering habitats. Although this methodology would theoretically reduce the ability for compensation, there is mounting

evidence sage-grouse harvest is additive. If harvest is additive harvest management actions should be taken to lessen the impacts of harvest. Moving the season later in the year would allow for broods and brood hens to break-up and disperse. The more dispersed population should help mitigate the increased susceptibility and impacts of harvest on brood hens and juveniles, and shift harvest onto demographics that are less meaningful to population growth. If managers do elect to use this method, monitoring should be implemented to ensure the intended result is occurring (harvest is shifting away from brood hens and broods, and onto adult males and non-brood hens).

Regulation of harvest through permits allows managers to more precisely control effort and in effect total harvest on a given area. Permits are already in use on Parker Mountain, and further restriction of hunter numbers and/or bag/possession limits may be required to achieve acceptable harvest rates for juvenile and hen grouse. On Parker Mountain the use of a daily bag limit may provide some protection to broods. A daily bag limit of 1 bird would prevent individual hunters from killing multiple birds in the same brood and may help to shift some of the harvest to other demographics. The use of daily bag limits is the most practical method to attempt and offset the increased susceptibility of hen and juvenile sage-grouse to harvest, when season take place during September - October.

A combination of management actions could help shift harvest and hunter paradigms. The hunting season could be moved later in the year to mitigate the increased susceptibility of brood hens and broods to harvest. Concurrently, a single bird limit could be implemented. The restrictive regulations may help shift hunter paradigms and views of sage-grouse toward being viewed as trophies. If sage-grouse are coveted as trophies,

the result could be an additional shift of harvest away from brooding hens and juveniles, and onto males. In essence, the regulations could help encourage and promote the selective harvest of adult males while not requiring all hunters to do so or to be readily able to distinguish adult males on the wing.

Unreported harvest (mainly crippling) may have a larger impact on sage-grouse than was previously expected. Banding studies alone are not equipped to investigate the effects of unreported harvest on populations. Crippling loss was a part of the harvest dynamic of sage-grouse that is largely ignored but needs to be addressed when establishing harvest regulations. Managers should take into account a ~5% crippling and unreported harvest loss when determining sage-grouse harvest recommendations. More research into the effects of crippling on sage-grouse populations is needed.

This research suggests back-mounted transmitters negatively affect survival of sage-grouse, and that the use of dorsally mounted transmitters on sage-grouse should be avoided, especially when assessing various survival and mortality parameters. Extreme caution should be used interpreting the results from dorsally mounted transmitters on sage-grouse, because of the potential for differential survival rates and increased risk of predation. More research is needed to determine if there are other attachment methods for GPS transmitters that could be suitable for use on sage-grouse, such as the leg-loop harness (Mallory and Gilbert 2008).

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Table 2-1 Test for acclimatization period using probability of death since capture date in greater sage-grouse (*Centrocercus urophasianus*) on Parker Mountain, Utah, USA, 2008-2009.

Days post capture	2008				2009				Both Years			
	At Risk	Mortalities	Probability of Death	95% CI	At Risk	Mortalities	Probability of Death	95% CI	At Risk	Mortalities	Probability of Death	95% CI
0-10 Days	30	3	0.1000	0.0259-0.2392	61	6	0.0984	0.0403-0.1893	91	9	0.0989	0.0488-0.1712
11-20 Days	27	8	0.2963	0.1480-0.4821	55	4	0.0727	0.0232-0.1609	82	11	0.1342	0.0720-0.2187
21-30 Days	19	3	0.1579	0.0418-0.3600	51	7	0.1373	0.0614-0.2485	70	10	0.1429	0.0743-0.2370

Table 2-2 Probability death was due to specific causes for greater sage-grouse (*Centrocercus urophasianus*) on Parker Mountain, Utah, USA, 2008-2010.

Mortality Causes	2008-2009		2009-2010		Both Combined	
	Probability of Death	95% CI	Probability of Death	95% CI	Probability of Death	95% CI
Reported Harvest	0.3529	0.1582-0.5890	0.0370	0.0022-0.1531	0.1591	0.0717-0.2850
Unreported Harvest	0.0588	0.0035-0.2344	0.1111	0.0289-0.2634	0.0909	0.0292-0.1987
Predation	0.5882	0.3544-0.7973	0.8148	0.6434-0.9293	0.7045	0.5608-0.8251
Other	0	0-0	0.0370	0.0022-0.1531	0.0227	0.0013-0.0963

Table 2-3 Models evaluated in program MARK to determine juvenile greater sage-grouse (*Centrocercus urophasianus*) survival on Parker Mountain, Utah, USA, 2008-2010. Only models with >0.01 model likelihood shown (t1, t2, etc. represent time periods and T2 represents a quadratic trend through time).

Model	AICc	Δ AICc	AICc Weights	Model Likelihood	Num. Par	Deviance
{S(T2 * year + sex + type)}	307.31	0.00	0.229	1.00	7	293.27
{S(T2 * year + type)}	307.95	0.65	0.166	0.72	6	295.92
{S(T2 * year + sex)}	308.17	0.86	0.149	0.65	6	296.14
{S(T2 * year)}	308.98	1.67	0.099	0.43	5	298.96
{S(T2 * year * type)}	309.41	2.10	0.080	0.35	8	293.36
{S(T2 * year * sex + type)}	311.07	3.76	0.035	0.15	9	293.01
{S(T2 * year * sex)}	311.79	4.49	0.024	0.11	8	295.75
{S(T2 + year + sex + type)}	311.89	4.58	0.023	0.10	6	299.86
{S(T2 + year + type)}	312.03	4.73	0.022	0.09	5	302.01
{S(T2 * type)}	312.58	5.28	0.016	0.07	5	302.56
{S(T2 + sex + type)}	312.61	5.31	0.016	0.07	5	302.59
{S(T2 + year + sex)}	312.85	5.54	0.014	0.06	5	302.83
{S(t1 T2, t2 . + sex + type)}	312.94	5.63	0.014	0.06	5	302.92
{S(T2 + year)}	313.04	5.73	0.013	0.06	4	305.02
{S(T2 + type)}	313.20	5.90	0.012	0.05	4	305.19
{S(t1 T2 , t2 . + year + sex + type)}	313.61	6.31	0.010	0.04	6	301.58
{S(t1 T2 , t2 . + year + type)}	313.81	6.50	0.009	0.04	5	303.79
{S(T2 * sex + type)}	314.47	7.16	0.006	0.03	6	302.44
{S(t1 T2 , t2 . + year + sex)}	314.63	7.33	0.006	0.03	5	304.62
{S(t1 T2 , t2 . + year)}	314.87	7.57	0.005	0.02	4	306.86
{S(T2 + sex)}	314.98	7.67	0.005	0.02	4	306.96
{S(t1 T2 , t2 . + type)}	315.15	7.84	0.005	0.02	4	307.14
{S(t1 T2 , t2 . + sex)}	315.29	7.98	0.004	0.02	4	307.27
{S(T2)}	315.55	8.24	0.004	0.02	3	309.54
{S(t1pre, t2sea, t3post, t4latefall, t5winter + sex + year + type)}	315.55	8.25	0.004	0.02	8	299.51
{S(t1 T2 , t2 . * year + sex + type)}	315.62	8.31	0.004	0.02	7	301.58
{S(t1 T2 , t2 . * year + type)}	315.81	8.51	0.003	0.01	6	303.79
{S(T3 * sex)}	315.99	8.68	0.003	0.01	6	303.96
{S(t1pre, t2sea, t3post, t4latefall, t5winter + year + type)}	316.00	8.69	0.003	0.01	7	301.96
{S(t1pre, t2sea, t3post, t4latefall, t5winter + sex + year)}	316.12	8.81	0.003	0.01	7	302.08
{S(t1pre, t2sea, t3post, t4latefall, t5winter + year)}	316.64	9.33	0.002	0.01	6	304.61
{S(T2 * sex)}	316.69	9.39	0.002	0.01	5	306.67
{S(t1 T2 , t2 . * type)}	316.73	9.42	0.002	0.01	5	306.71
{S(t1 T2 , t2 . * year)}	316.87	9.57	0.002	0.01	5	306.85
{S(t1 T2 , t2 . * sex)}	316.88	9.57	0.002	0.01	5	306.86
{S(t1 T2 , t2 .)}	317.57	10.26	0.001	0.01	3	311.56
{S(t1pre, t2sea, t3post, t4latefall, t5winter + sex + type)}	317.64	10.33	0.001	0.01	7	303.60

Table 2-4 Likelihood ratio test of top 4 models evaluated to determine juvenile survival of greater sage-grouse (*Centrocercus urophasianus*) on Parker Mountain, Utah, USA, 2008-2010.

Reduced Model	General Model	x^2	Df	P
S(T2 * year + type)	S(T2 * year + sex + type)	2.654	1	0.1033
S(T2 * year + sex)	S(T2 * year + sex + type)	2.873	1	0.0901
S(T2 * year)	S(T2 * year + sex + type)	5.69	2	0.0581

Table 2-5 Survival estimates by group of juvenile greater sage-grouse (*Centrocercus urophasianus*) using the model S(t2 * year + sex + type on Parker Mountain, Utah, USA, 2008-2010.

			Backpack			Necklace		
Year	Sex	Season	P	95% lower CI	95% Upper CI	P	95% lower CI	95% upper CI
2008	Female	Total	0.2225	0.0776	0.4934	0.4184	0.2072	0.6645
2008	Female	Fall	0.3259	0.1445	0.5806	0.5218	0.2992	0.7361
2008	Female	Winter	0.6828	0.3921	0.8778	0.8018	0.5702	0.9250
2008	Male	Total	0.0786	0.0126	0.3639	0.2283	0.0673	0.5481
2008	Male	Fall	0.1502	0.0402	0.4274	0.3322	0.1312	0.6211
2008	Male	Winter	N/A	N/A	N/A	0.6873	0.3708	0.8913
2009	Female	Total	0.4291	0.2382	0.6438	0.6120	0.4475	0.7545
2009	Female	Fall	0.4431	0.2524	0.6521	0.6234	0.4605	0.7625
2009	Female	Winter	0.9686	0.8378	0.9946	0.9817	0.9186	0.9961
2009	Male	Total	0.2394	0.0857	0.5140	0.4354	0.2450	0.6469
2009	Male	Fall	0.2528	0.0944	0.5233	0.4492	0.2584	0.6563
2009	Male	Winter	N/A	N/A	N/A	0.9691	0.8614	0.9937

Table 2-6 Test for acute effects of capture by transmitter type on juvenile greater sage-grouse (*Centrocercus urophasianus*) on Parker Mountain, Utah, USA, 2008-2009.

| Transmitter Type | Days post capture | 2008 | | | | 2009 | | | |
		At risk	Mortalities	Probability of death	95% CI	At risk	Mortalities	Probability of death	95% CI
Backpack	0-10	15	1	0.0667	0.0039 - 0.2621	18	2	0.1111	0.0194 - 0.3051
Backpack	11-20	13	3	0.2308	0.063 - 0.4951	16	1	0.0625	0.0037 - 0.2474
Backpack	21-30	9	3	0.3333	0.0955 - 0.6545	15	4	0.2667	0.0916 - 0.5153
Necklace	0-10	15	2	0.1333	0.0235 - 0.3576	43	4	0.930	0.0299 - 0.2030
Necklace	11-20	12	3	0.25	0.0689 - 0.5276	39	6	0.1538	0.0642 - 0.2874
Necklace	21-30	10	2	0.2	0.0364 - 0.4994	33	2	0.3333	0.1893 - 0.5023

Table 2-7 Beta coefficients of top model S(T2 * year + sex + type) used to evaluate juvenile greater sage-grouse (*Centrocercus urophasianus*) on Parker Mountain, Utah, USA, 2008-2010.

Label	Estimate	SE	95% Lower CI	95% Upper CI
intercept	7.7657674	1.1460571	5.5194954	10.012039
Year	1.2105494	0.8454273	-0.4464882	2.8675869
Sex	0.5302707	0.3202619	-0.0974426	1.157984
covariate	-0.5475721	0.3200617	-1.174893	0.0797489
T	-2.4052057	0.6147766	-3.6101678	-1.2002436
T2	0.3530096	0.0777408	0.2006376	0.5053816
y*T2	-0.0770152	0.0322469	-0.1402191	-0.0138112
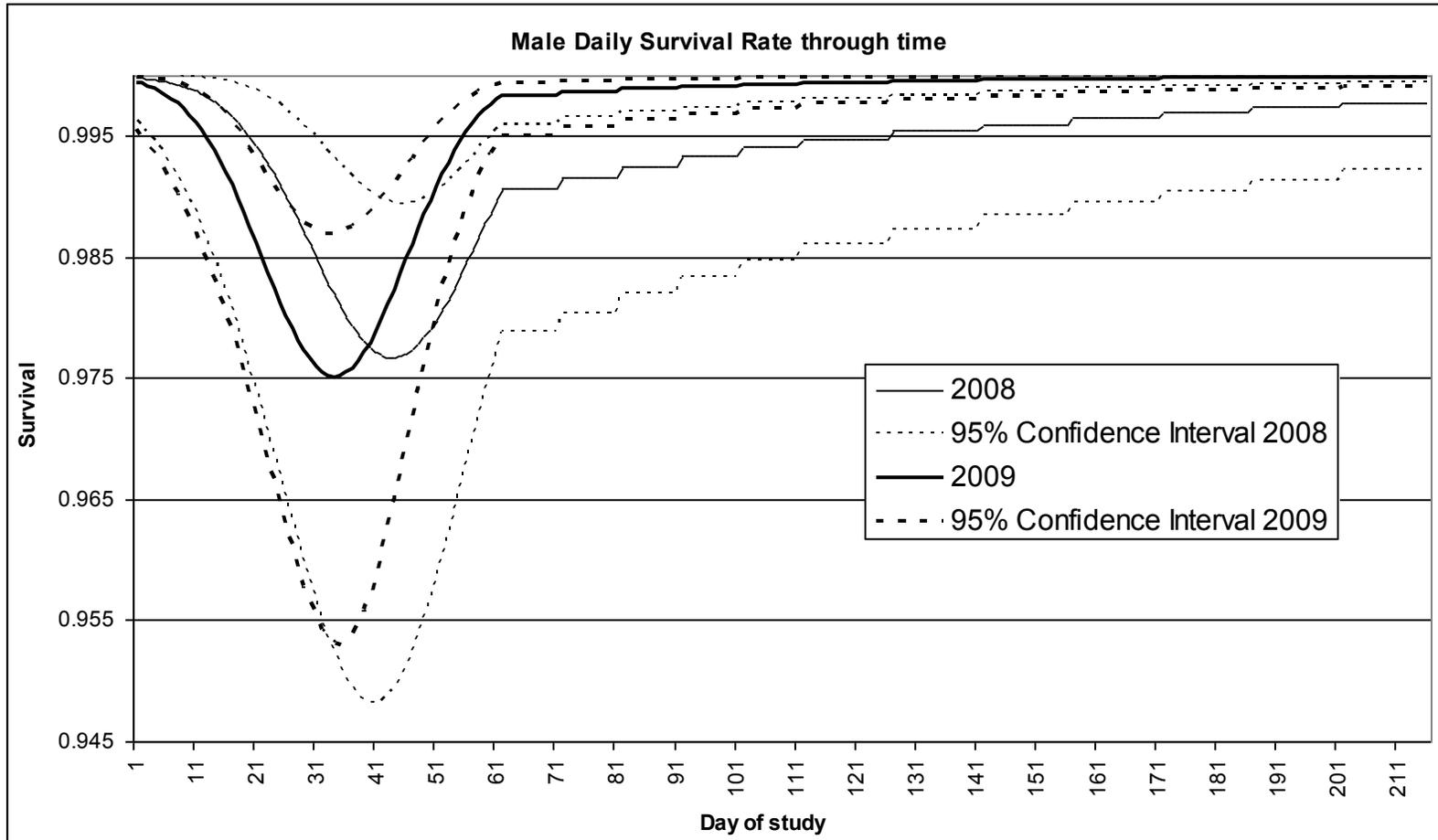
Figure 2-1 Juvenile male greater sage-grouse (*Centrocercus urophasianus*), fitted with necklace style radios, daily survival rate by day of study on Parker Mountain, Utah, USA, 2008-2010.
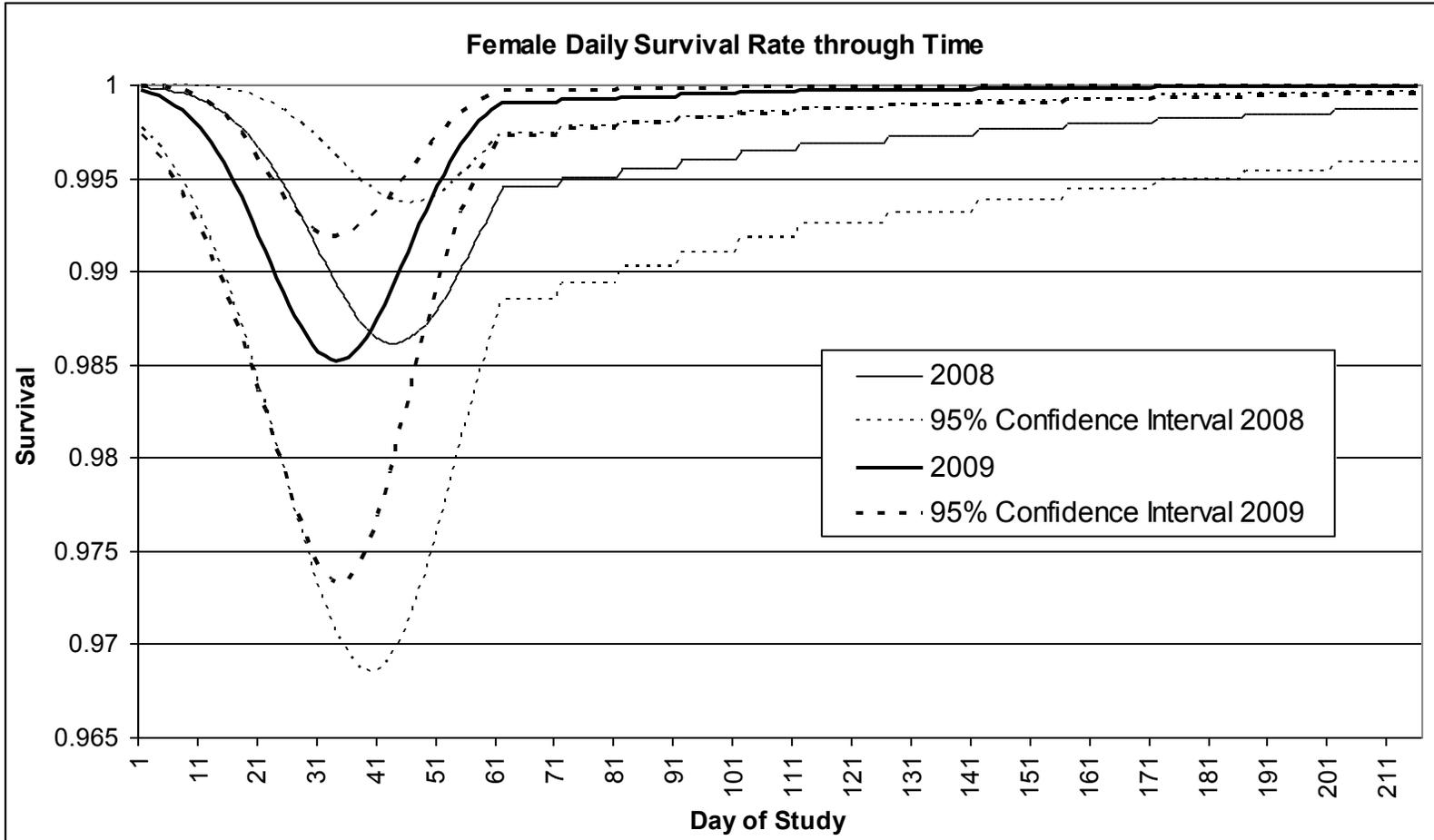
Figure 2-2 Female greater sage-grouse (*Centrocercus urophasianus*), fitted with necklace style radios, daily survival rate by day of study on Parker Mountain, Utah, USA, 2008-2010.
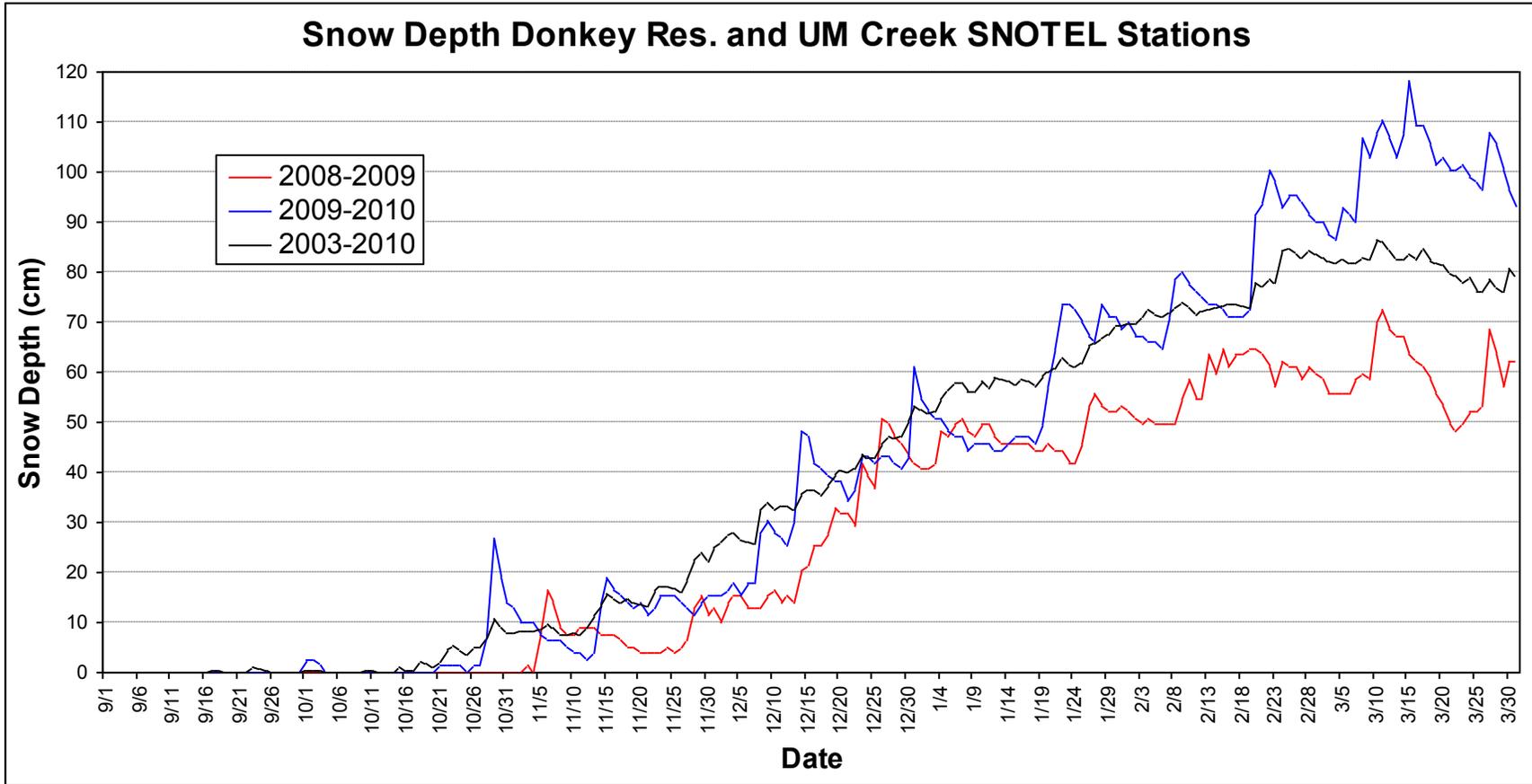
Figure 2-3 Historic winter snow depth for the Parker Mountain region, Utah, USA.
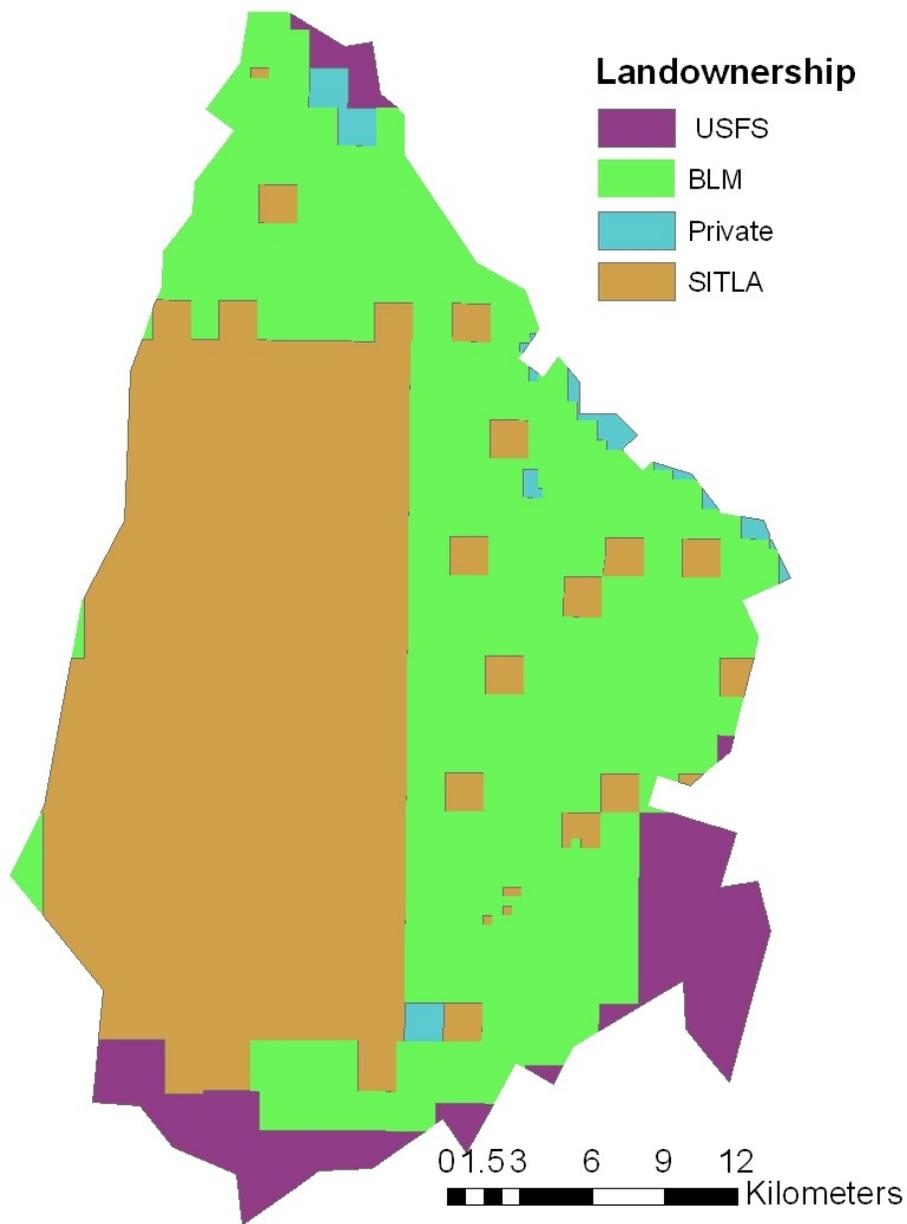
Figure 2-4 Landownership of Parker Mountain, Utah, USA, 2010.
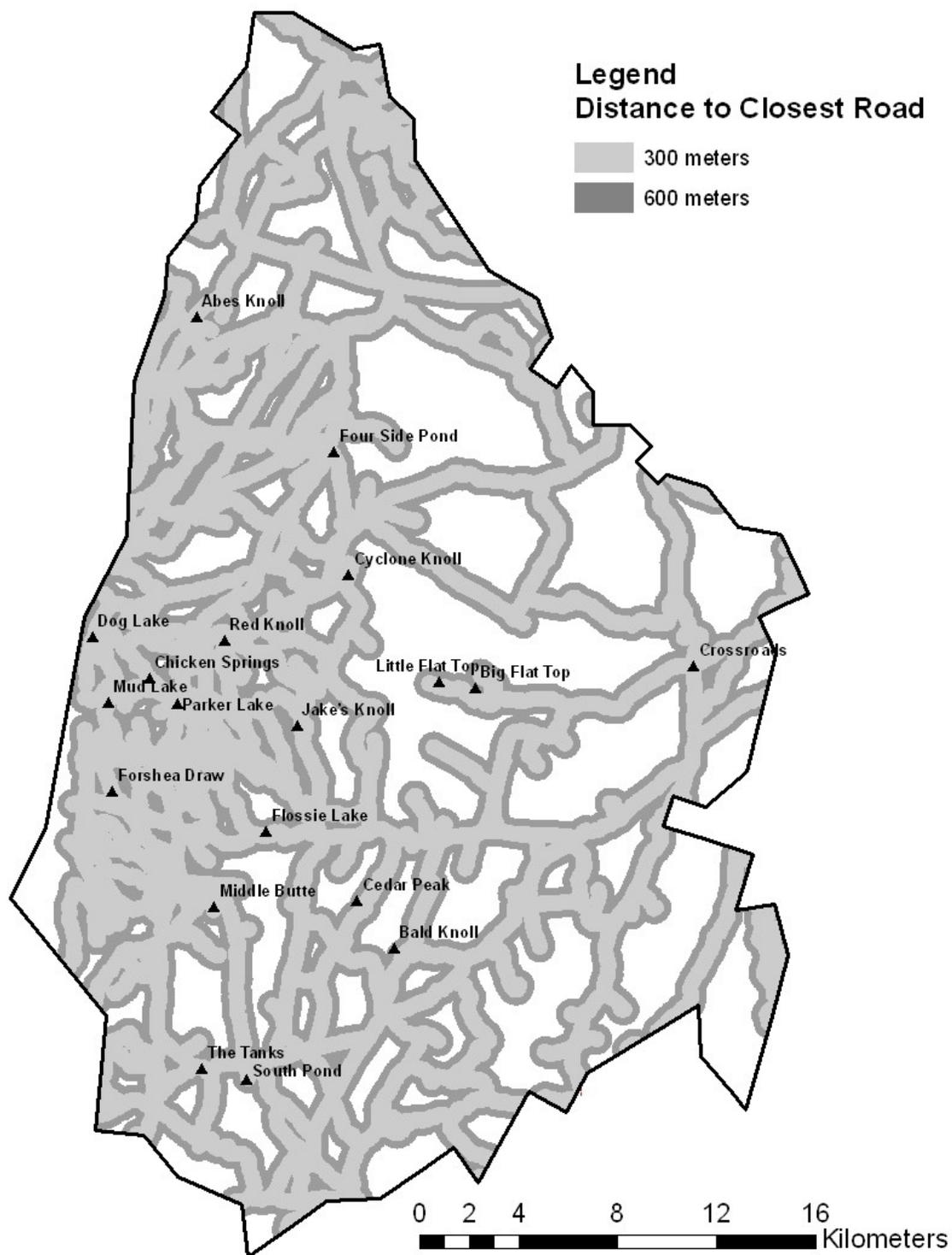
Figure 2-5 Distance to closest road on Parker Mountain, Utah, USA, 2010.
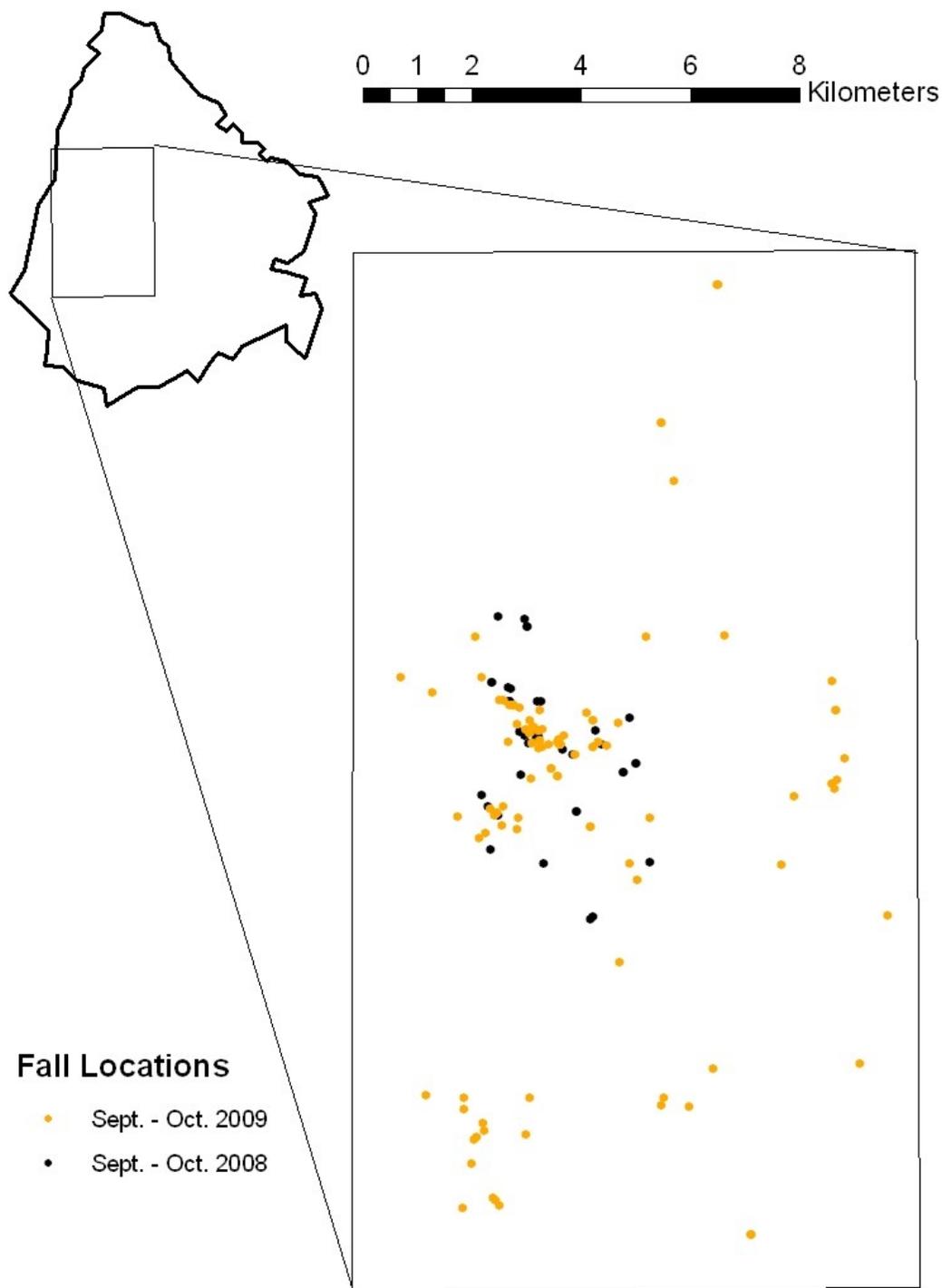
Figure 2-6 Fall locations of greater sage-grouse (*Centrocercus urophasianus*) on Parker Mountain, Utah, USA, 2008-2009.

CHAPTER 3

MOVEMENT AND WINTER HABITAT USE BY JUVENILE GREATER SAGE-GROUSE ON PARKER MOUNTAIN, UTAH

ABSTRACT: Greater sage-grouse (*Centrocercus urophasianu*s; hereafter sage-grouse) are dependent on sagebrush (*Artemisia* spp.) during winter months. Impacts to wintering areas could affect population size disproportionately. Sage-grouse literature characterized winter habitat as slopes ≤ 5% south to west in aspect. Gunnison sage-grouse (*C. minimus*) literature characterized winter habitat as drainages and slopes south to west in aspect. From 2008-2010 I radio collared and monitored 91 juvenile sage-grouse on Parker Mountain, in south-central Utah to study seasonal movements, identify winter habitats and determine home rages. Resource availability was calculated in ArcView 9.2 with the weighted sum overlay tool using land cover data and a digital elevation model. Resource use was calculated in ArcView 9.2 using kernel density estimation of radio marked individuals. Resource use versus availability was compared using a g-test. Home ranges were calculated in ArcView 9.2 utilizing the Home Range Extension (Rodgers et al. 2007) to create 100% minimum convex polygons. The juvenile sage-grouse studied used winter habitats characterized by 0-5% slopes regardless of aspect and slopes 5-15% south to west in aspect. Home ranges ranged from 711 - 11,429 ha. Movements to wintering areas varied between years. In 2008 movements to wintering areas occurred rapidly during November, whereas in 2009 movements were slow and meandering beginning in late September and continuing through November. A vast majority of significant winter use (areas with kernel density estimates of >.94

locations per km²) was on a small percentage, 3% (2910 ha), of the available habitat.

Some important wintering habitats may not be readily identifiable in typical years.   Low

elevation sagebrush sites with slopes ≤5% regardless of aspect and slopes 5-15% south to

west in aspect should be managed to ensure ample habitat remains available to mitigate

against severe winters.

INTRODUCTION

The historic range of greater sage-grouse (*Centrocercus urophasianus*; hereafter

sage-grouse) has declined in area by more than 55% (Connelly et al. 2004, Schroeder et

al. 2004). Sage-grouse are dependent on sagebrush for forage during the winter (Griner

1939, Patterson 1952, Dalke et al. 1963, Wallestad 1975), and exhibit some degree of site

fidelity to wintering areas (Eng and Schladweiler 1972, Berry and Eng 1985, Connelly et

al. 1988, Woodward 2006). Doherty et al. (2008) concluded impacts to wintering

habitats could disproportionately affect population size.

Burke et al. (1989) reported vegetation distribution in a mountain big sagebrush

(*Artemisia tridentata vaseyana*) steppe was dependent on wind exposure and topography.

During winter, sage-grouse (of all sex and age classes) typically use south to west aspects

(Beck 1977) with slopes less than 5% (Eng and Schladweiler 1972, Beck 1977, Bruce

2008). Eng and Schladweiler (1972) and Beck (1977) reported sage-grouse avoided the

use of slopes greater than 5-10%. Hupp and Braun (1989) reported Gunnison sage-

grouse (*C. minimus*) used drainages ("Narrow [<100m] flood plains of permanent and

intermittent streams, shallow eroded gulches on slopes) and slopes (>5° [8.75%]) with

south or west aspects. Doherty et al. (2008) reported slope was an important topographic

predictor of sage-grouse use. Snow cover can be an important parameter determining use areas (Beck 1977, Hupp and Braun 1989).   Sagebrush cover has been identified as an important parameter for winter habitat (Eng and Schlaweiler 1972, Woodward 2006, Battazzo 2007, Doherty et al. 2008, Swanson 2009).

Beck (1977) found nearly 80% of use occurred on areas comprising less than 7% of the total area. Carpenter et al. (2010) reported 72% of model validation location occurred in the highest quality wintering areas (2 highest Resource Selection Functions [RSF] bins), which accounted for only 13% of the study area. Swenson et al. (1987) reported lekking male sage-grouse declined by 73% as the proportion of ploughed wintering areas increased from 10% (1975) to 30% (1984). Woodward (2006) reported after 827 acres of winter habitat was chisel-plowed, sage-grouse returned to the plowed area despite seemingly good habitat elsewhere.

Swanson (2009) reported brood breakup was the 4 October (median range was 17 July - 8 November) at a median age of 134 days (range was 38 - 173). He reported breakup was usually initiated by the adult female and juveniles dispersed within days. Dunn and Braun (1986) noted juvenile sage-grouse moved to winter areas in November, and movements to wintering areas were linked to snowfall. Connelly et al. (1988) reported sage-grouse (of all sex and age classes) moved to winter areas beginning in Late August and continuing into December. Movements were slow and meandering. Likewise Swanson (2009) reported movements (of all sex and age classes) to wintering areas occurred over several months. Connelly et al. (1988) reported that juvenile sage-grouse moved an average of 14.9 km between summer and winter ranges. They also found that leks were in close proximity to wintering areas. Connelly et al. (1988)

reported fall movements and directional movements to wintering areas of adult and

juvenile sage-grouse were similar. Schoenberg (1981) reported winter ranges of 5,000-

25,000 ha and 6,400- 11,900 ha for males and females respectively. Sage-grouse

congregate in large flocks during the winter (Girard 1937, Rasmussen and Griner 1938,

Dalke et al. 1963, Ihli et al. 1973). In Colorado, winter flocks break-up during the first 2

weeks of April (Schoenberg 1981).

The purpose of this research was to identify core juvenile wintering areas on

Parker Mountain, and to determine if the winter habitat topographic features previously

described in the sage-grouse (both greater and Gunnison) literature also apply to the

Parker Mountain population. The Parker Mountain population is one of the southernmost

population in the United States. This population inhabits a high elevation plateau (>

2,200 m) and occupies habitat that does not fit the recommended guidelines for sage-

grouse (Connelly et al. 2000, Dahlgren et al. 2006).

STUDY AREA

Parker Mountain is in south-central Utah within Wayne, Piute, Sevier, and

Garfield Counties. Parker Mountain is a high elevation plateau that lies at the southern

edge of the range of greater sage-grouse (Schroeder et al. 2004). The study site ranges in

elevation from 2,200 to 3,000m and rises in elevation gradually from east to west. The

average temperature was 3.8 C. The mean maximum and minimum temperatures for

January and July were 1, -13 C and 27, 9 C, respectively. Parker Mountain experienced

65-80 frost-free days and received 40-50 cm of precipitation annually, most of which

occurred during the dormant season as snow (60%), and the remainder fell as rain in the

late summer (Jaynes 1982). The vegetation was primarily black sagebrush on ridges, and mountain big sagebrush in the swales. Quaking aspen (*Populus tremuloides*) clones were present in the higher elevations. Limited amounts of pinyon pine (*Pinus edulis*) and juniper (*Juniperus spp.*) occurred at lower elevations. The study area was located mainly on lands managed by the Utah School and Institutional Trust Lands Administration (SITLA) and the Bureau of Land Management (BLM); the agencies managed 46% (43,745 ha) and 44% (42,643 ha), respectively. The U.S. Forest Service (USFS) managed 9% (8327 ha) and private lands account for 1% (1363 ha) of the study area. The primary use of the land was cattle grazing. However, sheep grazing occurred on some parts of the study area. Historically, severe overgrazing caused the range to be unusable by cattle in the 1930s (Jarvis 1973). Big game hunting and upland bird hunting, including sage-grouse, were important recreational uses of the study area. The Parker Mountain sage-grouse hunt unit designated by the Utah Division of Wildlife Resources (UDWR) was 601,997 ha. However, most of this unit was unusable to sage-grouse (Fig. 3-1). Within the hunt unit a smaller study area (96,078 ha) was established using sagebrush cover-types (Fig. 3-2).

METHODS

Movements

Juvenile sage-grouse were captured using modifications of night spotlighting (Giesen et al. 1982, Wakkinen et al. 1992, Connelly et al. 2003). Trapping was conducted between 1 August-30 September, annually. Adults were distinguished from juveniles using characteristics of the first secondary (Beck et al. 1975). Juveniles were

sexed using length of primary feathers, molt progression (Beck et al. 1975), and DNA analysis. Individuals were fitted with either suture-on backpack or necklace-style transmitters (American Wildlife Enterprises, Monticello, FL). All transmitters weighed 15 grams and did not exceed 3% of the individual's body weight (Thirgood et al. 1995). The transmitters were battery powered and equipped with mortality switches set to trip after 12 hours of inactivity. The type of transmitter the individual received was randomly selected. Backpack transmitters were fitted using modifications of Burkepile et al. (2002). The sutures (2/0 suture thread) were inserted using 18 gauge x 3.81 cm sterile needles. Two sutures were inserted on the individuals back between the wings. Each side of the suture was threaded through a hole in the anterior and posterior end of the transmitter. Square knots were used to fasten the transmitter and the knots were secured using cyanoacrylate. Necklace transmitters were mounted using 27.3 kg. test black nylon coated steel wire threaded through the transmitter, then threaded through clear soft plastic tubing and crimped to itself using #4 black leader sleeves. Backpack transmitters were 35 mm long by 26 mm wide by 14 mm tall with an antenna length of ~250 mm. Necklace transmitters were 26mm long by 26 mm wide by 15 mm tall with an antenna length of ~300 mm. The study protocol was approved by the Utah State University Institutional Animal Use and Care Committee (IACUCC Number 942R).

Marked individuals were located monthly. Individuals were located by radio-telemetry following direction of antenna and signal strength until the individual was observed (Mech 1983) or by circling the location of the strongest signal strength (Springer 1979). Upon locating the individual, the Universal Transverse Mercator coordinates (datum, North American 1983; projection, UTM Zone 12) were documented.

If contact with the individual was not made, the UTM coordinates, azimuth (to estimated location), and estimated radius of the circle was recorded. Aerial radio-tracking (Mech 1983) was also used (bimonthly from January - March) to locate individuals. The aircraft was equipped with 2 side facing H-type antennas.

Resource Availability and Use

Resource availability was calculated using ArcView 9.2 (Environmental Systems Research Institute Inc., Redlands, CA). Southwest Regional Gap Analysis Project (SWReGAP) land cover data (USGS National Gap Analysis Program 2004) and 10 m resolution Digital Elevation Models (DEM) (obtained from the Natural Resources Conservation Services' geospatial data gateway) were the base data. The reclassify tool within the spatial analyst toolbox was used to reclassify SWReGAP into sagebrush dominant habitats and other. Sagebrush dominant habitats were assigned a value of 3 and other (non-sagebrush habitats) was assigned a value of 1. The DEM data were transformed to percent slope and aspect using the slope and aspect tools within the spatial analyst toolbox. Slope was then reclassified into 3 categories: ≤5% (assigned value of 3), >5%-15% (assigned value of 2), >15% (assigned value of 1). Aspect was reclassified into 157.5-292.5: representing south through west was assigned a value of 3, -1: representing flat land was assigned a value of 3, and all other aspects were assigned a value of 1. The weighted sum overlay tool within the spatial analyst toolbox was used to combine the three reclassified layers into a model for winter habitat (based on recommendations of Eng and Schladweiler 1972, Beck 1977).

Seasonal use areas were calculated in ArcView 9.2 (Environmental Systems Research Institute Inc., Redlands, CA). Animal Space Use 1.3 (Horne and Garton 2009) was used to calculate the bandwidth for kernel density estimations. When selecting a bandwidth for kernel density estimation both likelihood cross-validation (hereafter CVh) and least squares cross-validation (hereafter LSCVh) performed poorly. The CVh = 1602 over-smoothed the data, and LSCVh=447 under-smoothed the data. The 1000 m bandwidth fit the data well and is roughly the midpoint of the 2 bandwidth calculations (1024.5 is the true midpoint). A 1000 m bandwidth was used to perform calculations. The kernel density tool within the spatial analyst toolbox was used to perform the estimates for fall use (August - October) and 2 classifications were used for winter November - March and January - March. The subset of January - March was calculated to represent the period of constant snow cover on the study area. Locations from both years were pooled. The total area used, from 15 August to 31 March, was calculated using the weighted sum overlay tool within the spatial analyst toolbox using the kernel density estimates of fall (August - October) and winter (November - March). The January - March subset kernel density estimate was reclassified (using the reclassify to within the spatial analyst toolbox) and converted from raster to polygon data (using the raster to polygon tool within the conversion toolbox) to assess composition of slope and winter habitat at higher and lower use areas. Winter kernel densities were categorized using 10 natural break categories, which were grouped to create 6 biologically meaningful groups: 0-.94(3), .94-2.55(3), 2.55-3.39, 3.39-4.41, 4.41-5.53, and 5.53-6.66 locations per km² (number in parenthesis is number of natural break categories combined to create group). Winter habitat use versus availability was compared using a g-test.

Habitat use was defined by the density categories from the kernel density estimation and availability was defined as the percent occurring within the study area.

Home ranges for each individual surviving from 22 August through 1 March were calculated in ArcView 9.2 utilizing the Home Range Extension (Rodgers et al. 2007) to create 100% minimum convex polygons (hereafter MCP) (Mohr 1947).

RESULTS

In 2008, 30 juvenile sage-grouse were radio-collared from 7 - 21 September and tracked through 31 March. In 2009, 61 juvenile sage-grouse were radio-collared from 15 August - 22 September and tracked through 2 April. Three hundred and fifty-two locations were recorded over the 2 years of the study. Eighty-four locations were collected in January - March of both years for winter habitat use. Most of winter locations were obtained by aircraft. Although the backpack transmitter type was shown to negatively affect survival (see Chapter 2), both backpack and necklace transmitters were used to assess resource use and home ranges. Home ranges for both transmitter types were similar: backpack birds averaged 5007 ha (range 2006-8056 ha n=7) and necklace birds averaged 4443 ha (range 711-11429 n=27). Additionally, no mortalities were recorded from 1 December 2009 to 31 March 2010 (n = 27) and 4 January 2009 to 31 March 2009 (n = 7), which constituted the focal period for winter habitat use (January - March).

Resource availability was calculated using previously described sage-grouse winter habitat (Eng and Schladweiler 1972, Beck 1977, Hupp and Braun 1989). The weighted sum tool yielded Fig. 3-3 and Table 3-1. Only 7.9% of the study area was

composed of sagebrush habitat, ≤5% slope, and south to west oriented (score of 9).

Additionally, 10.7% of the study area was sagebrush habitat, >5-15% slope, and south to

west oriented (score of 8). The study area consisted of 22.7%, 25.4%, and 7.3% for

sagebrush slopes ≤5%, 5-15%, and >15%, respectively.

Winter habitat use versus availability for each density group was compared using

a g-test in Tables 3-4 and 3-5. The habitat model parameters were used

disproportionately to their availability at densities above 3.39 locations per km². The

"other" habitat category, indicating lower quality habitat, was used less than its

availability. The 2 "higher" quality habitats - sagebrush habitat, 0-5% slope and >5-15%

slopes, south to west aspects - were used more than their availability. Sagebrush slopes

were used disproportionately to their availability at densities above 0.94 locations per

km². However, the disproportionate use was due to the avoidance of sagebrush slopes

>15% for most of the densities. Sagebrush slopes 0-5% were used disproportionately

more than available at densities above 4.4 locations per km².

Individual home ranges from 15 August to 31 March averaged 4556.3 ha (range

711-11,429ha). Permanent snow coverage began in mid-December both years. Of all

known locations, 94.3% were on lands managed by SITLA, and 5.7% were on lands

managed by the BLM.

DISCUSSION

Doherty et al. (2008) reported slope was an important topographic predictor of

sage-grouse use. Past studies have shown that during winter sage-grouse typically use

slopes ≤ 5% (Eng and Schladweiler 1972, Beck 1977, Bruce 2008) south to west in

aspect (Beck 1977). Hupp and Braun (1989) reported Gunnison sage-grouse used drainages and slopes with south or west aspects. Sage-grouse on Parker Mountain used sagebrush slopes ≤ 5% in core wintering areas and avoided sagebrush slopes >15% during the winter. Use of slopes ≤ 5% was independent of aspect. Both ≤ 5% and >5-15% sagebrush slopes south to west in aspect were used more than available at densities above 3.4 locations per km². Juvenile sage-grouse on Parker Mountain used winter habitats similar to those described by Beck (1977) and Eng and Schladweiler (1972), as well as winter habitats described by Hupp and Braun (1989). However, juvenile sage-grouse on Parker Mountain did use slopes (5-15%), which contradicts the findings of Eng and Schladweiler (1972) and Beck (1977).

Beck (1977) found nearly 80% of use occurred on areas comprising less than 7% of the total area. Similar to Beck (1977), Parker Mountain significant-use areas (kernel density estimates of >.94 locations per km²) accounted for only 3% (2910 ha) of the study area. Carpenter et al. (2010) reported 72% of model validation location occurred in the highest quality wintering areas (2 highest Resource Selection Functions [RSF] bins), which accounted for only 13% of the study area. Swenson et al. (1987) reported lekking male sage-grouse declined by 73% as the proportion of ploughed wintering areas increased from 10% (1975) to 30% (1984). Woodward (2006) reported after 827 acres of winter habitat was chisel-plowed, sage-grouse returned to the plowed area despite seemingly good habitat elsewhere. Doherty et al. (2008) concluded impacts to wintering habitats could disproportionately affect population size. Braun et al. (1977) recommended no manipulation of sagebrush take place in any important winter areas known (within 10 years) to support sage-grouse.

The poor performance of both CVh and LSCVh in bandwidth determination was likely caused by the nature of the data set. The data exhibited a clumping in distribution and also had outliers. Methods such as the root - n method may provide more reliable bandwidth estimates for similar studies in the future (Steury et al. 2010).

A majority of the locations obtained were on lands managed by SITLA. However, the locations on the lands managed by the BLM may be critical areas. The lands managed by SITLA are at higher elevation areas of the study area while those managed by the BLM are lower in elevation, and may be particularly critical in years of heavy snowfall. During January through March, 21.4% of locations occurred on lands managed by the BLM. Additionally, in 2009 (January - March with below average snowfall Fig. 2-3) only 3% of locations occurred on BLM land. Whereas, in 2010 (January - March with above average snowfall Fig. 2-3 Chapter 2) 32.1% of locations occurred on BLM land.

Differences in fall dispersion between years were likely caused by earlier movements in 2009 to wintering range (Fig. 3-4 and Fig. 3-5). In 2008 movements to wintering areas were during November, similar to movements Dunn and Braun (1986) noted. However, in 2009 movements to wintering areas began in late September and continued through the end of November, similar to the movement patterns Connelly et al. (1988) and Swanson (2009) reported. Fall use areas were characterized by clumped high densities located in high elevations on the study area (Fig. 3-6). Winter use areas were characterized by low densities of locations with "hotspots" of higher densities (Fig. 3-7). Individual home ranges (for August - March) were smaller (711 - 11,429 ha) than the winter only home ranges reported by Schoenberg (1981) (5,000 - 25,000 ha).

More research is needed to determine the specific sagebrush species used. Although sagebrush is crucial to sage-grouse winter diet, selection of sites could also be tied to avoidance of predation or thermoregulation. The SWReGAP could not accurately predict sagebrush species on Parker Mountain (differentiate between mountain big sage and black sage) and consequently this study was unable to determine parameters surrounding each species of sagebrush. The addition of parameters in future models could increase their utility. Sagebrush cover has been identified as an important parameter for winter habitat (Eng and Schlaweiler 1972, Woodward 2006, Battazzo 2007, Doherty et al. 2008, Swanson 2009) and could be a useful aspect in future models.

MANAGEMENT IMPLICATIONS

Sagebrush habitat should be protected at lower elevations sites with slopes $\leq 5\%$ regardless of aspect and slopes >5-15% south to west in aspect. Identification and protection of wintering areas is critical. Although large expanses of habitat may be available, sage-grouse seem to use a small subset of available habitat. There could be some degree of sit fidelity to wintering areas (Eng and Schladweiler 1972, Berry and Eng 1985, Connelly et al. 1988, Woodward 2006). Some wintering areas may not be apparent in typical years, but may be crucial in severe winters. In this study use of low elevation lands managed by the BLM went from 3% in a low snowfall year to 32.1% in a high snowfall year. These lower elevation sites may be critical refuges in severe winters and should be managed accordingly to ensure their availability.

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Table 3-1 Quality of winter habitat on Parker Mountain, Utah, USA, 2010. Adapted from SWReGAP 2004 and 10 meter Digital Elevation Model. Weighted Sum tool in ArcView 9.2 ranks were determined as follows for aspect flat, south, west, and southwest received a value of 3 all others 1. For slope 0-5% received 3, 5-15% received 2, and above 15% received 1. For land cover sagebrush received 3 all others received 1.

Quality of Winter Habitat Parker Mountain Study Area

Additive Sum (score)	Count	Square Meters (Count x 900)	Hectares	Percent
9	84404	75963600	7596.36	7.91%
8	114044	102639600	10263.96	10.69%
7-3	868504	781653600	78165.36	81.40%
Totals	1066952			

Table 3-2 Greater sage-grouse (*Centrocercus urophasianus*) use of winter habitat on Parker Mountain, Utah, USA, 2008-2010.

Habitat Parameters	Use (Locations per km^2)						Available
	0 - .94	.94 - 2.55	2.55 - 3.39	3.39 - 4.41	4.41 - 5.53	5.53 - 6.66	
Other	81.52%	79.18%	72.04%	55.62%	67.21%	57.29%	81.40%
Sagebrush Habitat, 5-15% slope, South to West aspect	10.61%	11.80%	17.92%	30.50%	16.63%	27.06%	10.69%
Sagebrush Habitat, 0-5% slope, South to West aspect	7.87%	9.02%	10.04%	13.88%	16.17%	15.65%	7.91%

Table 3-3 Greater sage-grouse (*Centrocercus urophasianus*) winter use of slopes on Parker Mountain, Utah, USA, 2008-2010.

	Use (Locations per km^2)						
Slope	0 - .94	.94 - 2.55	2.55 - 3.39	3.39 - 4.41	4.41 - 5.53	5.53 - 6.66	Available
>15% sagebrush	12.40%	7.47%	5.62%	6.14%	5.08%	4.77%	12.25%
>5-15% sagebrush	42.62%	46.00%	54.04%	50.71%	31.87%	42.44%	42.77%
0-5% sagebrush	37.95%	45.16%	39.55%	43.15%	63.05%	52.79%	38.18%

Table 3-4 Winter habitat model categories availability vs. use by greater sage-grouse (*Centrocercus urophasianus*) on Parker Mountain, Utah, USA, 2008-2010. Availability other 81.40%; sagebrush habitat, 5-15% slope, south to west aspect 10.69%; sagebrush habitat, ≤5% slope, south to west aspect 7.91%.

Habitat Parameters	Use (Locations per km^2)																	
	0 - .94			.94 - 2.55			2.55 - 3.39			3.39 - 4.41			4.41 - 5.53			5.53 - 6.66		
	Observed	Expected	G-Test	Observed	Expected	G-Test	Observed	Expected	G-Test	Observed	Expected	G-Test	Observed	Expected	G-Test	Observed	Expected	G-Test
Other	81.5	81.4	0.1196	79.2	81.4	2.19	72.04	81.4	-8.8	55.6	81.4	-21.182	67.2	81.4	-12.9	57.3	81.4	-20.123
Sagebrush habitat, 5-15% slope, south to west aspect	10.6	10.7	-0.079	11.8	10.7	1.17	17.92	10.7	9.26	30.5	10.7	31.9802	16.6	10.7	7.351	27.1	10.7	25.135
Sagebrush habitat, ≤5% slope, south to west aspect	7.87	7.91	-0.041	9.02	7.91	1.18	10.04	7.91	2.393	13.9	7.91	7.80361	16.2	7.91	11.56	15.7	7.91	10.6771
Total			0.0004			0.16			2.852			18.6015			6.036			15.6886
G			0.0008			0.32			5.705			37.2031			12.07			31.3773
Df		2			2			2			2			2			2	
P			0.9996			0.85			0.058			8.3E-09			0.002			1.5E-07

Table 3-5 Sagebrush slopes availability vs. winter use by greater sage-grouse (*Centrocercus urophasianus*) on Parker Mountain, Utah, USA, 2008-2010. Sagebrush slope availability: slopes >15% -- 15.14%, slopes >5-15% -- 45.09, and slopes ≤5% -- 39.77.

| | Use (Locations per km^2) | | | | | | | | | | | | | | | | | |
| | 0 - .94 | | | .94 - 2.55 | | | 2.55 - 3.39 | | | 3.39 - 4.41 | | | 4.41 - 5.53 | | | 5.53 - 6.66 | | |
Slope	Observed	Expected	G-Test	Observed	Expected	G-Test	Observed	Expected	G-Test	Observed	Expected	G-Test	Observed	Expected	G-Test	Observed	Expected	G-Test
>15% sagebrush	12.4	12.3	0.15	7.47	12.3	-3.696	5.62	12.3	-4.38	6.14	12.3	-4.2421	5.08	12.3	-4.472	4.77	12.3	-4.4999
>5 - 15% sagebrush	42.6	42.8	-0.15	46	42.8	3.347	54	42.8	12.637	50.7	42.8	8.63332	31.9	42.8	-9.376	42.4	42.8	-0.3303
≤5% sagebrush	38	38.2	-0.23	45.2	38.2	7.577	39.6	38.2	1.4001	43.2	38.2	5.27532	63.1	38.2	31.62	52.8	38.2	17.0984
Total			-0.24			7.228			9.6572			9.66658			17.771			12.2682
G			-0.47			14.456			19.314			19.3332			35.542			24.5365
Df		2			2			2			2			2			2	
P			N/A			0.0007			6.4E-05			6.3E-05			1.9E-08			4.7E-06
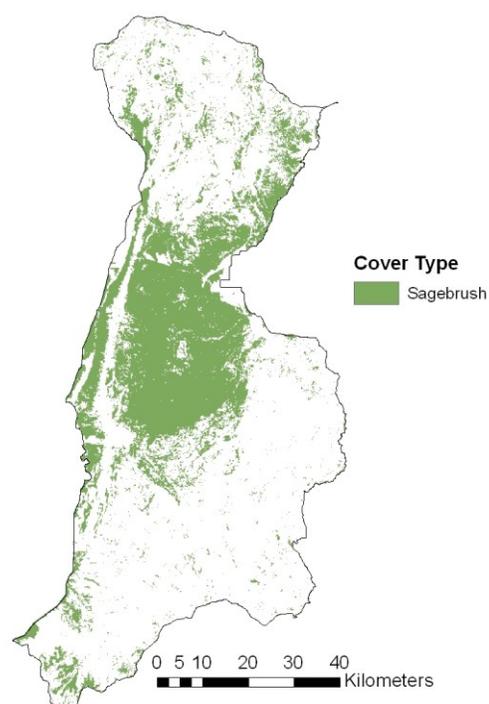
Figure 3-1 Sagebrush coverage within the Parker Mountain Utah Division of Wildlife Resources greater sage-grouse (*Centrocercus urophasianus*) hunt unit, Utah, USA, 2010.
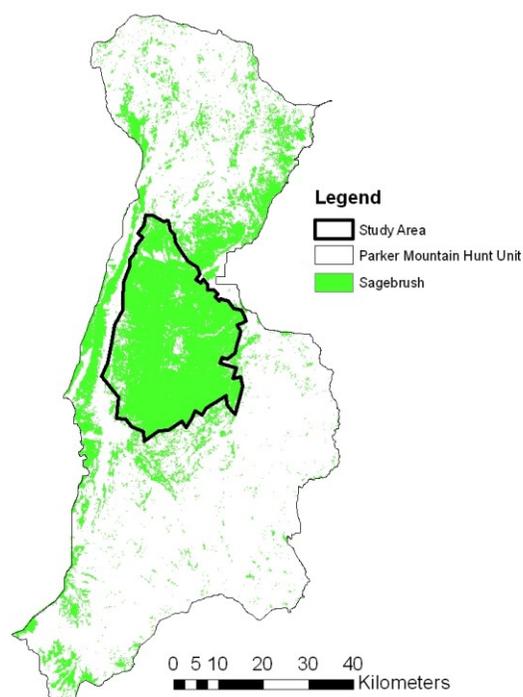
Figure 3-2 Parker Mountain study area within Parker Mountain Utah Division of Wildlife Resources greater sage-grouse (*Centrocercus urophasianus*) hunt unit, Utah, USA, 2010.
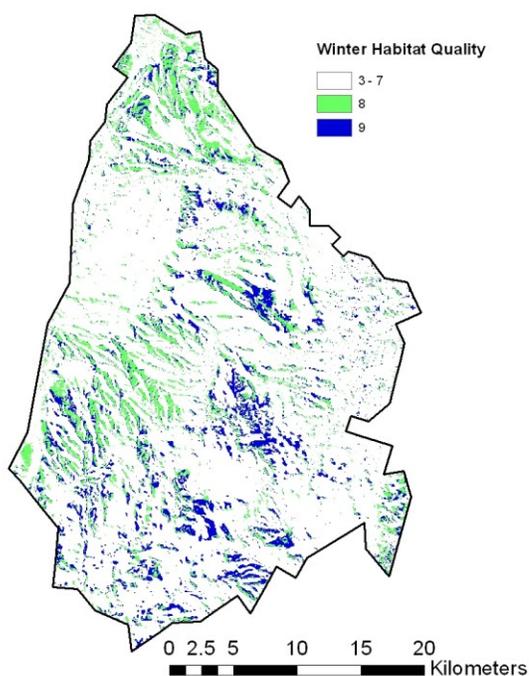
Figure 3-3 Greater sage-grouse (*Centrocercus urophasianus*) habitat quality based upon habitat recommendations from Eng and Schladweiler 1972 and Beck 1977 of Parker Mountain, Utah, USA, 2010.
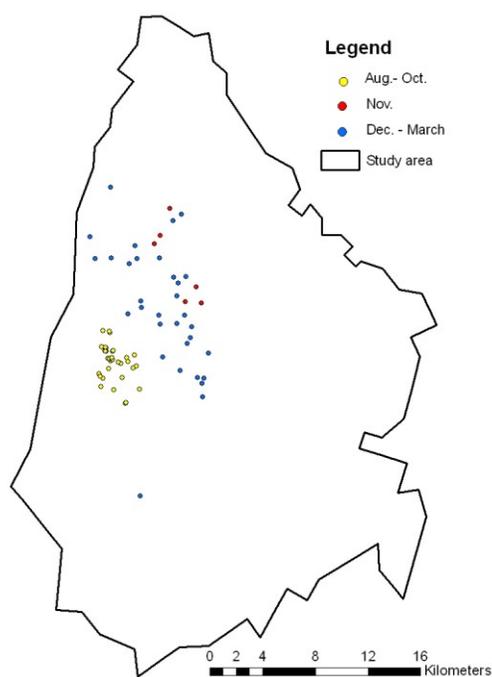
Figure 3-4 Locations of greater sage-grouse (*Centrocercus urophasianus*) 7 September 2008 to 31 March 2009 on Parker Mountain, Utah, USA.
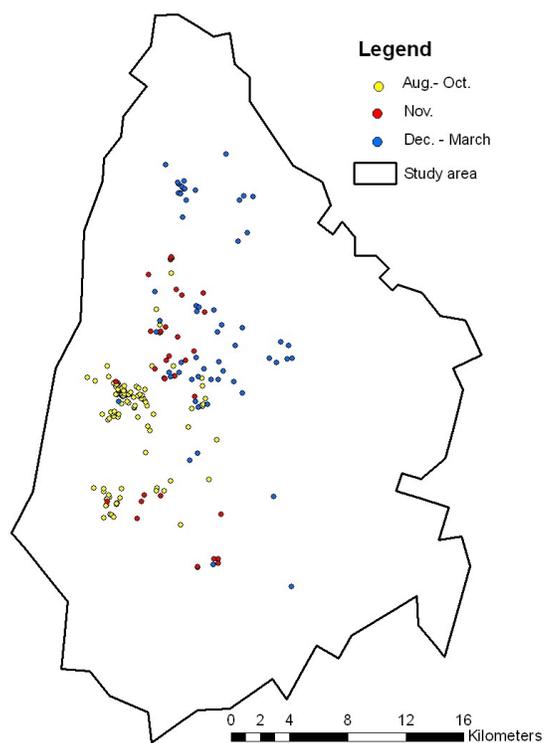
Figure 3-5 Locations of greater sage-grouse (*Centrocercus urophasianus*) 15 August 2009 - 31 March 2010 on Parker Mountain, Utah, USA.
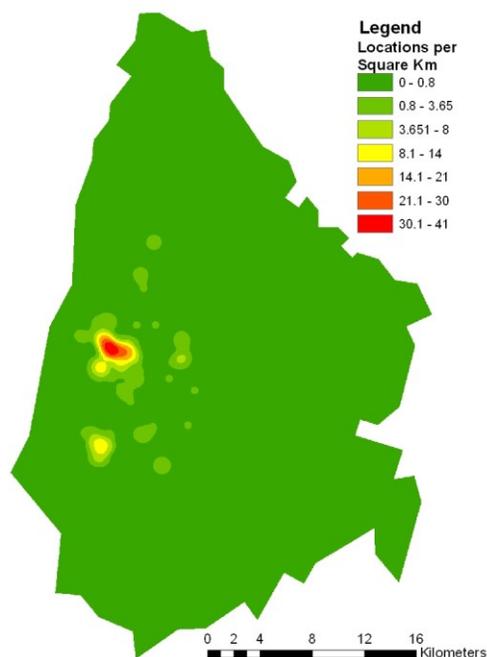
Figure 3-6 Kernel density of fall (August - October) locations of greater sage-grouse (*Centrocercus urophasianus*) on Parker Mountain, Utah, USA, 2008-2009.
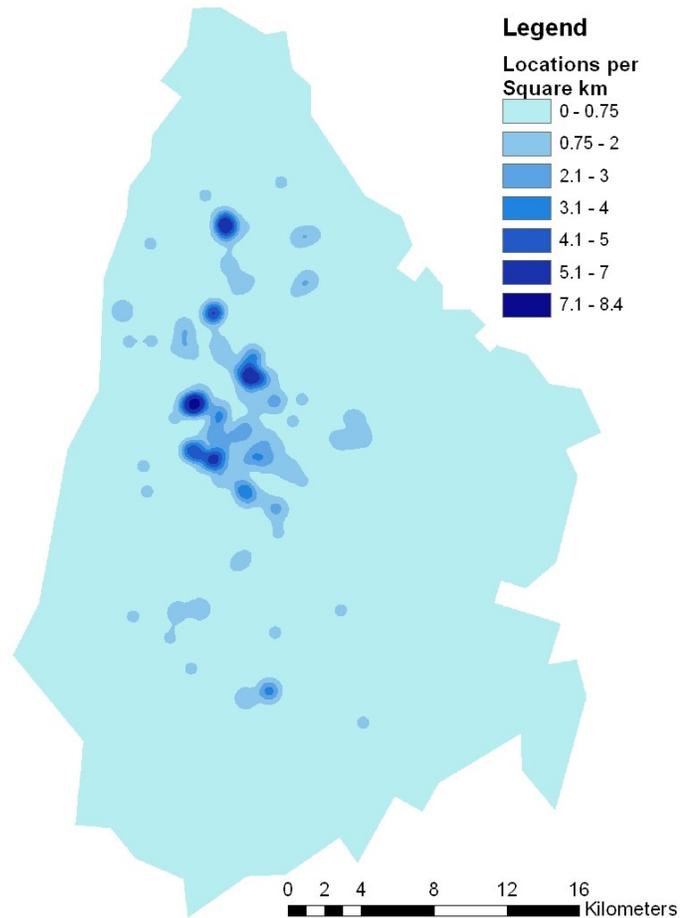
Figure 3-7 Kernel density of winter (November - March) locations of greater sage-grouse (*Centrocercus urophasianus*) on Parker Mountain, Utah, USA, 2008-2010.
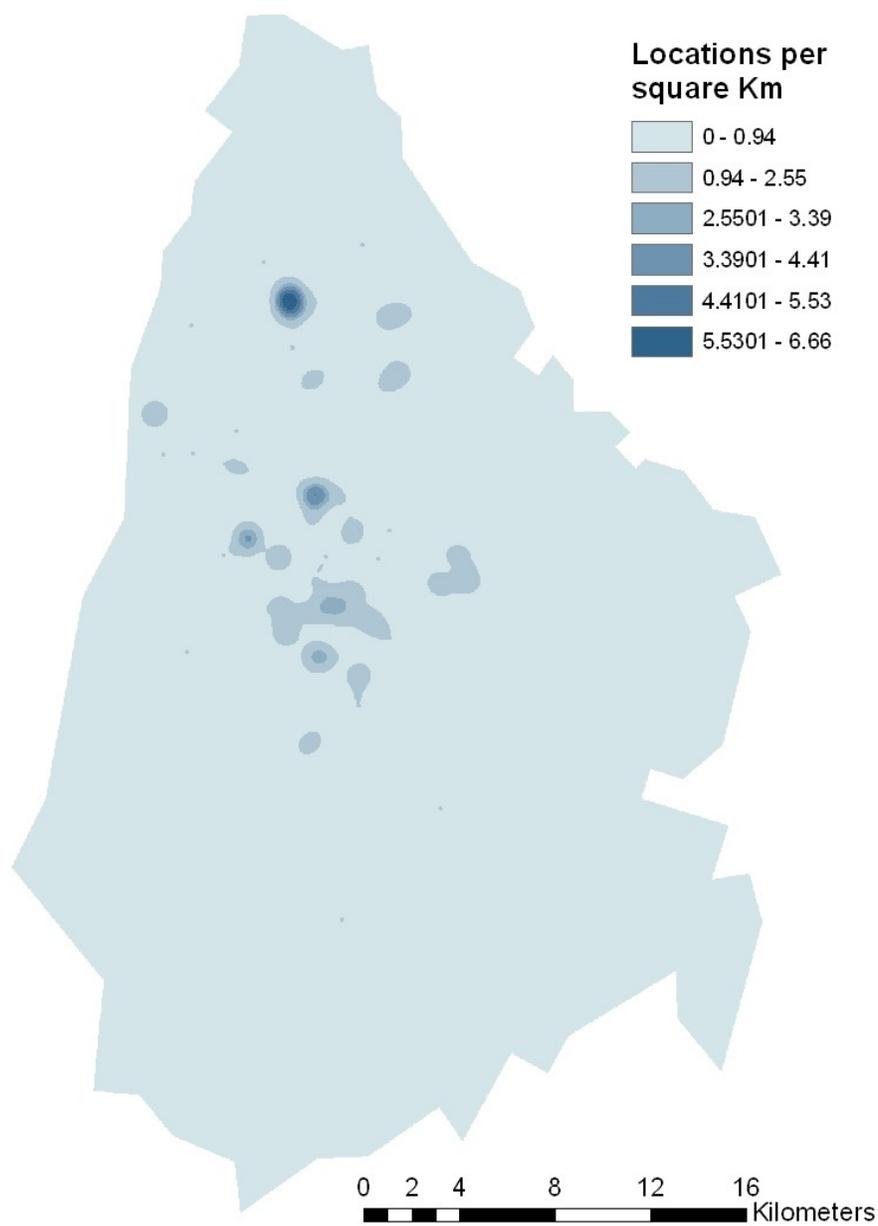
Figure 3-8 Kernel density of winter (January - March) locations of greater sage-grouse (*Centrocercus urophasianus*) on Parker Mountain, Utah, USA, 2009-2010.

CHAPTER 4

CONCLUSIONS

Survival of juvenile greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) is one of the least documented demographic parameters of greater sage-grouse, and has been identified as a parameter critical to population growth. On Parker Mountain juvenile sage-grouse experienced high over-winter survival (females: 0.8018 - 0.9817 and males: 0.6873 - 0.9691). Fall survival rates were 0.5218 - 0.6234 for females and 0.3322 - 0.4492 for males. Survival from fall through winter was 0.4184 - 0.616 for females and 0.2282 - 0.4354 for males. Sex ($p = 0.1033$) and transmitter type ($p = 0.0901$) affected survival. On Parker Mountain sage-grouse experienced lower survival rates than reported by Beck et al. (2006), and similar juvenile female fall, winter, and overall survival rates to those reported by Wik (2002). Additionally, survival rates on Parker Mountain were similar to those reported by Swanson (2009). However, comparison is difficult because he did not consider differential survival between sexes. Contrary to Beck et al. (2006), there was evidence to support a differential survival between sexes in this study. On Parker Mountain the main source of mortality was predation (probability predation caused death was 0.705 for both years combined). One mortality not attributed to predation or harvest was a fence strike. Probability death was caused by a fence strike was 0.037 for the year in which it occurred and 0.023 for both years combined. It is unlikely human causes (other than harvest) directly affect survival of birds on Parker Mountain. Most mortality occurred during fall (22 August to 1 December) and was similar to the seasonal patterns reported by Beck et al. (2006),

Anthony and Willis (2009), Wik (2002), and Swanson (2009). Juvenile birds on Parker

Mountain experienced high over-winter survival, and severe winter weather did not affect

survival.

Unreported harvest played role in the general harvest dynamic of juvenile sage-

grouse on Parker Mountain; the probability unreported harvest caused death was 0.091.

Unreported harvest (mainly crippling) may have a larger impact on sage-grouse than was

previously expected. Crippling loss is a part of the harvest dynamic of sage-grouse that is

largely ignored but needs to be addressed when establishing harvest regulations.

Managers should take into account a ~5% crippling and unreported harvest loss when

determining sage-grouse harvest recommendations. More research into the effects of

crippling on sage-grouse populations is needed.

Juveniles and the hens associated with them may be the demographic parameters

impacted and most susceptible to harvest. The increased susceptibility could be due to

the typically clumped distribution of brood hens with broods in mesic areas. The

probability of harvest was 0.087 (0.035-0.171) and 0.011 (0.001-0.039) for brood hens

and non-brood hens respectively. There is evidence that brooding hens are more

susceptible to harvest. However, the evidence from this study is inconclusive at $\alpha = 0.1$.

Harvest was a significant source of mortality (the probability harvest caused death was

0.159 for both years combined) for juvenile sage-grouse on Parker Mountain. Juvenile

sage-grouse could be more susceptible to harvest than hens. Future studies on harvest of

sage-grouse should include estimates of age-related survival and harvest rates. Past

studies that have examined harvest without juvenile birds in the sample may lead to

forming inaccurate conclusions on the impacts of harvest. Research is needed to

determine the acceptable harvest rate for juvenile sage-grouse. Future harvest

management actions should attempt to shift harvest away from juveniles and the hens

associated with them. Regulations should attempt to maximize the percentage of male

grouse in the harvest, and minimize the percentage of juvenile and consequently

successful hen grouse in the harvest. Harvest recommendation should focus on achieving

acceptable demographic specific (juvenile and female) harvest rates rather than total

population harvest rates.

There are several avenues of implementation through which to lessen the impact

of hunting on juveniles and hens on Parker Mountain. A male only hunting season for

sage-grouse has been suggested, however this approach is not likely feasible. Williams

and Austin (1988) reported high hen harvest rates for wild turkeys even during gobbler

only seasons, and noted approximately 40% of the time hunters miss identified wild

turkeys as to sex. Because hunters are unable to effectively identify the sex of an

extremely sexually dimorphic bird such as the wild turkey, then to expect hunters to

differentiate between sexes of sage-grouse on the wing is illogical. However, some

hunters have expressed interest in sage-grouse as trophies (Reese and Connelly 2011).

Protection of the mesic areas in which broods congregate could assist in

protecting juveniles and hens. There are 2 main ways to protect the mesic areas through

regulation: closure areas and timing of the season. Protecting the mesic areas by closing

them to hunting would provide protection to juveniles and hens in an early hunting

season (e.g. September - October). However, closure areas may be difficult in practice.

Defining the closure areas so that they are readily recognizable to hunters could be

problematic. Additionally, while identifying mesic areas on Wildlife Management Areas

and other public lands may be plausible, the identification and regulation of mesic areas on private lands may be impracticable. Protection of the congregated broods and hens could take place though timing of the hunting season, the season could take place after the broods have left the mesic areas for the wintering habitats. Although this methodology would theoretically reduce the ability for compensation, there is mounting evidence sage-grouse harvest is additive. If harvest is additive harvest management actions should be taken to lessen the impacts of harvest. Moving the season later in the year would allow for broods and brood hens to break-up and disperse. The more dispersed population should help mitigate the increased susceptibility and impacts of harvest on brood hens and juveniles, and shift harvest onto demographics that are less meaningful to population growth. If managers do elect to use this method, monitoring should be implemented to ensure the intended result is occurring (harvest is shifting away from brood hens and broods, and onto adult males and non-brood hens).

Regulation of harvest through permits allows managers to more precisely control effort and in effect total harvest on a given area. Permits are already in use on Parker Mountain, and further restriction of hunter numbers and/or bag/possession limits may be required to achieve acceptable harvest rates for juvenile and hen grouse. On Parker Mountain the use of a daily bag limit may provide some protection to broods. A daily bag limit of 1 bird would prevent individual hunters from killing multiple birds in the same brood and may help to shift some of the harvest to other demographics. The use of daily bag limits is the most practical method to attempt and offset the increased susceptibility of hen and juvenile sage-grouse to harvest, when season take place during September - October.

A combination of management actions could help shift harvest and hunter paradigms. The hunting season could be moved later in the year to mitigate the increased susceptibility of brood hens and broods to harvest. Concurrently, a single bird limit could be implemented. The restrictive regulations may help shift hunter paradigms and views of sage-grouse toward being viewed as trophies. If sage-grouse are coveted as trophies, the result could be an additional shift of harvest away from brooding hens and juveniles, and onto males. In essence, the regulations could help encourage and promote the selective harvest of adult males while not requiring all hunters to do so or to be readily able to distinguish adult males on the wing.

High accessibility, public ownership, and habitat characteristics on Parker Mountain have implications for harvest management. Because of these factors Parker Mountain is prone to high harvest rates, and managers should take into account the nature of the area when establishing harvest regulations. Additionally, differing fall dispersal timing could be important to harvest dynamics. In years when birds have not dispersed before or during the hunting season there could be an increased juvenile susceptibility to harvest along with the associated hens. In years when birds have dispersed prior to or during the hunting season, juveniles will be more dispersed throughout the mountain causing a less selective harvest.

Sage-grouse on Parker Mountain used sagebrush (*Artemisia* spp.) slopes $\leq$ 5% in core wintering areas and avoided sagebrush slopes > 15% during winter. Use of slopes $\leq$ 5% was independent of aspect. Both $\leq$ 5% and 5-15% sagebrush slopes south to west in aspect were used mort than available. The use of winter habitat on Parker Mountain is similar to Both the patterns reported for sage-grouse (Eng and Schladweiler 1972, Beck

1977, Bruce 2008) and Gunnison sage-grouse (*Centrocercus minimus*) (Hupp and Braun

1989). However, contrary to the findings of Eng and Schladweiler (1972) and Beck

(1977), sage-grouse on Parker Mountain did use slopes (5-15%). Sagebrush habitat

should be protected at lower elevations sites with slopes $\leq$ 5% regardless of aspect and

slopes >5-15% south to west in aspect. Identification and protection of wintering areas is

critical. This study found that although large expanses of habitat may be available, sage-

grouse seem to use a small subset of available habitat. On Parker Mountain areas of

significant winter use only accounted for 3% of the study area. Beck (1977) and

Carpenter et al. (2010) also noted the use of small subsets of available habitat. Some

studies suggest there could be some degree of sit fidelity to wintering areas (Eng and

Schladweiler 1972, Berry and Eng 1985, Connelly et al. 1988, Woodward 2006). Some

wintering areas may not be apparent in typical years, but may be crucial in severe

winters. In this study use of low elevation lands managed by the BLM went from 3% in

a low snowfall year to 32.1% in a high snowfall year. These lower elevation sites may be

critical refuges in sever winters.

Both radio-tags and bands have advantages and drawbacks. When radio-tags are

used, attachment method is a critical component (Fuller et al. 2005). Transmitter

attachment method effected survival of juvenile sage-grouse on Parker Mountain (p =

0.0901). Individuals fitted with suture-on backpack style radios had lower survival rates

vs. individuals fitted with necklace style radios. This research suggests back-mounted

transmitters negatively affect survival of sage-grouse, and that the use of dorsally

mounted transmitters on sage-grouse should be avoided, especially when assessing

various survival and mortality parameters. Extreme caution should be used interpreting

the results from dorsally mounted transmitters on sage-grouse, because of the potential

for differential survival rates and increased risk of predation. More research is needed to

determine if there are other attachment methods for GPS transmitters that could be

suitable for use on sage-grouse, such as the leg-loop harness (Mallory and Gilbert 2008).

Handling time and capture method may affect survival and future research is needed to

determine their effects.

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APPENDIX

FIELD NOTES

Four whole carcasses were recovered during this study. The carcasses were left in the field with a radio so they could be monitored. The carcasses were monitored for ~3-4 weeks and were never scavenged. The carcasses were not monitored past 4 weeks because decomposition began to show noticeable signs ~2 weeks and by 4 weeks the carcasses were severely decomposed.

It was noted on several occasions the grouse using "snow burrows" similar to those described by Back et al. (1987). However, on many occasions it also appeared the grouse would seek cover on the leeward side of small pockets (5-10 individual bushes) of mountain big sagebrush on ridges dominated by black sagebrush. Often the grouse were almost completely covered by the small snow drifts that formed on the leeward side and would not flush until the observer came within ~3m of the bird.

When trapping we used modifications of previously described night spotlighting techniques (Giesen et al. 1982, Wakkinen et al. 1992, Connelly et al. 2003). We trapped with a long handled net from a 4 wheeler. We wrapped the back rack of the 4 wheeler in pipe insulation to allow for someone to ride on the back all night. We almost always trapped with 2 people from one 4 wheeler. We trapped using a 2 million candle power spotlight and 10x42 binoculars and could easily spot birds at the edge of the spotlights range. We also tied the pocket of the net so the pocket was almost tight across the hoop of the net. When a bird was spotted the person with the net rode "side saddle" on the back rack of the 4 wheeler to allow for easy exit. The 4 wheeler approached with all lights off except the spotlight. We found we had much more success when we drove around spotting and attempting captures with only the spotlight on (4 wheeler headlights

off). The 4 wheeler approached at the maximum rate of speed the netter was comfortable dismounting the 4 wheeler 3-4 steps from the bird. The bird was kept 4-5 feet off the front right fender of the 4 wheeler. We found this was easiest for a right handed netter. When the 4 wheeler was 3-4 steps (plus the length of the net handle) the 4 wheeler driver veered slightly to the left allowing the netter to have a more direct path to the bird. Knee pads are a good idea for the netter. As the 4 wheeler veered the netter jumped off the back rack of the 4 wheeler and takes 3-4 quick steps and nets the bird using a low lateral movement of the net. Immediate scanning of the area is advisable as not all birds flush during a capture. If another bird is spotted, the driver keeps it in the spotlight while the netter but she first bird in a pillow case. For juvenile trapping in the fall, we found that after capture and processing searching the edge of the ridge top (where the black sage meets the mountain big) usually results in more captures. Additionally searching adjacent ridges was fruitful as large broods did not flush far, and surrounding ridges would be dotted with one and two bird groups that were far easier to catch in rapid succession. New moon nights were most successful. Trapping on full moon nights was not worth it. On full moon nights we never saw any birds for entire nights on ridge tops, with the exception of a few adult males. Radio telemetry confirmed the birds were still in the area, but they were not roosting on ridge tops.

There were 2 distinct routes the birds took to the wintering areas from the fall use areas. The first was very direct. It started in the Parker Lake area, and followed Long Hollow road past red knoll and down into the Cyclone Knoll, Black Point, Cedar Grove wintering areas. The second was route indirect; it started at Parker Lake for some birds and just northeast of the buttes area for others. The birds from Parker Lake traveled

towards Flossie Lake, then across to just below the buttes where they joined the group of birds from just north of the buttes area. Then both groups moved together to the area between Cedar Peak and Smooth Knoll. The concentration of birds in this area in November was phenomenal, and numbered in the hundreds. There were far too many birds flushing in multiple directions at different times to get an even roughly accurate figure as to numbers. The birds stayed in this area until permanent snow coverage began at which point they moved to the Cyclone Knoll, Black Point, Cedar Grove winter areas via the Bull Roost area.

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Table A-1. *a priori* candidate model sets to evaluate juvenile greater sage-grouse (*Centrocercus urophasianus*) on Parker Mountain, Utah, USA, 2008-2009. Time and Group Models were combined both additively and interactively to assess juvenile survival.

Time Structure Models	Covariate and Group Effect Models
$S(.)$	$S(type)$
$S(t)$	$S(sex)$
$S(t1_{Aug.-November} \ linear, t2_{Dec.-March} \ .)$	$S(year)$
$S(t1_{Aug.-November} \ ., t2_{Dec.-March} \ .)$	$S(weight)$
$S(t1_{Aug.-November} \ T2, t2_{Dec.-March} \ .)$	$S(sex + type)$
$S(T2)$	$S(sex * type)$
$S(T3)$	$S(sex + year)$
$S(t1_{preseason} \ . ,t2_{season} \ . ,t3_{14 \ days \ post \ season} \ . ,$	
$t4_{last \ week \ in \ Oct.-November} \ . ,t5_{Dec.-March} \ .)$	$S(sex * year)$
	$S(type + weight)$
	$S(type * weight)$
	$S(type + year)$
	$S(type * year)$
	$S(year + sex + type)$
	$S(year * sex + type)$

Table A-2. Capture data for greater sage-grouse (*Centrocercus urophasianus*) from 2008-2009 on Parker Mountain, Utah, USA.

							Primary length (mm)							
Frequency	Transmitter Type	Capture Date	Time	Molt	P5	Sex based on P5	P9	Sex based on 9	P10	Sex based on 10	DNA Sex	Sex	Weight	Capture Elevation
150.374	N	9/7/2008	1:02	7			197		155	F		F	785	9245
149.201	B	9/7/2008	1:50	7			192	F	153	F		F	980	9216
149.314	B	9/7/2008	2:39	7			220	M	190	M		M	1205	9170
150.339	N	9/7/2008	3:17	7			208	M	170	M		M	1210	9210
149.274	B	9/7/2008	23:30	7			191	F	146	F		F	970	9069
150.308	N	9/7/2008	23:30	7			217	M	162			M	1320	9069
149.435	N	9/8/2008	0:15	7			187	F	150	F		F	940	9194
149.254	B	9/8/2008	2:42	7			190	F	151	F		F	1000	9125
149.222	B	9/12/2008	0:42	7			215	M	170	M		M	1410	9300
149.804	N	9/12/2008	2:10	7			195		150	F		F	805	9140
149.634	N	9/14/2008	0:12	7			206	M	180	M		M	1355	9239
149.185	B	9/14/2008	0:12	7			212	M	17.5	M		M	1405	9239
149.23	B	9/14/2008	1:11	7			183	F	153	F		F	935	9170
149.714	N	9/16/2008	0:40	7			180	F	143	F		F	875	9070
149.285	B	9/16/2008	1:04	7			215	M	183	M		M	1190	9072
149.294	B	9/16/2008	1:47	7			207	M	165	M		M	1385	9221
149.792	N	9/16/2008	2:10	7			184	F	140	F		F	965	9166
149.554	N	9/16/2008	2:30	7			208	M	164	M		M	1460	9161
149.623	N	9/16/2008	2:54	7			189	F	149	F		F	785	9178
149.465	N	9/17/2008	0:38	7			180	F	145	F		F	805	9150
149.704	N	9/19/2008	0:52	7			209	M	165	M		M	1315	2783
149.242	B	9/19/2008	1:39	7			176	F	135	F		F	660	2816
149.363	B	9/19/2008	2:00	7			209	M	167	M		M	1410	2826

149.374	B	9/19/2008	23:33	7	179	F	140	F		F	825	2785
149.354	B	9/19/2008	23:50	7	190	F	149	F		F	1015	2785
149.694	N	9/20/2008	0:12	7	180	F	145	F		F	895	2790
149.334	B	9/20/2008	0:20	7	182	F	146	F		F	825	2790
149.952	B	9/21/2008	1:50	7	210	M	164	M		M	1425	2764
149.443	N	9/21/2008	1:50							F	795	2764
149.761	N	9/21/2008	2:23	7	195		155	F		F	915	2778
149.363	N	8/15/2009	23:50	6					F	F	640	2799
149.525	N	8/15/2009	23:50	4					M	M	620	2799
149.144	B	8/16/2009	0:40	6					M	M	700	2796
149.584	N	8/16/2009	0:40	6					M	M	830	2796
149.613	N	8/16/2009	1:40	6					M	M	1100	2809
149.813	N	8/16/2009	1:40	7	180	F	149	F		F	1070	2809
149.394	B	8/16/2009	2:19	6					M	M	670	2807
149.684	N	8/16/2009	2:40	6					F	F	650	2808
149.384	B	8/16/2009	2:40	6					M	M	960	2808
149.594	N	8/16/2009	2:40	6					F	F	640	2808
149.175	B	8/16/2009	3:00	6					M	M	770	2808
149.154	B	8/16/2009	3:40	5					M	M	770	2804
149.451	B	8/16/2009	3:50	6					F	F	610	2804
149.344	B	8/16/2009	4:00	7	185	F	140	F	F	F	890	2804
149.664	N	8/16/2009	4:22	6					F	F	720	2789
149.514	N	8/16/2009	22:58	6					M	M	1000	2785
149.02	B	8/16/2009	23:20	7	190	F	155	F	F	F	900	2783
149.114	B	8/16/2009	23:52	7	186	F	159		F	F	870	2785
149.274	N	8/17/2009	0:30	7	176	F	150	F	F	F	770	2786
149.744	N	8/17/2009	0:30	7	185	F	150	F	F	F	870	2786
149.042	B	8/17/2009	0:53	7	189	F	149	F	F	F	760	2771

149.505	N	8/17/2009	1:15	7	189	F	149	F	F	F	920	2766
149.634	N	8/17/2009	1:15	7	182	F	150	F	F	F	790	2766
149.222	N	8/17/2009	1:15	7	192	F	156	F	F	F	820	2764
149.474	N	8/17/2009	2:00	6					F	F	590	2770
149.075	B	8/17/2009	2:15	5					M	M	650	2768
149.242	N	8/17/2009	2:15	6					M	M	990	2768
149.485	N	8/17/2009	2:15	6					M	M	940	2768
149.059	B	8/17/2009	3:34	6					F	F	560	2758
149.674	N	8/17/2009	3:34	5					M	M	670	2758
149.094	B	8/17/2009	3:34	7	193	F	153	F	F	F	830	2758
149.554	N	8/17/2009	3:49	7	191	F	156	F	F	F	770	2765
149.694	N	8/17/2009	4:20	7	189	F	150	F	F	F	940	2767
149.004	B	8/17/2009	4:20	7	190	F	160		F	F	880	2767
149.965	N	8/18/2009	23:52	5					F	F	520	2806
149.643	N	8/18/2009	23:52	7					M	M	1200	2806
149.23	N	8/19/2009	0:50	6					M	M	1180	2822
149.294	N	8/19/2009	0:50	6					M	M	990	2822
149.761	N	8/19/2009	0:50	7	185	F	145	F	F	F	720	2822
149.654	N	8/19/2009	1:50	6					F	F	640	2815
149.952	N	8/19/2009	1:50	7	187	F	156	F	F	F	710	2815
149.185	N	8/19/2009	2:25	7	189	F	157		F	F	860	2818
149.824	N	8/19/2009	2:26	7	191	F	161		F	F	840	2818
149.564	N	8/19/2009	2:26	6					F	F	720	2820
149.544	N	8/19/2009	3:30	6					M	M	1090	2827
149.443	N	8/19/2009	3:30	6					F	F	690	2827
149.374	N	8/19/2009	3:30	6					M	M	670	2827
149.201	N	8/19/2009	4:06	6					F	F	610	2816
149.564	N	8/26/2009	0:17	7	190	F	156	F	F	F	840	2795

149.185	N	8/26/2009	0:17	7			190	F	158	F	F	F	750	2795
149.443	N	9/19/2009	22:42	8	196	F			160		F	F	940	2792
149.094	B	9/19/2009	23:50	8	185	F			158	F	F	F	900	2764
149.23	N	9/19/2009	23:50	8	196	F			158	F	F	F	810	2764
149.761	N	9/20/2009	1:08	8	184	F			149	F	F	F	970	2763
149.059	B	9/20/2009	1:08	8	191	F			158	F	F	F	990	2763
149.175	B	9/20/2009	1:59	6							M	M	940	2769
149.242	N	9/20/2009	1:59	7			220	M	181	M	M	M	1340	2769
149.674	N	9/22/2009	21:04	8	185	F			154	F	F	F	1020	2779
149.643	N	9/22/2009	21:30	7			185	F	147	F	F	F	860	2770
149.584	N	9/22/2009	21:30	7			297	M	165	M	M	M	1430	2770
149.394	B	9/22/2009	22:14	8	176	F			158	F	F	F	1000	2771