SAGE-GROUSE CONSERVATION AND MANAGEMENT THROUGH SCIENCE
The Utah Experience

A Summary of Greater Sage-grouse Research in Utah

1996-2015

Prepared by

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INTRODUCTION

The State of Utah has a long history and tradition of successful wildlife management and conservation.[1] In the case of the greater sage-grouse (*Centrocercus urophasianus*), significant contributions to the science, management, and conservation of the species have been achieved under state management authority. The first strategic plan for greater sage-grouse was developed in 2002,[2] revised in 2009[3] and again in 2013.[4] Each plan iteration has incorporated the latest research on local sage-grouse ecology and responses to management actions as well as consolidated state-wide strategies to guide future management and conservation in Utah. These cumulative actions validate the role and impact of state management authority and role of voluntary conservation measures in achieving certainty in sage-grouse conservation.

In March 2010, the U.S. Fish and Wildlife Service (USFWS) found that listing sage-grouse for protection under the Endangered Species Act (ESA) was warranted on a range-wide basis, but that further action was precluded because of higher ESA priorities.[5] The USFWS determined the range wide listing was warranted because of habitat loss and fragmentation, and a lack of a regulatory structure to protect habitat. Currently, the Bureau of Land Management (BLM), the U.S. Forest Service (USFS), and the other western states with sage-grouse populations and habitats, have initiated land use planning amendments and other actions designed to mitigate the identified threats, protect important sagebrush habitats, and develop adequate regulatory mechanisms to eliminate the need for a listing under the ESA.

The Utah Plan (2013) protects high-quality habitat, enhances impaired habitat, and restores converted habitat for the portion of the range-wide sage-grouse population inhabiting Utah by eliminating USFWS and State identified species conservation threats.[6] The Utah Plan embodies the best available science accumulated over the past 70 years and reflects the ecology of sage-grouse in Utah (Grainer 1939; Dalgren *et al.* 2015a, In Press). Utah's Plan is **not lek-centric** as

[1] Utah Code Title 23 establishes and defines the State's legal wildlife management authority within the Utah Division of Wildlife Resources.
[2] UDWR. 2002. Strategic management plan for sage-grouse. Utah Department of Natural Resources, Publication 02-20. Salt Lake City, Utah, USA.
[3] UDWR. 2009. Strategic management plan for sage-grouse. State of Utah Department of Natural Resources, Division of Wildlife Resources, Publication 09-17, Salt Lake City, Utah, USA
[4] Utah Plan. 2013. Conservation plan for greater sage-grouse in Utah. <https://wildlife.utah.gov/uplandgame/sage-grouse/pdf/greater_sage_grouse_plan.pdf >. Salt Lake City, Utah, USA
[5] *See* 75 FR 13910
[6] The Utah Plan was completed in accordance with the Utah Comprehensive Wildlife Conservation Strategy (UDWR 2005), Utah Local Working Group Plans (www.utahcbcp.org), range wide conservation strategies and assessments (Connelly et al. 2004, Stiver et al. 2006), the Bureau of Land Management (BLM) National Sage-grouse Habitat Conservation Strategy (USDI 2004), and the USFWS Greater Sage-grouse Conservation Objectives Final Report (COT; USFWS 2013).

are other state plans and protects 94% of the birds in Utah including small, peripheral populations as well as the southernmost population of sage-grouse across the range.

Greater Sage-grouse in Utah

Greater sage-grouse are managed as an upland game species as well as state sensitive species[7] by the Utah Division of Wildlife Resources (UDWR). Research conducted in the Gunnison Basin of southwestern Colorado and San Juan County in southeastern Utah found that two species of sage-grouse inhabit both states. Sage-grouse populations that occur south and east of the Colorado River in Utah (Grand and San Juan counties) constitute a recently described species of sage-grouse, known as the Gunnison sage-grouse (*C. minimus*; Barber 1991, Young et al. 2000). Greater sage-grouse are located throughout the rest of the state. A Gunnison Sage-grouse Conservation Plan was completed in 2000 by the San Juan County Gunnison Sage-Grouse Working Group (SWOG 2000). This document has been used to guide management of Gunnison sage-grouse in Utah. Therefore, Gunnison sage-grouse management and conservation strategies are not included in this narrative.

Utah supports an estimated 4-5% of the total range-wide sage-grouse population (Beck et al. 2003). These populations are distributed throughout the northern, western, and central parts of Utah where they occupy a discontinuous habitat base that reflects the natural topography and geography of the Utah landscape. Greater sage-grouse were thought to have been historically distributed in all 29 Utah counties. This belief is based largely on the historical distribution of sagebrush, pioneer records, and museum specimens (Beck *et al.* 2003). Current estimates suggest that sage-grouse may occupy up to 8 million acres (3,237,490 ha) or about 41% of the historic habitats in Utah (Beck *et al.* 2003). The largest Utah sage-grouse populations are found in western Box Elder County, on Blue and Diamond Mountains in Uintah County in northeastern Utah, in Rich County, and on Parker Mountain in south central Utah. Smaller populations are found dispersed throughout the state. The Utah Plan (2013) encompasses over 7.5 million acres (2,832,804 ha) of the currently occupied habitat providing the best opportunity to conserve the species in the state.

Utah established an extensive statewide database which documents more than 30,000 sage-grouse locations. This database, under the direction of Dr. Terry Messmer at Utah State University (USU), also includes seasonal habitat-use data recorded by graduate students and technicians supervised by research faculty at USU, Brigham Young University (BYU), and UDWR biologists using established range-wide protocols (Connelly et al. 2003). To date, the Utah database for sage-grouse is the most comprehensive source for local population occurrences of its kind as these records directly reflect sage-grouse habitat use.

Utah's Sage-grouse Local Working Groups:

As half of Utah's greater sage-grouse populations occur on private lands, successful conservation depends upon gaining broad support from local communities and private landowners. In 1997, USU Extension, through the Community Based Conservation Program (CBCP), began organizing and facilitating sage-grouse local working groups throughout Utah (Messmer *et al.*

[7] The sage-grouse was considered a sensitive species within Utah, and a Tier II species under the Utah Comprehensive Wildlife Conservation Strategy (UDWR 2005), also referred to as the State Wildlife Action Plan.

2014). The CBCP initiated a process that enhanced coordination and communication between community-based adaptive resource management working groups, private, and public partners. Additionally, the program developed and implemented "seamless" plans for designated Utah geographic areas that contribute to the conservation of sage-grouse and other wildlife species that inhabit Utah's sagebrush ecosystems and enhance the economic sustainability of local communities. Membership and participation in LWG meetings and has grown steadily in Utah. The LWG sage-grouse conservation plans, previous annual reports, and meeting minutes can be accessed at www.utahcbcp.org.

Currently, there are 10 regional Local Working Groups (LWGs) operating in Utah. Each LWG has developed a local conservation plan which fed into the development of the Utah Plan (2013). In fact, the LWG and their plans provided the basis of implementation of sage-grouse actions in Utah. The CBCP facilitators worked closely with LWG members, state and federal, and private partners to implement the Utah's Plan (2013) goal of protecting high-quality sagebrush habitat to address and ameliorate the threats facing the sage-grouse while balancing the economic and social needs of the residents of Utah through a coordinated program. The Utah Plan (2013) incorporates and enhances the earlier efforts of LWGs to protect sage-grouse and their habitats.

The CBCP LWGs conservation plans encompass the historical range of greater sage-grouse in Utah as identified in the Strategic Management Plan for Sage-grouse (UDWR 2002, 2009) and the Utah Plan (2013). The CBCP has provided long-term support to ensure the LWG administrative needs are met. Since inception, the CBCP has been financially supported by UDWR, Utah State University Extension, the Jack H. Berryman Institute, private landowners, public and private natural resources management and wildlife conservation agencies and organizations. Implementation of the Utah Plan (2013) will require enhanced communication and cooperative efforts among local, state, and federal agencies, working in concert with private interests. In addition to participating as active contributors to the Utah planning process, the LWGs continue to implement their local sage-grouse conservation plans (Messmer *et al.* 2014).

The CBCP also have developed and released an *app* based on the publication entitled "Sage-grouse Habitat in Utah: A Guide For Landowners and Managers" (Utah CBCP 2011). Over 5,000 copies of the publication have been distributed.[8] The app is the first of its kind, and although developed in Utah, is applicable throughout the sage-grouse range, which includes 11 western states and two Canadian provinces.[9] The app provides managers and landowners with immediate and pertinent information about sagebrush management and sage-grouse habitat needs and can be accessed from anywhere in the field. It can assist in planning management actions to help conserve the sage-grouse population. The app will help landowners, federal and state partners better recognize characteristics of favorable sage-grouse habitat and assist them in developing projects to benefit species conservation across its range.

The Utah Plan (2013) endorsed and incorporated the CBCP LWG process, network, education and outreach efforts, and local conservation plans. The Utah Plan (2013) provided additional guidance and support to continue area-specific management programs focused on maintaining, improving, and restoring local sage-grouse populations and their habitats. The LWGs now

[8] http://utahcbcp.org/files/uploads/LandownerGuideSageGrouse.pdf

[9] "Sage-grouse Habitat in Utah" is free of charge and is available in Android and iOS formats.

operate under the umbrella of the Utah Plan (2013). The LWG plans are based on research conducted by USU, Brigham Young University, UDWR, and the U.S. Forest Service (USFS). This research continues to provide the scientific basis for the Utah Plan.

THE SCIENTIFIC BASIS FOR UTAH'S SAGE-GROUSE MANAGEMENT AREAS (SGMAS)

The Sage-grouse Management Areas (SGMAs) represent the best opportunity for high-value, focused conservation efforts for the species in Utah. They were formulated to reflect the biological and geographical realities of areas currently occupied by a population or populations of sage-grouse. They are specifically designed, using Utah's greater sage-grouse data and research, to address known and documented seasonal movements and uses by Utah sage-grouse.

The USFWS has emphasized the need to focus conservation efforts on protecting and enhancing the priority habitats as the essential mechanism for species conservation (USFWS 2013). In addition, better knowledge of sage-grouse seasonal movements for a species is essential to conservation planning and implementation efforts (USFWS 2013). Generally, sage-grouse seasonal habitats have been defined using three broad categories: breeding, summer, and winter. Breeding habitats consist of areas where pre-laying, lekking, nesting, and early brooding activities occur; summer habitat consist primarily of late brooding areas; and winter habitat occurs in areas where sagebrush is available above the snow throughout the winter for food and cover (Connelly *et al.* 2000). Some populations may be considered non-migratory, using a specific landscape to meet all their seasonal habitat requirements while other populations may migrate > 50 km between seasonal habitats. Within populations, individuals may also exhibit unique movement strategies between seasonal habitats (Connelly *et al.* 2000, Leonard *et al.* 2000, Fedy *et al.* 2012, Reinhart *et al.* 2013).

The Utah Plan (2013) synthesized UDWR sage-grouse lek location data and seasonal movement information, obtained by two decades of research to delineate eleven SGMAs. This approach, based on the best available research and data, recognized and accepted current land uses and identified potential future uses which may conflict with species conservation (Utah Plan 2013, Dahlgren *et al.* 2015a, In Press).

Utah's SGMAs encompass > 90 percent of Utah breeding populations, seasonal movements, and the landscapes that provide the greatest potential to increase sage-grouse usable space through habitat protection and enhancements (Dahlgren *et al.* 2015a, In Press). The SGMAs incorporated sage-grouse radio-telemetry location data collected from 13 study areas from 1998 to 2013 to determine seasonal movements across populations. Similar to other studies (Doherty *et al.* 2011, Fedy *et al.* 2012), the Utah Plan (2013) considered all available sage-grouse seasonal habitat-use data.[10]

[10] These data indicated sage-grouse nearest lek to nesting, summer, and winter locations averaged 2.20 km (90^{th} percentile = 5.06 km), 3.39 km (90^{th} percentile = 8.45 km), and 3.76 km (90^{th} percentile = 7.15 km), respectively. Seasonal movements from nest to summer, nest to winter, and summer to winter locations averaged 5.55 km (90^{th} percentile = 13.09 km), 11.93 km (90^{th} percentile =26.68 km), and 14.79 km (90^{th} percentile = 30.75 km), respectively. Generally, distance from lek or seasonal ranges did not differ by male or female age class, or by sex. Successful nests were located slightly farther on average from leks than unsuccessful nests (x successful = 2.34 km, SE = 0.089, x unsuccessful = 2.04 km, SE = 0.090).

Seasonal Movement

The seasonal movements of Utah's sage-grouse populations reflect availability of habitat space. Populations occupying smaller isolated habitats moved shorter distances than populations occupying larger contiguous habitats, which are more typical of habitats in other states (Beck *et al.* 2003, Schroeder *et al.* 2004). The seasonal movement distances for Utah sage-grouse populations were generally less than those reported range-wide but were reflective of localized and the naturally non-contiguous nature of many sagebrush habitats in the southern Great Basin and Colorado Plateau. Fedy *et al.* (2012) reported nest to summer range movement averages of 8.07 km and a 90th percentile of 19.04 km for sage-grouse populations in Wyoming. For the Utah populations studied, the same movements averaged 5.88 km and a 90th percentile of 13.65 km.

Fedy *et al.* (2012) reported larger maximum distances moved between seasonal locations for the Wyoming populations studied. In Utah, nest to winter and summer to winter distances were less (11.6 km and 14.8 km, respectively). Fedy *et al.* (2012) reported averages of 14.4 km and 17.3 km, respectively. These results validate the emphasis of the Utah Plan on habitat objectives designed to increasing available and usable habitat space. Usable space may be more important than habitat quality in regulating wildlife population levels (Guthery 1997).

Coverage of Habitat within the Utah Plan

Based on telemetry-data, Utah's SGMAs encompassed 88%, 80%, and 89% of all nest, summer, and winter locations, respectively. When weighted by the sum of maximum males counted for each lek within each study area during the years with radio-marked sage-grouse, the percentages increased to 97%, 95%, and 96% of nest, summer, and winter locations, respectively. Based on this analysis, Utah's SGMAs achieved the COT report recommendations of targeting conservation efforts in priority areas (USFWS 2013). For comparison, Fedy *et al*. (2012) reported that 85% of summer and 65% of winter locations are within Wyoming's core area boundaries. If the sage-grouse habitat restoration objectives in the Utah Plan are met, usable space within SGMAs will increase over time benefitting the state's sage-grouse populations.

The Utah Plan (2013) was developed to protect habitat and associated populations of sage-grouse by implementing the strategic landscape planning principles included in the COT report. The Utah Plan designates priority areas for sage-grouse conservation (USFWS 2013). Using a strategic landscape management approach optimizes species conservation planning benefits by considering investment tradeoffs which favors areas that are likely to yield the greatest conservation returns over areas that have limited or compromised potential to respond positively to management actions (Margules and Pressey 2000, Carvell *et al.* 2011). These distinctions in tradeoffs across landscapes are becoming increasingly paramount to the success of future conservation efforts in the face of limited resources (Williams *et al.* 2004).

The Utah Plan (2013) further recognizes that sage-grouse population in the Rich County area of Utah are connected to populations in eastern Idaho and western Wyoming (Dettenmaier *et al.* 2012, Dettenmaier and Messmer 2013, 2014), populations in Box Elder, Tooele, Juab, and

Beaver Counties are connected to populations in southern Idaho and Nevada (Reinhart *et al.* 2013, Robinson and Messmer 2013), and populations in the Uintah and Daggett County areas are connected to populations in Wyoming and Colorado (Breidinger *et al.* 2013).

Sage-grouse conservation is achievable because sage-grouse are wide spread throughout western North America and large intact sagebrush communities still exist (Connelly *et al*. 2011a). These results provide a framework for more certainty for future sage-grouse management actions in Utah. However, because sage-grouse population growth rates are relatively slow compared to other gallinaceous birds (Dahlgren 2009, Taylor *et al.* 2012) and sagebrush systems respond over long time frames to restoration efforts, it may take several breeding cycles before management effects are noticeable (Pyke 2011, Messmer 2013).

Increasing Useable Space for Sage-grouse

Sage-grouse occupied habitat in Utah largely reflects the topography and geography of Utah. The geography is characterized by mountainous terrain, separated by broad valleys in the Great Basin, and by deeply incised canyons in the Colorado Plateau (West 1983). Sage-grouse habitat may be found in intact blocks or natural fragments in the Great Basin, or in disconnected "islands" of habitat in the Colorado Plateau (Perkins 2010).

The Utah Plan (2013) has placed emphasis on increasing usable space for sage-grouse in naturally fragmented habitat as a means of increasing both production and connectivity. The reduction and removal of juniper (*Juniperus* spp.) and pinyon pine (*Pinus edulis*; PJ) encroachment in SGMAs where the sagebrush and herbaceous understory is relatively intact may provide the greatest potential to create and enhance sage-grouse habitat in Utah.

Conifer encroachment into sage-grouse habitat has been identified as a threat to sage-grouse populations (Miller *et al.* 2011, Baruch-Mordo *et al*. 2013, USFWS 2013). Recent research suggests sage-grouse will use areas within SGMA where PJ has been removed within a short period of time (< 1 to 3 years) post-treatment, especially if the treatment site has sagebrush remaining in the understory, mesic areas nearby, and the site is near existing sage-grouse use areas (Frey *et al.* 2013, Cook and Messmer 2015, Under Review). Field observations in 2015 have documented a sage-grouse female successful nesting in areas where conifer removal projects were being conducted. The female nested under sagebrush in an area where the conifer canopy have been removed by a bullhog (Sandford *et al.* 2015, Under Review). In the four years previous to the bullhog treatment, sage-grouse use had never been documented in the area during on-going habitat use studies where we were monitoring radio-marked birds. These data and observations validate that the Utah Plan's effort to increase usable space through PJ removal projects has the potential to benefit sage-grouse populations in Utah.

Enhancing Sage-grouse Brood-rearing Habitats

Sage-grouse have the lowest reproductive rate of any North American game bird. Thus it is believed populations may be less able to recover from population declines as quickly as those of most other game birds (Connelly *et al.* 2011b). However, recovery rate may also be affected by favorable environment conditions (Guttery *et al*. 2013, Caudill *et al.* 2014a). Research conducted on Parker Mountain SGMA has provided new knowledge regarding this relationship.

Parker Mountain is located in south-central Utah in Garfield, Piute, and Wayne counties. Parker Mountain is approximately 107,437 ha (265,584 acres) and is managed by private, state, and federal entities. The Parker Mountain Adaptive Resources Management Local Working Group (PARM) was organized in 1997 with one central goal – they wanted to "grow more grouse" to mitigate the risks of the species being listed. Although concerns about declining sage-grouse populations led to the formation of PARM, the group's commitment to sustaining their community and it's natural resources through research and management has been the driving force keeping the group working together (PARM 2006, Messmer *et al.* 2014).

In the past decade, PARM's efforts have increased sage-grouse populations from an estimated 125 males counted on leks in 1996 to over 1,400 in 2007. The habitat work conducted to "grow more grouse" has been accomplished largely with funding provided through conservation provisions of USDA's Farm Bill. The PARM has implemented a long-term adaptive resource management habitat monitoring and research program to evaluate the effects of management actions on greater sage-grouse and other wildlife populations. This research is part of a long-term database that has provided new insights regarding the effects of management actions on sage-grouse vital rates and ultimately recruitment in Utah and range-wide. These contributions are discussed below.

Increasing Chick Survival

Obtaining timely and accurate assessment of sage-grouse chick survival and recruitment is an important component of species management and conservation (Connelly *et al.* 2011b). Dahlgren *et al.* (2006) studied the effects of reducing sagebrush canopy cover to enhance forb availability for sage-grouse chicks in the Parker Mountain SGMA. Low chick survival was identified as major factor limiting recruitment (PARM 2006). Dahlgren *et al.* (2006) evaluated the effects of two mechanical (Dixie harrow and Lawson aerator) treatments and one chemical (Tebuthiuron) treatment on sage-grouse use of brood-rearing habitats. To conduct this experiment, Dahlgren *et al*. (2006) identified 19 40.5-ha plots that exhibited 40% mountain big sagebrush (*A. tridentata vaseyana*) canopy cover and randomly assigned 16 as treatment or controls (4 replicates each). The Tebuthiuron and Dixie-harrow-treated plots exhibited increased forb cover than the control plots post-treatment. Sage-grouse brood use was higher in Tebuthiuron than control plots and the increased use was attributed to increased herbaceous cover, particularly forbs. In all plots, sage-grouse use was greatest within 10 m of the edge of the treatments where adjacent sagebrush cover was still available. Although the treatments studied resulted in the plots achieving sage-grouse brooding-rearing habitat guidelines, they recommended caution in applying these observations at lower elevations, in areas with less annual precipitation or a different subspecies of big sagebrush.

Based on these results, PARM implemented a long-term management program where up to 500 acres (200 ha) of sage-grouse breeding habitat where sagebrush cover exceeded 40 % canopy cover were treated annually with low rate applications of Tebuthiuron. Utah State University in partnership with PARM, UDWR, BLM, and the USFS continued to monitor and sage-grouse populations in response to the treatments and also evaluated the survey methodology used to determine sage-grouse response.

Dahlgren *et al.* (2010a) compared the effectiveness of walking, spotlight, and pointing-dog surveys to detect radio-marked and unmarked chicks within broods of radio-marked hens in Utah. Walking surveys detected 72% of marked chicks, while spotlight and pointing-dog surveys detected 100% and 96%, respectively. They found no difference between spotlight and pointing-dog counts in number of marked and unmarked chicks detected. Spotlight counts were slightly more time efficient than pointing-dog surveys. However, spotlight surveys were nocturnal searches and perceived to be more technically arduous than diurnal pointing-dog surveys. They suggested pointing-dog surveys may offer greater utility in terms of area searched per unit effort and an increased ability to detect unmarked hens and broods.

Using the above techniques, Dahlgren *et al*. (2010b) examined factors that influenced chick survival. They radio-marked 1- to 2-day-old sage-grouse chicks in 2005–2006 on Parker Mountain and monitored their survival to 42 days. They then modeled effects of year, hatch date, chick age, brood-female age, brood-mixing, and arthropod abundance on chick survival. Their best model revealed an average survival estimate of 0.50 days to 42 days, which was the highest level ever documented range wide for the species.

Brood-mixing (chicks leaving natal brood to join with other non-natal broods) occurred in 21% (31/146) of chicks and 43% (18/42) of broods they studied. Moreover, yearling females had more chicks leave their broods than did adults. They found that survival may be higher among chicks that switch broods compared to those that stayed with their natal mother until fledging. Thus, brood-mixing may be an adaptive strategy leading to increased sage-grouse chick survival and higher productivity, especially among chicks born to yearling females. Their findings also indicated that arthropod abundance may be an important driver of chick survival, particularly during the early brood-rearing period and, therefore, sage-grouse populations may benefit from a management strategy that attempts to increase arthropod abundance via brood habitat management (Dahlgren *et al*. 2006).

Guttery *et al.* (2013) refined this research by studying the effects of landscape scale environmental variation on sage-grouse chick survival. Effective long-term wildlife conservation planning for a species must be guided by information about population vital rates at multiple scales (Connelly *et al.* 2011b). Sage-grouse population growth rates appear to be particularly sensitive to hen and chick survival rates (Taylor *et al.* 2012). While considerable information on hen survival exists, there is limited information about chick survival at the population level.

Guttery *et al*. (2013) analyzed sage-grouse chick survival rates from the Parker Mountain SGMA and south central Idaho across 9 years to further determine what landscape variables may affect survival and ultimately recruitment. They analyzed the effects of 3 groups of related landscape-scale covariates (climate, drought, and phenology of vegetation greenness). Models with phenological change in greenness (NDVI) performed poorly, possibly because seasonal variation in forb and grass production was being being masked by sagebrush canopy. The top drought model resulted in substantial improvement in model fit relative to the base model and indicated that chick survival was negatively associated with winter drought. These results suggest possible effects of climate variability on sage-grouse chick survival if winter droughts become a common occurrence.

Juvenile Sage-grouse Survival

Little information has been published on mortality of juvenile sage-grouse or the level of production necessary to maintain a stable population. Among western states, long-term juvenile to hen ratios have varied from 1.40 to 2.96 juveniles per hen in the fall. In recent years, this ratio has declined to 1.21 to 2.19 juveniles per hen (Connelly and Braun 1997). It has been reported that at least 2.25 juveniles per hen should be present in the fall population for stable to increasing sage-grouse populations (Connelly and Braun 1997, Connelly *et al.* 2000). Caudill *et al.* (2013) and Caudill *et al*. (2014) provided new range wide insights regarding the role of juvenile sage-grouse ecology.

Sage-grouse are entirely dependent on sagebrush for food and cover during winter (see Connelly *et al.* 2011b for review). Thus the loss or fragmentation of important wintering areas could have a disproportionate affect on population size. To study the juvenile sage-grouse winter habitat-use, Caudill *et al.* (2013) radio-marked and monitored 91 juvenile sage-grouse in south central Utah from 2008 to 2010 (Parker Mountain SGMA). Thirty-four individuals survived to winter (January to March) and were used to evaluate winter habitat use.

They found that juvenile sage-grouse used winter habitats characterized by 0 to 5% slopes regardless of aspect and slopes 5 to 15% with south-to-west facing aspects. The importance of high slope (5 to 15%) wintering habitats has not been previously documented in the sage-grouse literature. Most winter use was on a small proportion (3%; 2,910 ha) of available habitat. These important wintering habitats may not be readily identifiable in typical years, and consequently, due to their elevation, may be more susceptible to land management treatments focused on increasing early season livestock or big game winter forage, rendering them unsuitable for winter use by sage-grouse. Prior to implementing land management treatments in lower elevation sagebrush sites with slopes ≤5% regardless of aspect and slopes 5 to 15% south to west in aspect, managers should consider the potential effects of such treatments on the availability of suitable winter habitat to mitigate against winters with above-normal snowfall. This information has been incorporated in the Utah Plan (2013) and is the basis of an ongoing research effort coordinated by USU to model general and essential winter habitats.

Adult sage-grouse females and juvenile survival has been reported to influence population growth rates (Dahlgren *et al.* 2010b, Taylor *et al.* 2012). However, assessing the sensitivity of population growth rates to variability in juvenile survival has proven difficult because of limited information concerning this potentially important demographic rate. Sage-grouse survival rates are commonly assessed using necklace-type radio transmitters. Recent technological advances have lead to increased interest in the deployment of dorsally mounted global positioning system (GPS) transmitters for studying sage-grouse ecology. However, the use of dorsally mounted transmitters has not been thoroughly evaluated for sage-grouse, leading to concern that birds fitted with these transmitters may experience differential mortality rates.

Caudill *et al.* (2014a) also evaluated the effect of transmitter positioning (dorsal vs. necklace) on juvenile sage-grouse survival using a controlled experimental design with necklace-style and suture-backpack very high frequency (VHF) transmitters. They monitored 91 juveniles captured in the Parker SGMA from 2008 to 2010. Nineteen females were equipped with backpacks, 14 males with backpacks, 39 females with necklaces, and 19 males with necklaces. They used Program MARK to analyze juvenile survival data. Although effects were only marginally significant from a statistical perspective, sex and transmitter type had biologically meaningful impacts on survival. Dorsally mounted transmitters negatively affected daily survival. Temporal variation in juvenile sage-grouse daily survival was best described by a quadratic trend in time, where daily survival was lowest in late September and was high overwinter. An interaction between the quadratic trend in time and year resulted in the low point of daily survival shifting within the season between years (27 vs. 17 Sep for 2008 and 2009, respectively). Overall (15 Aug–31 Mar) derived survival ranged 0.42–0.62 for females and 0.23–0.44 for males.

For all years pooled, the probability of death due to predation was 0.73, reported harvest was 0.16, unreported harvest was 0.09, and other undetermined factors were 0.02. They reported 0% and 6.8% crippling loss (from hunting) in 2008 and 2009, respectively. Caudill *et al.* (2014a) recommended the adoption of harvest management strategies that attempt to shift harvest away from juveniles and incorporate crippling rates. In addition, they recommended that future survival studies on juvenile sage-grouse should use caution if implementing dorsally mounted transmitters because of the potential for experimental bias. This has implications of studies that use rump mounted global positioning system (GPS) radio-collars to assess sage-grouse survival rates. The use of GPS radio-collars without comparable vital rate data collected by using VHF radio-collars could bias sage-grouse survival rate estimates.

Sage-grouse Female Reproduction Costs and Climate

Research on long-lived *iteroparous* species has shown that reproductive success may increase with age until the onset of senescence and that prior reproductive success may influence current reproductive success. These complex reproductive dynamics can complicate conservation strategies, especially for harvested species. Further complicating the matter is the fact that most studies of reproductive costs are only able to evaluate a single measure of reproductive effort.

Caudill *et al.* (2014b) evaluated the effects of climatic variation and reproductive trade-offs on multiple sage-grouse reproductive vital rates. Based on over a decade of field observations obtained from sage-grouse inhabiting the Parker Mountain SGMA, they hypothesized that reproduction was influenced by previous reproductive success. They studied hen reproductive activity from sage-grouse radio-marked and monitored from 1998–2010 on the SGMA to assess effects of climate and previous reproductive success on subsequent reproductive success. Neither nest initiation nor clutch size were affected by climatic variables or previous reproductive success. However, they found that both nest and brood success were affected by climatic variation and previous reproductive success. Nest success was highest in years with high spring snowpack, and was negatively related to previous brood success. Brood success was positively influenced by moisture in April, negatively associated with previous nest success, and positively influenced by previous brood success. Both positive and negative effects of previous reproduction on current year reproduction were reported suggesting high levels of individual heterogeneity in female reproductive output (Dahlgren *et al.* 2010b). Their results supported previous research in indicating that climatic variability may have significant negative impacts on reproductive rates (Guttery *et al.* 2013). These results support the Utah Plan objectives of increasing the sage-grouse habitat base. The creation of a larger habitat base will increase the potential for increased production and recruitment in years when climatic conditions are favorable (Dahlgren *et al*. 2010b, Guttery *et al.* 2013, Caudill *et al.* 2014b).

ACTIVE MANAGEMENT TO ADDRESS THREATS

The Utah Plan (2013) protects high-quality habitat, enhances impaired habitat, and restores converted habitat for the portion of the range-wide sage-grouse population inhabiting Utah by eliminating USFWS and State identified species conservation threats. In addition to Utah efforts, the Bureau of Land Management (BLM), the U.S. Forest Service (USFS), and the other western states with sage-grouse populations and habitats, have initiated planning and other actions designed to mitigate the identified threats, protect important sagebrush habitats, and develop adequate regulatory mechanisms to eliminate the need for a listing under the ESA. The science used to develop the Utah Plan (2013) is the basis of the BLM and USFS planning processes in the state. The following are elements of Utah's active management to address threats to greater sage-grouse.

Sage-grouse Hunting in Utah

Although hunting was not cited as a high priority threat by the USFWS (2010), stakeholders question why state wildlife agencies continue to allow sage-grouse hunting given the status of the species (Belton et al. 2009, UDWR 2009). Limited hunting of sage-grouse is currently allowed by permit only in the Box Elder, Rich-Morgan-Summit, Uintah, and Parker Mountain-Emery SGMAs. These SGMAs have the largest stable populations. Hunt quotas are determined annually based on very conservative estimates, and are based on criteria found in the Utah Sage-grouse Strategic Management Plan (UDWR 2009). Decreases in population in any particular year due to natural or human caused events, will lead to a reduced number of hunting permits or cancellation of the hunt for the year.

Fees collected from hunters are typically expended only for the benefit of species that is hunted. If sage-grouse were not hunted, expenditures from that funding source for the species' benefit would cease. Sage-grouse hunting also maintains the interest of the sportsman's community by continuing a viable hunting program and allows for collecting scientific data regarding recruitment from the birds harvested (UDWR 2009, Utah Plan 2013).

In 2008, the demand for sage-grouse hunting permits in Utah exceeded their availability, raising questions about why hunters choose to pursue this species. Guttery *et al.* (2015) hypothesized that the pending ESA listing decision increased hunter demand for permits. They surveyed randomly selected hunters who obtained permits to hunt sage-grouse in Utah in 2008-2010 (n = 838) to determine their motivations for hunting sage-grouse and determinants of hunter satisfaction. The most commonly reported reasons for hunting sage-grouse were to spend time with family, for tradition, and meat. Although the potential ESA listing was not a major motivational factor in 2009 or 2010, the percentage of respondents selecting this option did increase by 7%. Hunter awareness of the ESA listing status increased by 18% during this period.

Sage-grouse hunter participation rates declined by 1.63% between 2008 and 2009 continuing a trend documented by UDWR since 2004 (UDWR, unpublished data). However, participation rates experienced an approximate 5% increase between 2009 and 2010.

Guttery *et al*. (2015) recommended that conservation strategies for sage-grouse must carefully weigh the social and biological implications of hunting. Because of the role of long-lived adult females in brood-mixing, and ultimately production (Dahlgren *et al.* 2010b), the UDWR delayed the opening of the sage-grouse hunt reduce the harvest on adult females. This change allowed for increased amalgamation of the individual broods into larger flocks to reduce adult brood female risks to harvest (Dahlgren 2009). Guttery *et al.* (2015) concluded the adaptive harvest regulations adopted by UDWR that link sage-grouse hunting opportunities to annually estimated population sizes and female reproductive contributions constitute an effective and conservative harvest management strategy based on the best available science.

Tracking Population Response to Management Using Lek Counts

Obtaining valid population estimates is essential to understanding the effects of management and conservation strategies on population trajectories (Connelly *et al.* 2004). The Utah Plan (2013) proposes specific strategies to protect, maintain, improve, and enhance sage-grouse populations and habitats within the established SGMAs. Unlike other state plans, the Utah Plan (2013) establishes specific annual population and habitat objectives. Specifically for sage-grouse populations, the Utah Plan proposes to sustain an average male lek count of 4100 males (based on a ten-year rolling average on a minimum of 200 monitored leks) and increase the population of males to an average of 5000 (based on the same ten-year rolling average on a minimum of 200 monitored leks) within the established SGMAs.

Leks are the center of breeding activity for sage-grouse. Male sage-grouse begin to congregate on leks in late February/early March and perform a ritualized courtship display. Courtship displays are strongly correlated to pre and early dawn hours and quickly wane within a couple of hours following sunrise (Connelly *et al.* 2011b, Guttery *et al.* 2011). Females are attracted to leks by the male courtship displays and mating is thought to primarily occur on the lek. Lek attendance may continue as late as early June, but typically peaks during April in Utah (UDWR 2009, Guttery *et al.* 2011).

As sage-grouse populations decline, the number of males attending leks may decline or the use of some leks may be discontinued. Likewise, as populations increase, male attendance may increase and/or new leks may be established or old leks reoccupied (Connelly *et al.* 2011b). There is little or no evidence that suggests lek habitat is limiting (Schroeder *et al.* 1999). Additional lek habitat can be created if needed, but does not guarantee that sage-grouse males will utilize the created lek habitat.

Count indices are often used to monitor and assess wildlife population status (Bibby *et al.* 1992, Pollock et al. 2002). Lek counts have been widely used as an index for sage-grouse population change and to guide management decisions (Connelly *et al*. 2004, UDWR 2009, Garton *et al.* 2011). Counts of male sage-grouse attending leks during the breeding season have also been used to estimate the breeding population size by assuming a detection probability and sex ratio. In the latter case, managers often assume a 2:1 female biased ratio. However, this sex ratio has not been validated and may result in biased population estimates. The UDWR had assumed a 75% detection rate for male sage-grouse on leks and a 2:1 female biased sex ratio (UDWR 2002, 2009).

Guttery *et al.* (2011) evaluated the validity of using lek-counts to estimate populations in Utah. They concluded that the standard UDWR counts which are used to monitor most sage-grouse leks may omit, on average, 2 males. Additionally, they found that only 56% of all available males were actually attending leks at any given time. Their estimates of lek attendance were similar to the findings of Walsh et al. (2004) but well below the estimates provided by Emmons and Braun (1984). Their results demonstrated that male lek attendance rates fluctuate throughout the breeding season, but typically peaked at or before sunrise. As such, they recommended that lek counts should be conducted as early as possible to obtain the most accurate counts. This may result in fewer leks being counted per morning but will provide more representative data.

Guttery *et al.* (2013b) also evaluated sex ratios at hatch, 42 days of age, and at harvest to determine if sex ratios were biased for sage-grouse in Utah. Sex ratios at hatch and at 42 days of age did not differ from parity. Harvest data suggested that sage-grouse may exhibit a slight female-biased sex ratio (1.458:1) in the fall. The Utah Plan (2013) has incorporated this new information into sage-grouse population estimates based on lek count data.

The validity of lek counts for monitoring changes in population numbers remains suspect (Walsh *et al*. 2004, Guttery *et al.* 2011). However, their utility as a measure of population production has never been evaluated. Dahlgren *et al.* (2015b, Under Review) evaluated using standard lek count protocols which followed range wide guidelines (Emmons and Braun 1984, Connelly *et al.* 2003) to determine if they reflected lambda. They concluded that male-based leks counts of sage-grouse can be an effective index to overall population change. These results have range wide implications as they provide a basis for states to track sage-grouse population responses to management and conservation actions.

Translocations to Augment Declining Populations

Translocations have been recommended to reestablish, augment, and sustain genetic diversity in declining wildlife populations, including sage-grouse (Reese and Connelly 1997). Utah has experimented with sage-grouse translocations intended as conservation efforts to establish and/or enhance existing populations. The sage-grouse populations on Wildcat and Horn Mountains (Carbon SGMA) provides an example of a successful translocation. From 1987-1990 15 males and 35 hens with juveniles were released in the area. The populations still exist with 27 strutting males observed in 2008 (Perkins 2010).

The Strawberry Valley SGMA in central Utah provided a dramatic example of the decline of sage-grouse in Utah. Griner (1939) estimated that 3,000-4,000 sage-grouse inhabited this high mountain valley in the 1930s. Bunnell (2000) estimated the Strawberry Valley SGMA population at 250-350 sage-grouse in 1999, representing a population decrease of 88-94%. Most of this decline was attributed to anthropogenic causes (roads, Strawberry Reservoir, non-native predators, and reductions in habitat quantity and quality). The population in Strawberry Valley SGMA is now estimated at > 500 breeding adults. This increase is attributed to the success of translocation efforts, habitat improvements, and predator control (Baxter *et al.* 2007, Baxter *et al.*

2008, Baxter *et al*. 2013). Characteristics common to successful sage-grouse translocations include suitable contiguous sagebrush habitats enveloped by geomorphic barriers, a residual resident population, pre-nesting releases, and active mammalian predator management (Baxter *et al.* 2008, Baxter *et al.* 2013).

Because of increasing habitat fragmentation, UDWR wildlife managers were interested in learning if translocations can be used to sustain smaller meta-populations that inhabit remote landscapes that exhibited suitable habitat but lacked geomorphic barriers. From 2009-2010, Gruber (2012) compared vital rates and behaviors of 60 translocated and 15 resident radio-marked female sage-grouse and their broods on Anthro Mountain, in the Ashley National Forest of northwest Utah. Translocated birds were released within 200 m of an active lek on Anthro Mountain. Anthro Mountain consists of 2,500 ha of suitable but non-contiguous breeding habitat ranging in elevation of 2,400-2,800 m. The sage-grouse that were translocated were captured on the Parker Mountain SGMA. The Parker birds were selected as the source population for the translocation because the population was robust and stable, ≥ 100 km from the release site, and was genetically compatible to Anthro Mountain sage-grouse (Briedinger *et al.* 2013). The source area also exhibited topography and elevations similar to Anthro Mountain.

Adult survival, nest success, and brood success estimates for both resident and translocated birds varied annually, but were lower than range wide averages (Gruber 2012, Gruber *et al*. 2015, Under Review). Adult survival was higher in 2010 than 2009 and survival differed among resident status (i.e., resident, newly translocated, and previously translocated). Nest success was higher for resident than translocated birds and was positively related to grass height. In 2009 and 2010, chick survival to day 50 was higher for chicks of resident than translocated females. Chick survival for both groups was positively related to grass cover and grass height. Area of occupancy for translocated (45 km$^{2)}$ and resident females (40 km^2) overlapped by 68%.

Although the translocated birds were genetically similar to the resident birds (Breidinger *et al.* 2013), and exhibited similar behavior patterns, the low overall vital rates for both groups suggested that managers may need to fully consider the potential interaction of vegetation structure, seasonal habitat juxtaposition, and their potential relationship to predation when planning future translocations to augment isolated and remote sage-grouse populations that occupy space limited and fragmented habitats.

Predation Management

Increased predation has been identified as a population threat in several SGMAs. This threat has primarily been associated with increased populations of corvids (primarily ravens) and emergence of non-native canids (Baxter *et al.* 2007, Baxter *et al.* 2013, Robinson and Messmer 2013). While predator control has not been recognized as a long-term solution to a general range-wide decline in populations of greater sage-grouse, it may be an effective tool to increase survival of specific populations (USFWS 2010, Hagen *et al*. 2011, Baxter *et al.* 2013).

Baxter *et al.* (2013) studied the survival rates of sage-grouse that had been translocated to the Strawberry Valley SGMA over a 13 year period. Their objectives were to estimate seasonal and annual survival rates for resident and translocated sage-grouse and identify environmental and behavioral factors associated with survival to include mammalian predator control. They captured and radio-collared 535 individual sage-grouse (male and female, resident and translocated). Their top model of survival, which accounted for 22% of the AIC*c* weight, included 3 seasons that varied by year where rates were influenced by residency, sex, and whether a female initiated a nest. A group-level covariate for the number of canids killed each year was supported as this variable improved model fit. Annual estimates of survival for females ranged between 28% and 84% depending on year and translocation source. Survival was consistently highest during the fall–winter months with a mean monthly survival rate of 0.97 (95% CI = 0.96–0.98). They suggested managers consider enhancing nesting habitat, translocating sage-grouse, and controlling predators to improve survival rates of sage-grouse (Baxter *et al.* 2007, Baxter *et al.* 2013).

Predation is often tied to habitat quality, particularly in areas where an interface exists between human disturbance and the remaining habitat (Utah Plan 2013). Many of Utah's sage-grouse populations inhabit naturally-fragmented habitats. Robinson and Messmer (2013) studied sage-grouse populations that inhabit the Sheeprock and Ibaph SGMAs in Utah's West Desert. These areas are geographically separated by the Great Salt Lake. Livestock grazing by domestic cattle was the dominate land use, and mammalian predator control for livestock protection was conducted in both SGMAs. However corvid control was conducted only in the Sheeprock SGMA. During the study, they also documented 6 new leks that had not been previously surveyed.

Habitat structure was similar at brood-rearing and random sites for both SGMAs. They also reported higher nest and brood success and the ratio of chicks per successful brood for both populations in 2005 than 2006. Spring precipitation in 2005 was twice the 30-year average following a 5 year drought. However, chick recruitment estimates for both populations regardless of year were lower than reported in the published literature. Adult sage-grouse survival rate estimates in Sheeprock and Ibaph SGMAs were lower and higher, respectively, than published reports indicated. They believed these observations reflected difference in meso-predators communities.

Habitat Management, Arthropods, and Sage-grouse Production

Arthropods are an important component of early brood-rearing habitat (Patterson 1952). Ants (*Hymenoptera*) and beetles (*Coleoptera*) are often the most important groups of arthropods eaten by young sage-grouse (Johnson and Boyce 1990, Gregg et al. 1997, Gregg 2006). Braun et al. (1977) suggested that low-quality early brood-rearing habitat was related to declines in sage-grouse population recruitment. Thompson et al. (2006) found sage-grouse productivity was positively associated with arthropods (medium-sized *Hymenoptera* and *Coleoptera*) and herbaceous components of sagebrush habitats. Insect abundance may be related to plant diversity within sagebrush systems (especially intact sagebrush communities) but may be more highly associated with annual productivity (moisture dependent) within specific habitats (Wenninger and Inouye 2008). However, the direct relationship between insect availability and sage-grouse chick survival in a natural setting is poorly understood.

Robinson and Messmer (2013) reported that increased precipitation in 2005 in the Sheeprock and Ibaph SGMAs in Utah's West Desert contributed to the subsequent increase in forb production. They hypothesized that increased forb production translated into an increase in number and volume of arthropods collected in 2005 vs 2006. During both years of their study, the numbers and volumes of arthropods collected were also greater at brood than in random sites. Potts (1986) and Drut et al. (1994) also reported an increase in arthropod abundance with forb cover. This increase in forbs and arthropods may have contributed to the higher number of chicks per successful brood in 2005, compared to 2006 (Robinson and Messmer 2013).

Although Dahlgren *et al*. (2010b) reported no direct relationship between arthropods and vegetation measurements, they suggested that arthropod abundance in the immediate vicinity of broods may have influenced chick survival during the early brood-rearing period for sage-grouse inhabiting the Parker Mountain SGMA. This observation was consistent with findings for captive reared sage-grouse chicks (Johnson and Boyce 1990). *Fischer et al.* (1996) also found that sage-grouse broods selected specific habitat with higher abundance of *Hymenoptera* than random sites.

Grazing and Sagebrush Treatments: Consequences for Winter Habitat

Conservation of sagebrush communities remains is one of the most difficult and pressing concerns in western North America (Connelly *et al*. 2011c). Many of these communities are grazed by domestic livestock. The implementation of management experiments of sufficient scale to evaluate sage-grouse responses to range management practices remains problematic. However, long-term case studies across large landscapes can provide important insights regarding sage-grouse responses to livestock grazing and related range management practices.

Dahlgren *et al.* (2015c) analyzed 24 years of sage-grouse population data collected across 3 large landscapes in northern Utah and southwestern Wyoming to assess sage-grouse responses to corresponding land management in the Rich SGMA. During this period sage-grouse populations on Deseret Land and Livestock (DLL), a privately-owned ranch, increased compared to surrounding populations that inhabited BLM allotments as small scale sagebrush removal treatments (< 200 ha) were being conducted within a prescriptive grazing management framework (Danvir *et al.* 2005). The increased sage-grouse populations were maintained for nearly 15 years where after they declined to approximate levels reported in surrounding populations. The declines were attributed to prolonged, adverse winter weather conditions accompanied increased snow accumulations.

The authors attributed the DLL sage-grouse population increases to the small scale sagebrush treatments which translated into larger broods than recorded on adjacent BLM grazing allotments. However, the small annual reductions in sagebrush may have culminated in reduced availability of sagebrush winter cover. During the winter sage-grouse use sagebrush for both food and cover, with specific use areas selected based on sagebrush type, nutrition, availability of sagebrush above the snow (Schroeder et al. 1999, Remington and Braun 1985, Thacker *et al.* 2012, Frye *et al.* 2013). This reduced availability of winter habitat coupled with an extreme winter (e.g., 2010-2011), where cold wet conditions continue into the nesting period, may have resulted in decreased survival of adult sage-grouse and possibly nest success contributing to the corresponding decreases in lek counts over subsequent years (Moynahan *et al.* 2006, Anthony and Willis 2010). This case study highlights the importance of maintaining sagebrush habitats with adequate amounts of tall sagebrush for sage-grouse to use during extreme winters and nesting periods and the role of monitoring sage-grouse populations using lek and broods counts and hunter surveys to determine their response to management (Dahlgren *et al.* 2006; Dahlgren *et al.* 2010a; Dahlgren *et al.* 2015a, In Press; Guttery *et al.* 2015). Research is continuing to evaluate sage-grouse responses to prescribed and seasonlong grazing in the Rich SGMA (Dettenmaier *et al.* 2012, Dettenmaier and Messmer 2013, Dettenmaier and Messmer 2014) .

Thacker *et al.* (2010) provided new insights in determining sage-grouse sagebrush winter forage preferences. The identification and protection of important winter habitats is a conservation priority. Thus better information is needed regarding sage-grouse sagebrush winter dietary preferences for application to management. The objective of their research was to determine if chemical analysis of fecal pellets could be used to characterize winter sage-grouse diets as a substitute for more invasive methods. To conduct this research, they collected and analyzed fecal pellets and sagebrush samples from 29 different sage-grouse flock locations in the Box Elder and Parker Mountain SGMAs. Using gas chromatography, they were able to identify crude terpene profiles that were unique to Wyoming sagebrush and black sagebrush (*A. nova*). They subsequently used the profiles to determine sagebrush composition of sage-grouse fecal pellets, to better reflect sage-grouse winter diets. This technique provided managers with a tool to determine which species or subspecies of sagebrush may be important in the winter diets of sage-grouse populations.

Wildfires: Using Green Stripping to Protect Sage-grouse Habitats

In the Great Basin Region of the western United States cheatgrass (*Bromus tectorum*) and other invasive vegetation species have increased the frequency of wildfires in sagebrush ecosystems exacerbating sage-grouse habitat loss. Habitat loss due to fire and replacement of (burned) native vegetation by invasive plants is the single greatest threat to sage-grouse that inhabit SGMA in Utah's Great Basin region (Utah Plan 2013). While wildfires may occur, the subsequent response to fire can have a large impact on the severity of the impacts and subsequently rehabilitation or restoration efforts (Pyke *et al.* 2011).

Immediate, proactive means to reduce or eliminate the spread of invasive species, particularly cheatgrass, after a wildfire, is a high priority in the Utah Plan (2013). Managers have used greenstrip firebreaks that have been planted with fire-retardant vegetation such as forage kochia (*Bassia prostrata*) to mitigate wildfire risks. However, no information has been published regarding sage-grouse potential use of kochia greenstrips as cover or forage.

Graham (2013) conducted lek surveys, measured vegetation attributes, and monitored 53 radio-collared sage-grouse from 2010-2012 on a 4,800 ha seasonal range (i.e., Badger Flat) that was greenstripped during the fall and winter of 2010 in northwestern Box Elder County, Utah, to evaluate sage-grouse potential responses in a highly fragmented landscape to the firebreak. She also described the potential effects of linear disturbances to sage-grouse nest success and mortalities. To determine sage-grouse use of kochia as winter forage they collected kochia samples and sage-grouse fecal pellets from the Badger Flat study area and the Tabby Wildlife Management Area (WMA) in north central Utah which had been greenstripped in 2004. They used microhistological techniques to analyze the relative presence of kochia and sagebrush in sage-grouse fecal pellets.

Shrub canopy cover and densities were reduced during the Badger Flat firebreak seedbed preparation. Two years post-treatment, the frequency of invasive species between treated and untreated sites were similar. Sage-grouse preferred untreated areas and used the greenstripped areas primarily as an extension of an existing lek. The number of males counted on the Badger Flat lek were stable from 2010-2014. Kochia was established and remained confined to the greenstrip seedbed. Sagebrush was the dominant plant material in the fecal pellets sampled. Pellets collected from Tabby WMA contained a greater percentage of kochia (2.7%) than pellets from Badger Flat (0.7%). This difference may be an artifact of stand longevity and thus kochia availability in the greenstrips.

Sage-grouse nests in the Badger Flat study area that were located closer to roads had higher predation rates. Also, most adult and juvenile bird mortalities (86%) were located within 450 m of a road. Road type did not affect mortality rates. These observations suggest that the greenstrip seedbed preparation, which reduces or further fragments existing sagebrush cover, may also increase sage-grouse predation risks. To mitigate these risks, managers should place greenstrip firebreaks adjacent to existing roads or disturbances. The timeframe of the study precluded an assessment of firebreak effectiveness. This information is being used to plan and implement future greenstrips in high wildfire risk areas of the Utah's SGMAs in the Great Basin.

Tall Structures and Sage-grouse

Most existing utility corridors (pipelines, roads, major overhead electrical transmission lines) within Utah SGMAs are well-defined (Utah Plan 2013). Connelly *et al.* (2004) suggested that structures associated with energy transmission and development (e.g. power lines, communication towers, wind turbines, and other installations) and associated operation and maintenance activities in sage-grouse habitat may impact the species through habitat avoidance and increased predation rates. The USFWS has recommended the use of various buffer distances between tall structures and occupied sage-grouse habitats to mitigate the potential impacts (USFWS 2003).

In 2005 the Western Association of Fish and Wildlife Agencies (WAFWA) convened the Greater Sage-grouse Range-wide Issues Forum (Forum) to engage stakeholders in the identification of strategies to address species conservation issues identified by Connelly *et al.* (2004). One of the issues identified by the Forum was the effect of tall structures on sage-grouse. Tall structures were defined as power lines, communication towers, wind turbines, and other installations excluding livestock fencing (Stiver *et al*. 2006).

In 2010 the Utah Wildlife-in-Need Foundation (UWIN) in cooperation with Rocky Mountain Power/PacifiCorp (RMP) and the UDWR facilitated a public input process (i.e., focus group workshops) which included a synthesis of existing literature and contemporary federal, provincial and state tall structure siting policies to address Forum concerns. The specific products were: 1) literature synthesis of existing information (published and unpublished) regarding the predicted and potential effects of tall structures on sage-grouse, 2) summary of contemporary policies regarding siting and other requirements to mitigate potential effects, 3) identification of knowledge gaps, and 4) prioritization of research needs regarding tall structures effects on sage-grouse conservation.

Stakeholders reviewed published information to evaluate the scientific basis for the potential impacts of tall structures on sage-grouse. At the time of the UWIN review there were no peer-reviewed, experimental studies reported in the scientific literature that specifically documented increased avoidance or predation on sage-grouse because of the construction, operation, and maintenance of tall structures (UWIN 2010). A review of the scientific literature regarding sage-grouse since completion of the 2010 review produced no new published information, but recent unpublished reports have begun to address the issue (Messmer *et al*. 2013).

Stakeholders were concerned that the science upon which tall structure siting decisions are based was lacking. Because the science was lacking, "effective" temporal and spatial setbacks and buffers stipulations may differ by governmental agency. Stakeholders concluded viable estimates of sage-grouse mortality resulting from power line collisions and predation are also lacking. They believed a better understanding of the extent and causal factor of mortality attributed to tall structures would help state and federal agencies refine siting criteria and develop BMPs and other conservation measures to mitigate potential impacts (Messmer *et al.* 2013).

Contemporary sage-grouse BMPs are largely lek-centric. The stakeholder review of the literature could not identify a consistent source or scientific basis for recommended buffer zones. The USFWS (2010) acknowledged similar concerns in the sage-grouse status review. Stakeholders concluded no research has been conducted to evaluate the effectiveness of current BMPs or buffers. For effective BMPs to be developed, stakeholders concurred that better science-based information will be needed regarding the effects of tall structures on sage-grouse reproductive success, recruitment, and survival at the population level (Messmer *et al.* 2013).

To adequately assess the impacts of tall structures on sage-grouse, conditions before and after the activity in question must be compared (UWIN 2011). Stakeholders identified specific questions regarding the relationship between sage-grouse and tall structures that need additional study (Messmer *et al.* 2013). These questions included: 1) Do sage-grouse avoid tall structures and in particular what are they avoiding, 2) If sage-grouse avoid tall structures, what are the individual and population impacts, and when would the impacts be manifested, 3) Will the effects be permanent, 4) Will the effects be limited to the area of disturbance, 5) What measures (BMPs) can be implemented to mitigate impacts and alleviate the negative impacts, and, 6) Will these BMPs be universally effective?

To address stakeholder concerns, UWIN facilitated a consortium process in 2011 that engaged sage-grouse biologists, statisticians, and managers from agencies, academia, industry, and others in a process to develop a standardized research protocol for assessing the potential impacts of tall structures on sage-grouse. The protocol was subsequently endorsed by WAFWA Directors in 2011 as the standard for assessing the potential impacts of tall structures on sage-grouse (UWIN 2011).

Until better information is available, the Utah Plan (2013) recommends siting new electrical transmission lines, and where feasible and consistent with federally, required electrical separation standards, in existing corridors, or at a minimum, in concert with existing linear features in sage-grouse habitat. Siting linear features accordingly is deemed to be mitigation for the siting of that linear feature. Mitigation for the direct effects of construction is still required.

Genetic Connectivity

Because of concerns regarding the potential for increased energy development to further fragment sagebrush habitat, thus isolating sage-grouse populations and resulting, in genetic drift, inbreeding, local extinction, or rapid divergence (USFWS 2010), Breidinger *et al.* (2013) conducted a genetic survey of 3 remote sage-grouse populations in northeastern Utah to assess mitochondrial diversity relative to other portions of the species' range. They did not detect any unusual haplotype compositions in these populations. However, haplotype composition of the Anthro Mountain population and Strawberry Valley SGMA reference populations differed from haplotype compositions of other northeastern Utah populations. These populations are spatially separated by Desolation Canyon of the Green River. This canyon constitutes a geographic barrier to gene flow in this area, given low population densities and reduced dispersal potentials. This potential barrier will be an important consideration in future conservation efforts such as translocations. The halotype composition of the Anthro Mountain and Strawberry Valley reference populations have subsequently been altered by translocations subsequent to our sampling effort (Gruber 2012, Baxter *et al.* 2013).

The mitochondrial (Breidinger *et al.* 2013) and nuclear (Oyler-McCance 2005) data confirm that there is restricted gene flow between Utah populations west of the Green River and other adjacent populations to the north and east. State biologists have corroborated the results of these research projects using seasonal movement data of radio-collared sage-grouse.

Funding Partners

The longevity, continuity, consistency, and hence accuracy of the sage-grouse database used to develop the Utah Plan (2013) attests to the commitment and resolve of the partners that have funded and support the research. These partners included Utah Reclamation, Mitigation, and Conservation, UDWR, BLM, USFWS, USFS, Sportsmen for Fish and Wildlife, BYU, Western Alliance to Expand Student Opportunities, Berry Petroleum, S. J. and Jessie Quinney Foundation, USU Extension, USU Quinney College of Natural Resources, Quinney Professorship for Wildlife Conflict Management, Jack H. Berryman Institute, Enduring Resources LLC, the Parker Mountain Grazing Association, Deseret Land and Livestock, Pheasants Forever, Natural Resource Conservation Service, Idaho Fish and Game Department, Rich County Coordinated Resource Management Group, Rich County Commission, West Box Elder Coordinated Resource Management Group, Utah Department of Agriculture and Food, USDA Wildlife Services, Anadarko Petroleum, Bill Barrett Corporation, Utah Chapter of the Wildlife Society, Cooperative Sagebrush Initiative, Rocky Mountain Power, PacifiCorp, Utah Wildlife in Need Foundation, Utah Department of Natural Resources, SUFCO Mine (Canyon Fuel Company), Kerr River Pipeline, Ruby Pipeline, Utah Public Lands Policy Coordination Office, Utah Legislature, Utah Community-Based Conservation Program, Della Ranches, Utah Conservation Districts, Grouse Creek Livestock Associations, USDA Poisonous Plants Lab, USDA Animal Research Service, and the Utah Cooperative Wildlife Management Association.

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