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Protocols for Investigating the Effects of Tall Structure on Sage-grouse (Centrocercus urophasianus)

T. A. Messmer
Utah State University

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Protocol for Investigating the Effects of Tall Structures on Sage-grouse (Centrocercus spp.) within Designated or Proposed Energy Corridors

A Collaborative Consortium

Table of Contents

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Purpose

The Western Association of Fish and Wildlife Agencies (WAFWA) authorized the preparation of the *Greater Sage-grouse Comprehensive Conservation Strategy* (Strategy) (Stiver et al. 2006). The Strategy embraced a multi-partner planning effort to develop a consolidated regional and national approach for the conservation of greater sage-grouse (*C. urophasianus*; hereafter sage-grouse). In this regard, the Strategy identified a need to document and thereafter mitigate the potential impacts of tall structures (e.g., power lines, communications towers, wind turbines, and other installations) on sage-grouse. The Strategy identified four goals that needed to be accomplished to address this need (Appendix C, pages 29-31, Stiver et al. 2006). The goals are:

Goal 1: Compile and evaluate existing published research on effects to sage-grouse due to direct impacts of existing tall structures.

Goal 2: Develop a research protocol for conducting new studies to assess direct impacts of tall structures.

Goal 3: Develop scientific and consistent siting criteria and Operation and Maintenance (O&M) activities for "tall structures" in sage-grouse habitat that will minimize negative impacts on populations.

Goal 4: Develop best management practices (BMPs) and appropriate mitigation measures that can be implemented for siting and O&M activities associated with tall structures.

Recognizing that the Strategy's goals had not been met, Utah Wildlife in Need (UWIN), a nonprofit foundation, in cooperation with Rocky Mountain Power (RMP) and the Utah Division of Wildlife Resources (UDWR) facilitated a public process to identify stakeholder information needs and synthesize contemporary knowledge regarding the effects of tall structures on sage-grouse. For the purpose of this process tall structures were defined specifically as electric distribution and transmission lines and associated facilities. The project assessed the adequacy of existing information to predict and mitigate the potential impacts of tall structures on sage-grouse, identified information gaps, and prioritized the research needed to provide new knowledge for BMP development.

Goal 1 was accomplished in September, 2010, with UWIN's publication of the report entitled *"Contemporary Knowledge and Research Needs Regarding the Effects of Tall Structures on Sage-grouse (Centrocercus urophasianus and C. minimus)"* (UWIN 2010). (The report and supporting documents can be viewed at www.utahcbcp.org under the Tall Structure Information tab.)

The UWIN (2010) report identified eight specific tall structure related questions. Participants in the 2010 workshops also prioritized research needs for the eight questions as either **"Must Have"** or **"Like to Have."** Participants believed that before generally accepted BMPs and appropriate mitigation measures can be identified for siting and O&M activities associated with tall structures, science-based answers were needed for the **"Must Have"** questions. The **"Must Have"** questions are summarized below.

1. Do Sage-grouse Avoid Tall Structures and if so, What are They Avoiding?

Participants concluded they **Must Have** additional knowledge of sage-grouse avoidance of tall structures and this information must be specific to structure type. Specifically, 1) Do sage-grouse avoid tall structures and if so, what are they avoiding, 2) If sage-grouse avoid tall structures, what are the individual and population impacts, and how long would these impacts take to be manifested, 3) Will the effects be short- (construction related) or long-term (O&M activities), 4) Will the effects be limited to the area of disturbance, 5) What measures (construction and O&M activities) can be implemented to mitigate impacts and alleviate the negative impacts, and 6) Will these measures be effective?

2. Do Tall Structures Increase Predation on Sage-grouse?

Participants also concluded they **Must Have** additional research to determine if tall structures increase raptor and corvid perching and nesting activity, and subsequently support higher densities in energy corridors areas relative to the surrounding landscapes. If raptor and/or corvid perching, nesting, and densities increased because of tall structures, would predation on sage-grouse also increase, and if so, would it be significant at the population level. Participants expressed similar concerns regarding the potential impacts for tall structure construction and O&M activities to increase mammalian predation on sage-grouse.

3. Do Tall Structures Fragment Sage-grouse Habitat?

Finally, participants concluded they **Must Have** better knowledge on sage-grouse habitat fragmentation. They desired more knowledge on the impacts from the different types of commonly used tall structures in lekking, nesting, brood-rearing, and winter habitats. They recommended knowledge must be based on the linear footprint of transmission and distribution lines.

This protocol was developed to guide applied research implemented to specifically determine if tall structures affect sage-grouse production, survival rates and habitat-use at local and landscape scales within designated or proposed energy corridors. Thus, the protocol is not intended to be used as a permitting requirement, but rather to provide a template for those conducting research in selected areas to answer the **Must Have** questions.

Endorsement of UWIN and Partner Efforts to Identify Standard Research Protocol

The Greater Sage-grouse Executive Oversight Committee (EOC) was established 2008 by a Memorandum of Understanding between WAFWA and federal wildlife and land management agencies. The EOC includes western provincial and state's wildlife agency directors and the directors of the U.S. Forest Service (USFS), the Bureau of Land Management (BLM), U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey (USGS), Natural Resources Conservation Service (NRCS) and the Farm Service Agency (FSA). The primary function of the EOC is to implement the Strategy (Stiver et al. 2006). The EOC endorsed the UWIN report on 28 October 2010.

The EOC encouraged UWIN and its partners to pursue the Strategy's **Goal 2 -** Develop research protocol for conducting new studies to assess direct impacts of tall structures on greater sage-grouse. The EOC recognized that standardized protocol are a prerequisite to achieving **Goals 3 and 4** (e.g., applied research leading to the development of scientific and consistent siting and O&M criteria, accepted BMPs, and appropriate mitigation measures for transmission and distribution lines in sage-grouse habitat).

Existing Research Protocol for Assessing Wind Energy Development Impacts on Sage-grouse

The National Wind Coordinating Collaborative (NWCC) Grassland/Shrub Steppe Species Sage-grouse Research Collaborative published the "*Protocol for Assessing Impacts of Wind Energy Development on Greater Sage-grouse."* This document identified protocol to guide research to assess the potential impacts of wind facilities on sage-grouse. The NWCC protocol focused on facilities immediately associated with wind generation to include wind turbines, access roads, and short haul transmission lines. Although the NWCC protocol did not address long distance electric transmission and distribution lines, it recognized that an evaluation of the effects of these tall structures on sage-grouse was an important research need. The tall structure research protocol identified in this publication is designed to be compatible with and allow comparison with the research being conducted by the NWCC. This protocol recognizes that there is need for frequent communication between the tall structure and the NWCC research teams to maximize project benefits and ensure that the conclusions are comparable.

A Research Protocol to Assess the Direct Impacts of Tall Structures on Sage-grouse

To address this need, UWIN received funding from the Avian Power Line Interaction Committee (APLIC), RMP, Northwestern Energy, and Idaho Power. UWIN partnered with the EOC to solicit input from leading sage-grouse management and population experts, sagebrush and landscape ecologists, biometricians, federal, state, NGO, and industry wildlife and land management biologists, and transmission design engineers to develop the research protocol. As part of this effort, UWIN worked with invited experts in a two day facilitated workshop to identify and build consensus on a set of protocol to assess and guide research on the potential impacts of tall structures on sage-grouse and related habitats. The workshop was conducted on March 8-10, 2011, at Utah State University's Bear Lake Research Facility, Garden City, Utah.

The workshop transmission design discussion focused on high voltage transmission line classes of 230 KV, 345 KV and 500 KV constructed with lattice or tubular steel structures. Workshop participants learned that the height, span length, number of structures per mile, and structure type required is a function of terrain and transmission design and engineering requirements. They subsequently recommended that sage-grouse responses to tall structures must include studies that focus on both lattice and tubular steel structures. The most immediate evaluation priority remained how to effectively evaluate sage-grouse responses to currently proposed high voltage transmission lines. The protocol recognizes that the paired treatment and control sites required to complete this evaluation must be spatially separated, located in similar habitats, and incorporate designated or proposed energy corridors across multiple western states where transmission lines have a high probability of being constructed in occupied sage-grouse habitat.

Following the workshop, UWIN complied and distributed the minutes of the meeting to the participants. Comments on the minutes and workshop protocol were compiled by Dr. Terry Messmer to prepare a draft protocol. The draft protocol was subsequently reviewed by workshop participants and other invited reviewers. Their comments were incorporated into this document.

Research Tenets

The UWIN (2010) participants also identified 12 tenets they believed were essential to conducting research to address the **Must Have** questions knowledge gaps. These included: 1) a rigorous, replicable research protocol developed by a committee of experts, 2) a Before-and-After-Control-Impact (BACI) experimental design (Underwood 1994), 3) adequate replication representative of the sagebrush (*Artemisia* spp.) landscapes currently inhabited by sage-grouse, 4) current industry technology, 5) current research technology including the use of global positioning system (GPS) transmitters, 6) "court" defensible results, 7) experimental designs that simultaneously address multiple knowledge gaps, 8) metrics assessing individual and cumulative impacts of each tall structure type, 9) a collaborative process, 10) mechanisms that allow preliminary results to be employed in an adaptive management approach leading to the refinement of effective BMPs, 11) transparency and open dialogue with frequent partnership updates, and 12) industry incentives to include mitigation credits for proactively funding research.

The protocol is predicated on the use of paired treatment (e.g., the proposed electric distribution and transmission line corridor and construction area - tall structures) and control research study sites (areas with no construction or no tall structures), located in occupied seasonal sage-grouse habitats, that are monitored during pre-construction, construction, and post-construction to assess the effects of tall structures on sage-grouse populations. The use of the paired treatment and control areas will increase the power to detect an effect particularly at greater distances from the tall structure construction area. The paired areas must be similar in vegetation cover, topography, and environmental conditions.

The protocol incorporates a BACI design, 2-3 years of pre-development study (the pre-development period could be truncated if pre-construction data were available because of on-going studies that approximate protocol methodology), construction phase, and 5 years of post-construction study. Based on this design and for current planning purposes, the anticipated duration of the entire study would be a minimum of 8 years. Specific metrics to be studied include lek attendance trends, female and male survival, population productivity (vital rates), spatial and temporal patterns of seasonal habitat use and migrations between breeding and wintering areas, and habitat connectivity (See Table 1 in the Appendices). In some research areas, because sage-grouse are a relatively long-lived species it may be necessary to extend the post-construction monitoring period for an additional 1-2 years to fully document sage-grouse responses over multiple generations. This type of decision would be made by a Science Oversight Committee (SOC) (Appendix A) with the concurrence of the research partners during late winter annual research review and coordination meetings. During these meetings, the SOC and research partners also would review research progress and problems encountered in the previous field seasons. Modifications of the research protocol, if needed to address potential changes to tall structure construction schedules or O&M activities would be reviewed and decided at these coordination meetings. However, research needs would not dictate changes in construction schedules or required O&M activities.

Study Area

This protocol has been developed to guide research to assess the effects of tall structures on sage-grouse in priority habitats within designated or proposed energy corridors where construction of new transmission lines are being evaluated. The actual location and size of the study sites will largely depend on the location of the proposed transmission line construction corridor relative to known leks or lek complexes (see section on Defining the Study Gradient). As a precursor to selecting the study sites, all known leks within the proposed energy corridors must be identified and plotted using geographical information system (GIS) technology. Existing transmission or distribution lines and other anthropogenic activities must also be plotted using GIS technology. The leks must be categorized by size, cover-type, status (e.g., active or inactive), topography, slope, elevation, and distance from the study corridor and other anthropogenic influences. These attributes must be used to subjectively classify leks and/or local sage-grouse populations as increasing, stable, or declining. This information will be used to develop a sample universe of gradients from classified leks along the proposed transmission line corridors that incorporates current recommended siting guidelines and variations based on topography. The desired study site criteria are summarized below. These criteria were developed to identify optimal research conditions to produce scientifically defensible results. However, they do not preclude research partners from studying smaller populations that may be near existing or proposed tall structure projects. These smaller scale investigations will provide important cumulative data sources.

Study Site Selection Criteria

1. ***Reasonable certainty that a transmission line (i.e., treatment) will be built within the study site.***
2. ***The research project partners are committed to conducting the study using the protocol for the duration of the project.***
3. ***Paired treatment and control study sites are of similar land use and existing land management policies will remain in effect for the duration of the study.***
4. ***All construction challenges or limitations that could affect data collection must be identified a-priori. This would include tall structure construction and post-construction O&M activities.***

5. ***Sage-grouse populations and seasonal habitats must be located within recommended study gradients (< 15 km perpendicular from the axis of the corridor in opposite directions) from the energy corridor. The populations must be able to accommodate the research protocol. For example, the protocol requires a sample size of up to 140 and 60 sage-grouse equipped with VHF and GPS radio-collars for each paired treatment and control study site, respectively. To achieve this sample size may require local populations exceeding 1000 birds.***
6. ***The study sites should have seasonally accessible roads for ATV or vehicle travel.***
7. ***Study sites should be devoid of other large-scale anthropogenic activities that are believed to impact sage-grouse (e.g., existing transmission, transportation corridors, communication towers, heavy recreational use sites, energy developments). Sites with these confounding factors should be avoided or accounted for in study design and analysis.***
8. ***Study site selection must be coordinated with and supported by the state, federal, and private land and wildlife management authorities.***

Primary Research Questions

1. Do Sage-grouse Avoid Tall Structures and if so, What Are They Avoiding?

The UWIN (2010) literature synthesis concluded that no experimental BACI studies have been published that definitively document local and landscape effects of tall structures on sage-grouse. In addition there has been limited research on the effects of different structure types, the influence of topography, habitat conditions, associated infrastructures, and related O&M activities on sage-grouse population dynamics. The lack of a definitive body of research on the relationship between tall structures and sage-grouse has resulted in diverse and often inconsistent BMPs (UWIN 2010).

Anthropogenic features, such as tall structures, when added to largely treeless sagebrush steppes where sage-grouse evolved are believed to cause avoidance, and as such, may displace birds from traditional use sites (USFWS 2010, UWIN 2010). The general basis for statements regarding sage-grouse and other prairie grouse species avoidance of tall structures in open habitats originates from concerns that they constitute novel elements in the environments where bird species are not habituated to their presence (Braun 1998).

Pruett et al. (2009) evaluated lesser (*Tympanuchus pallidicinctus*) and greater prairie-chicken (*T. cupido*) movements near energy infrastructure (power lines and paved highways). They tracked 463 lesser prairie-chickens and 216 greater prairie-chickens for seven and three years, respectively. After analyzing movement data, they concluded that individuals of both species avoided power lines by at least 100 m and lesser prairie-chickens avoided one of the two highways by 100 m. Prairie-chickens crossed power lines less often than expected if birds moved randomly, but highways did not seem to be a movement barrier. Home ranges of lesser prairie-chickens overlapped power lines less often than would be expected by chance.

Similar experimental research is lacking regarding the impacts of anthropogenic landscape features on sage-grouse (Connelly et al. 2004, UWIN 2010, Johnson et al. 2011). Stevens (2011) provided some recent insights into the effects fencing, as a novel structure placed near leks, could have on sage-grouse mortality risks. He reported that sage-grouse fence collisions during the breeding season were relatively common in his Idaho study area. Connelly reported that over 51,000 km of fences were constructed on Bureau of Land Management (BLM) managed land in the western United States from 1962–1997 with an additional 1,000 km added annually from 1996–2002 (Connelly et al. 2004). Because of the wide spread occurrence of fences in sage-grouse breeding habitat, these structures could have range wide conservation implications (Stevens 2011).

In addition to being novel, managers are concerned that O&M activities associated with tall structures in shrub-steppe or grassland habitats may further disrupt breeding or other behaviors. Reduced lek attendance, increased direct and indirect mortality, lower nesting rates and nest success, reduced recruitment, and ultimately reduced productivity have been cited as possible consequences if the birds are displaced from high quality habitat (USFWS 2010). For resident and non-migratory species, disruptions may be more difficult to avoid and thus may affect a larger area than the immediate vicinity of the structure. Additional disturbances related to the tall structure O&M activities and associated corridors may include road improvements and increased traffic volumes, fire ignition or suppression, and vegetation management practices that may increase direct mortality or disrupt normal behaviors (UWIN 2010, Appendix B).

Defining Avoidance

Wildlife avoidance of anthropogenic activities or features has been defined as a lower density of animals than expected based on habitat availability in zones near the source of the impact (Vistnes and Nelleman 2001). Avoidance of wildlife may manifest itself as a redistribution of animals resulting in lower densities near and higher densities farther away from the source of the impact than expected based on habitat availability alone.

Prior to the 1990's most studies of wildlife avoidance focused on direct disturbance of the individual animal, such as physical loss of habitat (Maki 1992, Voigt and Broadfoot 1995), flight distances (McLaren and Green 1985, Tyler 1991, Cassirer et al. 1992), fright behavior (Horejsi 1981, Harrington and Veitch 1991), or short-term increases in cardiac activity (MacArthur et al. 1982, Weisenberger et al. 1996, Krausman et al. 1998). More recently, investigations of avoidance behavior in ungulates have demonstrated physiological stress responses in the individual animal may substantially underestimate environmental impacts, thereby failing to fully describe the cumulative impacts of development (Cameron and Ver Hoef 1996, Nellemann and Cameron 1998, Wolfe et al. 2000).

Documenting Sage-grouse Avoidance

Avoidance research must incorporate pre-construction, construction, and post-construction data to document any changes in selected population parameters (e.g., sage-grouse densities, seasonal habitat use and distribution, survival of chicks and adults, and reproductive success and survival of sage-grouse). The null hypothesis to be tested is that pre-construction sage-grouse densities, seasonal habitat-use patterns, and vital rates do not differ post-construction and are comparable to control sites. Collecting these data over multiple post-construction years may also provide insights as to whether sage-grouse may return to an area they initially avoided (diminished perceived threat), effects of habituation, and possible differences in behavior among sage-grouse cohorts.

Defining the Study Gradient

The avoidance question consists of two components; 1) do sage-grouse avoid the immediate vicinity of tall structures and if so, 2) how far away from the line (e.g., gradient) would the potential impacts of avoidance be manifested? The rights-of-way (ROW) width or immediate impact area for a high voltage transmission line would depend on the line voltage and terrain but typically would encompass an 80-110 m wide zone (J. Burruss, PacifiCorp, personal communication). However, the potential for sage-grouse to avoid tall structures or associated habitats could conceivably be manifested along gradients in both directions beyond the immediate ROW area. The width of this gradient could depend on if sage-grouse are displaced by construction and O&M activities, or if sage-grouse simply avoid any visual association with tall structures.

Thus, defining a standard potential impact or avoidance study zone for tall structures may be problematic and will likely depend on habitat and terrain. For example, Stevens (2011) in a study of sage-grouse mortality risks of fences in Idaho reported that broad-scale fence collision risks were strongly reduced by even moderate increases in topographic ruggedness. This situation is further compounded by the fact that sage-grouse can move long distances (Connelly et al. 2011a). Thus, if avoidance occurs in the immediate vicinity of the tall structure, the impacts could 'dissipate' through the landscape as the birds move between seasonal habitats.

Connelly et al. (2004) attempted to define the potential impact distance of Interstate 80 in Wyoming on sage-grouse populations using retrospective lek data. They reported that sage-grouse no longer occupied leks within 2 km of Interstate 80 in Wyoming. Male attendance at leks within 7.5 km of Interstate 80 also declined at a greater rate than at leks located between 7.5 and 15 km from the road. However, they did not account for potential changes in habitat quality as a consequence of other land uses. Aldridge et al. (2008) reaffirmed the importance of sage-grouse cover to sage-grouse persistence and extirpation. Persistence of sage-grouse was expected in habitats containing at least 25% sagebrush cover within 30 km from historical range edge.

Dr. Brad Fedy and colleagues examined the annual maximum inter-seasonal distances moved by sage-grouse in Wyoming. They calculated maximum Euclidean distance between seasons for > 800 radio-collared sage-grouse. Average inter-seasonal movement distances between nest and summer/late brood rearing habitat and the subsequent winter ranged from 7-15 km. The 90th percentile for inter-seasonal movements ranged between 18 km and 34 km (B. Fedy, USGS, personal communication).

Although these studies did not specifically involve tall structures, they identified a possible range of potential impact zones (2-30 km) for anthropogenic activities. The actual impact zone study gradient for a transmission line would depend largely on its proximity to lek or lek complexes in the construction corridor relative to other landscape features (e.g., topography, vegetation cover, and habitat type). Thus, the size of the study area needed to detect avoidance and potential impacts on sage-grouse vital rates and habitat use must encompass distances perpendicular to the center axis of designated tall structure ROW. However, the initial research emphasis should be placed on the identification of potential avoidance impacts within the average inter-seasonal movements from breeding habitats to winter range from both sides of the ROW. Using 7-15 km as a guide, the initial potential total width of the avoidance impact area for this protocol would range from 14 to 30 km. If meeting sample size objectives required a tradeoff between study sites that are long and narrow (e.g., less than 30 km wide) along the transmission line vs. study sites that are more rectangular, the focus on long and narrow corridors would better address the avoidance and demography questions.

Changes in Lek Trends as a Measure of Avoidance

The current methods for estimating regional sage-grouse population trends are based on data obtained through lek counts (Connelly et al. 2004, Garton et al. 2005). Empirically based corrective models have been used to generate less-biased estimates of sage-grouse demographic and population parameters. However additional experimentation will be needed to provide better scientific basis for these models (Johnson et al. 2011). Until this research is conducted, the use of standardized lek counts to determine population trends in response to specific activities in sage-grouse habitat will remain the standard (Connelly et al. 2003). Pre-construction research may provide information to refine these models and allow for retrospective adjustments in population parameters.

Measuring sage-grouse changes in breeding densities in response to the placement of tall structures will require standardized surveys of leks and lek complexes located at variable distances or gradients from the center of the transmission corridor. The width of this study gradient must reflect pre-construction sage-grouse movement data and be wide enough to accommodate known leks or lek complexes in both directions perpendicular to the axis of the tall structure corridor. The leks or lek complexes selected should have multiple year history (> 5 years) of lek count data collected using a standardized methodology (Connelly et al. 2003).

This standard methodology requires that lek counts be conducted from approximately mid- to late-March through early May. All historic and any new leks identified during monitoring will be surveyed a minimum of four times each during the breeding season (March-May). Lek censuses should be conducted in the following manner:

1. A location that provides good visibility of the entire lek will be selected to conduct observations. If the lek is large, two or more vantage points may be needed.
2. From these locations, the observer scans a given lek from left to right (or vice versa), counting all displaying males. Females present are also counted.
3. The observer waits one to two minutes, than re-counts the lek from right to left (opposite direction of first count).

4. After waiting a minimum of one to two minutes, the observer then repeats the process until three counts have been completed. The maximum number of males and females observed during all scans are recorded separately. The counts are terminated one hour after sunrise.

Changes in Seasonal Habitat Patterns as a Measure of Avoidance

Sage-grouse populations frequently engage in seasonal movements, thus they can have large annual ranges and use several habitats at different times of year. For example, vegetation types selected during the nesting season may not be important during the winter months (Connelly et al. 2011a). Given that tall structures are a predominate landscape feature within the geographic range of sage-grouse (Connelly et al. 2004), research to determine if sage-grouse avoid tall structures should; 1) define the second-order selection of habitat based on home ranges of individuals or subpopulations (e.g., birds associated with a lek or lek complex), 2) assess the condition of various seasonal habitat components (e.g., breeding and winter habitats), within the home range (third-order selection), and 3) describe the quality and quantity of food or cover at particular use sites (fourth-order selection). To accomplish these objectives, sage-grouse seasonal movements or migrations should be quantified. By spatially plotting movement data, important seasonal habitats can be identified. Aerial photos, satellite imagery, and digitized maps can be used to measure the size and juxtaposition of these habitats. An assessment of landscape characteristics should include habitat patch sizes, measures of habitat quality (structure, percent cover), connectivity (availability of corridors connecting patches), amount of edge and distance between habitat patches (Johnson 1980).

Documentation of the physical habitat characteristics (e.g., height, density, and percent cover) associated with sage-grouse use and non-use sites by seasonal ranges will allow inferences to be made regarding biological costs associated with movements and habitat selection relative to the placement of tall structures. Sage-grouse may select and use different areas as a result of tall structure construction and O&M activities. If there are no differences in the physical habitat characteristics between the new use areas and sites used prior to construction, there may be no measureable habitat effect of sage-grouse avoidance of the transmission line if pre-construction vital rates remain similar. However, if the vital rates of the impacted population decrease there could be a biological cost and information on habitat quantity and quality will help identify the underlying reasons for this cost and ultimately guide mitigation efforts. The steps in this process should include the development of spatial maps of all potential sage-grouse seasonal habitats under variable environmental conditions and a subsequent comparison of the structural and nutritional characteristics of habitat vegetation in breeding and winter during pre-construction and post-construction periods in treatment and control areas.

Lek surveys and radio-telemetry monitoring of male and female sage-grouse should be integrated to identify treatment and control use sites for comparison of structural habitat parameters. Use locations must be paired with random points, selected from within an area of the approximate size of the seasonal home range to allow the assessment of habitat selection (Jones 2001). Random sites are used to compare relative use (e.g. occupancy) versus availability. The UTM

coordinates for all locations are recorded and plotted to support site-specific and landscape-level analyses and the linkage between habitat variables and key demographic parameters.
Sage-grouse habitat use may be assessed directly (e.g. observations or counts) or indirectly (e.g. pellets). Quantification of habitat availability is less certain. The biological hypothesis to be tested is that the preferred (and hence selected) habitat will be of higher quality (suitability) than non-selected habitat ("non-habitat"). In the case of sage-grouse and tall structures, the null hypothesis to be tested would be that habitats are used in proportion to their availability (e.g. sage-grouse will spend the most time in the most abundant/widespread habitat type) irrespective of the presence of a tall structure. Habitat selection usually assessed statistically via a chi-square test with 95% confidence intervals calculated using a Bonferroni z statistic (see Neu et al. 1974, Sparks et al. 1994).

Measuring Habitat Structural Attributes

Standard procedures for measuring vegetation (Connelly et al. 2003) must be used on all treatment and control (use and random) sites. Grass, forb, shrub, and tree height and density, and percent canopy and overall cover should be recorded. These vegetation attributes should be measured using four 15-m transects that are placed in the four cardinal directions from the center of the nest bowl, sage-grouse use, and random locations. Canopy cover of shrubs and trees should be estimated using a line-intercept technique (Canfield 1941) and canopy cover of grasses and forbs estimated using Daubenmire plots (Daubenmire 1959). The grasses, forbs, and shrubs present should be identified to species. Identification to species will be important to determine if tall structure construction and post-construction O&M activities result in an increase in species composition to include invasive and woody species.

Vegetation visual obstruction readings (VOR) should be recorded from the center of the nest bowl, use and random areas can be measured using a Robel pole (Robel et al. 1970). Comparing VOR for paired treatment and control sites relative to habitat metrics may provide insights regarding potential differences in recorded sage-grouse vital rates.

Habitat structural characteristics, ground cover measurement, and landscape features (e.g., topography, elevation, distance to other anthropogenic structures, cliffs, trees, roads, railroads, etc.) collected at sage-grouse and random sites (UTM data) should be plotted and layered on high resolution (1 m or less) color infared aerial images of the areas. These layered maps should be used to generate “viewsheds” (Aspbury and Gibson 2004) around each use or random site to map environmental and habitat structural characteristics selected by sage-grouse. Aerial images can be obtained to identify areas of high structural quality, track changes in the structural quality over time at the landscape level, and identify potential nesting and breeding habitats (Connelly et al. 2000, Hagen et al. 2007). Investigating multiple spatial scales for some variables will be important to determine if vital rates are also affected by scale. This analysis will be important to determine how the width of buffer zones may differ across variables (e.g., percent sagebrush cover).

Measuring Habitat Nutritional Quality

Sage-grouse habitat has historically been evaluated in terms of structure (e.g., vegetation cover, height, density, etc.). By describing vegetation characteristics associated with sage-grouse use and random sites, inferences can be drawn regarding relationships of habitat quality and selection to productivity (Connelly et al. 2003). If sage-grouse use different areas as a result of tall structure construction and post-construction O&M activities, but there is no observable difference in terms of vegetation structure between the new areas, even though the birds were displaced, there may be no measureable effect of the transmission line on habitat use patterns. However, if the vital rates change as a result of the displacement, the biological costs of the displacement could be underestimated by relying solely on vegetation structural measurements. Expanding the traditional definitions of sage-grouse habitat suitability to include nutritional quality of sagebrush and other important forage plants may provide greater insights into the biological costs of displacing birds from traditional seasonal habitats.

Habitat suitability is at least partially a function of nutritional quality in selection analyses. Sage-grouse disproportionate use of a plant or plant community relative to availability at the individual level might be explained by nutritional-based hypotheses if the vegetation nutritional quality, opposed to its ability to provide cover and concealment was the basis for selection. Evaluating this order of selection would be helpful in identifying the mechanism for higher orders. However, different mechanisms (e.g. nutrition vs. concealment) for habitat selection are not mutually exclusive. For example, a sage-grouse can select the same species of sagebrush in the winter for nutrition as well as for cover and concealment.

Nutritional analysis of sagebrush and other forage plants relative to the potential habitat displacement of sage-grouse by tall structures was identified as a "like to have" research question by UWIN workshop participants (UWIN 2010). The methodology for this analysis is presented under the heading entitled "Like to Have Research" located at the end of the protocol.

Changes in Vital Rates as a Measure of Avoidance and Biological Consequence of Displacement

If sage-grouse are avoiding tall structures once constructed and thus displaced from previously documented preferred pre-construction habitats, documenting sage-grouse vital rates (e.g., survival of males, survival and nesting rates of females, nest success and survival from hatch to recruitment) along a gradient from the tall structure corridor will provide important insights regarding the potential impacts on local and regional populations. Collecting these data along with an on-going assessment of habitat conditions on treatment and control study areas over multiple post-construction seasons and years will provide information regarding the potential effects of displacing birds relative to habitat quality. The null hypothesis to be tested is that vital rate metrics for sage-grouse that may be displaced by tall structures do not differ from control populations given similar habitat conditions.

Sampling Protocol

Estimating sage-grouse vital rates requires adequate samples of individually marked birds. Both males and females must be captured in association with leks or lek complexes along the tall structure corridor gradient using night-lighting and hoop-netting techniques (Giesen et al. 1982, Wakkinen et al. 1992, Connelly et al. 2003). Annually for the duration of the study (pre- and post-construction), a population of 50-70 adult and yearling male and female sage-grouse (ideally 40 females and 20 males) should be maintained through the spring captures on paired treatment and control study sites. The captured birds should be fitted with necklace-style very high frequency (VHF) radio transmitters. The radio-transmitters should be equipped with mortality sensors to document seasonal and annual mortality. Mortality data will be used to estimate and compare survival rates for treatment and control sites using standard statistical techniques in Program Mark.

Individual grouse should be sexed and aged as juveniles (has not entered into its first breeding season), sub-adults (has entered its first breeding season but not completed its second summer molt, generally 10-17 months old) or adults (has entered or is about to enter its second breeding season, generally ≥15 months old) based on characteristics of the outer wing primaries (Dalke et al. 1963, Connelly et al. 2003). All captured sage-grouse should be weighed, measured, and released at the point of capture. Blood samples should be collected from clipped grouse toenails on Nobuto blood filter strips. Silver nitrate should be applied to the toenail if bleeding does not stop after applying pressure with a cotton ball. Analysis of these biological data in concert with previously published information and molecular genetics can provide a better understanding of interaction of the species and relative to potential changes in their environment (Oyler-McCance and Quinn 2011). Genetic sampling was identified by UWIN (2010) participants as "like to have" research. Suggested methodologies to conduct this research is also discussed under the section entitled "Like to Have Research" located at the end of the protocol.

All individual male and female sage-grouse captured during this study, including those not radio-collared, should be fitted with uniquely engraved aluminum leg-bands (size 14 for females, 16 for males). These leg bands can provide additional information from non-radio-collared sage-grouse regarding harvest, movements, survival, and recaptures.

If the desired sample size cannot be achieved in the spring, an additional sample of juveniles and adult females can be captured and radio-marked during late summer – early fall on both treatment and control areas. If 70 sage-grouse are radio-collared on paired treatment and control sites, a total of 140 sage-grouse would be initially marked with VHF radios during the first full field season. The initial cost of these radio-collars based on 2011 prices would be $25,000. To maintain this sample size, trapping efforts in subsequent years should focus on capturing additional sage-grouse to replace known mortalities and missing birds. Depending on the study area 30-50% (42-70 collars) of the study population could be expected to be replaced annually. The annual replacement cost for radio-collars could range from $7,500-$13,000. This cost could be reduced by re-using or refurbishing radio-collars recovered from mortalities.

The VHF radio-collared grouse would be subsequently located to assess vital rates and habitat use. Marked females should be located at least twice weekly during the spring until the female begins nesting. Nest status should be checked 2-3 times weekly (without flushing females) until nests hatch or fail (See Connelly et al. 2003 for specific field guidance). If the female is in the same location on two successive radio-tracking sessions, incubation is generally assumed. Nest locations should be recorded using GPS coordinates and inconspicuous land marks. Researchers should avoid disturbing nesting sage-grouse because hens readily abandon nests following disturbance (Fischer et al. 1993, Sveum et al. 1998, Chi 2004, Holloran 2005, Baxter et al. 2008). The use of GPS technology may reduce the number of nest visitations and may mitigate nest abandonment because nesting females could be monitored remotely. Sage-grouse hen unique nesting behaviors can readily be detected using GPS technology and incubation confirmed within 10 days after its on-set. There is a possibility that nests that are initiated, predated, and/or abandoned within this 10 day period may not be recorded. Thus GPS technology may underestimate nesting attempts. After the nest is located, follow up visits prior to hatching should be conducted if the behavior of the female suggests she has abandoned the nest. As the hen approaches her anticipated hatching date, nest visits should increase to several per week to ensure accurate assessment of initial brood size (J. Kehmeier, SWCA Environmental Consultants, personal communication).

The use of GPS technology to monitor nest success in conjunction with VHF radio telemetry will allow for the detection of and/or compensation for any potential experimental bias to include underestimating nest initiations. Because of the paucity of published sage-grouse vital rate data for GPS radio-collars, the use of traditional VHF radio-collars will allow for comparison of previously published vital rates (Connelly et al. 2011b).

Nesting effort is estimated as the proportion of hens alive at the onset of nesting period that attempt to nest. Re-nesting effort is estimated as the proportion of hens that survive an initial nest failure, which then attempt to re-nest. Nest, hatching and hen success, clutch size, egg fertility, and nest site fidelity are determined by inspecting nests of radio-marked hens as soon as possible after the hens have left the site. A nest is considered successful if at least one egg in the nest hatches.

Nest success is calculated as the proportion of nests in which at least one egg hatches. Eggshell fragments with separated membranes and typical hatching pattern of the shell (Rearden 1951) indicate a hatch. Hatching success is determined as the proportion of all eggs laid in successful nests that hatch. Hen success is then calculated as the proportion of hens that hatch at least one egg, regardless of the number of nesting attempts. Clutch size is typically determined for successful nests by counting the number of un-hatched and hatched eggs present at a nest site after hatching occurs. Egg fertility can be calculated as the proportion of all eggs laid in successful nests that are fertile, based on a successful hatch or presence of a partially developed embryo in un-hatched eggs. Nest site fidelity is calculated as the mean distance moved from an initial nest site from one year to the next, using only females that survive and nest in consecutive years.

To determine brood success, broods must be located and can be flushed and counted at six weeks of age using several methods to include trained hunting dog (Dahlgren et al. 2010). Brood size is calculated as the mean number of chicks per hen at six weeks of age, using all hens alive at the onset of nesting. Chick survival is calculated as the number of chicks that survive to six weeks of age from all eggs that hatch in successful nests (Lukacs et al. 2004). Dahlgren et al. (2010) and others have documented a high rate of brood-hopping (chicks being adopted by females that are not their mother) in some populations. If brood-hopping occurs, this may bias estimates of chick survival and brood success if the chicks that brood-hopped are presumed mortalities. They recommended radio-collaring and monitoring chicks as one method to address this bias (Burkepile et al. 2002).

The distance from lek of capture to initial nest and re-nest sites can be calculated for all hens that attempt to nest. Spring and summer, movements must be estimated for individual grouse by calculating a mean distance from lek of capture to all subsequent locations. A median distance moved must be calculated for the study population. Seasonal and annual movements should be described using temporal and spatial scales and home ranges estimated. This information may best be provided by subset of sage-grouse marked with GPS radio-transmitters. All movement and home range estimates should be derived using ArcGIS (Environmental Systems Research Institute 2006). Using these techniques, a 95% fixed kernel (FK) home range can be estimated.

After hatching, females with broods should be located at least weekly and brood size determined every 2-3 weeks using spotlight counts or pointing dogs (Dahlgren et al. 2006). Broods should be followed until independence in September/October. During the remainder of the year female sage-grouse should be located 1-2 times a month. Male grouse should be located 1-3 times weekly throughout the breeding season and 1-2 times a month throughout the rest of the year. Care must be taken to minimize repeated flushing of radio-collared sage-grouse. Locating sage-grouse equipped with VHF collars in the winter may require the use of a helicopter or fixed-wing aircraft equipped with radio-telemetry receivers. Aircraft flights should also be used to locate sage-grouse that cannot be detected by ground crews.

Because sage-grouse hens are typically captured and radio-collared near leks, there is no assurance that these birds will select nests site within the project study area. To mitigate for this potential problem, study site selection must encompass known leks or lek complexes located within or adjacent to the designated or proposed transmission line corridor. If this problem persists, the initial sample sizes of radio-collared males and females could be increased to compensate for marked birds that have moved out of the designated study area. Another option could be to recapture the radio-collar birds that have moved out of the study area, remove the transmitters, and transfer them to other birds. This recapture and replacement technique should also be considered to enhance the sample data obtained from birds initially equipped with GPS collars that move out of the study area.

The protocol is built on the premise that quantifying sage-grouse population vital rates will be an important metric to understand potential direct and indirect responses to tall structures. Currently the protocols recommend using VHF transmitters to obtain these data. The protocol however recognizes that the investigators should have the flexibility to select the most appropriate tracking technology for answering these questions. Depending on the location of the study sites, traditional VHF transmitters may not provide the information needed to define vital rates if the radio-marked birds cannot be relocated in a timely fashion because of migrations or the terrain. Under these circumstances, GPS technology could also be used to document vital rates.

While the initial cost of the GPS transmitters is substantially higher that then VHF, the reduction in monitoring effort and workforce that results from using GPS technology may offset the up-front cost differences over longer term studies. Through the use of GPS technology, researchers would be able to collect vital rate data, detect finer scale movements, define movement corridors, and determine subtle avoidance of tall structures and changes in habitat use. However, quantification of differences in the structural and nutritional quality of the habitat will require periodic site visits.

Estimating Survival

Annual survival of radio-marked sage-grouse can be calculated monthly using Program Mark (White and Burnham 1999). The sage-grouse included in survival estimates must have survived for at least one week after being radio-collared to ensure that mortalities are not related to capture stress or injury. Radio-collared sage-grouse harvested during upland game bird hunting seasons, or found to be illegally taken, during or off-season should be included in the survival estimates.

Seasonal and annual survival of adult females is typically estimated using known fate approaches implemented in Program Mark (Moynahan et al. 2006, Anthony and Willis 2009). Site-specific (including distance from transmission lines) and landscape vegetation variables should be incorporated into these analyses as temporal variables. Nest survival can also be modeled using maximum likelihood approaches incorporating environmental covariates. However, some recent studies have found that apparent nest survival is biased high following calculation using maximum likelihood approaches (Kolada et al. 2009, Coates and Delehanty 2010). Capture mark recapture (CMR) methods can also be used to assess annual survival of radio-marked males, recruitment of males, rate of population increase (λ), probability of attending a lek and probability of movement among leks.

Using these methods, given the BACI design, population vital rates (i.e., survival, recruitment and λ) can be compared pre- and post-construction for treatment and control by gradients from various landscape and environmental parameters (e.g., vegetation, cover type, patch size, relative to distance from tall structures). Unique relationships between vital rates and environmental parameters such as distances from tall structures can provide insights regarding the potential effects of displacing sage-grouse on local populations.

Gradient analysis also can be used to assess if any relationship exists between distance from the transmission project and study reference areas in terms of abundance (lek surveys) and seasonal habitat-use patterns. The differences between sage-grouse habitat use patterns (i.e., time of, duration, and frequency of movements and distance moved), during pre- and post-construction periods by distance from the tall structure can be calculated. The averages of these differences by distance gradient can be compared against the null hypothesis value of 0 using *t*-tests and confidence intervals to test whether a reduction in density is statistically significant and to identify the distance at which it occurred.

Pellet Counts as a Measure of Habitat Selection

Researchers have used alternative methods to determine bird use of experimental management plots. These methods when used in conjunction with radio-telemetry can provide important information regarding individual or populations response to land-use or management activities. Dahlgren et al. (2006) successfully used pellet counts and bird dog surveys to evaluate sage-grouse response to 40 ha sagebrush treatments conducted in late brood-rearing habitats. A similar methodology could be used to detect sage-grouse before and after use of the actual tall structure construction corridor. This technique is described under the section entitled "Like to Have Research" located at the end of the protocol.

2. Do Tall Structures Increase Predation on Sage-grouse?

The UWIN (2010) workshop participants expressed concern about the potential for tall structures to increase sage-grouse predation. They were concerned that sage-grouse may avoid tall structures because they constitute new avian predator perches. They were also concerned that service roads and O&M activities could create travel routes for terrestrial predators. To understand the possible effects of tall structures on increasing sage-grouse predation rates, it will be important to also understand how tall structures may increase predator populations, in particular avian predators (UWIN 2010).

Hagen (2011) reported that range-wide sage-grouse nest success rates and adult survival are relatively high and that few studies have demonstrated a link between habitat quality, predation, and mortality rates. He also acknowledged that the dynamics of a predator community can be influenced by anthropogenic changes. Bui et al. (2010) reported higher raven densities in areas in western Wyoming where the habitat was fragmented because of anthropogenic activities (e.g. roads, oil and gas development). They speculated that increased raven predation as a consequence of the fragmentation could limit sage-grouse population growth (Bui et al. 2010). Previous research has documented increased raptor and corvid use of power lines for perching and as nest sites (see UWIN 2010). These studies however did not document any direct relationship between power lines and increased predation risks for sage-grouse.

Blomberg and Sedinger (2009) assessed the impact of Sierra Pacific Power Company's Falcon-Gondor transmission line on sage-grouse vital rates relative to habitat conditions. Their results suggested that sage-grouse nests with more total shrub cover had a greater probability of success than nests with less cover regardless of distance from the transmission line (J. Sedinger, UNR, personal communication). Kolada et al. (2009) also reported higher sage-grouse nest success in Mono County, CA with increasing shrub cover. Coates (2010) hypothesized that the potential risk for tall structures to increase raptor and corvid predation on sage-grouse could be mitigated by maintaining and restoring sagebrush canopy cover.

In addition to avian predators (e.g., corvids and raptors) sage-grouse, their nests and young, may be preyed on by ground squirrels (*Spermophilus* spp.), badgers (*Taxidea taxus*), coyotes (*Canis* *latrans*), red fox (*Vuples vulpes*), weasels (*Mustela* spp.), and skunks (*Mephitis* spp.). However, in the case of ground squirrels, Coates et al. (2008a) suggested previous studies reporting evidence of ground squirrel predation on sage-grouse eggs were the result of misclassification. They reported several species of squirrels were not capable of opening eggs and thus did not predate nests.

Mammalian predators could benefit from tall structures if the corridors increase their access to sage-grouse habitats or result in a change in the composition or abundance of the predator community. Smith et al. (2008) reported increased use of 50 m wide transmission line ROW in Tennessee by coyotes, dogs, and bobcats (*Lynx rufus*) when compared to non-ROW areas. They reported no difference in ROW use by small-bodied predators such as red fox and raccoons.

Although mammalian predator populations may change in response to tall structures, monitoring mammalian predator population trends may be difficult because of their behavior patterns. Because the dynamics of a predator population and its primary food source can also impact sage-grouse populations (Schroeder and Baydack 2001), data regarding the relative abundance of potential sage-grouse predators pre- and post-construction should be quantified as part of any tall structure/fragmentation causation studies.

The protocol contains methodology designed to assess if there is a causal relationship between tall structure construction, O&M activities, and sage-grouse vital rates (e.g., decreased productivity attributed to direct disturbance and/or species displacement). By incorporating environmental covariates directly into models of nest and brood success, investigators will be able to determine if any observed differences between treatment and control sites can be attributed to predation and increased predation is an artifact of displacement. Incorporating site-specific variation (distance from transmission lines and time) along with landscape variables (e.g., vegetation, topography) will allow determination of functional relationships between the direct or indirect impacts of tall structures on sage-grouse vital rates while controlling for variation in environmental or habitat factors. The use of these time dependent effects also will allow investigation of lag effects in changes in predator communities as well as habituation by sage-grouse to the structures.

Determining the Predator

Determining the actual predator of an adult sage-grouse can be problematic. Investigators typically examine the condition of the remains to determine if death was caused by a mammalian or avian predator or from other causes (e.g., power lines, human interaction, accidents, sickness, etc.). If bones and feathers were broken or matted (i.e., chewed), death may be attributed to mammalian predation. These field examinations should be conducted with extreme caution because mammals can scavenge predations caused by avian predators. Additionally, radio-collared sage-grouse mortality signals must be investigated immediately. The more time that lapses between a mortality signal and recovery may increase the probability of researcher misclassifying the kill as mammalian.

If a mammalian predator is implicated, the surrounding area may be searched for sign, to include hair, scat, tracks or evidence of a den to identify the specific predator. If the remains consist of the entire carcass with feathers intact, partially plucked, or if only the breast was eaten, the cause of death may be attributed to avian predator. If there was an insufficient amount of evidence or information at the mortality site, the cause of death should be designated as unknown.

Nest fate is typically determined by examining the remaining contents of the nest for egg shell fragments and membranes (Reardon 1951, Connelly et al. 1993). A membrane that is detached from the eggshell will be classified as a successful hatch (Klebenow 1969). Confirming the identity of predators at depredated sage-grouse nests can best be accomplished using around-the-clock videography (Coates 2007). By combining this information with the microhabitat characteristics of depredated nests, investigators can test the hypothesis that nests with less surrounding vegetation (concealment) are more likely to be depredated by visually cued predators such as corvids. Coates et al. (2008a) described the protocol for video-monitoring sage-grouse nests. Video-monitoring enables unambiguous identification of sage-grouse predators. This information will allow modeling the probability of depredation by each predator species in relation to distance from the tall structures and relative to habitat features. To obtain this information, Coates et al. (2008a) recommended deploying 15–20 digital video recording systems annually for the study duration. A system, based on 2011 prices, would cost $700 and consist of a camera and batteries.

Determining Sage-grouse Mortalities as a Result of Collisions with Tall Structures

Contemporary research has not documented a high incidence of mortality associated with sage-grouse collisions with power lines (UWIN 2010). However, it is difficult to quantify mortalities caused by collision because targeting the populations that would be affected with radio-telemetry is difficult and predation detections probabilities are very low using surveys. For example, extensive surveys conducted by USGS on a small isolated population of grouse in the Virginia Mountains of Nevada at a site with newly erected meteorological towers only detected two female sage-grouse mortalities from collisions with guy wires. One grouse was incubating a clutch nearby and broke its wing from the collision. A video camera on the nest and documented this abnormal behavior. The hen eventually abandoned the eggs and died near its nest (P. Coates, USGS, personal communication). Coates and Delehanty (2008b) video documented that sage-grouse fly to and from their nests during very low light conditions at incubation recess. These flights patterns may increase the probability of collision in nesting areas with newly erected structures such as fences (Stevens 2011).

Avian Predator Surveys

Changes in abundance of avian and mammalian predators must be monitored using standardized transects in the immediate vicinity and at gradients throughout the tall structure (treatment) and control study areas (Garton et al. 2005). Monitoring trends of potential sage-grouse predators in concert with changes in vital rates along tall structure corridor gradients will provide data to corroborate any observed differences in vital rates between treatment and control sites.

Raven populations have increased >300% in the past 29 years within the U.S. (Sauer et al. 2008). Knight and Kawashima (1993) and Boarman (1999) documented raven preferences for nesting on power lines. Previous research (see Appendix C) has also documented increased raptor use of tall structures. However, it remains unclear if avian densities near the structures studied exceeded those in adjacent habitats because of the placement of tall structures.

Coates and Delehanty (2010) compared a priori models of sage-grouse nest survival (microhabitat variables) to models of sage-grouse nest survival that included common raven abundance as covariates. They focused on ravens, because the species has been identified as a major synanthropic predator (Boarman et al. 2006). They conducted strip transect surveys (see Garton et al. 2005 for a description of the methodology) of ravens at sage-grouse lek complexes every 3–7 days during morning (0600–1200 hr) from March-June. Their objective was to investigate how raven abundance affected sage-grouse nest success, not to estimate raven population density. They estimated an increase in one raven per 10-km transect survey was associated with a 7.4% increase in the odds of nest failure. Through the use of video monitoring, they also determined the probability of raven predation increased with reduced shrub canopy cover and subsequently suggested that wildlife managers may mitigate the effect of raven populations on sage-grouse by restoring and maintaining shrub canopy cover in nesting areas. However, in areas with the highest raven indices nearly all nests failed and all predation was caused by ravens, according to the video images. They suggested that the costs of elevated raven numbers negated the benefit of increased shrub cover (Coates and Delehanty 2010).

Luginbuhl et al. (2001) assessed the relationship between predation on artificial nests and corvid abundance using a variety of techniques including point-count surveys, transect surveys, and the broadcast of corvid territorial and predator attraction calls. Point counts of corvid abundance had the strongest correlation with predation on artificial nests containing eggs. They recommended using the maximum value for each corvid species attained from multiple temporally replicated point-count surveys conducted on days with light winds (<20 kph) and little or no precipitation.

To assess avian predator abundance during the breeding season, paired tall structure treatment and control sites should be annually monitored in sage-grouse breeding habitat between late-March to mid-July during pre- and post-construction periods from specific points on transects randomly distributed in treatment and control areas. Winter surveys to determine eagle and other raptor use of paired tall structure treatment and control areas should be initiated in January and continued through late March.

At each survey point along the transect, binoculars should be used to count the number of ravens, other corvids, and raptors flying or perched, within approximately 500 m of the point during a three minute period. Double counting can be mitigated by separating survey points by an 800 m distance and recording avian species previously counted prior to moving to the next survey point. The survey routes should be located along unimproved or gravel roads within the study corridors. The same surveys route should be used annually following the same methodology. Binoculars should be used to count the numbers of avian predators, flying or perched, at each point. Rangefinders and compasses should be used to calculate a UTM coordinate for each observed avian predator.

If roads are not readily available in the paired study areas, a random point design should be implemented. Randomized points should be stratified by vegetation type to obtain a better represent the cover types. The use of random points can further reduces biases associated with spatial correlation (within transect) and are more compatible with distance sampling and resource selection function modeling (P. Coates, USGS, personal communication).

Raven and raptor use of tall structure type for nesting and perching should be determined by surveying constructed transmission lines in the study corridor. This also will enable investigators to determine if any differences exist in nest and perch frequency by tower designs. Raptor nests and perches should be searched for the remains of sage-grouse. These surveys when used in combination with systematic pellet and mortality searches of power lines, can provide important insights regarding seasonal diets of raptors (Prather and Messmer 2010).

Once the proposed ROWs are known, avian surveys should be conducted before the study on the line and at different distances from the line to evaluate before and after effects because the distribution of ravens and raptors across the landscape may change over time. The areas with structures may have greater numbers, whereas areas away but adjacent to structures may have fewer numbers after the development. The study areas should be surveyed twice a day, 3 days a week, weather permitting, between 0800–1100 hr and 1400–1700 hr (Stahlecker 1978). The starting points should be randomly selected and the alternative routes should be used to arrive at the starting points to avoid disturbing any birds already perched. Observers should spend 5 minutes at the starting point and each survey point along the transect. Survey points should be separated by 0.5 km. All birds perched on the tall structures and distribution poles should be recorded. Observations should include species, numbers, and perch locations on individual structures.

Mammalian Predator Surveys

Mammalian predators are difficult to survey because of their relative rarity across the landscape, nocturnal activity patterns and wariness toward humans (Gese 2001). Biologists typically monitor animal abundance by direct methods of counting the animals themselves, or indirectly by counting animal sign. Estimating animal abundance requires consistent and standardized application of a technique to be able to detect changes or differences with some degree of accuracy, precision, and power. Regardless of technique used the protocols for the survey or count must be consistently applied over all research areas to allow for direct comparisons over time.

Coyote Surveys

Coyotes are common mammalian predators of sage-grouse. Because of the cosmopolitan presence of this species and the location of the designated tall structure corridors (e.g., sagebrush-steppe habitats) mammalian predator surveys should be conducted to assess the relative abundance of this species. One of the most common sign surveys utilized for indexing coyote abundance is scent-post or scent-station surveys (Smith et al. 1994, Sargeant et al. 1998, Smith et al. 2008).

Scent-post or scent-station surveys involve placing a scented tablet (e.g., fermented egg extract, mackerel oil) or other attractant within a 1m circular area of sifted dirt. Tracks left by an animal are identified to species, and presence or absence of the species is recorded. Typically, stations are spaced at a predetermined interval along roads or trails and then visited for three to four consecutive nights to record tracks; the sifted area is swept smooth after each night.

The movement patterns and home-range size of the animals to be surveyed should be considered when determining the location and spacing of the stations. The frequency of animal visitations to usable stations (i.e., not disturbed by wind, rain, vehicles) can be used as an index of abundance. Knowlton (1984) reported a positive correlation ($r^2 = 0.79$) between coyote scent-station indices and estimated coyote density. Seasonal changes in habitat use and visits to multiple stations by a single animal can contribute to invalid correlations of animal density and visitation rates. Misidentification of tracks, problems with the weather (mostly wind and precipitation), wariness of animals in relation to the sifted substrate, and a fairly labor intensive technique are items to be addressed when considering scent-station surveys. Sargeant et al. (1998) provided several recommendations regarding sample unit specification and interpretation of scent-station surveys.

If well-established roads are present in the treatment and control areas, scat deposition transects can be used to obtain an estimate of relative abundance of coyotes. The methodology involves setting up transects along roads, removing all scats from the transects, and then returning two weeks later to collect all the new scats. A scat index is computed as the number of scats collected per transect per 14-day period. If transects vary in length, or the time periods vary in the number of days between collections, then the index can be standardized to scats/km/day. Scat deposition rates for coyotes were found to be correlated ($r^2 = 0.97$) with estimates of animal density derived from mark-recapture techniques using radioisotope tagging of feces (Knowlton 1984).

For long-term monitoring, scat transects should be conducted along the same routes at the same time of year to avoid introducing biases associated with differential prey digestibility (i.e., differential scat deposition rates) and seasonal changes in foods items consumed. Mis-identification of scats and heavy vehicle traffic on roadways can be problems encountered when using scat deposition counts.

Other Mammalian Predators

Spotlight surveys are a cost effective method typically used for assessing the relative abundance of nocturnal animals. Estimates of relative abundance can be obtained for red fox, stripped skunk and badgers which are mammalian predators of sage-grouse. These surveys usually involve two observers standing in the back of a truck being driven slowly (16-24 km/hr) along roadways scanning the road surfaces and roadsides using a 1 million candle power spotlight. When an animal is detected, usually by eye shine, the driver stops the vehicle and the observers identify the animal (using binoculars or a spotting scope). The mileage and time of detection is recorded for each sighting. An index of animals/km can then be calculated (Gese 2001).

Spotlight counts can be used to estimate population size with line-transect methodology if the perpendicular distance to the sighted animal is recorded. Transects should be > 10 km and conducted in similar habitats if comparisons are needed. Surveys can be conducted over several nights (repeated counts) to obtain a measure of sampling error. Large samples (>50 detections) with replication are needed to detect changes in population size with any statistical power. Surveys can be conducted seasonally and annually for population trend analysis. However, because spotlight counts do not work well in areas containing low densities of mammalian predators, they may not be applicable to assessing the abundance of red fox, skunks, and badgers in tall structure corridors. To determine relative densities of the above predators and if spotlight counts may be applicable, a pilot study should conducted.

Tracks left by carnivores along river beds, dry washes, sandy fire breaks or roads, or on snow-covered roads and trails have been used as a relatively simple and inexpensive measure of relative animal abundance for several species of canids and mustelids. Carnivores that occupy regions that receive snow have been monitored through the use of counting tracks along established transects within one to two days following fresh snowfall. Misidentification of tracks and low power to detect population changes can occur when using track counts. Precision can be increased by increasing sampling effort (more transects), or increasing the length of transects if dealing with a wide ranging species such as coyotes. When working in snow, the condition and consistency of the snow, variable depth of snow (i.e., no snow negates data collection), temperature, and time of year should also be recorded. Standardized observer training will compensate for differential experiences in interpreting tracks and contribute to consistent and reliable monitoring.

The choice of and ultimately success of these techniques in evaluating relative changes in mammalian predator abundance in tall structure treatment and control study areas will depend on the investigators ability to identify potential mammalian predators and suitable substrates to conduct the surveys. These techniques, when used appropriately, can provide viable, cost effective methods to estimating relative mammalian abundance. When used in combination with population vital rates, they can be used to determine if a causal relationship exists between the presence of and O&M activities associated with tall structures and sage-grouse predation rates.

3. Do Tall Structures Fragment Sage-grouse Habitat?

Although by the USFWS (2010) definition, tall structures and associated infrastructures that bisect contiguous sagebrush habitats are considered venues for fragmentation, their role in functional habitat loss of the surrounding areas is not well studied. Most researchers view habitat fragmentation as a process involving both the loss of habitat and breaking apart of habitat (Farhig 2003). Use of the phrase “habitat fragmentation” should be limited to actions or activities that break contiguous expanses of habitat into smaller components (Farhig 2003).

Although transmission lines may fragment habitats, they may not constitute functional habitat loss if there are no changes in vital rates or productivity. Rigorous testing is needed to know if habitat protection and restoration will allow sage-grouse to persist in areas where tall structures occur. Measuring the vegetation characteristics of the treatment study site will be important to distinguish the fragmentation effects of tall structures on sage-grouse from the effects of habitat loss.

Measuring Sage-grouse Habitat Fragmentation

Standard procedures for evaluating sage-grouse habitat selection incorporate nest, use, and random sites where radio-tagged individuals are located. The vegetation metrics collected can be used to compare treatment and control study sites or determine habitat preferences. These protocols are described in several studies (Canfield 1941, Daubenmire 1959, Drut et al. 1994, BLM 1996, Connelly et al. 2003) and include line intercept estimates of total shrub cover and sagebrush cover along standard transects. Percent cover of understory vegetation along with residual grass height should be recorded in Daubenmire plots placed along transects used to estimate shrub cover in both use and random sites. At larger scales (up to several km) remotely sensed imagery provides the most effective method for assessing landscape level variables, such as proportion sagebrush land cover type within a given radius of used or random points.

Site specific habitat variables (e.g., shrub cover) summarized using standard methods (e.g., Holloran 2005) and key landscape level habitat variables obtained based on the locations of radio-tagged sage-grouse for treatment and control study sites will enable investigators to determine if any difference in habitat use can be attributed to tall structure design, construction and O&M activities. Sage-grouse location points must be buffered for a reasonable distance (e.g. 100 m) and percent cover of landscape level vegetation variables (e.g. cover types) estimated. It may be appropriate to consider larger scale habitat features, such as percent sagebrush cover within a 1 km circle. Also, because sage-grouse may move long distances, multiple scales (> 1km) should be assessed as each scale may differ based on vegetation cover and landscape features resulting in additional variation in demographic rates among habitat types. These latter analyses will be appropriate if response by sage-grouse to development is reflected in displacement from one major habitat type into another in response to tall structure placement and O&M activities.

Monitoring Large Scale Sage-grouse Movements as a Measure of Fragmentation

Sage-grouse are a landscape species that requires large areas of contiguous sagebrush to complete their annual life cycles. Historically, sage-grouse management decisions have been largely based on state jurisdictional boundaries and thus may have underestimated the conservation importance of large scale movements at the regional level. Conservation of the species will depend on identifying and protecting important sagebrush habitats (USFWS 2010). Because seasonal movements of individuals within populations can vary based on environmental conditions and in response to a changing landscape, standard VHF technology, based on an observer relocating a radio-marked bird, can underestimate the temporal and spatial scale of the movements. However, this bias can be mitigated with the increased number of relocations and smaller sampling intervals. Also, utilization distributions using kernel methods can be calculated with appropriate sample sizes from VHF radio-collared sage-grouse.

Published literature regarding the specific effects of anthropogenic factors (e.g., cumulative effects of energy development and related infrastructures) on sage-grouse was based on observational studies that used standard VHF radio-telemetry transmitters (Holloran 2005, Holloran et al. 2010). This technology allows investigators to assess and evaluate habitat-use patterns, seasonal movement, and mortality using relocation data (Connelly et al. 2003). Biologists also have been using this technology since the 1960's to estimate daily, seasonal, and annual survival rates.

Standard VHF radio-telemetry may have limitations if the research questions require more detailed knowledge of bird movements (i.e., exact and multiple daily locations) and behavioral responses to tall structures. 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 effect of increased transmitter weights on sage-grouse survival.

Recent technological advances have led to commercial production of smaller (22-30 g), solar-powered, GPS satellite transmitters that can be mounted using a leg-loop harness (i.e., rump-mount) rather than a backpack harness. Newer GPS transmitters have several advantages over traditional 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.

Pruett et al. (2009) used GPS technology to examine lesser prairie-chickens and greater prairie-chickens movements near power lines and paved highways. Based on GPS movement data, they concluded that individuals of both species avoided power lines by at least 100 m and lesser prairie-chickens avoided one of the two highways by 100 m. Prairie-chickens crossed power lines less often than expected if birds moved randomly, but highways did not seem to be a movement barrier. Home ranges of lesser prairie-chickens overlapped power lines less often than would be expected by chance. Although Pruitt et al. (2009) did not have GPS movement data from the birds prior to the construction of the power lines, they hypothesized that the construction of new power lines contributed to prairie chickens avoiding previously suitable habitat and created barriers to movement for prairie chickens.

There is no published information regarding similar responses in sage-grouse. New information on local and landscape-level impacts of transmission lines on sage-grouse is needed to develop appropriate management recommendations and design meaningful mitigation measures. The use of GPS technology in combination with BACI would provide an accurate assessment of the effects of tall structures on the spatial and temporal movements of sage-grouse. To answer the fragmentation question and in particular if tall structures reduce habitat permeability, up to 30 sage-grouse (15 male and 15 females) should be equipped with GPS radio-transmitters in each paired treatment and control study area. The GPS data can be used to document seasonal movements, define habitat pathways used between seasonal habitats, and map landscape connectivity. Both male and female movements should be tracked from breeding to winter areas to determine the timing and extent of specific movement.

Rump-mount attachments should be used for camouflaged GPS units painted to match the color and venation of a sage-grouse to reduce reflected light and decrease visibility to predators. A thin layer of neoprene can be glued to the bottom side of the transmitter to ensure that contact between the transmitter material and the bird‘s lower back is padded and insulated. The harness material should be 0.25-in wide, brown Teflon ribbon (Bally Ribbon Mills). A 4.7-in (12-cm) length of 0.22-in (0.55-cm) wide elastic cord should be sewn into the center of a 36-inch (75-cm) length of Teflon ribbon such that 1.5-2.4-in (4-6 cm) of stretchy Teflon ribbon extends out from the 18 attachment points on either side. The elastic gives the harness flexibility when the bird extends its legs during take-off and when males are displaying. Yearling harnesses should be sewn with more elastic 6.3 in (16 cm) to accommodate increases in body size over time. Harnesses are fit with the bird held in a standing position. Transmitters should be fitted snugly enough to prevent birds from dropping them. Any transmitters that become inactive because of bird mortality or detachment should be collected and redeployed in subsequent years. The above methodology follows protocols described in an ongoing Colorado Division of Wildlife Study (http://wildlife.state.co.us/Research/Birds/GreaterSageGrouse/).

During the monitoring period, location data should be programmed to automatically upload four locations per day from the GPS transmitter to a secure server. The location data may then be remotely accessed from any computer workstation. Data can be downloaded from the server and organized into a regularly maintained spatial database to investigate migratory movements, important movement corridors, and migratory habitat selection of sage-grouse in treatment and control sites. This time-stamped, spatial location data will enable investigators to produce high-resolution spatial database and maps for comparing sage-grouse movement in treatment and control areas during pre-construction, construction, and post-construction periods. These movement data will also allow investigators to determine if tall structures or other landscape features constitute movement barriers (Pruitt et al. 2009).

Because GPS technology affords investigators the ability to access data remotely, sage-grouse movement patterns can be continuously studied over a larger geographic area without concerns over observer bias. However, because of the added costs of the transmitter ($4000) and satellite access for data downloads, the number of birds that can be studied is reduced. Another problem investigators may encounter in using this technology is that the initial birds radio-collared may engage in wide ranging seasonal movements which may take them beyond the scope of the project. This may require investigators to re-capture select individuals to address the avoidance questions. This statement however also applies to sage-grouse that are fitted with VHF transmitters.

The ability to detect migratory elements of the population (females that move long distances) is a benefit of GPS technology. The technology enables researches to fully map the home range of individuals in the population and provides insight into the behavior and response of the population as a whole. The data from the GPS transmitters will also provide estimates of what proportion of the population is migratory versus non-migratory. Knowledge of how tall structures impact both migratory and non-migratory grouse behavior will be beneficial for future planning efforts in areas where both types of populations occur.

The initial equipping of 60 sage-grouse (30 male and 30 females) in a paired treatment and control tall structure study areas would cost $240,000. Because of mortalities, additional GPS collars will need to be deployed. However, by recovering the initial collars the costs of maintaining the desired sample size will be considerable lower than the initial investment. While initial costs associated with GPS technology are higher than conventional VHF transmitters, cost savings would accrue over time in terms of personnel, time, study logistics, and a reduction in the number of VHF units deployed.

4. Like to Have Research Methodologies

Using Genetics as a Measure of Fragmentation

The deployment of VHF and GPS radio-transmitters to document sage-grouse vital rates and movement in response to tall structure construction and O&M will provide a short-term perspective (< 10 years) regarding fragmentation effects and population consequences. These studies will track a small number of individuals relative to local and regional populations. However, combining these data with genetic information obtained from the study population and genetic data from the larger population at-large over time can provide a broader understanding of the potential fragmentation effect of tall structures on population connectivity (Oyler-McCance and Quinn 2011).

The emergence of the field of landscape genetics has bolstered our ability to use molecular genetic data to assess impacts of landscape features on gene flow. Using individual-based approaches, the genetic impacts of a transmission line may be detectable within only a few generations if the transmission line functions as an absolute barrier to the movement of individuals and entirely prohibits gene flow across the line (Landguth et al. 2010a). However, it could take much longer to detect the genetic impacts of impeded movement of individuals if transmission lines represent a barrier to movement and gene flow (Landguth et al. 2010b).

Because study personnel will regularly survey leks within the study areas multiple times in April and May, they should be encouraged to collect feathers for genetic analysis from each lek. Much of this material will be collected from males. Additionally, blood and feather samples should be obtained from birds trapped for radio collaring during pre- and post-construction periods. The genetic samples should be provided to a genetic laboratory for analysis. The samples should be analyzed by period to determine population genetic structure. After completion of the field studies, additional samples should be collected over the next 10 year period, and analyzed to determine if the genetic structure differs pre- and post-construction by treatment and control. From a conservation standpoint, the movement of genes through the landscape is the most important type of movement (i.e. more than the movement of reproductively unsuccessful individuals). Genetic analyses over multiple generations subsequent to the initial research can determine how/if the tall structures impact the genetic connectivity of individuals and populations.

Nutritional Analysis as a Measure of Habitat Selection

This research would require an assessment of the nutritional and chemical components present in plants sage-grouse prefer to determine if dietary constituents can be used to predict diet selection and how they may relate to productivity. This may be best accomplished by monitoring dietary selection of an individually radio-marked sage-grouse and collecting samples from plants eaten by that individual. These comparisons must be conducted pre- and post-construction.

To determine the nutritional characteristics of the sagebrush plants used, plant tissue collections should be collected from December to March on each treatment and control study area. Nutritional quality of shrubs (e.g., nitrogen (protein) digestibility, amino acids, and chemical composition) browsed by radio-marked grouse can then be compared to that of unbrowsed plants. Browsed sagebrush are those that have visual signs of herbivory by a sage-grouse (Remington and Braun 1985, Sauls 2006) and non-browsed shrubs are nearest neighbors (within 1 m) of the same subspecies that show no signs of herbivory. At least 20 grams (wet weight) of leaf tissue must be collected from two sets of browsed plants and paired non-browsed plants and from two random plants of each subspecies present within a half square mile at the foraging site. This collection should be done for at least 20 different randomly-selected radio-collared female sage-grouse at each study areas. Plant tissue collections should be repeated at least three times for the same birds within study areas to provide a more comprehensive assessment of diet selection over the winter and early spring period.

During field collections, leaf tissue must be stored on ice until being transferred and stored in a freezer prior to analysis. If successful, this research could be used to develop alternative metrics to identify, map, and conserve the dietary quality of habitats for sage-grouse. A map of the most palatable sagebrush plants could identify key foraging sites across landscapes and predict important winter and early spring use areas for sage-grouse (J. Connelly, Idaho Game and Fish Department, personal communication).

Pellet Counts as a Measure of Habitat Selection

To conduct the pellet counts, Dalgren et al. (2006) divided their study plots into thirds and distributed transects throughout each plot, and placed a random transect encompassing the entire plot within each plot. Transects were slowly walked by researchers who recorded pellet type (regular pellets or cecal castes), the number of pellets or cecal castes per cluster, distance of pellets or cecal castes per cluster from the center of the transect centerline, and estimated distance of pellet to edge of habitat type (meters), and habitat type where the pellet cluster was found. Sage-grouse cecal castes are semi-liquid dark colored scat that is the end product of the functioning appendices, which extract another level of nutrition from the food in the intestinal tract. These droppings are usually voided in early mornings and are often associated with roost piles or found on active leks.

The edge of habitat was determined by a change in species of dominant shrub, or abrupt change like an edge of a treated area or road. Roost piles (> 10 pellets in very close proximity usually with a cecal caste) were counted separately, but equaled one cluster occurrence (Dahlgren et al. 2006). Pellet counts, cluster densities and probability of detection by treatment type were calculated using program DISTANCE (Buckland et al. 2001), then cluster densities and probabilities of detection were compared between treatments, and treatments to control using a *z*-test with a 0.05 alpha level.

Summary

UWIN (2010) participants identified the need to conduct additional research to answer the three general **Must Have** questions. The additional research was needed to determine if tall structures resulted in sage-grouse avoiding adjacent sagebrush habitats, increased avian or mammalian predation rates, and created any habitat fragmentation resulting in functional habitat loss due to these impacts. This protocol describes numerous methodologies that can be incorporated into research studies designed to document the relationship between tall structures and sage-grouse.

In accordance with these needs, the **Must Have** research methodologies to be used on paired treatment and control study sites pre- and post-construction must at a minimum include; 1) adequate sample size of sage-grouse fitted with VHF and GPS radio-transmitters to document sage-grouse vital rates, seasonal movements, and possible avoidance, 2) measurements of physical habitat vegetation attributes for sage-grouse use and random sites, 3) seasonal standardized surveys to detect potential changes in avian and mammalian predator abundance, and, 4) the use of GIS technology to spatially and temporally plot and analyze sage-grouse vital rates, movements, and habitat-use data relative to tall structure construction and O&M.

UWIN (2010) participants also identified a number of research questions that they would **Like to Have** answered regarding the potential effects of tall structures on sage-grouse. In the case of the research methodologies these included, 1) identification of the actual sage-grouse predator (e.g. video-monitoring of sage-grouse nests), 2) nutritional analysis of sagebrush habitat vegetation, 3) the use of pellet counts to determine habitat-selection, and 4) genetic analysis to determine the potential effects of tall structures on population connectivity as a measure of fragmentation. Regarding the last **Like to Have** question, investigators should however be encouraged to collect and store sage-grouse DNA samples for future genetic research regarding the effects of tall structures on population connectivity should sage-grouse exhibit initial avoidance behavior.

Literature Cited

Aldridge, C.L., and M.S. Boyce. 2007. Linking occurrence and fitness to persistence: habitat-based approach for endangered greater sage-grouse. Ecological Applications 17:508–526.

Aldridge, C.I., S.E. Nielsen, H.I. Beyer, M.S. Boyce, J.W. Connelly, S.T. Knick, and M.A. Schroeder. 2008. Range-wide patterns of greater sage-grouse persistence. Diversity and Distributions 14:983-994.

Anthony, R.G., and M.J. Willis. 2009. Survival rates of female greater sage-grouse in autumn and winter in southeastern Oregon. Journal of Wildlife Management 73:538-545.

Aspbury, A., and R.M. Gibson. 2004. Long-range visibility of greater sage grouse leks: a GIS-based analysis. Animal Behaviour 67:1127-1132.

Baxter, R.J., J.T. Flinders, and D.L. Mitchell. 2008. Survival, movements, and reproduction of translocated greater sage-grouse in Strawberry Valley, Utah. Journal of Wildlife Management 72:179–186.

Blomberg, E.J., and J.S. Sedinger. 2009. Dynamics of greater sage-grouse (*Centrocercus urophasianus*) populations in response to transmission lines in central Nevada. Unpublished report, University of Nevada Reno.

Boarman, W.I., M.A. Patten, R.J. Camp, and S.J. Collis. 2006. Ecology of subsidized predators: Common ravens in the Central Mojave Desert, California. Journal of Arid Environments 67:248-261.

Boarman, W.I. and B. Heinrich. 1999. Common raven (*Corvus corax*). Pages 1-31 *in*: A. Poole and F. Gill, editors. The Birds of North America, No. 476. The Birds of North America, Inc., Philadelphia, PA.

Boyko, A.R., R.M. Gibson, and J.R. Lucas. 2004. How predation risk affects the temporal dynamics of avian leks: Greater sage-grouse versus golden eagles. The American Naturalist 163:154-165.

Bradbury, J.W., S.L. Vehrencamp, and R.M. Gibson. 1989. Dispersion of displaying male sage grouse. I. Patterns of temporal variation. Behavior Ecology and Sociobiology 24:1-14.

Braun, C.E., O.O. Oedekoven, and C.L. Aldridge. 2002. Oil and gas development in western North America: effects on sagebrush steppe avifauna with particular emphasis on sage-grouse. Transactions of the North American Wildlife and Natural Resources Conference 67:337-349.

Braun, C.E. 1998. Sage-grouse declines in western North America: what are the problems? Proceeding of the Western Association of State Fish and Wildlife Agencies 78:139-156.

Bruce, A.M., R.J. Anderson, and G.T. Allen. 1982. Observations of golden eagles nesting in western Washington. Journal of Raptor Research 16:132-134.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press Inc., Great Clarendon Street, Oxford OX2 6DP, New York, USA.

Bui, T.V.D., J.M. Marzluff, and B. Bedrosian. 2010. Common raven activity in relation to land use in western Wyoming: implications for greater sage-grouse reproductive success. Condor 112:65-72.

Burkepile, N.A., J.W. Connelly, D.W. Stanley, and K.P. Reese. 2002. Attachment of radio transmitters to one-day-old sage grouse chicks. Wildlife Society Bulletin 30:93-96.

Bureau of Land Management. (BLM) 1996. Sampling vegetation attributes. Technical Reference 1734-4, Denver, Colorado, USA.

Cameron, R.D. and J.M. Ver Hoff. 1996. Declining abundance of calving caribou in an arctic oil field complex. Abstract in Northwest Section Meeting, The Wildlife Society, 29-31 March 1996, Banff, Alberta, Canada.

Canfield, R. 1941. Application of the line interception method in sampling of range vegetation. Journal of Forestry 39:386–394.

Cassierer, E.F., D.J. Freddy, and E.D. Ables. 1992. Elk responses to disturbance by cross-country skiers in Yellowstone National Park. Wildlife Society Bulletin 20:375-381.

Chi, R.Y. 2004. Greater Sage-Grouse on Parker Mountain, Utah. M.S. Thesis, Utah State University, Logan, UT.

Coates, P.S. 2007. Greater sage-grouse (*Centrocercus urophasianus*) nest predation and incubation behavior. Ph.D. Dissertation, Idaho State University, Moscow.

Coates, P. S., J. W. Connelly, D. J. Delehanty. 2008a. Predators of greater sage-grouse nests identified by video monitoring. Journal of Field Ornithology 79:421–428.

Coates, P. S. and D. J. Delehanty 2008b. Effects of environmental factors on incubation patterns of greater sage-grouse. Condor 110:627-638.

Coates, P.S., and D.J. Delehanty. 2010. Nest predation of greater sage-grouse in relation to microhabitat factors and predators. Journal of Wildlife Management 74:240-248.

Commons, M.L., R.K. Bayback, and C.E. Braun. 1999. Sage-grouse response to pinyon-juniper management. USDA Forest Service Proceedings RMRS-P-9. pages 238-239.

Connelly, J.W., E. T. Rinkes, and C. E. Braun. 2011a. Characteristics of greater sage-grouse habitats. Chapter 4 in Studies in Avian Biology, No. 38. University of California Press.

Connelly, J. W., C. A. Hagen, and M. A. Schroeder. 2011b. Characteristics and dynamics of greater sage-grouse populations, Chapter 3 in Studies in Avian Biology, No. 38. University of California Press.

Connelly, J.W., S.T. Knick, M.A. Schroeder, and S.J. Stiver. 2004. Conservation assessment of greater sage-grouse and sagebrush habitats. Western Association of Fish and Wildlife Agencies. Unpublished Report. Cheyenne, Wyoming.

Connelly, J.W., K.P. Reese, and M.A. Schroeder. 2003. Monitoring of greater sage-grouse habitats and populations. College of Natural Resources Experiment Station Bulletin 80, University of Idaho, Moscow, ID.

Connelly, J.W., M.A. Schroeder, A.R. Sands, and C.E. Braun. 2000. Guidelines to manage sage-grouse populations and their habitat. Wildlife Society Bulletin 28:967-985.

Connelly, J. W., R. A. Fischer, A. D. Apa, K. P. Reese, and W. L. Wakkinen. 1993. Renesting of sage-grouse in southeastern Idaho. Condor 95:1041–1043.

Dahlgren, D.K., T.A. Messmer, E.T. Thacker and M.R. Guttery. 2010. Evaluation of brood detection techniques: Recommendations for estimating greater sage-grouse productivity. Western North American Naturalist 70:233-237.

Dahlgren , D.K., R. Chi, and T.A. Messmer. 2006. Greater sage-grouse response to sagebrush management in Utah. Wildlife Society Bulletin 34:975-985.

Dalke, P. D., D. B. Pyrah, D. C. Stanton, J. E. Crawford, and E. F. Schlatterer. 1963. Ecology, productivity, and management of sage-grouse in Idaho. Journal of Wildlife Management 27:810-841.

Daubenmire, R.F. 1959. A canopy-coverage method of vegetation analysis. Northwest Science 33:224–227.

Delong, A.K., J.A. Crawford, and D.C. Delong, Jr. 1995. Relationships between vegetational structure and predation of artificial Sage Grouse nests. Journal of Wildlife Management 59:88-92.

Doherty, K.E., D.E. Naugle, B.L. Walker, and J.M. Graham. 2008. Greater sage-grouse winter habitat selection and energy development. Journal of Wildlife Management 72:187-195.

Drut, M.S., J.A. Crawford, and M.A. Gregg. 1994. Brood habitat use by sage-grouse in Oregon. Great Basin Naturalist 54:170–176.

Ellis, K.L., J. Parrish, J.B. Murphy, and G.H. Richins. 1989. Habitat use by breeding male sage grouse: a management approach. Great Basin Naturalist 49:404-407.

Ellis, K.L., J.R. Murphy, and G.H. Richins. 1987. Distribution of breeding male sage grouse in northwestern Utah. Western Birds 18:117-121.

Ellis, K.L. 1985a. Distribution and habitat selection of breeding male sage-grouse in northeastern Utah. M.S. Thesis, Brigham Young University, Provo, UT.

Ellis, K.L. 1985b. Effects of a new transmission line on distribution and aerial predation of breeding male sage grouse. Final report, Deseret Generation and Transmission Cooperative, Sandy, UT. 28 pp.

Ellis, K.L. 1984. Behavior of lekking sage-grouse in response to a perched Golden Eagle. Western Birds 15:73-38.

Fahrig, L. 2003. Effect of Fragmentation on Biodiversity. Annual Review of Ecology and Evolution System 34:487-515.

Fischer, R.A., A.D. Apa, W.L. Wakkinen, K.P. Reese, and J.W. Connelly. 1993. Nesting-area fidelity of Sage Grouse in southeastern Idaho. Condor 95:1038–1041.

Garton, E.O., J.T. Ratti, and J.H. Giudice. 2005. Research and experimental design. Pages 43–71 in C.E. Braun, editor. Techniques for wildlife investigations and management. Sixth Edition. The Wildlife Society, Bethesda, Maryland, USA.

Gese, E.M. Monitering terrestrial carnivore populations. 2001. Pages 372-396 *in* Carnivore Conservation. J.L. Gittleman, D.W. MacDonald, and R.K. Wayne, eds. Cambridge University Press and the Zoological Society of London

Gibson, R.M. and G.C. Bachman. 1992. The costs of female choice in a lekking. Bird Behavioral Ecology 3:300-309.

Giesen, K.M., T.J. Schoenberg, and C.E. Braun. 1982. Methods for trapping sage grouse in Colorado. Wildlife Society Bulletin 10:224-231.

Graul, W.D. 1980. Grassland management practices and bird communities. Pages 38-47 *in* R.M. DeGraaf and N.G. Tilghman (compilers). Workshop proceedings; Management of western forests and grasslands for nongamebirds. U.S. Department of Agriculture, Forest Service General Technical Report INT-86, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Hagen, C.A. 2011. Predation on greater sage-grouse: Facts, process, and effects. Chapter 8 in Studies in Avian Biology, No. 38. University of California Press.

Hagen, C.A., J.W. Connelly, and M.A. Schroeder. 2007. A meta-analysis of greater sage- grouse *Centrocercus urophasianus* nesting and brood-rearing habitats. Wildlife Biology 13:42-50.

Hall, F., and E. Haney. 1997. Distribution and trend of sage grouse (*Centrocercus urophasianus*) in relation to overhead transmission lines in Northeastern California. California Department of Fish and Game. Unpublished Report.

Harrington, F.H., and M. Veitch. 1991. Short-term impacts of low-level jet fighter training on caribou in Labrador. Arctic 44:318-327.

Hartzler, J.E. 1974. Predation and the daily timing of sage grouse leks. Auk 91:532-536.

Holloran, M.J., R.C. Kaiser, and W.A. Hubert. 2010. Yearling greater sage-grouse response to energy development in Wyoming. Journal of Wildlife Management 74:65-72.

Holloran, M.J. 2005. Greater sage-grouse (*Centrocercus Urophasianus*) population response to natural gas field development in western Wyoming. Dissertation, University of Wyoming, Laramie.

Horejsi, B.L. 1981. Behavioral response of barren ground caribou to a moving vehicle. Arctic 34:180-185.

Jones, J. 2001. Habitat selection studies in avian ecology: a critical review. The Auk 118:557-562.

Johnson, D.J., M.J. Holloran, J.W. Connelly, S.E. Hanser, C.L. Amundson, and S.T. Knick. 2011. Influences of environmental and anthropogenic features on greater sage-grouse populations, 1997-2007. Chapter 17 in Studies in Avian Biology, No. 38. University of California Press.

Johnson, D.J., and M.M. Rowland. 2007. The utility of the lek counts for monitoring greater sage-grouse. Page 15-23 in K.P. Reese and R.T. Bowyers (eds). Monitoring populations of sage-grouse. Bulletin 88. Idaho Forest, Wildlife, and Range Experiment Station, College of Natural Resources, University of Idaho, Moscow.

Johnson, D. H. 1980. The comparison of usage and availability in measuring and evaluating resource preferences. Ecology 61:65-71.

Klebenow, D. A. 1969. Sage grouse nesting and brood habitat in Idaho. Journal of Wildlife Management 33:649–662.

Knowlton, F. F. 1984. Feasibility of assessing coyote abundance on small areas. Final Report, Work Unit 909:01, Wildlife Research Center, Denver, Colorado, USA.
Knight, R.L. and J.Y. Kawashima. 1993. Responses of raven and red-tailed hawk populations on linear right-of-ways. Journal of Wildlife Management 7:266-271.

Kolada, E.J., M.L. Casazza, and J.S. Sedinger. 2009. Ecological Factors Influencing Nest Survival of Greater Sage-Grouse in Mono County, California. Journal of Wildlife Management 73:1341-1347.

Krausman, P.R ., M.C. Wallace, C.L. Hayes, and W. Deyoung.19 98. Effects of jet aircraft on mountain sheep. Journal of Wildlife Management 62:1246-1254.

Kuck, L., G.L. Hompland, and E.H. Merrill. 1985. Elk calf response to simulated mine disturbance in south-east Idaho. Journal of Wildlife Management 49:751-757.

Lack, D. 1968. Ecological adaptations for breeding in birds. Methuen, London.

Lammers, W.M., and M.W. Collopy. 2007. Effectiveness of avian predator perch deterrents on electric transmission lines. Journal of Wildlife Management 71:2752-2758.

Landguth, E., S. Cushman, M. Schwartz, K. McKelvey, M. Murphy, and G. Luikart. 2010a. Quantifying the lag time to detect barriers in landscape genetics. Molecular Ecology 19:4179-4191.

Landguth, E.L., S. Cushman, M. Murphy, and G. Luikart. 2010b. Relationships between migration rates and landscape resistance assessed using individual-based simulations. Molecular Ecology Resources 10: 854-862.

Luginbuhl, J.M., J.M. Marzluff, J.E. Bradley, M.G. Raphael, and D.E. Varland. 2001. Corvid survey techniques and the relationship between corvid relative abundance and nest predation. Journal of Field Ornithology 72:556-572.

Lukacs, P.M., V.T. Dreitz, F.L. Knopf, and K.P. Burnham. 2004. Estimating survival probabilities of unmarked dependent young when detection is imperfect. Condor 106:926-931.

Lyons, A.G. and S.H. Anderson. 2003. Potential gas development impacts on sage grouse nest initiation and movement. Wildlife Society Bulletin 31:486-491.

MacArther, R.A., V. Geist, and R.H. Johnston. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. Journal of Wildlife Management 46:351- 358.

Maki, A. 1992. Of measured risks: the environmental impacts of the Prudhoe Bay, Alaska, oilfield. Environmental Toxicology and Chemistry 11:1691-1707.

Manzer, D.L., and S.J. Hannon. 2005. Relating grouse nest success and corvid density to habitat: A multi-scale approach. Journal of Wildlife Management 69:110-123.

Marzluff, J.M., S.T. Knick, M.S. Vekasy, L.S. Schueck, and T.J. Zarriello. 1997. Spatial use and habitat selection of golden eagles in southwestern Idaho. Auk 114:673-687.

McGahn, J. 1968. Ecology of the Golden Eagle. Auk 85:1-12.

McIntyre, C.L. 2002. Patterns in nesting area occupancy and reproductive success of golden eagles (*Aquila chrysaetos*) in Denali National Park and Preserve, Alaska, 1988-99. Journal of Raptor Research 36 (1 Supplement): 50-54.

McLaren M.A., and J. E. Green. 1985. The reactions of muskoxen to snowmobile harassment. Arctic 38:188-193.

Moynahan, B. J., M.S. Lindberg, and J.W. Thomas. 2006. Factors contributing to process variance in annual survival of female greater sage-grouse in north-central Montana. Ecological Applications 16:1529–1538.

Nelleman, C., and R.D. Cameron. 1998. Cumulative impacts of an evolving oilfield complex on the distribution of calving caribou. Canadian Journal of Zoology 76:1425-1430.

Nelson, O.C. 1955. A field study of Sage Grouse in southeastern Oregon with special reference to reproduction and survival. M.S. Thesis, Oregon State College, Corvallis.

Neu, C.W., C.R. Byers, and J.M. Peek. 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management 38:541-545.

NWCC. 2010. Protocols for assessing impacts of wind energy development on greater sage-grouse.

Olendorff, R.R. 1976. The food habits of North American golden eagles. American Midland Naturalist 95:231-236.

Oyler-McCance, S.J., and T.W. Quinn. 2011. Molecular insights into the biology of greater sage-grouse. Chapter 5 in Studies in Avian Biology, No. 38. University of California Press.

Patterson, R.L. 1952. The sage grouse in Wyoming. Sage Books Inc., Denver, CO. 341pp.

Pitman, J.C., C.A. Hagen, R.J. Robel, T.M. Loughlin, and R.D. Applegate. 2005. Location and success of lesser prairie-chicken nests in relation to vegetation and human disturbance. Journal of Wildlife Management 69:1259-1269.

Prather, P., and T.A. Messmer. 2010. Raptor and corvid response to power distribution line perch deterrents in Utah. Journal of Wildlife Management 74:796-800.

Pruett, C.L., M.A. Patten, and D.H. Wolfe. 2009. Avoidance behavior by prairie grouse: Implications for development of wind energy. Conservation Biology 23:1253-1259.

Reardon, J. 1951. Identification of waterfowl nest predators. Journal of Wildlife Management 15:386-395.

Remington, T.E., and C.E. Braun. 1985. Sage grouse food selection in winter, North Park, Colorado. Journal of Wildlife Management 49:1055-1061.

Robel, R.J., J.N. Briggs, A.D. Dayton, and L.C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23: 295-297.

Sargeant, G.A., D.H. Johnson, and W.E. Berg. 1998. Interpreting carnivore scent-station surveys. Journal of Wildlife Management 62:1235-1245.

Sauer, J.R., W.A. Linkand, and J.D. Nicholas. 2003. Estimation of changes in populations and communities from monitoring and survey data. (http://www.nebirdmonitor.org/tools-resources/methodspdfs/saueretal03/view).

Sauls, H.S. 2006. The role of selective foraging and cecal microflora in sage-grouse nutritional ecology. Masters. The University of Montana, Missoula.

Schroeder, M.A., and R. K. Baydack. 2001. Predation and the management of prairie grouse. Wildlife Society Bulletin 29:24-32.

Smith, M.B., D.A. Aborn, T.J. Gaudin, and J.C. Tucker. 2008. Mammalian predator distribution around a transmission line. Southeastern Naturalist 7:289-300.

Smith, W.P., D.L. Borden, and K.M. Endres. 1994. Scent-station visits as an index to abundance of raccoons: an experimental manipulation. Journal of Mammalogy 75:637-647.

Sparks, E.J., J.R. Belthoff, and G. Ritchison. 1994. Habitat use by Eastern Screech-Owls in central Kentucky. Journal of Field Ornithology 65:83-95.

Stahlecker, D.W. 1978. Effect of a new transmission line on wintering raptors. Condor 80:444–446.

Steenhof, K., M.N. Kochert, and T.L. McDonald. 1997. Interactive effects of prey and weather on Golden Eagle reproduction. Journal of Animal Ecology 66:350–362.

Steenhof, K., M.N. Kochert, and J.A. Roppe. 1993. Nesting by raptors and common ravens on electrical transmission line towers. Journal of Wildlife Management 57:271-281.

Steenhof, K., and M.N. Kochert. 1988. Dietary responses of three raptor species to changing prey densities in a natural environment. Journal of Animal Ecology 57:37-48.

Stevens, B.S. 2011. Impact of fences on greater sage-grouse in Idaho: collisions, mitigation, and spatial ecology. MS Thesis, University of Idaho, Moscow. 210 pps.

Stiver, S.J., A.D. Apa, J.R. Bohne, S.D. Bunnell, P.A. Diebert, S.C. Gardner, M.A. Hilliard, C. W. McCarthy, and M. A. Schroeder. 2006. Greater sage-grouse comprehensive conservation strategy. Western Association of Fish and Wildlife Agencies. Cheyenne, WY. Unpublished report.

Sveum, C. M., W. D. Edge, and J. A. Crawford. 1998. Nesting habitat selection by sage-grouse in south-central Washington. Journal of Range Management 51:265-269.

Sveum, C.M. 1995. Habitat selection by Sage Grouse hens during the breeding season in south-central Washington. M.S. Thesis, Oregon State University, Corvallis.

Tyler, N.J.C. 1991. Short-term behavioural responses of Svalbard reindeer *Rangifer tarandus platyrhynchusto* direct provocation by a snowmobile. Biological Conservation 56:179-194.

Underwood, A. J. 1994. Beyond BACI: Experimental designs for detecting human environmental impacts on temporal variation in natural populations. Australian Journal of Marine and Freshwater Research 42:569-587.

U.S. Fish and Wildlife Service (USFWS). 2010. Notice of 12-Month Petition Findings for Petitions to List Greater Sage-grouse as Threatened or Endangered (http://www.regulations.gov and www.fws.gov)

Utah Wildlife in Need (UWIN). 2010. Contemporary knowledge and research needs regarding the potential effects of tall structures on sage-grouse (*Centrocercus urophasianus* and *C. minimus*). http://www.utahcbcp.org/htm/tall-structure-info

Verlinden, A. 1997. Human settlements and wildlife distribution in the southern Kalahari of Botswana. Biological Conservation 82:129-136.

Vistnesi, I., and C. Nelleman. 2001. Avoidance of cabins, roads, and powerlines by reindeer during calving. Journal of Wildlife Management 65:915-925.

Vistnesi, I ., C. Nelleman, P. Jordhoy, and O. Strand. 2001. Wild reindeer: impacts of progressive infra-structure development on distribution and range use. Polar Biology 24:531-537.

Voight, D.R., and J.D. Broadfoot. 1995. Effects of cottage development on white-tailed deer, *Odocoileus virginianus*, winter habitat on Lake Muskoka, Ontario. Canadian Field-Naturalist 109:201-204.

Wakkinen, W.L., K.P. Reese, J.W. Connelly, and R.A. Fischer. 1992. An improved spotlighting technique for capturing sage grouse. Wildlife Society Bulletin 20:425-426.

Walker, B.L., D.E. Naugle, and K.E. Doherty. 2007. Greater sage-grouse population response to energy development and habitat loss. Journal of Wildlife Management 71:2644-2654.

Weisenberger, M.E., P.R. Krausman, M.C. Wallace, D.W. DeYoung, and O.E. Maughan. 1996. Effects of simulated jet aircraft noise on heart rate and behavior of desert ungulates. Journal of Wildlife Management 60:52-61.

White, G.C., and K.P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 (suppl):120-139 B-1

Wiley, R.H. 1973. Territoriality and non-random mating in sage-grouse, *Centrocercus urophasianus*. Animal Behavior Monographs 6:87-169.

Wisdom, M.J., C.W. Meinke, S.T. Knick, and M.A. Schroeder. 2011. Factors Associated with extirpation of sage-grouse. Chapter 19 in Studies in Avian Biology, No. 38. University of California Press.

Wolfe, S.A., B. Griffith, and C.A.G. Wolfe. 2000. Response of reindeer and caribou to human activities. Polar Research 19:63-73.

Wolff, J.O., T. Fox, R.R. Skillen, and G. Wang. 1999. The effects of supplemental perch sites on avian predation and demography of vole populations. Canadian Journal of Zoology 77:535-541.

Wyoming Wildlife Consultants, LLC. (WWC). 2009. Greater sage-grouse winter habitat selection relative to natural gas field infrastructure in northern portions of the Pinedale Anticline Project Area Sublette County, Wyoming. Annual Report. Pinedale, WY.

Young, J.R. 1994. The influence of sexual selection on phenotypic and genetic divergence among Sage Grouse populations. Ph.D. Dissertation, Purdue University, West Lafayette, IN.

Appendix A. Research-Governance Structure and Responsibilities – Conceptual Design

Governance Structure and Responsibilities

Governance Committee (GC)- (5-6 members from the WAFWA/EOC, Energy Industry, Chair of SOC and Director of FRPMF)

- Strategic oversight and general management
- Adopt changes to the research protocol
- Award research proposals
- Approve and sign off on contracts
- Authorizes release of research funds
- Monitor and advises SOC and FRPMF

Scientific Oversight Committee (SOC) – (4-6 members which may include independent research experts and technical advisors)

- Review pre-release requests for proposals (RFP)
- Review and recommend proposals to GC
- Conduct annual research review and recommend changes to protocol
- QA/QC of research to insure compliance with protocol

Fund Raising and Project Management Foundation (FRPMF)

- Solicit funding for research
- Hold, disperse and track research funding
- Prepare and issue RFPs
- Negotiate and administer research contracts
- Coordinate meetings and provide administrative support to GC and SOC

Appendix B. Literature Review of Sage-grouse Avoidance of Tall Structures

Reports cited in the literature regarding the relationship of tall structures and sage-grouse focus on disruptions of leks. Braun (1998) and Braun et al. (2002) are commonly cited as documentation of sage-grouse avoidance of tall structures. Braun et al. (2002) reported sage-grouse leks within 0.25 miles from a new power line had significantly slower growth rates compared to leks located further from the line. They hypothesized the slower growth rates were a result of increased raptor predation but did not provide data to quantify increases in mortality or decreases in growth rates.

More recent citations reporting avoidance of sage-grouse of tall structures reference CBNG and energy development. Avoidance behavior by grouse of lek sites and habitats that are near energy developments have been reported by Lyons and Anderson (2003), Holloran (2005) (also see Walker et al. 2007, Doherty et al. 2008, Holloran et al. 2010). However, the CBNG studies report avoidance as a cumulative effect involving a broad spectrum of anthropomorphic impacts without isolating specific mechanisms.

Hall and Haney (1997) are cited in state siting policies as evidence that sage-grouse avoid tall structures but not by the USFWS (2010) in the listing decision. Hall and Haney (1997) reported observing 82 disturbances of sage-grouse at a lek. Of those, 29 were caused by raptors (25 golden eagles, 5 others), which were observed to be perching on nearby power lines. Wild ungulates caused 18 disturbances. The methodology of the study was not discussed. They also did not describe any causal link or correlation between energy development and lek attendance by males or nest initiation rates.

Braun (1998) is cited by the USFWS (2010) and other authors as a source for the statement "power lines may fragment sage-grouse habitat even in the absence of raptors." Braun (1998) cites Graul (1980), Ellis (1984), and Ellis et al. (1987) as supporting documentation. The author also reports unpublished data to document that sage-grouse use of suitable habitat near power lines increased as distance from the power line increased from up to 660 yd and based on unpublished data reported the presence of power lines may limit sage-grouse use within 0.6 miles of otherwise suitable habitat. Some state transmission line siting guidelines cite Braun (1998) to support the following relationships with energy developments: 1) avoidance behavior by grouse of lek sites and habitats that are near anthropogenic sites 2) higher mortality rates of breeding sage-grouse in oil and gas fields, 3) lower nest initiation rates and success, 4) loss or degradation of critical habitat, and 5) increases in avian predator populations.

Johnson et al. (2011) and Wisdom et al. (2011) analyzed lek and distribution data from within the conservation area defined by Connelly et al. (2004) to determine the effects of anthropogenic factors on sage-grouse populations and risk of extirpation, respectively. These authors acknowledged the retrospective nature of their studies in that many of the factors were in place prior to their studies and thus, the effects of historical factors might be masked by more recent changes.

Johnson et al. (2011) did not detect any relationship between lek distance to secondary roads and power lines with lek trends. However, lek count trends were negatively related to proximity to the closest communications tower and to the number of towers within 18 km. They explained their seemingly disparate results by stating that communication towers typically indicated high human-use areas, whereas power lines (especially transmission lines) are more uniformly distributed across the landscape. Most power lines were placed prior to their study period, and any effects they had may have already occurred. Thus, the lower trends at sage-grouse leks near towers may be in response to these spatially associated activities and not the towers themselves. However, towers themselves may be stressors, and differences in relations between lek trends and the two types of vertical structures may be due to the different times they were erected. Communications towers have only recently become common in the area, and sage-grouse populations may have responded to them during the study period.

Johnson et al. (2011) stated that their results should be viewed with caution because the lek counts and the surveyed leks may not be representative of the entire population (Johnson and Rowland 2007). Currently there are no scientifically defensible methods for estimating regional sage-grouse populations based on lek counts (Connelly et al. 2004). They also acknowledged that their study was observational, rather than experimental. Thus the associations observed in the data do not reflect causation.

Wisdom et al. (2011) analyzed differences in 22 environmental variables between areas of former range (extirpated range), and areas still occupied by the Gunnison (*C. mimimus*) and greater sage-grouse (occupied range). They reported that 15 of the 22 variables they analyzed differed between extirpated and occupied ranges. Five variables: sagebrush area; elevation; distance to transmission lines; distance to cellular towers; and land ownership correctly classified >80% of sage-grouse historical locations in extirpated and occupied ranges. Three anthropogenic variables, distance to transmission lines, distance to cellular towers, and land ownership differed between occupied and extirpated ranges. The authors stated that these variables received little attention in landscape research on sage-grouse. Wisdom et al. (2011) concluded that the two variables strongly associated with sage-grouse extirpation, distance to transmission lines and distance to cellular towers, have unknown relations with regional sage-grouse population dynamics. They stated new mechanistic research will be needed to more completely understand the potential relationship of these variables to sage-grouse extirpation and to establish effective management options. As an example they noted that the use of raptor perch deterrents on vertical structures may not mitigate the effects of these structures if sage-grouse population declines result from avoidance of habitats in close proximity and not reduced survival due to changes in predator distributions (Lammers and Collopy 2007).

Although prairie chickens (*Tympanuchus* spp.) and sage-grouse are both lekking species that occupy broad geographic landscape, they differ in morphology, behavior, life history, seasonal habitat use patterns, and distribution. These differences may confound comparisons regarding their individual and population responses to tall structures. However, the U.S. Fish and Wildlife Service (USFWS 2010), in the Notice of 12-Month Petition Findings for Petitions to List Greater Sage-grouse as Threatened or Endangered (http://www.regulations.gov and www.fws.gov), cited results reported by Pruett et al. (2009) regarding lesser (*T. pallidicintus*) and greater (*T. cupido*) prairie chicken in support of Braun's (1998) statements that sage-grouse avoid suitable habitat near power lines. Braun's (1998) comments were based upon unpublished data. Most state policies regulating siting of power lines do not include citations that reference prairie chicken studies. Pruett et al. (2009) was cited in a recent NWCC report that lumps sage-grouse and prairie chickens into the category of "prairie grouse" (**http://www.nationalwind.org//publications/bbfactsheet.aspx?idevd=2F910A046ACD11DEA5DEEC6455D89593&idevm=ccc382da3ab54cc185d952d0766b3bd3&idevmid=334498**).

Robel et al. (2004) and Pitman et al. (2005) reported that lesser prairie-chicken nests were farther from all anthropogenic features – except unimproved roads – than would be expected by chance. The number of roads and extent of each type of road are not described, but included improved roads (graveled or paved). These authors concluded that lesser prairie-chicken avoidance behavior, particularly for nesting females, creates "avoidance buffers" around anthropogenic features in the landscape that fragment, isolate, and reduce available habitat. They suggested that avoidance buffers should be measured for species in various landscapes to assess the true impact of human disturbances.

Appendix C. Literature Review Regarding the Potential Effects of Tall Structures on Increasing Predation Rates in Sage-grouse.

Sage-grouse are a lek species. Lack (1968) argued that predation and sexual selection were equally as important in the evolution of lekking behavior. However, most evolutionary models assume that sexual selection, not predation, is a major determinant of lekking behavior. Boyko et al. (2004) used a stochastic dynamic game model to study how the risk of predation by golden eagles (*Aquila chrysaetos*) could affect greater sage-grouse lek dynamics. Although observations of golden eagle successful predation are scarce, numerous authors have documented attacks by golden eagles on lekking male sage-grouse (Patterson 1952, Wiley 1973, Hartzler 1974, Bradbury et al. 1989, Gibson and Bachman 1992). The Boyko et al. (2004) model predicted that high mean levels of predation risk coupled with small lek size (< 12 birds) should reduce lek attendance. However, the relative tendency of golden eagles to attack large (>50 birds) versus small leks had little influence on lekking behavior.

Corvids may also prey on sage-grouse nests, chicks and juvenile birds (Batterson and Morse 1948, Patterson 1952, Nelson 1955, Young 1994, Delong et al. 1995, Sveum 1995). Common ravens and crows have been implicated as important predators of sage-grouse and other prairie grouse nests (Manzer and Hannon 2005, Coates 2007).

Connelly et al. (2000) and Connelly et al. (2004) suggested that because of the potential for raptors and corvids to use transmission line towers and distribution line poles as new perches and nest sites, placement of these facilities in seasonal sage-grouse habitats could impact the species through increased predation of adults, juveniles, and nests or result in sage-grouse abandoning sites. Wolff et al. (1999) reported that although the addition of perches in prairie chicken habitat can increase raptor visitations, they may have little effect on high-density prey populations.

Manzer and Hannon (2005) in a study on effects of corvid density on sharp-tailed grouse (*Tympanuchus phasianellus*) in Alberta reported that the ecological processes that influence nest success occurred at scales < 50 m and > 1600 m rather than the immediate area used by nesting hens. Grouse nests were more vulnerable to corvid predation if they were close to perch sites (< 75 m) unless adequate cover was available. They suggested that efforts to improve nest success by increasing cover and removing perches may have limited success if larger scale factors that influence predator densities are overlooked. Coates and Delehanty (2010) did not find this to be the case with sage-grouse. They found that grouse with less shrub cover at the nest site were more likely to be depredated by ravens. This is an important distinction because ravens may be in the environment but have a difficult time locating grouse in areas with increased shrub cover.

Citations commonly used to document increased predation on sage-grouse because of increasing local predator populations and hunting efficiency attributed to tall structures include Ellis (1984, 1985a, 1985b), Ellis et al. (1987, 1989), Steenhof et al. (1993), Knight and Kawashima (1993), Hall and Haney (1997), Braun (1998), Connelly et al. (2000), and Coates and Delehanty (2010). Ellis (1984) described lekking sage-grouse responses to a golden eagle perched on an oil well located 500 m from two leks. This reference has been incorrectly cited in the literature to substantiate statements that the presence of transmission lines may change sage-grouse dispersal patterns and habitat fragmentation. Records of disturbance at leks by avian predators were correlated with counts of avian predators along a transmission line within 20 km of leks (Sedinger et al. 2010).

Ellis (1985b) was cited by the USFWS (2010) to support the statement that increased abundance of raptors and corvids within occupied sage-grouse habitats can result in increased predation. This report was not peer-reviewed. Ellis (1985a,b) reported sage-grouse predation rates increased from 26 to 73% after a transmission line was constructed within 220 yd of an occupied lek in Utah. He did not report any data regarding changes in corvid and raptor abundance or habitat changes as a result of the power line, but concluded its construction near the lek fragmented that habitat and resulted in its abandonment. Ellis et al. (1989) reported on sage-grouse habitat day-use. They concluded that sage-grouse use areas near leks constitute 0.25 sq. km. They recommended that if the day-use areas cannot be identified, managers should maintain sagebrush cover within 3 km of leks.

Knight and Kawashima (1993) studied linear right-of-ways to determine if any relationships exist between these rights-of-ways and vertebrate populations. Specifically they examined the relationship between these areas and common raven and red-tailed hawk (*Buteo jamaicensis*) populations in the Mojave Desert of California. Their data suggested that ravens are more abundant along highways because of automobile-generated carrion, whereas both ravens and red-tailed hawks are more common along power lines because of the presence of superior perch and nest sites. They recommended that land managers evaluate possible changes in vertebrate populations and community-level interactions when assessing the effects of future linear right-of-way projects. This study is cited to substantiate statements that power lines create perches and nesting platforms for raptors and corvids and thus contributed to increased species abundance and hence greater sage-grouse predation risks.

Steenhof et al. (1993) is frequently cited as documentation of the effects of power lines on increasing raptor and corvid abundance. They attributed population increases in four raptor species and common ravens in their southern Idaho and Oregon study areas to the use of nesting platforms placed during construction of the line and towers in 1980. Artificial nesting platforms were installed on 37 of the 1,608 towers, chosen non-randomly. Raptors and common ravens began using the towers within a year after construction. By 1989, the number of pairs using towers increased to 133; ravens were the most common species in each year. Golden eagles nested on the towers in all years; growing from a single pair to eight pairs during the study. Towers provided new and alternative nesting substrate, as a pair shifted from natural substrate to towers. New pairs that had not previously nested in the study area nested on the towers. In total, 274 of 1,608 available towers were used. They reported higher nest success rates for the towers than for natural substrates, but were not higher for towers with platforms than for those without or for other manmade substrates, except for golden eagles, which did not nest successfully on towers without platforms. They concluded that the lack of a nesting substrate had been a limiting factor that was removed when the towers were built. They also noted that nesting densities of these species elsewhere in the area were as high as or higher than before the power line was erected.

Coates and Delehanty (2010) reported increased common raven numbers had negative effects on sage-grouse nest survival, especially in areas with relatively low shrub canopy cover. Evidence suggested that variation exist in incubation patterns as well as nest site selection among females. Those that recess during light hours and spend longer times off the nest are more likely to be depredated by ravens. They encouraged wildlife managers to reduce interactions between ravens and nesting sage-grouse by reducing the anthropogenic footprint and restoring and maintaining shrub canopy cover in sage-grouse nesting areas. However, no similar peer-reviewed studies report similar effects for golden eagles. The potential impacts of golden eagles and corvids increased use of tall structures on sage-grouse relative to the species foraging potentials are discussed below.

Marzluff et al. (1997) reported shrub-steppe communities provide important foraging habitat for the golden eagle. Small to medium-sized mammals such as hares (*Lepus* spp.), ground squirrels (*Citellus* spp.), marmots (*Marmota* spp.), mountain beaver (*Aplodontia rufa*) and birds (e.g., pheasant, grouse) are important prey for golden eagles (McGahan 1968, Olendorff 1976, Bruce et al. 1982, Steenhof and Kochert 1988, Marzluff et al. 1997). Steenhof et al. (1997) and McIntyre (2002) reported increased productivity in golden eagles in years with higher abundance of hare.

Continental populations of the common raven, American crow (*Corvus brachyrhynchos*), and black-billed magpie (*Pica hudsonia*) are increasing (Sauer et al. 2003). Boarman and Heinrich (1999) reported that daily forays of common ravens differ by region and breeding status, but they can travel >10 km from nest or roost sites. Non-breeding ravens traveled daily an average 6.9 km in Idaho (up to 62.5 km) to 27 km in Michigan (range 0.8 – 147 km) from roost sites to distant food sources (Boarman and Heinrich 1999). Breeding pairs hunted on average 0.57 km from the nest (Boarman and Heinrich 1999).

Connelly et al. (2004) estimated that a minimum of 15,296 km^2 of contemporary sage-grouse range contained large power lines. Based on this estimate and the foraging distances of golden eagles and corvids they projected the power lines, as a potential source of additional perches, could influence 672,344 to 837,390 km^2 or 32-40% of the available sagebrush habitats. Their estimate did not account for the effects of environmental conditions (i.e., habitat conditions, primary prey abundance) on raptor or golden eagle densities.

Hagen (2011) reviewed the published literature in regards to the impacts of predation on sage-grouse. He reported that range wide sage-grouse nest success rates and adult survival are relatively high and that few studies have demonstrated a link between habitat quality, predation and mortality rates. He concluded that in areas where the habitat is fragmented or predator populations are sustained at higher levels because of anthropogenic activities predation may limit population growth (Bui et al. 2010).

Table 1. Summary of Methodologies for Investigating the Effects of Tall Structures on Sage-grouse (*Centrocercus* spp.) within Designated Energy Corridors

Species/ Metric	Telemetry/Technology				Habitat				Specimen/Individual					Survey								Data Analysis								
	VHS	GPS	GIS	Video	Line Inter-cept	Robel Pole	Dauben-mire Frame	Plant Chemistry	DNA	Wing Data	Carcass	Nest Site	Weight /age	Banding	Lek Count	Bird dogs	Mark recap-ture	Spot-light Counts	Point Counts	Pellet Counts	Scat Tran-sects	Track Counts	Scent Station	Program Mark	Maxium like-lihood	Fixed Kernal	Gradient Analysis	CMR	Regres-sion	Distance
Sage-grouse																														
Nest Success	x				x	x	x		x	x		x	x											x	x					
Nest Predator		x								x																				
Brood Success		x				x	x	x				x					x		x						x					
Female survival	x	x									x			x			x							x						
Male Survival	x	x									x			x			x							x				x		
Juvenile Survival	x	x									x			x			x							x						
Chick Survival	x										x														x					
Lek Attendance	x	x												x														x		
Mortality Factors	x	x									x																			
Population Trends	x	x													x									x						
Population Estimates	x	x												x	x		x			x				x						
Movement		x	x	x																								x		
Seasonal Habitats	x	x	x		x	x	x	x												x						x	x			
Occupancy patterns	x	x	x													x		x		x				x		x				
Fragmen-tation	x	x	x		x	x	x	x	x																					
Habitat Quality	x	x	x		x	x	x	x																						
Habitat Selection	x	x	x		x	x	x	x								x		x		x									x	
Mammalian Predators																		x		x		x						x		
Presence/Absence																		x	x		x	x	x						x	
Abundance																		x	x		x	x	x							
Avian Predators																				x							x			
Presence/Absence																			x										x	
Abundance																														