Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed.

Theme/topic	Question or Issue	Citation
Sage-Grouse Biology		
Adaptation	How well can sage-grouse adapt to rapidly changing environments?	18
Adaptation – Genetics	Are there adaptive differences among sage-grouse populations across the range?	18
	How do we identify and conserve adaptive genetic variation?	18
	Are sage-grouse populations genetically adapted to local conditions?	9
Behavior	Inform interpretation of behavior, such as vocalizations, food habits, characteristics and causes of dispersal and migration, territoriality, seasonal site fidelity, and differences in behavior and productivity by sex, age, and region.	6
	Are there other behaviors in sage-grouse that can have relevance to improved survey methodologies, productivity, survival, and management?	6
	Determine population-level responses to a suite of specific stressors (e.g., road density, development intensity, traffic volumes, noise, recreators).	13
Behavior – Genetics	Relationship between genetics and behavior (dispersal) and management (population size or landscape fragmentation) remain relatively unexplored.	6
	Testing, elucidation, and detailed consideration of parentage, inbreeding, outbreeding, and relationships between genetics and behavior and fitness.	6
	Expand and improve local and regional population genetic information—relationships and elucidation regarding dispersal behavior, reproductive patterns, population size, and habitat connectivity/isolation.	6
Connectivity – Genetics	Collect genetic and movement data to evaluate the potential for open or closed populations.	12
	Using results of population genetic testing review prioritization of inter-population linkages.	9
	A more detailed account of sage-grouse sub-populations would be instrumental in determining mechanisms that may be limiting gene flow.	12
	How are primary populations interconnected across regions of lower population densities and less suitable habitat?	17
	Population genetics and the effects of connectivity between populations.	10
	What is the relative importance of landscape features and relevant spatial scales that influence gene flow?	17
	What are the (long-term) connections between habitat/population connectivity, population genetics, and likelihood of a bottleneck (or similar, limiting/reducing effect) event, and the long-term survival/conservation of the species?	17
	Robust range-wide genetics.	15
	How well are populations/subpopulations connected—level of genetic isolation?	11, 15, 18
	Range-wide genetic and habitat connectivity (dispersal dynamics both fine-scale—how individuals move through a habitat matrix- and coarse-scale – gene flow).	18
	Improve link/knowledge regarding population connectivity, gene movement, genetic diversity, and sage-grouse conservation.	14
Fitness – Genetics	What is the mutation rate and heritability in sage-grouse?	9
	What is an adequate genetic effective population size to avoid accumulating mutations?	9
	Parentage, inbreeding, outbreeding, and relationships between genetics and behavior and fitness.	6
Food	How does food availability and quality influence sage-grouse at multiple life stages?	18
Food – Insects	Identify and monitor insect availability, abundance and diversity within specific sites to gain an understanding of their importance to sage-grouse.	1
	Interactive effects of climate and land use, including pesticides and herbicides, on insect-vegetation timing/availability and sage-grouse behavior, brood-rearing, etc.	17
Habitat selection – Habitat quality	Better translation of scales of sage-grouse habitat selection into measures of habitat condition/pattern and management planning and actions – use scale to better connect otherwise/often disparate considerations.	17
	Sage-grouse habitat suitability model.	9

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Sage-Grouse Biology—Continued		
Habitat selection – Seasonal	Determine seasonal habitats such as breeding, nesting, brood rearing.	2
Habitat selection – Veg-Pop linkage	Correlate bird health with habitat condition parameters.	2
	Determine/verify use (food and shelter) of sagebrush taxa used by the various sage-grouse populations (Big vs. Black/Silver), especially in wintering habitats.	10
	Better define and establish the relationship between sage-grouse habitat selection and multi-scale assessment of habitat conditions and multi-scale considerations for planning and policy, and multi-scale considerations for implementation (relevant scales, topics, concerns, foci, etc.).	11
	Uncertainties about potential differences in habitat selection associated with sex, age, season, management, region, weather, breeding success, and survival.	6
	Link between occupancy and habitat characteristics – Causal vs. Correlative.	13
Habitat selection – Winter	Winter habitat selection and availability – test and examine the interplay of depth of snow, movement of snow and height of sagebrush; likely requires micro-habitat delineation and assessment(s).	17
Landscape – Genetics	What is the sage-grouse "genetic landscape"?	9
Methods – Genetics	Develop and refine, if it proves feasible, techniques to obtain DNA from sage-grouse fecal droppings.	9
Monitoring – Genetics	Can genetics be used as a standard technique to monitor and evaluate population structure, spatial configuration, and health?	6
	Genetics of feathers/pellets to monitor population size or trends.	6
Mortality	Assess sage-grouse mortality rates, factors that influence them, and effectiveness of actions taken to reduce them.	4
	Variation in survival due to age, sex, region, habitat, and management.	6
	Initiate studies to better understand sage-grouse mortality rates, factors that influence these rates, and effectiveness of management actions to change them.	4, 5
Mortality – Brood-rearing	Determine the cause(s) of chick mortality during early brood-rearing.	1
Mortality – Causes	Determine the causes of mortality in different sage-grouse age and sex classes and the consequences for population dynamics.	9
	Are there population impacts from research-related mortalities?	10
	Understanding annual survival and seasonal mortality is critical and largely undocumented.	12
Mortality – Juveniles	Evaluate and publish the effects of predation, insecticides, disease, and other sources of mortality on the juvenile segment of sage-grouse populations.	10
	Determine when, where, and why sage-grouse chicks fall out of the population will be important both to determine risks and recommend conservation actions.	2
Movement patterns	How does movement vary by sex, age, region, habitat, landscape, weather, and management?	6
	Characterize brood movement patterns.	12
	Determine movement patterns.	2
	Continuing, expanding, initiating additional radio/GPS marked grouse studies to better capture/relate specific distributions and behavior to conditions.	13
Movement patterns – Connectivity	Level of connectivity of populations and the sedentary and/or migratory behavior of sage-grouse.	12
	Condition, roles, and risks to "fringe populations" (ND, SD, northern MT, Canada, and WA?)	13
Movement patterns – Dispersal	Evaluate the potential for dispersal of individuals into currently unoccupied suitable habitat.	9
	Natal dispersal parameters in sage-grouse.	3
	Natal dispersal of sage-grouse, and how that process impacts the spatial structuring of populations.	12

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Sage-Grouse Biology—Continued		
Movement patterns – Migratory	Identify resident and migratory populations of sage-grouse, key habitats, and movements, relevant to local conservation efforts.	4
	Need a better understanding of sage-grouse movements, habitat selection, and which areas should be considered high priorities for sagebrush management efforts.	8
	Identify the migratory status of all sage-grouse populations.	12
Movement patterns – Seasonal	Identify and protect traditional breeding, brood-rearing, migration corridors, and wintering habitats (local populations).	10
	Movements of grouse from leks to nesting and brooding areas.	5
	Movements from summer to winter habitat.	5
	A better understanding of sage-grouse movement patterns and seasonal ranges and its application to management actions.	2, 12
	Identifying seasonal movements and migrations are key factors in assessing and monitoring core sage-grouse habitats (seasonal and yearlong).	12
Multi-scale condition – Monitoring – Methods	Develop, adapt, coordinate, and unify implementation of monitoring and monitoring protocols for sage-grouse distribution, population trends – should link with habitat monitoring.	14
	Development of a monitoring program that adequate resources are appropriately assigned to both large-scale and small-scale measurements to achieve sufficiently precise estimates of key population parameters.	2
Population – Biases – Monitoring	Observational biases associated with observer, habitat, region, and topography.	3, 6
	Bias associated with using "trend" leks to assess population change.	2
Population – Brood survey – Monitoring	How do estimates from brood surveys compare/correlate with lek counts and harvest surveys (if at all)?	6
	Do brood surveys or routes provide useful information that can be applied to the long-term monitoring of sage-grouse populations or to the identification of critical habitat?	6
	Do brood surveys/routes provide useful information that can be applied to monitoring?	6
Population – Cycles/Trends	Do sage-grouse populations in certain areas have cyclic population trends?	9
Population – Demographics	What should target population levels be for a sage-grouse management zone (SMZ) and how do they vary geographically based on inherent productivity of associated landscapes/ ecosystems?	18
	Evaluate nest success based on sagebrush plant structure in addition to sagebrush and herbaceous plant cover and height.	1, 12
	Better understanding of realized contributions of individual demographic rates to sage-grouse population growth would provide a better understanding of the causal factors that have contributed to long-term declines.	18
	Little is known regarding population demographics of the isolated populations.	7
Population – Demographics – Genetics	Investigate the demographics and population dynamics of sage-grouse. Sex ratio, male genetic contribution per generation, dispersal, and other parameters that determine effective population size and population viability.	3
Population – Demographics – Monitoring	Population demographics are challenging due to seasonal mortality differences and low productivity – what are the implications for population viability? And what are links to habitat loss/fragmentation trends?	13
	Population demographics – breed propensity, nesting likelihood – habitat condition/use * behavior interaction (need insight across multiple years and seasons).	13
	Describe, develop, and otherwise standardize (accepted/common) methods for population demographics?	13
	Assess density dependence in sage-grouse populations to improve population dynamics estimates.	13
	Understanding demographic parameters within population management units.	2
Population – Demographics – Productivity	How do the different parameters (nest likelihood, clutch size, renesting likelihood, nest success, hatchability) associated with productivity compare across regions?	6
	How do aspects of productivity fit into a sensitivity/elasticity analysis?	6

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Sage-Grouse Biology—Continued		
Populations – Genetics	Do populations vary genetically and if so how do they vary?	9
	What is the relative amount of genetic diversity contained in each population?	9
	Genetic variability within populations.	9
	What population size is necessary to avoid inbreeding depression? Current thought is 500 but appears to be low.	9
	Population size necessary for balancing between mutation and genetic drift?	9
	What are the effects of genetic isolation of small, isolated populations? – Is there inbreeding depression? – Is there loss of genetic variability?	10
	Genetic health (represented by adequate genetic heterogeneity) of sage-grouse populations.	3
	Fine-scale, population-level genetic analyses – within and inter population comparisons (e.g., sage-grouse vs. GUSG vs. Lyon-Mono)	13
	Fine-scale genetics work: Example: How do lek counts relate to actual and effective population sizes?	18
	What are biologically meaningful populations?	18
Population – Isolated	Determine and publish the susceptibility of small isolated and fringe populations to habitat and population factors, and the contributions of these populations to the larger meta-population.	10
Population – Isolated – Monitoring	Develop a more effective approach to determine sage-grouse populations in isolated areas.	7
Population – Juveniles	Mortality of juvenile sage-grouse or the level of production necessary to maintain a stable population.	10
	Developing a better understanding of survival rates, especially for juveniles under different conditions is also important to develop effective conservation actions.	2
Population – Leks – Monitoring	Develop standardized methods for estimating breeding population size of both males and females.	13
	What are the best methods to effectively survey lek complexes?	3
	What are the best methods to effectively survey the variability in lek counts within a year and its relevance to long-term monitoring?	3
	What are the best methods to effectively survey the relationship between productivity in one year and the coefficient of variation in lek counts in the subsequent year?	3
	Evaluate typical “baseline” data; early vs. modern count methods; known/suspected cycling.	14
	Development of a statistically reliable trend monitoring protocol for inventorying lek attendance of male sage-grouse.	4, 5
	Limitations associated with extrapolation and trend analysis from the lek count data.	2
	Lack of standard definitions for lek status.	2
	Develop a probabilistic sampling scheme for lek counts.	2, 12
	Develop and implement a probability based, spatially balanced sample of breeding males AND females. Approach recommended (Garton and others, 2011) with wide survey across all habitat, systematic sampling of large leks, and intensive sampling at sentinel leks.	13
	What are the attendance rates of males and females?	6
	Variation in attendance due to age, time of day, time of year, and relationship with the peak of female nesting.	6
	What data are necessary to estimate attendance rates?	6
	Can lek attendance rates be used to provide an indication of the previous year’s productivity? Are there other techniques that can be applied to the issue such as infra-red photography, GPS transmitters, active transponders, and PIT tags?	6
	Can female attendance provide useful information related to the timing of nesting, male visitation, habitat condition, and estimation of sex ratio?	6

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Theme/topic	Question or Issue	Citation
Sage-Grouse Biology—Continued		
Population – Leks – Monitoring	Improve value of lek counts by better connecting to population numbers, accounting for variation in male and female attendance rates, seasonal and daily attendance rates, among sampling approaches, and among observers, habitats, regions and topography.	6
	What is the relationship between lek attendance and the previous years' productivity?	6
	What is the influence of lek attendance on population estimates?	9
	What is the influence of disease (e.g., avian malaria) on lek attendance rates and lek counts?	9
	How does body condition influence lek attendance?	9
	Determine and publish the relationship of lek attendance to the population as a whole, effects of possibly double counting males, and reasons for unoccupied leks.	10
	What percentage of leks are actually counted? Are there biases based on population size and lek size?	9
	Evaluate whether sage-grouse lek counts can be calibrated and measurements of accuracy and precision can be assessed using mark-resight or sightability models.	9
	Examine the correlation (and time lag) between the variation in annual sage-grouse productivity and subsequent lek counts and its impact on the precision of population estimates.	9
	Develop technique to use in searching for new or previously unknown sage-grouse leks.	9
	What are the rates of inter-lek movements by male and their influence on population estimates?	9
	What is the female/male ratio and how does it vary annually and regionally?	9
	All sage-grouse leks have not been located and the majority are not monitored on an annual basis.	4
	How close do lek counts reflect sage-grouse population size and change?	10
	Continue searching for unidentified leks.	10
	Uncertainty in lek counts (and other pop. estimates) confounds information in data – need to better elucidate and account for these sources of variability.	17
Population – Mapping	Improve spatial delineation of breeding populations of sage-grouse.	17
Population – Monitoring	Develop inventory technique for searching "vacant/unknown" habitat areas for sage-grouse use.	9
	Establish standardized wing collection protocol to evaluate the influence of environmental conditions on sage-grouse productivity and population trends.	4
	Protocols sufficient to insure the consistent collection of data throughout the range?	6
	Determine the most efficient survey aircraft and survey design for operational surveys.	2
	Develop a monitoring protocol that would more accurately document long-term population trends.	1
	Develop and refine techniques to measure productivity where wing data are unavailable.	1
	Evaluate and adapt population monitoring techniques.	3
	Establish protocols for future population monitoring and record keeping, including mechanisms to assure consistent implementation and reporting.	9
	Develop and evaluate protocols for the inventory and monitoring of sage-grouse populations and to evaluate factors that influence the population ecology of sage-grouse.	9
	Evaluate alternative methods for estimating sage-grouse population abundance (e.g., line transects or DNA fingerprinting using fecal samples).	9
	Refine methods to estimate population sizes.	12
	Develop an efficient method for estimating population size, especially for regions where only a subsample of leks can be monitored.	12
Population – Multi-scale condition – Monitoring	Develop local statistical relationships between key demographic parameters and environmental variables, such as vegetation characteristics or predator abundance, to bridge the gap between large-scale population monitoring and detailed demographic studies.	2

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Sage-Grouse Biology—Continued		
Population – Multi-scale condition – Monitoring	Inventory and monitoring methods/implementation to assess individual populations and habitats as well as regional conditions.	14
	How effective are data collected from a small numbers of leks or single populations at assessing conditions across regions/rangewide? – Related to connecting survey and sentinel approaches (e.g., for monitoring).	13
Population – Pellet counts – Monitoring	Are pellet counts an effective survey technique for sage-grouse abundance or presence/absence?	6
Population – Productivity	Does productivity vary by age, region, habitat, weather, predation pressure, and management?	6
Population – Recruitment	A better understanding of recruitment and more accurate measure of recruitment in certain areas is vital to developing management recommendations for nesting and early brood rearing habitats.	2
	Some components of recruitment, such as post-fledgling survival and female nesting propensity, are poorly understood.	18
	Because recruitment at the population-level is an aggregate of multiple individual vital rates, it is important to understand the contributions of each and the ecological factors that affect them.	18
Population – Regulation	Determine the nature of interaction between population status of sage-grouse, as expressed by estimated vital rates, and habitat condition.	4
	What portion of sage-grouse life-history are limiting?	15
	What role do top-down and bottom-up processes play in regulating sage-grouse populations?	18
	How do top-down and bottom-up mechanisms influence individual vital rates, and how those vital rates contribute to population growth?	18
Population – Reproduction	Determine relationships between condition of the hen during the pre-laying period and the weight of chicks at hatching and chick survival.	2
	Determine relationships between brood-rearing habitat components and chick survival.	2
	Determine the factors that are important in regulating chick survival (and ultimately population conservation) by comparison of health and reproductive parameters, habitat components, and chick survival rates.	2
Population – Scoring – Monitoring	What metric should be used to develop a region-wide score-card to track progress toward desired outcomes and point to areas or population needing improvement?	6
Population – Sex ratio – Monitoring	Sex ratio for sage-grouse – The data needed to accurately estimate sex ratio and the potential techniques to provide a reliable estimate of sex ratio are not clear.	6
Population – Spring Count – Monitoring	Can another tool be developed (e.g., distance sampling) to monitor numbers in late summer or early fall that would be less confounded by previous year's conditions and management than spring lek counts when evaluating annual management?	18
	Statistical relationship between lek counts and populations. Sampling design so states do not have to spend time sampling every lek.	18
Population – Survival	Determine survival rates.	2
Population – Technology – Monitoring	Variation in the technology used to capture and mark birds for monitoring.	6
	New techniques for capturing and monitoring sage-grouse?	6
	Development and application of improved techniques and technology including satellite transmitters, GPS transmitters, and transmitters capable of recording physiological data.	6
	Are there new methods, approaches, technologies to population estimates that could improve the accuracy, reduce effort, decrease time-frames for estimation?	6
	Can modern technologies improve accuracy of counts?	6
Population – Translocation – Monitoring	Evaluate translocation methods (egg transplant, captive incubation, captive breeding and release as young, release as adults, etc.) to develop protocol for future sage-grouse translocations.	3, 9, 10

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Theme/topic	Question or Issue	Citation
Sage-Grouse Biology—Continued		
Population – Trends – Monitoring	Develop statistically defensible methods to estimate sage-grouse population size and/or trends.	9
	Causal mechanism for population cycles in sage-grouse populations.	2, 3
	A rigorous monitoring protocol is needed to assess population status and trend at the fine and mid-scale.	4
	Develop a monitoring strategy that will measure long-term statewide sage-grouse abundance and distribution trends.	4
Population – Trends – Monitoring	Develop robust methods for be establishing estimated population size.	12
	Relate variation in annual rates of population change to habitat and environmental change/ trend/conditions (ID/define/characterize causal linkages between populations and habitat).	13
Risk assessment	What is the definition of an at-risk sage-grouse population?	9
	Identification, at a broad scale, of ecosystem units (hundreds or thousands of acres) which constitute strongholds for large populations of sage-grouse, which are in relatively good ecological health, but which are 'at risk' by threat of wildfire and/or imminent invasion of cheatgrass or other exotic species from adjacent areas.	2
	Prioritize sage-grouse populations by risk status.	1
Risk assessment – Population modeling	Legitimate population viability analysis that focuses on threats, population dynamics, and habitat that leads to range-wide prioritizing for conservation efforts.	18
	Refine the population viability assessment of sage-grouse based on more accurate and precise estimates of demographic parameters.	9
	Importance of understand threats and their influence on population viability.	9
	Is a 500-breeding-bird-minimum a biologically defensible population count to maintain or sustain a healthy sage-grouse population?	10
	Population viability analysis (PVA) – number of populations required for long-term conservation.	15
	Refine and improve PVA inputs, estimation of quasi-extinction thresholds, variances in growth rates, etc. Improve upon the classic approaches, including models that are based on estimates of both long-term changes (time or year effects) in carrying capacity recent changes in rates of change in the last 20 years (period effects) and a variety of forms of density dependence (linear vs. log-linear and zero- to two-year time lags).	13
	Using a hierarchical analytic structure (similar to orders/levels of selection), identify regions where greater sage-grouse are likely to persist and whether we can focus conservation actions on specific regions or components to avoid global extinction.	13
	Holistic assessment of a diverse set of environmental factors (including , but also beyond those typically considered in literature) including biotic, abiotic and anthropogenic as predictors/determinants of sage-grouse population persistence/extirpation potential.	13
	Population viability analysis.	10
Seasonal	Identification of seasonal habitats and movements (migratory or non-migratory) for all populations, including those on private lands (local populations).	10
Seasonal – Nesting	How does the lag time in grass cover for spring nest concealment from prior and this year's precipitation affect nest success? How about for summer forbs?	18
Seasonal – Winter	How adaptable are grouse to changing winter conditions, especially snow depths? Can this be monitored with winter survival rates?	18
Translocation	What is the effectiveness of re-introduction of sage-grouse into formerly occupied portions of their range?	6
	What protocols need to be developed for translocation and how is project success determined?	6
	How effective is it to augment existing populations of sage-grouse with birds from different populations?	6
	Where are populations sufficiently robust to allow trapping of birds to transplant where genetically appropriate?	18

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Theme/topic	Question or Issue	Citation
Habitat Management		
Condition – Composition	How do sage-grouse relate to habitat composition at landscape scales, and how do landscape-scale requirements interact with site-specific vegetative composition?	18
	Determine the reason for suppressed herbaceous understory (e.g., soil condition, historical grazing management, drought) and identify/implement methods for improving understory health.	5
Condition – Grazing	Identify reasons for lack of grass and forb cover in sagebrush communities and recommend/implement practices to increase the native herbaceous understory.	4, 5
Condition – Habitat quality	Identify areas of dense mature cover that do not appear to be serving as quality habitat and assess condition and value of these areas within the context of a larger landscape.	4
Condition – Historic	Assessment and comparison of long-term/historic grazing, and other dominant land-use effects, on condition and function of the sagebrush ecosystem – comparisons with relict and protected sites; historic interpretation; field tests.	17
Condition – Mapping	Identify and evaluate habitat suitability.	6
	Map and inventory areas believed to be deficient in quality of habitat or exhibiting poor health.	4
	Identify and map key sage-grouse habitats and where other wild (all, discriminantly?) herbivores are having significant impacts. Is the use seasonal? What is timing of overlap? Condition of overlapping use areas?	4, 5
	Identify and map land cover, species specific canopy cover of sagebrush, age distribution, and herbaceous understory of sagebrush habitats. Evaluate habitat quality of herbaceous understory of sage-grouse habitats at local levels. Develop methods for regular updates.	1, 4, 5, 6, 7, 9, 10
	Except for a few areas, accurate vegetation data to delineate existing and potential habitats at the subbasin scale for sagebrush steppe are lacking.	4
	Maintaining (current) data on populations, habitat conditions/suitability, connectivity, seasonal delineations, and threats – e.g., habitat maps.	15
	What regions within the sage-grouse range share common ecological attributes?	6
Condition – Monitoring	Monitoring long-term changes in habitat quantity and quality.	6
	Document (and frequently update) current conditions.	6
Condition – Monitoring – Methods	Habitat monitoring techniques available to monitor long-term change in habitats.	6
	What is the most effective way to conduct a range-wide scale assessment of habitat condition?	6
	Develop, adapt, coordinate, and unify implementation of monitoring and monitoring protocols for habitat conditions. (This will also require development of methods/scales/indices/etc. for interpretation of range/habitat conditions.)	14
	Calibrate monitoring with sage-grouse orders of habitat selection (multi-scale),	6
	Develop, consolidate, document, and otherwise implement “established habitat monitoring techniques.”	6
	Universally adopted methodology or process in place for evaluating and monitoring habitat characteristics.	7
Condition – Other wildlife	What is/are the effects of “increased use” (and/or other land-use ramifications) of non-priority areas on sagebrush and other semi-arid habitats, and species.	13
	Assess habitat characteristics/values for multiple species, across multiple scales – landscape scale matrix-patch distribution, community structure, and variability within “the matrix” (patch heterogeneity). Can the habitat distribution/requirements and behavior of sage-grouse and other sagebrush obligates be used to define the range of conditions (landscape and within patch) required across the landscape to support these species?	13
Condition – Recommendations	How general or specific do habitat recommendations need to be given the similarities and/or differences in habitat requirements among populations and regions?	18
Condition – Soil	Develop high quality, consistent, and accessible soil and vegetation data and models that describe how changes occur in response to stress and disturbance.	7

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Theme/topic	Question or Issue	Citation
Habitat Management—Continued		
Condition – Surface water	How can changes in water management increase the productivity of sagebrush ecosystems and enhance sage-grouse populations? What is importance of surface-water flow? Importance of "free water" for sage-grouse?	4, 6
Condition – Variability	What is the influence of shrub steppe habitat variability on sage-grouse populations (distributions, use, seasonal, etc.)?	13
	Where on the landscape are habitats meeting the Guidelines (Connelly and others, 2000a)?	6
	Increase understanding of limiting factors such as drought, grazing management, predation, human disturbance, soils, and other environmental variables on sagebrush ecosystems.	4
Condition – Veg-Pop linkage	Evaluate the impact of vegetation condition on sage-grouse populations.	9
	Evaluate the effects of vegetation "quality" (e.g., vegetation structure, sagebrush canopy height/cover, forb/grass height, diversity, and abundance, nutrition available to sage-grouse) on sage-grouse productivity, adult survival, and population dynamics.	6, 9, 12
	Investigate and elucidate connections (especially causal) between habitat quality and response/effects on sage-grouse populations.	17
	Assess, monitor, and evaluate shrub cover characteristics capable of supporting sage-grouse seasonal habitat requirements.	1
Condition – Veg-Pop linkage – Ecosystem function	Age, vigor, or health of sagebrush ecosystems and the subsequent impacts on sage-grouse.	6
Condition – Vegetation structure	Within each ecological unit, determine the appropriate range and distribution of canopy cover classes for each sagebrush alliance.	4
Configuration – Composition	Identify the appropriate mix of sagebrush habitats and seral stages necessary for sustainable sage-grouse populations, consistent with site capabilities.	9
	Determine multi-scale changes in land cover composition and configuration in sagebrush ecosystems.	6, 9
Configuration – Connectivity	How do plans/abilities/implementation of habitat conservation, enhancement and restoration promote and/or enable movement, connectivity and genetic diversity within sage-grouse pops.	14
	Is there a difference (relative importance) between improved connectivity (of habitats/sub-populations) and increased habitat area? Is more simply better, or is configuration more important that total area? What is the balance? Is there a threshold?	17
	How do position and patterns in the landscape distribution of sagebrush habitats affect connectivity of sage-grouse populations?	13
	Evaluate, prioritize, and map connectivity linkages that are most important to sage-grouse movements and dispersal. How linked are small populations with large populations?	3, 9, 10
	How does the loss of habitat or degradation of habitat affect the connectedness/continuity of populations?	10
	Identify habitat fragmentation effects on sage-grouse. Determine the sufficient minimum habitat patch size for sage-grouse, as it relates to habitat fragmentation.	9
	Identify the habitat interspersion and juxtaposition that meets habitat requirements and facilitates connectivity among groups.	4
	Is there a difference between natural and unnatural fragmentation?	6
	Investigate the suggestion "that sage-grouse may have adapted to a scale of natural fragmentation in sagebrush habitats organized at 4.5 to 9 km…"	17
	Need to determine optimum patch sizes and connectivity for year round habitat needs. Important to understand dynamic needs within and across years as likely affected by weather/climate; development/reclamation patterns; underlying population cycles; etc.	18
	What type of habitat 'barrier' or how much distance between occupied sub-populations is needed to effectively restrict the movement of sage-grouse?	6
	Identify how habitats are connected and determine if improvements can be made.	10

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Theme/topic	Question or Issue	Citation
Habitat Management—Continued		
Configuration – Connectivity	Better understand relationships between landscape-scale habitat patterns, sage-grouse seasonal use, and connections to population genetics.	17
	Identification and prioritization of "intact" existing habitats, large areas, connected networks and connective habitats and relationship to population connectivity, dispersal and migration.	13
	Role of areas with perceived "lower biological values" but may have particular values as transitional, connective or other habitats,	13
	Importance of habitat features (vegetation types, core habitat areas, etc.) for maintaining connectivity within and among populations.	13
	What landscape features act as barriers to or facilitate movement?	18
	What blocks of habitat have highest priority for protection for birds nesting in one country or state that traverse international and state borders and the intervening scores of miles to adequate wintering habitat? What is the network of connectivity among habitats and birds across federal, state, and private lands?	18
Configuration – Mapping	Where are the areas of habitat loss and fragmentation?	9, 11
	Use remote sensing and other techniques to determine the current state of fragmentation in sage-grouse habitat.	9
Configuration – Quantity	Determine habitat loss thresholds for sage-grouse populations using spatially explicit landscape models (i.e., how much habitat is needed to sustain a population).	9
	What are the causal mechanisms between habitat loss, juxtaposition, and population demographics? – sage-grouse declines with habitat conversion as low as 1.5–2.5 percent results in declining counts; 16 percent causes substantial decline and 25–27 percent extirpation.	17
	Investigate the quantity of habitat (i.e., patch size) needed to sustain sage-grouse.	9
	What is the optimal size and configuration of habitat patches occupied by sage-grouse and what are the effects of habitat fragmentation on sage-grouse? (Direct impacts on habitat selection and movement and indirect impacts on genetic interchange and extinction risk.)	1, 4, 6, 9
Conifer encroachment – Mapping	Map current area of conifers and evaluate expansion rates. Prioritize areas with greater potential loss.	16
Disturbance – Mapping	Use and refine existing vegetation and other map data to develop a better understanding of piñon-juniper/mountain shrub, industrial, agricultural, and urban encroachment on sage-grouse habitat.	9
	Application of GIS and remote sensing to map habitat and habitat threats (Cheatgrass, juniper, restoration progress).	6
	Developed habitats – areas where vegetation manipulation or other activities have fragmented, degraded, or removed habitat.	4
	Develop maps of sage-grouse habitats for both statewide and local conservation planning and management efforts. Include documented positive or negative influences to sage-grouse or their habitat (e.g., land treatments, wildfire, utility corridors, etc.).	1
Disturbance – Monitoring	Evaluation and re-evaluation (monitoring of status and trends) of balance between multiple-uses and wildlife habitat requirements.	17
Dynamics – Mapping	Quantify vegetative changes during the last 50 years in terms of overall cover, species composition, sagebrush community seral changes, and sage: grass: forb: bare ground ratios. Investigate correlations between vegetative and sage-grouse population changes.	1
Ecosystem function – Disturbance	Define the capability of ecosystems and vegetation communities to withstand stress and/or disturbance and maintain capability of full recovery.	7
	Acquire quantitative knowledge of ecological thresholds, indicators of change, and key decision points in the framework of comprehensive monitoring systems	7

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Habitat Management—Continued		
Ecosystem function – Resilience	Identify and differentiate establishment, survival and growth requirements for sagebrush and perennial herbs and model potential effects on future landscape and habitat conditions given: fire, grazing/herbivory, and weather/climate.	13
	In addition to sage-grouse, a broader understanding of other aspects of the sagebrush ecosystem such as invasive plants, natural dynamics, restoration processes, wild and domestic grazing effects, disease, climate, and other drivers of system function and habitat conditions is needed.	13
	Identification and details of causes of degradation or invasion of sagebrush ecosystems (habitats), including remedies.	13
	Better characterize recolonization and growth of key spp. and community composition and functions with respect to disturbance, reclamation, and landscape restoration.	13
	Development of "accelerated restoration" processes to decrease community recovery rates and ultimately increase the probability of reestablishing sage-grouse use, post-development.	13
	Test this statement: "Climate, soils, precipitation, and characteristics of the previous community affect resistance and resilience of sagebrush communities to disturbance" – and use results to help guide prioritization and implementation.	13
	Does the resistance and resilience of sagebrush communities increase with increasing moisture?	13
Effectiveness – Monitoring	Improve upon and standardize disturbance buffers. Monitor the effectiveness of recommended disturbance buffers.	7
	What are "suitable" buffer distances for different/similar anthropogenic features/ disturbances?	14
	Determine the effectiveness of habitat management methodologies including other wildlife.	3
	Develop and implement a valid monitoring plan for reclamation activities in sage-grouse habitat.	9
	Effectiveness Monitoring – protocols/methods development, distribution, compilation of data, analyses.	15
	Develop and maintain cumulative records for all vegetation treatments to determine and evaluate site specific and cumulative impacts to sage-grouse habitats and identify best management practices for successful vegetation treatments.	1
	Provide objective appraisal of conservation actions, plans, treatments, etc. via monitoring of effects and effectiveness – local projects/actions in the context of regional; regional assessment that includes treated and non-treated site conditions.	14
	Evaluate impacts of treatments and policy implementation.	6
	Assess habitat restoration, disturbance-recovery, and sage-grouse utilization.	6
	What monitoring protocols/methods are best for assessing restoration success?	15
	What are the appropriate response variables that should be used to monitor management effectiveness? Understanding how management actions promote positive changes to sage-grouse populations requires appropriate post-treatment monitoring.	18
Effectiveness – Monitoring – Methods	What are the best protocols for recording vegetation treatments and monitoring efforts?	6
	How (e.g., what scales, what indicators) do we estimate that … "at least 70 percent of the land cover provides adequate sagebrush habitat"? AND – will this "maintain or increase current populations"?	14
	Develop a consistent approach for monitoring, evaluating and reporting restoration efforts.	7
Habitat selection – Scaling	At what scales (temporal and spatial) should we focus research regarding sage-grouse ecology? More information is needed on what scales capture individual ecological relationships (e.g., habitat selection or reproductive success).	18
	Research should focus on resolving issues with identifying appropriate scales for specific influential environmental factors.	18

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Habitat Management—Continued		
Landscape – Modeling – Management and policy	Improve science-based tools for predicting habitat distributions across areas of concern is important for effective management planning.	18
Landscape – Monitoring – Methods	Protocols to assess landscape change (disturbance and dynamics).	13
Maintenance/Rehabilitation/ Restoration – Conditions	Define what constitutes meaningful mitigation to meet site- and/or issue-specific sage-grouse population and/or habitat objectives.	9
	What are the current conditions, including values for wildlife and livestock, in historic (circa 1950–79) habitat treatments (plow and seed with crested wheatgrass)?	13
	Design and implement vegetation manipulations that benefit sagebrush ecosystems in the long-term with consideration for the needs of sage-grouse.	1, 4
	Monitor, compile, compare, and assess the effects of rest (passive restoration) and active restoration on condition and function of degraded sagebrush range.	17
	Relative role/importance/value of different habitat components for sage-grouse in different seasons; Is there net benefit or loss for sage-grouse when "mature sagebrush" is treated? short- vs. long-term impacts; grouse vs. vegetation community.	17
Maintenance/Rehabilitation/ Restoration – Conditions – Veg-Pop linkage	How strong is the population-habitat relationship? Can habitat restoration compensate for other disturbances and influences?	14
	Can we quantify objectives related to habitat quantity and condition as they are expected to affect sage-grouse population numbers/trends? (Is this even practical, meaningful, attainable, etc.)?	14
	Evaluate the role of habitat treatments (current role/impact of historic treatments) as sage-grouse habitat, or keeping livestock off sage-grouse habitat or … What is the current role, could it be improved (with sagebrush planting, for example)?	14
	What is the role/suitability (ability) of mitigation to provide usable and used habitats? (If we re-build it, will they come?)	14
Maintenance/Rehabilitation/ Restoration – Connectivity	Test the ability/role of restored habitats to support connectivity, dispersal and migration – Do corridors and habitat islands have value for birds? What are interactions between habitat characteristics, environmental patterns/circumstances and sage-grouse behavior (use of those habitats)?	13
Maintenance/Rehabilitation/ Restoration – Effectiveness	What is the effectiveness of herbicides, fires, and mechanical treatments for improving conditions for sage-grouse? Are negatives compensated for by positives?	4, 6, 9
	Effectiveness, effects, and differentiation of effects (based on environmental and land-use covariates) of conservation reserve program (CRP) easements and SGI habitat management; can comparable program for public lands be implemented?	17
Maintenance/Rehabilitation/ Restoration – Effectiveness – Ecosystem function	Effects of management actions, and related disturbances, including Rx burn, wildfire, invasive spp., veg. restoration, other forms of sagebrush reduction… on sagebrush ecosystem conditions and habitat values [and how do birds respond].	13
	Effects of management actions – should also include recovery rates, environmental factors/ correlates, monitoring/BACI, etc.	13
Maintenance/Rehabilitation/ Restoration – Effectiveness – Veg-Pop linkage	Evaluate whether vegetation treatments improve sage-grouse habitat in a way that affects sage-grouse population parameters, such as nest success.	9
	Document and evaluate the demographic and population level response of sage-grouse to habitat creation and/or improvement are desperately needed.	9
	Response of sage-grouse to habitat modifications in a rigorous (i.e., replicated, controlled, experimental) fashion.	9
	Examine the effects of different habitat treatments on the quality, quantity, and configuration of sage-grouse habitat, and the responses of sage-grouse populations.	9
	Determine the ecological relevance of the "70/30 objective" using monitoring and inventories.	12

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Habitat Management—Continued		
Maintenance/Rehabilitation/ Restoration – Management and policy	Design/develop post-restoration management guidelines/best management practices (BMP) to ensure/promote long-term value and persistence.	14
Maintenance/Rehabilitation/ Restoration – Mapping	Identify potential locations where there may be opportunities for offsite mitigation for sage-grouse. Identify suitable mitigation practices within those areas.	9
	Create a central GIS database to track all sagebrush modification treatments and natural disturbances across sage-grouse range.	9, 12
Maintenance/Rehabilitation/ Restoration – Methods	Design, plant, evaluate, and report on field trials for establishing desired vegetation to serve as sage-grouse habitat in CRP, cropland, and large monocultural non-native grass plantings.	9
	Improve the commercial availability and supply of native grasses and forbs suitable for restoration in arid and semi-arid environments.	7
	What management practices and policies maintain or recover sagebrush habitat? What practices have worked/not worked in the past?	6
	Methods for rehabilitating areas lost to fire, so that cheatgrass invasions are minimized.	12
	Develop techniques to increase herbaceous diversity and density in sagebrush steppe.	4
	Research practical methods for restoring the forb component required by sage-grouse.	3
	What are the available restoration methods and their effect across the full range of habitat types and degrees of disturbance? What are the best planting techniques? How can specialized equipment be improved and increase durability?	6
	Document and publicize both effective and ineffective sagebrush treatment methodologies to enhance knowledge of treatment technologies and avoid repeating treatment failures in similar sites.	10
	What are the procedures for growing and producing desired seed species?	6
	What are the priorities for developing propagation procedures?	6
	What species will be required and the amount of seed necessary to restore identified restoration sites on an annual basis?	6
	When should non-native species be used to meet community restoration goals?	6
	What are the best methods for determining the restoration potential of particular habitats that have been degraded?	6
	What are the desired attributes of restored habitat (by region and life cycle requirements of sage-grouse) and what techniques are likely to achieve those results?	6
	What is the most effective monitoring program to evaluate the effectiveness of treatments and management adjustments toward meeting restoration goals?	6
	Establish common sampling, methods, protocols, metrics, for monitoring effectiveness of restoration treatments and management adjustments at local, regional, and range-wide scales. Included sampling in areas reflecting life cycle requirements.	6
	What are the potential seed and equipment needs for implementing restoration efforts?	6
	Develop more effective habitat restoration techniques for sage-grouse habitat to improve success of rehabilitation efforts to restore previously degraded sagebrush communities, meadows, and riparian areas in uplands.	10
	Documentation will help evaluate levels of surface disturbance needed for sagebrush seeding, identify the best seed mixes for local use, and help other land managers benefit from previous restoration efforts and results.	3
	Research is needed to improve current knowledge of habitat maintenance (prevention) and enhancement (rehabilitation).	12
	Effectiveness and use of nonnative plantings (namely crested wheatgrass) as a stabilizing mechanism for disturbed sagebrush communities.	12
	Methods to return sites planted with non-native to native shrublands and grasslands.	12
	What are the ecological ramifications of seed type selection?	6
	What are the seed viability and germination rates?	6
	Importance of locally adapted seeds?	6

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Habitat Management—Continued		
Maintenance/Rehabilitation/ Restoration – Methods	Developed programs to produce or increase production of native seeds for rehabilitation efforts, preferably seeds of 'local' origin?	4, 6
	What are the best techniques for revegetation?	6
	Can inter-seeding be used to re-establish specific types of vegetation in native habitat or CRP?	6
	Develop and research techniques to re-establish sagebrush vegetation and how do these techniques differ by basic habitat type, region, soil type, and landscape configuration?	6, 7
	Develop and implement techniques to increase herbaceous diversity and density within ecological limits.	5
	Identify large areas of introduced crested wheatgrass (*Agropyron cristatum*) and determine if restoration efforts are appropriate (used by wildlife, decrease pressure on adjacent habitats, etc.).	5
	Expansion, application and effectiveness evaluations for suite of range condition treatments for a range of starting conditions (slightly degraded to poor condition).	17
	Restoration methods to restore functioning sagebrush ecosystem.	15
	Lack of understanding of the processes necessary to restore sagebrush ecology.	15
	Determine how to restore historical habitat functionality, including connectivity, total area and condition.	14
	Develop native seed sources, harvest areas, etc. – including target species, and range/ environmental considerations; also consider potential future climate and long-term viability and ecosystem productivity.	14
	How do we restore herbaceous plants (grasses and forbs) in the intershrub spaces without killing sagebrush?	18
	Are there techniques that can be employed to decrease the amount of bare ground and restore biological soil crusts in locations where they are missing?	18
	What is the ideal size and pattern of burned sites for enhancement of foods for sage-grouse chicks?	9
	How do we restore ecosystem functions? Can we increase the rates of growth and recovery of perennial vegetation? What about soil nutrients, stability and moisture retention capabilities? What level constitutes "restoration"? How long does it take?	14
	Develop, design, enhance, and improve recovery and restoration methods to reduce invasion by noxious spp., and improve native spp. Responses – especially sagebrush re-establishment.	14
Maintenance/Rehabilitation/ Restoration – Monitoring	How do we determine restoration success when establishing a functioning sagebrush ecosystem may require decades or centuries?	15
	Develop protocols for assessment of restoration effects/effectiveness on sage-grouse populations (demography and behavior).	13
	Develop and implement a valid monitoring plan to assess sage-grouse habitat restoration and to measure success with respect to sage-grouse.	7, 9
	Develop and publish methods to better evaluate the effects of habitat improvement projects on sage-grouse populations; and use those methods to monitor and evaluate the effects.	10
	Develop a consistent approach for monitoring, evaluating, and reporting restoration efforts.	7
Maintenance/Rehabilitation/ Restoration – Planning	Development of approaches/case studies for collaborative, landscape and conservation planning; inter-agency, trans-boundary, inter-office coordination and integration.	13
Maintenance/Rehabilitation/ Restoration – Population response	Determine whether sage-grouse will move to mitigation areas as mine and energy development sites develop in active habitat.	9
Maintenance/Rehabilitation/ Restoration – Prioritization	Develop priorities and implement habitat enhancements in historical or potential sage-grouse habitats.	1
	Develop priorities and implement habitat enhancements in areas currently occupied by sage-grouse.	1

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Habitat Management—Continued		
Maintenance/Rehabilitation/ Restoration – Prioritization	What is a realistic extent (acres and/or percent of historic) that can be restored to support the needs of sage-grouse?	6
	What is the appropriate scale for assessing restoration potential?	6
	Where are areas that restoration can be accomplished via management changes versus active intervention?	6
	Where and what is the extent of historic range that is unlikely to be restored without substantial mechanical involvement or cost? What is the definition of unlikely?	6
	Where and what is the extent of area likely to be restored with adjustments in management, limited involvement, and/or reasonable cost? What is the definition of likely?	6
	What are the important criteria for prioritizing likely restoration areas, by SMZ?	6
	Identify and prioritize areas for restoration.	3
	Prioritize implementation of projects/areas based on environmental variables that improve chances for success – these priorities and variables need to be defined/developed and implemented.	14
	Identify restoration potential (characteristics of these areas, and the methods for delineation/ definition, are also needed) – prioritize base on the value/context of the site coupled with the site restoration potential.	14
	Determine potential to replace lost priority habitat caused by disturbances; increase connectivity via restoration/mitigation.	14
	Develop and refine regional prioritizations, assess restoration potentials, assess restored habitat conditions for potential threshold in condition that leads to increasing use – regional assessments of current habitat status.	13
	Development of habitat restoration directives/directions – broad perspectives/priorities, restoration potentials, economic barriers and opportunities, environmental effects/ covariates; multi-scale habitat selection – nested habitat restoration approaches.	13
Maintenance/Rehabilitation/ Restoration – Recovery	Does the short-term increase in forb cover post-fire offset the long-term recovery of sagebrush canopy? (Addressed with respect to the distribution, abundance and quality of seasonal sage-grouse habitats.)	9
Maintenance/Rehabilitation/ Restoration – Veg-Pop linkage	Better characterize the relationships and behavioral responses between sage-grouse and disturbance, reclamation and landscape restoration – if we repair it, how long until grouse re-establish and use these areas?	13
	Habitat restoration (vs. typical restoration) – characterization of conditions, actions and activities, measures and monitoring required for successful habitat restoration (characterized by condition and use).	13
Maintenance/Rehabilitation/ Restoration – Prioritization – Viability	Interactions of restoration cost/values, long-term recovery rates and climate change effects on spp. and ecosystem potentials – when/where are efforts warranted? Where are risks of disturbance/stochasticity greatest (to avoid)?	13
Maintenance/Rehabilitation/ Restoration – Weather/ Climate	Investigate potential impacts/influences of climate/climate change on restoration practices and long-term success.	14
Methods – Mapping	Can SPOT imagery be used to develop a habitat layer where other methods (e.g., QuickBird) are not affordable?	18
	Repeatable, rapid approach to broad-scale habitat mapping.	18
	How can remotely sensed data (e.g., Landsat, MODIS, NDVI) relate to aspects of the environment (at various spatial resolutions) – when is use of these data layers informative, and in which contexts are they not informative. Ultimately, if we can get a remotely sensed layer that accurately reflects life-history needs of sage-grouse, then we could do all kinds of landscape-ecology analyses (some have been done, already), including relevant measures from FRAGSTATS.	18
	Use remote sensing to map sage-grouse habitats.	6

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Habitat Management—Continued		
Methods – Monitoring	What are the best long-term monitoring protocols to measure the effectiveness of the conifer treatments?	6
Methods and Coordination – Mapping	Develop mapping techniques that are consistent.	1
	Coordinate mapping efforts within and among agencies to eliminate duplication of effort.	1
	Integrate sage-grouse mapping with across state boundaries where sage-grouse are a concern.	1
	Evaluate alternatives to a radial buffer approach in sage-grouse habitat, such as incorporating local topographic conditions or habitat communities for defining geometry.	9
Multi-scale condition – Monitoring – Methods	What is the best sampling strategy that can be used to monitor habitats at the site scale and aggregate up to the range-wide scale? How effective are current habitat monitoring efforts?	6
	Investigate multi-scale implications from sage-grouse habitat selection orders to multi-scale habitat condition monitoring: connecting plant community structure, sage-grouse behavior, and landscape/land-use patterns to distributions and demographics.	14
	Investigate, develop, coordinate and otherwise adapt implementation and assessment of NRCS NRI, BLM AIM, and other methods for integrated habitat condition assessments, cooperative analyses and products, and direct feedback for management/planning.	14
	How can habitat monitoring schemes across multiple jurisdictions and multiple time periods be "joined" with more sophisticated statistical techniques?	18
Population dynamics	How do habitat characteristics influence population dynamics? A holistic approach that combines selection and success, and focuses on the overall importance of habitat at the population level is needed.	18
Prioritization	Define and identify source habitats – based on assessment of population dynamics and places where sage-grouse populations are increasing or stable.	4
	Define and identify "scarce habitats" – as areas that are limited and/or limiting and help define priority for maintenance and restoration.	4
	Prioritize areas of importance and those needing protection to maintain sage-grouse populations.	8
	Preliminary priority habitats have been identified/delineated; evaluate conditions and threats within; evaluate sage-grouse use in and around these areas.	14
	What are the best criteria for assessing and prioritizing habitats? By region and seasons?	6
Prioritization – Mapping	Sagebrush communities and potential restoration areas that are susceptible to agricultural development should be identified.	7
	What sites have appropriate characteristics (e.g., soil characteristics, sagebrush understory; also review historical photographs) to support sagebrush communities?	9
	Where can habitat easements be most effective when considering future land use and climate change?	18
	Develop an approach that will allow managers to identify critical habitats and prioritize those habitats for protection and management using strategies that will also maximize connectivity.	18
Priority Areas – Management and policy	What is the landscape juxtaposition of protected areas and land uses on persistence of sage-grouse?	15
	Determine the relationship between designated sage-grouse habitat and occupied sage-grouse habitat. Evaluate habitat designations based on outcome.	10
	Should specific areas be set aside for the protection of localized sage-grouse populations?	6
	Testing and evaluation of effects and effectiveness of sage-grouse priority areas (SGPA) (theoretical value and effectiveness as implemented).	17
	Is the "priority area strategy" affective for protecting current populations (e.g., use within vs. use outside)? Do current priority area designations continue to have the (same) value in the future – after time for changes in populations and environments?	17
	Priority habitat designation needs evaluation; many pops. multiple regions, and rangewide	14

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Habitat Management—Continued		
Priority Areas – Management and Policy	What is the ability/capability of designated "General Habitats" to provide safe migration, movement, foraging and otherwise provide connection and intermediate habitats within/between "Priority Habitats"?	14
	Risk, Cumulative Effects and Policy Integration – multiple approaches/perspectives, one is evaluation of effects of SGPA approach – considering things like: values protected, values sacrificed, population response, habitat conditions with and outside, etc.	13
Priority Areas – Other wildlife – Management and policy	In sagebrush habitats that are not Priority or General designations – what/where are the protected, rare and otherwise valuable resources/species in these areas?	14
Priority Areas – Viability – Management and policy	What location, size, configuration, or management of refuge areas would be needed to support a viable population of sage-grouse?	4, 6
	The SGPA policy should be evaluated for capacity to maintain long-term viability of sage-grouse populations, including critical winter habitat; connectivity; science-based evaluation; etc.	18
Risk assessment	What habitats are at risk? – Areas with a reasonable, foreseeable development potential, e.g., conversion to cropland. [Manier and others, 2013, does this rangewide, not locally explicit.]	4
	Develop predictive models for risk assessment and identification of use areas for wildlife species dependent on sagebrush ecosystems.	6
Seasonal – Brood-rearing	Map important brood-rearing habitat by vegetation type, range site, seral stage, and annual weather patterns.	1, 4, 5, 6, 9, 10
	Better understanding of chick habitat, especially forage, requirements; composition and abundance of forbs and insects.	17
Seasonal – Conditions	Analyze springs, seeps and pipelines to determine effects on habitat conditions.	14
Seasonal – Configuration	Evaluate juxtaposition requirements between seasonal sage-grouse habitats (i.e. mosaic requirements for nesting and early brood-rearing habitats).	1
Seasonal – Leks	Identify and map lek and lek associated habitats.	1, 4, 6, 9, 10
Seasonal – Mapping	Can we predict/identify good winter habitat across a landscape?	18
	Identify areas of overlap between seasonally important sage-grouse habitat and aquatic and riparian ecosystems.	9
	Map important nesting habitat by vegetation type, range site, seral stage, and annual weather patterns.	1, 4, 5, 6, 9, 10
	Habitat selection assessments that utilize approaches that address multiple spatial scales to represent selection processes of the animals; and development of linkages between assessments and management planning and implementation at these multiple scales.	17
	Mapping of seasonal habitats via population tracking and use patterns.	6
	Determine and map each population's seasonal habitats.	10
Seasonal – Population – Methods	What is the most effective way to assess seasonal habitat use?	6
Seasonal – Predation	Better understand, improve connection between habitat quality, nest site quality, predator behavior and predation avoidance – especially w.r.t. grass/stubble heights, community composition/structure/condition, landscape/land-use context.	17
Seasonal – Winter	Is there sufficient understanding and protection of winter habitat?	18
	Map winter habitat by vegetation type, range site, seral stage, and annual weather patterns. Develop a measure of snow depth on the landscape for predicting winter habitat. Where does severe winter range occur?	1, 4, 5, 6, 9, 10
Soils – Data	Establish baseline information for evaluating soil conditions and ecological processes and when monitoring seasonal sage-grouse habitats.	5
	Refined, improved, updated soils (complete SSURGO) – provide detailed and accurate state-transition models to compliment ESDs and SSURGO mapping – to directly inform habitat management and planning.	11

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Theme/topic	Question or Issue	Citation
Habitat Management—Continued		
Soils – Models	Develop/enhance/adapt Ecological Site Descriptions (NRCS ESDs) within priority sage-grouse habitats; identify/confirm site potentials and BMPs for ecosystem and sage-grouse habitat.	14
	Can NRCS state-transition models be evaluated as a basis for connecting habitat management efforts to annual grouse population responses from an annual life history perspective?	18
Treatment – Chemical	Effects of herbicide and pesticide treatments on sage-grouse and sagebrush habitat (direct and indirect)? Effects of each product on individual birds and in actual rangeland applications.	1, 4, 5, 7, 9, 10, 12
	Evaluate ecological consequences of using pesticides to control grasshoppers or other insects.	4
	Evaluate ecological consequences of broadcast herbicide use on forbs and other important sage-grouse foods.	4
	Investigate effects of herbicide application on sage-grouse other than desired effects (sagebrush removal) – effects on forage base, direct effects on health, etc.	4
	Are pre-emergent herbicides (e.g., Oust, Plateau) effective for controlling cheatgrass germination?	6
	Evaluate ecological consequences of using pesticides to control grasshoppers or other insects on sage-grouse food availability and vegetation cover in control versus treatment areas.	5, 7
	What are the risk, occurrence and distribution of poisoning by pesticides?	6
	Occurrence, distribution, potential and mitigation of risk/threat of poisoning by pesticide and/or herbicides (agricultural chemicals) and/or industrial toxins (e.g., Ozone at CBM sites).	17
Treatment – Conifer encroachment	What are the effects of management actions in pinyon-juniper and other conifers on species of concern and their habitats?	6
	How does reduction of conifer encroachment effect sage-grouse populations or lek attendance.	7
	What are the most effective control measures for encroaching conifer species within greater sage-grouse habitat?	6
	What are the most effective techniques for restoration of sagebrush and a perennial herbaceous understory in areas with a conifer overstory and depleted sagebrush understory?	6
Treatment – Grazing	Evaluate effects of different habitat (grazing) treatments on sage-grouse productivity, survival, and habitat use.	1
Change Agents		
Behavior – Landscape effects	Interactive and/or predictive roles/comparison of habitat distribution, landscape disturbance (especially fire), fragmentation (e.g., by roads and infrastructure), and human activity levels (correlated with development and use) leading to aversion behaviors and lek abandonment (fear vs. fidelity).	13
Behavior – Regional effects	Better relate home-range/seasonal-range requirements, spatial buffer distances, landscape patterns, population interspersion, reproductive rates and environmental covariates that help predict variations in size and impacts/impact distances, etc.	17
Behavior – Site effects	Investigate impacts and relationship between site fidelity, disturbance, restoration/mitigation, use/behavior and population demography and dynamics.	14
Demographics – Connectivity – Genetics	Better understand the effects of fragmentation, isolation, and landscape barriers on sage-grouse dispersal and population genetics.	17
Demographics – Landscape effects	Relationship between landscape-scale change (land use and development, natural disturbance, etc.) and sage-grouse behavior and population demographics. Consider/differentiate rates of change, types of disturbance, and recovery potential; link landscape conditions to carrying capacity.	13

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Theme/topic	Question or Issue	Citation
Change Agents—Continued		
Demographics – Regional effects	Demographic responses to habitat change: Example: How are populations affected by habitat treatments, grazing disturbance, energy development, fire, etc.?	18
Human footprint	Better understanding of the Human Footprint – especially interactions, accumulation and synergism.	13
Human footprint – Population response	Develop human- footprint models specific to sage-grouse, more effort needs to be undertaken to accurately assess the distribution of human resources throughout the range of sage-grouse.	13
Human footprint – Renewable energy	What the development impacts on sagebrush and sage-grouse – especially new/renewables?	15
Long-term scenarios	What are the long term effects of cumulative human impacts?	10
Roles and impacts	What are the relative roles and effect magnitude of stressors (recognizing variability by region); consider and characterize details of land-use patterns/practices within broad categories. What is the causal relationship? Where are mitigation opportunities?	13
	Model the cumulative effect of human activities on wildland systems in the Western United States including the zones of influence of infrastructure features on sage-grouse behavior and habitat use.	6, 7
	Assessment of different effects (on sage-grouse) of different "types of infrastructure" and different use/visitation/maintenance patterns at industrial sites [e.g., oil and gas (O&G) wells].	17
	Evaluate and publish the effects of wind development, disturbance densities, noise, recreation, mitigation efforts, and rehabilitation and other disturbances on sage-grouse populations (e.g., increases in noxious weeds, predators, infrastructure, etc.).	10
Roles and impacts – Degradation	Role of human disturbance (general, interactions among factors, cumulative, etc.) on habitat degradation.	11
Roles and impacts – Habitat condition	Increased understanding of anthropogenic development/use impact on habitat quality.	11
	Develop a spatially explicit population model that incorporates current estimates (with appropriate estimates of temporal and spatial variation) of demography and movement in order to evaluate the relative effects of changing land-uses on sage-grouse populations.	9
	Evaluate land use that may influence habitat conditions.	6
Roles and impacts – Interactions	Where is the balance between modern disturbance regimes (land use, fire suppression, grazing) with historic/natural regimes and the habitat requirements for sage-grouse and other wildlife, e.g., loss and fragmentation, degradation, invasion, etc.?	13
	Assess, compare and address the relative magnitude, intensity, distribution, accumulation of modern (anthropogenic) disturbances vs. of historic regimes, historical range of variation (HRV) and similar.	13
	Relationship between disturbance type, frequency and intensity and condition of the sagebrush community (including fire, herbivory, treatments).	13
	Elucidate relationships between AUM (grazing), off-highway vehicles (OHV) access, land use and land cover conversion, invasive spp., fire and fire prevention and habitat quality – most are poorly understood.	13
	What are the combinations/interactions among stressors that have the most detrimental effects on sage-grouse populations? What combination of mitigation/reduction of multiple (different) stressors has the most beneficial effect on sage-grouse populations?	13
	Habitat effects of multiple land uses including: urban/exurban development, fire, grazing (livestock, equid and wildlife), fragmentation, roads, structures, invasive species, West Nile virus (WNV)/mosquito habitats, habitat quality and quantity.	13
	Are relatively minor sources of mortality somewhat cumulative and do they combine to have a notable impact on populations?	6
	How to protect quality sage-grouse habitat from wildfire, invasive species, pinyon/juniper succession, improper livestock grazing practices, urban encroachment, roads and transmission lines, tall structures, and energy development.	6
Roles and impacts – Local effects	Improve understanding of the local effects of land uses and how legacies of past actions influence current ecosystem processes – including cumulative effects.	13

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Change Agents—Continued		
Roles and impacts – Methods	What methods/approaches are useful to assess and address cumulative effects (biological and socio-economic) across the range?	6
Roles and impacts – Stress	Well-designed field studies are needed to fully understand impacts of noise and other changes to the ecosystem on stress levels, and further estimate stress effects on population vital rates and seasonal space-use patterns.	18
Scales and interactions – Recovery	Landscape-scale habitat patterns, disturbance-recovery in sagebrush, population response to different disturbance patterns.	17
Scales and interactions	What is/are the scales of effects (local v. regional) of stressors, including invasive plants, over grazing, etc.?	13
	Land use imposes multi-scale effects on a background of natural disturbance, details quantifying amount/level of disturbance with response and differentiation among sagebrush systems (interactions of land use with disturbance and other environmental patterns) in determining system conditions (better determine, elucidate and/or discriminate to improve understanding of causal and predictive relationships).	13
Vulnerability assessment – Habitat condition	What are the future conditions of current sage steppe habitats in relation to a multi-variate picture of climate change, energy development, and agricultural policy?	18
	Explicitly combining information about the vulnerability of landscapes to anthropogenic risk enables conservation planners to consider aspects of urgency as well the probability for success of a given conservation strategy.	13
Change Agents – Anthropogenic Influences		
Agriculture – Easements – CRP	Assess potential for CRP lands to support sage-grouse (including current role/values), include restoration/modifications by planting sagebrush (and other native spp.) – especially nesting and brood-rearing habitat. Prioritize areas, refine seed/planting/ composition practices, monitor use along with other environmental variables.	13
	Effectiveness and effective use of Conservation Easements, CRP program, etc. for sage-grouse conservation.	13
	What are the characteristics of CRP (field age, species planted, and configuration with native habitat, field size, and region) that are important for sage-grouse and can be applied over broad regions? What is the impact if expired lands are plowed?	3, 6, 9
	Evaluate the potential impact of (and techniques for) converting CRP to sagebrush habitat on sage-grouse distribution and population viability.	9
	Design, plant, evaluate, and report on field trials for establishing desired vegetation to serve as greater sage-grouse habitat in CRP, cropland, and large monocultural non-native grass plantings.	9
Agriculture – Easements – Policy	Can a national priority area be designated for CRP that prioritizes placement in such a way that there is an increased positive effect on sage-grouse?	6
	What areas are susceptible to agricultural development and which incentives are effective for retention of sagebrush habitats in agricultural areas?	6, 7
	Do farm programs, other than CRP, have a positive impact on sage-grouse and can they be extended and expanded?	6
Agriculture – Habitat condition	Interaction and interplay in impact of agriculture (sagebrush removal, toxins) and potential value during summer (or other seasons), such as CRP or similar.	13
	What agricultural lands are associated with sage-grouse habitat? Are restored croplands or non-native grasslands serving as sage-grouse habitat?	1, 6, 9
	Identify the types of agricultural practices that are beneficial or detrimental to sage-grouse.	6, 9
	What agriculture harvest techniques reduce bird mortality?	6
Agriculture – Land conversion	What are the impacts of agricultural conversion on sage-grouse populations (both short- and long-term)?	16
Dispersed recreation – Lek viewing	Short-term and long-term responses of sage-grouse to human activity at lek sites.	9
	Recreational viewing of sage-grouse at leks or on wintering grounds is also a concern if the number of visits becomes high or the actions of those viewing the birds are not appropriate.	2

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Change Agents – Anthropogenic Influences—Continued		
Dispersed recreation – Management	What management practices can help avoid, reduce or eliminate the disturbance or displacement of sage-grouse by dispersed recreation activities?	6
Dispersed recreation – Mapping	Where are the high-use areas of dispersed recreation in sage-grouse habitat?	6, 9
Dispersed recreation – OHV	Evaluate and publish the effects of OHV use on sage-grouse populations and habitats; evaluate the efficacy of deterrents, penalties, and enforcement of laws and mandates.	7, 10
Dispersed recreation – Population response	Evaluate the effect of recreational activities on sage-grouse mating behavior, nesting and brood-rearing success, and winter flocks.	9
	Evaluate the effect of recreational activities on recruitment and long-term population dynamics of sage-grouse.	9
	Evaluate the effect of recreational activities (e.g., lek viewing, hiking, camping, off-road vehicles, etc.) on the behavior, distribution, demography, and population dynamics of sage-grouse.	9
	Influences of dispersed recreation on nesting chronology and fecundity for a local grouse population.	9
	What are the impacts of dispersed recreation on sage-grouse?	5, 6
	What are the impacts of dog trials, snowmobiles, bird watching, and military training activities on sage-grouse?	6
Energy and Mineral Development	What are the specific effects/stressors associated with renewable energy facilities (wind, solar, geothermal) and how do these activities affect habitat conditions, sage-grouse behavior, population demographics, movement and migration, etc.?	17
Energy and Mineral Development – Corridors	Length of disturbance along buried pipe and power lines. Does continued human use of areas diminish effects of restoration efforts?	9
	What are the effects of existing energy corridors and associated facilities on sage-grouse and sagebrush habitats (e.g., fragmentation, invasive species, and noise disturbance)?	6
	What are the potential effects of proposed energy corridors on sage-grouse and sagebrush habitats (e.g., fragmentation, invasive species, and noise disturbance)?	6
	What are the best criteria and management guidelines for locating energy corridors and the continued operation and maintenance of facilities and corridors that cross sage-grouse habitat in order to minimize impacts of sage-grouse and sagebrush habitat?	6
Energy and Mineral Development – Disturbance footprint	How do individual components of oil and gas development impact sage-grouse?	9
	How do surface disturbance and fragmentation caused by energy development affect quality of sage-grouse habitats?	9
	How do impacts vary by energy type such as coal-bed methane, strip mining, oil wells, and wind turbines – differentiate size of the ‘footprint’, different ‘setbacks’, and the sex, life history stage, habitat, and region.	6
	What are the mechanisms for impacts (e.g., indirect avoidance of disturbance such as noise or vertical structures or direct mortality due to collisions or predation)?	6
	Need additional research on tolerance to energy developments – including pad densities, distance, seasonal restrictions, noise limitations and infrastructure – different effects in large populations? In more fragmented habitats and/or populations?	10
Energy and Mineral Development – Disturbance footprint – Buffers	What is the appropriate buffer distance around well pads?	9
	What are the appropriate set-backs or the ramifications of insufficient set-backs?	6
	What are the key sage-grouse habitats in need of buffering?	6
Energy and Mineral Development – Disturbance footprint – Cumulative Effects	What are the cumulative impacts to sage-grouse from energy development? Synergistic effects?	9
	Develop an impacts modeling/assessment for energy and mineral development scenarios that consider (1) reclamation efforts and results; (2) long-term changes; (3) the various stages/ intensities of energy development.	9

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Theme/topic	Question or Issue	Citation
Change Agents – Anthropogenic Influences—Continued		
Energy and Mineral Development – Habitat condition – Groundwater	Potential impacts of changes in groundwater levels, due to energy production especially oil shale, on riparian and other mesic habitats with resulting potential for impacts on sage-grouse.	17
Energy and Mineral Development – Infrastructure	Evaluate the impacts of infrastructure, energy, and mineral development (including reclamation efforts following development), on the quality, quantity, and configuration of sage-grouse habitat.	9
	Evaluate the impact of utility corridors, communication towers, wind turbines and other infrastructure on predator effectiveness and resulting effects on sage-grouse populations.	9
Energy and Mineral Development – Minerals	What are the effects of Metallic/Non-metallic Minerals extraction on sage-grouse and sagebrush habitats?	6
	Evaluate the effect of mining development on the behavior, distribution, demography, and population dynamics of sage-grouse.	9
	Better characterize the effects of mining activities on sage-grouse and habitats.	17
	Connect/expand assessment and monitoring of mineral estate leases from local to landscape; local disturbances and restoration activities need to be evaluated locally for effects/ impacts AND within a context of landscape scale habitat condition and disturbance.	13
	What are the effects of Surface Coal extraction on sage-grouse and sagebrush habitats?	6
Energy and Mineral Development – Mixed effects	Enhance our understanding of effects of energy development through pre-activity inventory, monitoring over the life of the development, and annual evaluation thereafter.	5
	Further elucidation and differentiation of the effects of energy development, especially traditional oil and gas, oil shales, and cola bed methane, on grouse, in different seasons and habitat conditions (sagebrush type, topography, burn/treats, etc.); searching for thresholds in distance and/or level of use where sage-grouse are minimally affected (as opposed to measurable population declines).	17
	Better elucidate the effects of energy development (e.g., oil and gas) on habitat and sage-grouse behavior, and importantly, with explicit consideration of differences in "biotic potential" among sites and the interaction of potential and disturbance in determining effects, conditions, resilience, etc.	13
Energy and Mineral Development – Monitoring – Methods	What are the most appropriate monitoring techniques for assessing the effects of new facilities and energy corridors?	6
Energy and Mineral Development – Noise	Expand understanding of the effects of anthropogenic/industrial noise on sage-grouse behavior and population demography.	9, 17
	Further investigate evidence that noise, especially intermittent noise, is a key disruptor of sage-grouse behavior.	14
Energy and Mineral Development – Oil Shale	What are the effects of Oil Shale/Tar Sands extraction on sage-grouse and sagebrush habitats?	6
Energy and Mineral Development – Population response	Study, monitor, and attempt to quantify impacts to sage-grouse from oil and gas development and mining operations (e.g., intensity, duration, and timing).	9
	Evaluate the impact of energy development on the behavior, distribution, demography, and population dynamics of sage-grouse. How specific factors affecting population parameters are influenced by energy development; and the relative impact of specific aspects of oil and gas development (e.g., intensity, duration, and timing).	1, 4, 6, 8, 9, 10
	Investigate the specific factors affecting sage-grouse population parameters (e.g., causes of female and chick mortality, effects of noise on sage-grouse habitat use or avoidance, wind direction, and topography influence on noise impacts), and how they are influenced by energy development.	9
	Studies in Pinedale, Wyoming area (Pinedale Anticline O&G development) indicated "sage-grouse declines area explained in part by lower annual survival of females…" – investigate the potential connection between development and female mortality.	14

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Theme/topic	Question or Issue	Citation
Change Agents – Anthropogenic Influences—Continued		
Energy and Mineral Development – Population response – Buffers	Investigate the need/effect/size for buffers around energy development in winter habitats. Are birds more, or less or equally, sensitive to noise disturbance in winter (i.e., compared to nesting)? Do visitation limits (anthropogenic use intensity) and/or development intensity (well pad density) affect response of sage-grouse?	14
Energy and Mineral Development – Population response – Monitor	Develop and implement a valid monitoring plan to assess the impacts of energy and mineral development on sage-grouse.	9
Energy and Mineral Development – Prioritization	Identify important areas for grouse (wintering, nesting, etc.) that require additional protection or conservation during land use planning and leasing of energy reserves.	4, 5
Energy and Mineral Development – Restoration/Mitigation	Determine the effectiveness of energy and mining mitigation actions, stipulations, and BMPs in maintaining sage-grouse populations and/or habitat across the landscape.	9
	Quality, quantity, and/or juxtaposition of mitigated habitat and its compensatory response.	9
	Management experiments that document and evaluate the demographic and population-level response of sage-grouse to habitat creation and/or improvement.	9
	How effective might it be to create new sage-grouse habitats or improve historic habitats?	9
	Need research to understand the efficacy of recommended mitigation (onsite and offsite) to avoid, minimize, or reduce the effects of surface-disturbing activities (onsite), or replace or enhance suitable habitat (offsite).	10
	What are effective mitigation practices (e.g., habitat equivalency, mitigation ratios, mitigation banking) in areas of non-renewable energy development?	6
	Need research on the effectiveness of rehabilitating or restoring sage-grouse habitat following energy development or other surface disturbing activity (this will help determine if off-site mitigation is a viable option).	10
	Provide for long-term monitoring of siting requirements to assess effects of current and future energy development on sage-grouse.	4
	Long-term impacts after oil and gas reclamation are not clearly understood.	4
Energy and Mineral Development – Stipulations	Determine the effectiveness of energy and mining mitigation actions, reclamation, existing stipulations, and BMPs in protecting sage-grouse habitat and populations.	9
	Assess the effects of proposed/implemented buffers and/or development density restrictions on habitat patterns and sage-grouse use and behavior.	14
Energy and Mineral Development – Technology	What technologies and practices can be used to offset, reduce and/or minimize disturbance associated with resource recovery activities?	6
Energy and Mineral Development – Mapping	Identify key sage-grouse areas located within potential energy development areas, to better address cumulative impacts to sage-grouse.	9
	Identify key sage-grouse areas that are not already leased for energy and mineral development.	9
	Map energy development infrastructure within sage-grouse habitat to reflect current and historic development levels, patterns, and conditions.	9
Fences – Population response	What are the direct and indirect impacts of fencing on sage-grouse? What are high risk situations? Local or population level effects?	5, 6, 7, 9, 10, 12
Fences – Structure	What fence design, siting or modifications are best at mitigating the direct and indirect effects of fences on sage-grouse?	1, 6, 7, 9
	Evaluate structural range improvements for effects on sage-grouse habitat – especially fencing.	14
Habitat conditions – Landscape dynamics	Develop monitoring systems that track and predict how changes in land use and cover affect ecosystem function across spatial scales on rangelands.	7
Harvest – Big game	Effects of sage-grouse hunt overlapping with big game season?	10

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Theme/topic	Question or Issue	Citation
Change Agents – Anthropogenic Influences—Continued		
Harvest – Demographics	How does the timing of the hunt affect sage-grouse populations and demographics?	10
	Hunting, predation, and additive vs. compensatory mortality? When, and where, can sage-grouse still be hunted? Do slow growth rates and high over-winter survival create a low threshold between additive and compensatory?	17
	Ratio of males – females in population and harvests – does harvest skew population numbers or take more females than males?	17
Harvest – Genetics	Identify genetically isolated subpopulations that could be at risk of overharvest.	4
Harvest – Methods	Links between harvest data and other survey data (leks, broods, etc.).	6
Harvest – Monitoring	Assessment of techniques for conducting harvest surveys. Questionnaires, bag count, wing collection.	6
	How do estimates from hunter questionnaires, bag counts, wing collections relate to/correlate with lek counts and brood surveys? New or complimentary information?	6
Harvest – Monitoring – Methods	Identify and implement more effective techniques to collect sage-grouse hunter statistics,	9
Harvest – Poaching	Are there population impacts from poaching?	2, 10
Harvest – Population response	What are the harvest impacts to sage-grouse relative to season length, bag limits, and sex?	1, 3, 4, 5, 6, 7, 9, 10, 12
	Is harvest additive or compensatory mortality? What are optimal/sustainable/maximum harvest rates?	1, 3, 4, 5, 6, 7, 9, 10, 12
	Implement an intensive monitoring system of sage-grouse population and harvest to refine the adaptive harvest model periodically, to affect season length and bag limit.	9
	Survivorship of sage-grouse in both the presence and absence of hunting.	4
Harvest – Population viability	Define sustainable and huntable populations.	10
	What is the range-wide standard for sustainable sage-grouse populations with sustainable harvest?	6
	Hunting Management – need thresholds (compensatory vs. additive), short-term feedback/adaptive rates.	13
	Potential role (if any) for sport hunting – additive vs. compensatory mortality; effects of variations in harvest season on demographics of mort., breeding, etc.	13
	Differential effects of sport hunting (if any) – season timing, length, bag and possession limits and season limits examined for each population with local biologically informed regulations.	13
	Harvest management (mortality effects, levels, additive vs. compensatory).	13
Mapping	Identify human features relative to existing and potential developments and sage-grouse habitat.	16
Monitoring – Methods	Develop, refine, standardize inventory and methods development for assessment and monitoring of cumulative effects of human activities.	17
Military training – Behavior	Do military “flyovers” have an effect on sage-grouse behavior?	2
Mixed issues – Movement patterns	What are the effects of anthropogenic structures (e.g., power transmission lines) on sage-grouse populations? Do these effects influence movement patterns and seasonal space-use?	18
Mixed issues – Population response	Evaluate the effect of powerlines, fences, roads, and other human infrastructure on the behavior, distribution, demography, and population dynamics of sage-grouse.	9
	Does disturbance associated with infrastructure (powerlines, fences, roads, etc.) have a negative impact on sage-grouse and what is the mechanism of that impact (i.e., visual impacts, collision risk, disturbance intensity, disturbance frequency)?	6
	Can roads, fences, power lines, and pipe lines be built or configured in such a way that the negative impacts to sage-grouse are minimized?	6
Mixed issues – Seasonal habitat	Roles, differences and potential value of seasonal use closures (industrial and recreation use restrictions during lek and nesting) – are they effective? Practical? Useful for management of human effects?	17

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Theme/topic	Question or Issue	Citation
Change Agents – Anthropogenic Influences—Continued		
Mixed issues – Vital rates	Which vital rates are affected by anthropogenic structures (e.g., power transmission lines), and are any negative impacts caused by direct effects (e.g., collision or avoidance) or indirect effects (e.g., subsidized predation), or a combination of both?	18
Renewable Energy Development – Geothermal	Effects of geothermal energy development on sage-grouse ecology.	18
Renewable Energy Development – Solar	Effects of solar energy development on sage-grouse ecology.	12
Renewable Energy Development – Wind	Habitat change: Example: Need to understand the impacts of proposed wind development on habitat loss and alterations of habitat use by grouse – this includes all infrastructure along with all development.	18
	Research and monitoring of the effects of wind energy development in sage-grouse habitats with respect to sage-grouse survival, habitat-use and behavior including: abandonment of leks, nesting, brood rearing or winter habitat and the distance from the wind turbines that effects are experienced.	3, 7, 12
	Not known if birds avoid the vicinity of turbines due to disturbance from noise, motion, or human activity, or if the area is avoided because tall structures are perceived as potential raptor perches.	3, 7
Research – Monitoring	What influence do research activities have on monitored sage-grouse?	18
Residential Development	Identify direct and indirect impacts of urbanization/domestic development on sage-grouse, including habitat quality and behavioral response.	17
	Identify occupied and seasonally important sage-grouse habitats and leks that are at highest risk of urban/suburban/ex-urban development.	6, 7, 9
	Investigate impacts of residential development on sage-grouse behavior, distribution, demography and population dynamics, due to noise, pets, and increased activity.	1, 9
	Identify potential contaminants associated with housing developments (e.g., household chemicals, fertilizers, sediments) that could impact sage-grouse.	9
Surface disturbance – Monitoring	How do we evaluate anthropogenic surface disturbance? What data? What indicators? How measured? What scale(s)?	14
Tall structures – Buffers	How far do elevated structures need to be from sage-grouse to have no effect (behavioral, predation etc.)?	9
Tall structures – Mapping	Identify and map existing utility corridors, wind turbines, communication towers, and designated utility corridors in sage-grouse habitat.	9
	Map and quantify smaller power distribution lines (<138 kv) and telephone lines in sage-grouse priority areas (SGPA). Identify specific potential problem areas.	7
Tall structures – Mixed effects	Link between powerline construction and population-level impacts (predation and direct mortality from collision).	9
	Evaluate the impacts of utility corridors on sage-grouse habitats (i.e., fragmenting effects on habitat).	9
	Evaluate the impacts of communication towers, wind turbines, and associated infrastructure on sage-grouse (both disturbance impacts and habitat fragmentation impacts).	9
	How do powerlines/poles and other tall structures affect sage-grouse populations?	5, 6, 10
Tall structures – Policy	What are the best siting and Operation and Maintenance criteria for tall structures in sage-grouse habitat that minimize negative impacts?	6
Tall structures – Population response	Population dynamics in relation to the distance from the transmission line.	2
Tall structures – Predation	Relationship between tall structures (cellular towers and transmission line poles) and sage-grouse behavior and population dynamics. Should include parallel/simultaneous assessment of predator behaviors with regards to these features and hunting sage-grouse.	13
	How far elevated structures must be from sage-grouse to have no effects on the birds (e.g., behavioral changes, increased predation).	9

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Change Agents – Anthropogenic Influences—Continued		
Tall structures – Predation	Evaluate sage-grouse response to new and existing power lines as associated with habitat conditions and avian predator densities.	7
	Evaluate the impact of utility corridors, communication towers, wind turbines and other infrastructure on predator effectiveness and behavior effects on sage-grouse populations.	9
Tall structures – Structure	Does modification of poles to limit perching prevent electrocution of raptors and decrease predation on sage-grouse?	4
Transportation – Collisions	Influence of collisions with vehicles, fences, and transmission lines on survival.	6
	Are there population level impacts of road collision mortality?	9
	What are the impacts of vehicle mortality/collisions (leks near roads/travel corridors crossing roads)?	10
Transportation – Fire – Invasives	Identify utility, railroad, road rights of way where invasive plants increase fire risk.	7
Transportation – Habitat condition	What are the net effects of roads, trails and OHV use on the condition/value of sagebrush habitats? including habitat loss, fragmentation, invasive plants.	17
	Elucidate and differentiate road effects, including size of road, road use/traffic levels, proximity of roads to habitat and nature of disturbance to birds (noise, dust, sight; infrastructure vs. activities).	17
	What are the effects of existing roads, trails and railroad corridors and associated facilities on sage-grouse and sagebrush habitat?	6
Transportation – Mapping	Identify, categorize (e.g., 2-track, gravel, unpaved, paved), and map roads in sage-grouse range.	9
	Identify, map, quantify, and evaluate impacts of existing roads, including 2-tracks, in relation to known lek locations and sage-grouse winter ranges.	5
	Identify, map, quantify, and evaluate impacts of existing roads, including 2-tracks, in relation to known lek locations and sage-grouse winter ranges.	4
	Accurate local, regional and range-wide Inventory of roads.	13
	Map and quantify secondary and other roads (e.g., paved county, gravel, two tracks) in SGPAs. Identify specific potential problem areas.	7
Transportation – Monitoring – Methods	What are the best monitoring plans to measure effectiveness of BMPs and mitigation measures in minimizing effects of roads and railroads on sage-grouse and sagebrush habitats?	6
Transportation – Population response	Evaluate the effects of road placement and traffic levels on sage-grouse and sage-grouse habitat.	9
	The biological meaning of particular linear density values to sage-grouse is unknown – what are the effects of different road-densities (land-use intensity) on sage-grouse distributions?	7
	What are the net effects of roads, trails and OHV use on sage-grouse behavior/populations? including displacement and avoidance behavior, noise, direct encounters.	17
	Elucidate and differentiate road effects, including size of road, road use/traffic levels, and nature of disturbance to birds (noise, dust, sight; infrastructure vs. activities)	17
Transportation – Prioritization	Identify and prioritize areas for road buffers, removal, realignment, or seasonal closures where appropriate to avoid degradation of habitat.	5
	What are the best criteria and management guidelines to locate, construct, maintain, or close roads and railroads, to minimize impacts to sage-grouse and sagebrush habitat?	6
	Travel management should evaluate the need for permanent or seasonal road and/or area closures for sage-grouse.	14
Transportation – Seasonal habitat	Evaluate impacts of existing roads, including 2-tracks, in relation to known lek locations and sage-grouse wintering areas.	4

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Theme/topic	Question or Issue	Citation
Change Agents – Natural Processes		
Conifer encroachment – Other wildlife	What are the habitat relationships of wildlife associated with pinyon-juniper and other conifers (all phases) which have invaded sagebrush habitats, plant and animal species of concern (e.g., ferruginous hawk, gray vireo, juniper titmouse, pinyon jay) in particular?	6
Disease – Interactions	Distribution, disease ecology, effects on sage-grouse, risk assessment for WNV.	13
	Understanding long-term impacts of WNV will require intensive monitoring of radio-marked populations. Population models suggest that, except during severe outbreaks (Walker and others, 2004), natural geographic and temporal fluctuation in vital rates that drive population growth can mask impacts of WNV in any given year.	13
	Long-term response of different sage-grouse populations to WNV is expected to vary markedly depending on factors that influence susceptibility, including: (1) annual and seasonal temperature precipitation profiles, (2) land uses that influence the distribution of surface water, (3) population size, (4) genetic diversity, and (5) connectivity with other populations. Small, isolated, or genetically depauperate populations.	13
Disease – Monitoring	Implement range-wide disease monitoring – risk assessment, prediction, and make explicit connections to sage-grouse demographics.	13
	Systematic, or opportunistic, range-wide infectious disease surveillance for sage-grouse – requires protocol development, training and equipment.	13
Disease – Other diseases	What are the effects of bacterial, fungal, viral and parasitic diseases including Tularemia, Aspergillosis, hermatozoa, WNV, Avian Pox, Avian Malaria, Cestodes, coccidian, and other viral and bacterial pathogens on sage-grouse populations? When do outbreaks occur?	1, 2, 4, 6, 9, 10
	Elucidate understanding of coccidiosis, including connections with landscape patterns, habitat use, and concentrations of animals/population distributions.	17
	Disease Management – population level effects of parasites, infectious disease, reactions to toxins are rare; WNV effects, environmental triggers, risk.	13
	Potential interactions among disease, parasites, sage-grouse and climate change, anthropogenic disturbance, stress, etc.	13
	Focus on WNV – but the long-term impacts of most macro- and microparasites and their associated infectious diseases on greater sage-grouse populations remain largely unknown. We recommend that avian infectious bronchitis virus and other avian corona viruses, avian retroviruses, Mycoplasma spp., and the Eimeria coccidians and associated enteric bacteria be evaluated or at least monitored more closely in addition to WNV.	13
	What are the effects of disease on sage-grouse (especially WNV)?	11
Disease – West Nile Virus	How do agricultural water management and infrastructure contribute to the threat of WNV?	6
	WNV impact on population trends and the role of the virus in terms of observed mortality rates in subsequent years.	1, 2, 3, 4, 5, 8, 9, 10
	Determine the impact of wet conditions on mosquito production as it relates to the potential for catastrophic disease in sage-grouse. Determine the risk factors and potential of catastrophic disease in sage-grouse populations.	9
	Determine the level of susceptibility to WNV and survival patterns of each sage-grouse age and sex class. Examine whether sage-grouse can develop immunity to WNV and whether the immune response can be inherited.	2, 9
	Examine the spatial interaction of mosquito species that are the main vectors of the virus (e.g., *Culex tarsalis* and *C. pipiens*) with seasonal habitat use by sage-grouse (e.g., evaluate whether sage-grouse are more likely to be exposed to the virus in relatively wetter brood-rearing habitat than in lekking and nesting habitats).	9
	WNV exposure risk, survival potential, habitat and seasonal covariates.	17
	Research and testing of potential conservation measures for WNV.	7
	Determine alternate hosts for WNV in greater sage-grouse habitats.	2
	Effects of land management activities on WNV and its vectors.	12

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Change Agents – Natural Processes—Continued		
Disease – West Nile Virus	Risk mapping to predict the potential for WNV epizootics in greater sage-grouse.	18
	Continue to develop and test methods for vaccination of sage-grouse to protect against WNV infection for populations identified as high risk through risk mapping and that are particularly susceptible to stochastic events (small, isolated/endangered).	18
	Develop and evaluate management techniques designed to reduce WNV transmission especially in populations at risk.	18
	Evaluate the relative impacts of WNV versus other stressors and design mitigation strategies that will reduce the risks of the greatest threats to long-term population viability.	18
	Determine the risk of WNV in agricultural sage habitats vs. more pristine sage habitat. Where does WNV amplification occur in sage-grouse habitat?	18
Fire and fuels management – Effects/recovery	Recovery time required to reestablish sagebrush after fire, by site condition, species composition, and size/intensity of fire.	7, 9
	Where do uncharacteristic wildfires result in adverse impacts (e.g., invasive species, reduced fire return intervals)?	3, 6
	What are the effects of size of burn or treatment on response of sage-grouse individuals and populations?	17
Fire and fuels management – Landscape dynamics	Improve understanding of spatial variability in ecosystem conditions, fire history, fire regimes, recovery rates and landscape scale patch and matrix dynamics. What is the appropriate/desirable ratio of early, mid and late seral communities to provide habitat values and maintain productive ecosystems and landscapes?	14
	Test this statement (fire history, HRV, etc.): "Disturbance in some form has been an integral component of sagebrush systems throughout their evolutionary history."	13
	Better understanding of the relationship between natural disturbances, especially fire, and the sagebrush ecosystem, including return intervals, recovery rates, historic fire behavior vs. current observations, fuel accumulation, ignition sources and frequency, seasonal patterns, variability among regions...with an eye towards informing and improving range conditions through better understanding of dynamics.	17
	Better understanding of the relationship between fire and vegetation conditions (pre and post fire) in sagebrush ecosystems – historic, desired and current/likely responses.	17
	Sagebrush fire recovery rates, eco/bio limitations, historic regimes, environmental and condition covariates.	13
	Characterize sage-grouse habitat degradation due to fire suppression, fuels management, and/or decreased fire-return intervals.	11
	Identify/describe/characterize (balance in) the role of fire in protecting and maintaining healthy sagebrush communities and loss of intact sagebrush required for habitat.	17
Fire and fuels management – Mapping	Map all burns and fuel treatments in sage-grouse habitat. Assessment of pre-burn plant species composition and diversity.	6, 7, 9
Fire and fuels management – Methods	What are the best methods for area-specific fire suppression for sage-grouse habitat? Location of fire camps, staging areas, and helibases?	4, 6
	How should habitat mosaics and fuels be managed to improve and reduce possibility of damaging wildfires?	6
	Are green strips and/or fire breaks within and adjacent to sage-grouse habitat effective at slowing or stopping wildfires? Potential fragmentation impacts?	6
	Develop criteria for managing fuels and other risks to sage-grouse habitat.	4, 5
	What are the most effective means for wildfire suppression?	6
Fire and fuels management – Monitoring	What protocols are best for long-term monitoring of the response of habitat to wildfire, prescribed burns, and mechanical fuel reduction treatments?	6
Fire and fuels management – Planning	Develop firefighting plan to protect important seasonal sage-grouse habitats.	16

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Change Agents – Natural Processes—Continued		
Fire and fuels management – Planning	Identify strategic locations for fire lines.	16
Fire and fuels management – Prioritization	Where and how should wildfire be managed and utilized to improve sage-grouse habitat?	6
	Where and how should wildfire be contained and suppressed in important sage-grouse habitat? What are the priorities for protection of sage-grouse habitat versus structures and other developments?	1, 2, 3, 4, 5, 6, 7, 10
	Identify and prioritize specific areas for habitat restoration and fuels modification (e.g., cheatgrass) and areas bordering roads, railroads, farmlands or other areas where cheatgrass or other vegetation poses a high fire risk.	7
Fire and fuels management – Regime	Influence of fine fuel continuity (cheatgrass) and woodland encroachment on temporal and spatial variability of fire return intervals.	13
	Expand and re-assess estimates of historic fire regimes, HRV and similar attributes, to improve perspectives on long-term trends, and regional and local return intervals.	14
	Several theories/applications regarding the role of fire and disturbance need better examination and testing – e.g., historic disturbance regime and HRV; disturbance interval vs. recovery rates (including climate, herbivory, etc.); effects of changed (shortened or lengthened) return interval on plants and animals.	13
Fire and fuels management – Restoration/Mitigation	Large-scale wildfires are likely to continue throughout the Western United States, and a better understanding of effective habitat rehabilitation following these events is needed to reduce threats of long-term conversion to exotic grassland is needed.	18
	Improve understanding of spatial variability in ecosystem conditions, fuel profiles, fire history and response of systems (post-fire) – and importantly link to sage-grouse populations and sagebrush habitat conservation.	14
	Develop more effective habitat restoration techniques for sage-grouse habitat to improve success of rehabilitation efforts after wildfire. What are the priority habitat conditions for post-fire rehab and restoration objectives when restoring sagebrush/sage-grouse habitats?	6, 10
	Develop post-fire Emergency Stabilization and Rehab. Approaches/methods/designs that maintain, improve, or minimally affect habitat distribution and quality.	14
	Develop fuels management approaches/methods/designs that reduce wildfire threats and maintain, improve, or minimally affect habitat distribution and quality.	14
Fire and fuels management – Vulnerability	Identify a process to identify fire vulnerable sagebrush habitats and spatially delineate these habitats.	16
Herbivory Effects – Domestic livestock – Economics	Conduct a cost-benefit analysis of the economic impact of different grazing management options that benefit sage-grouse	9
	Identify critical sage-grouse areas, and adjust grazing to minimize conflict between production of commodities and protection of societal values.	5
Herbivory Effects – Domestic livestock – Habitat condition	Browsing impacts on nutritional quality of plants, production, standing biomass.	9
	Link between grazing and increased big sagebrush cover.	3
	Expand our limited understanding of livestock grazing impacts on vegetation at large time and spatial scales.	7
	Can livestock management be used to improve range condition for sage-grouse?	6
	Determine land management practices, particularly grazing management, that result in optimum forb and insect density, diversity, and abundance.	1, 6
	Interactions between livestock, stocking levels, grazing seasons and seasonal habitat requirements, habitat quality, sage-grouse use, predator success.	13
Herbivory Effects – Domestic livestock – Habitat condition – Environment	Assess the effects of grazing intensity (grazing system) on habitat condition across environmental gradients – evaluate capacity and potential compared to demands, consider environmental covariates; directly assess impacts on sage-grouse habitat condition and behavior/use of those areas.	13
Herbivory Effects – Domestic livestock – Habitat condition – Fire	Evaluate and describe interactions between fire and grazing and effects on habitat diversity, distribution and condition – consider local and landscape perspectives.	1

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Change Agents – Natural Processes—Continued		
Herbivory Effects – Domestic livestock – Habitat condition – Interactions	Separation of drought and grazing impacts on forb abundance and sage-grouse populations.	9
	Experimentally manipulated studies to separate grazing impacts from other confounding factors.	9
Herbivory Effects – Domestic livestock – Habitat condition – Practices	Can/could/should grazing systems, BMPs and related practices, be revised/improved to reduce negative effects and improve system functions (including primary production – forage – and habitat values – food and cover)?	17
	Review and evaluate different grazing systems and their effects on the vegetation parameters (habitat conditions) important to sage-grouse.	9
	Investigate the effects and effectiveness of grazing management to meet seasonal sage-grouse habitat requirements – season/timing of grazing and grouse use; numbers of livestock, distribution of livestock, intensity of use, type of livestock.	14
	What grazing management systems (season of use, grazing duration, kind of livestock, and stocking intensity) are conducive to meeting sage-grouse habitat conditions (i.e., changes in species composition, residual cover, and forb production) and sage-grouse populations within similar Ecological Sites?	1, 6, 7, 9, 10
	Regional differences in vegetation response depending on grazing system (rotation, season, stocking rate etc.). Northern latitudes and higher elevation sites with high moisture vs. dry, lower elevation sites.	9
	What are the influences of livestock species, habitat type, region, weather, and past management practices?	6
	Design and implement grazing management systems that maintain or enhance herbaceous understory cover, height, and species diversity that occurs during the spring nesting season.	12
	Identify and evaluate effects of various grazing management plans on the interaction of sage-grouse, commodity production, and societal values.	4, 5
	Design and implement livestock grazing management practices (riparian pastures, seasonal grazing, development of off-stream water facilities, etc.) to achieve riparian management objectives.	4
	The importance of grazing pressure, rest, and rotation on the condition of sagebrush-dominated habitats and the capability of sagebrush-dominated habitats to support sage-grouse.	6
	Large replicated livestock grazing study that could focus on how different grazing systems impact sage-grouse habitat.	18
	What would be the short (1–3 years) vs. longer-term (3–10 year) impacts of livestock removal in comparison to best grazing practices for sage-grouse on fire risk (fuels) and sage-grouse habitat?	18
Herbivory Effects – Domestic livestock – Habitat condition – Trampling	What is the potential for livestock to trample nests and are there differences between grazing systems?	6
Herbivory Effects – Domestic livestock – Habitat condition – Utilization	Improve the understanding of relationship between condition of habitat, grazing and management practices using long-term productivity, composition, structure. Look for balance between agriculture and habitat to achieve system management and habitat goals.	17
Herbivory Effects – Domestic livestock – Historic impacts	What are the lasting impacts of historic overgrazing? Separate current grazing from historic impact.	9, 17
	Analyze whether the historic shift from sheep to cattle has resulted in vegetative changes.	1
Herbivory Effects – Domestic livestock – Mapping	Identify and map areas where potential conflicts may be occurring with human activities related to sheep bedding and leks.	7

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Change Agents – Natural Processes—Continued		
Herbivory Effects – Domestic livestock – Monitoring	Monitor the response of forbs (kinds, vigor, and production), and the compositional diversity of native species with respect to livestock grazing.	4
	Monitor the response of forbs (kinds, vigor, and production) and the compositional diversity of native species with respect to livestock grazing.	5
	What are the best standardized monitoring protocols for addressing the effects of grazing management systems to detect trends in vegetation response (vigor, production, diversity) and similarity to condition outlined in the sage-grouse habitat guidelines?	6
Herbivory Effects – Domestic livestock – Monitoring – Methods	Identify monitoring methods that are best suited to the type of grazing management being incorporated at a site. Note: proper use will vary with the type of grazing system, e.g., rest rotation vs. deferred.	4
Herbivory Effects – Domestic livestock – Population response	Identify and evaluate how domestic grazing directly affects sage-grouse – consider different life stages also – e.g., nestlings, juveniles, lekking, nesting females, etc.	2, 6, 9, 10
	What are the direct impacts of grazing on sage-grouse?	3
	Identify differential effects of grazing (location, timing, and system) and sage-grouse use/response?	13
Herbivory Effects – Domestic livestock – Seasonal habitat	How do grazing regimes affect seasonal grouse distributions from year to year on a landscape level?	18
	Identify and evaluate how domestic grazing indirectly affects sage-grouse – evaluate all seasons and seasonal habitats (nesting, brood rearing, and winter).	2, 6, 9, 10
Herbivory Effects – Domestic livestock – Water and other infrastructure	Effects of fencing and stock tanks on grazing pressure and habitat condition.	9
	Consider effects of livestock and wildlife distribution on sage-grouse prior to developing additional water sources.	5
	How do water developments affect sage-grouse and their habitat (directly and indirectly)?	10
	Impacts of infrastructure and rangeland 'improvements' associated with livestock, including fences, water provision and the removal of sagebrush (either mechanically or with fire or chemicals).	6
	Role of natural and artificial water sources (in arid environments) in providing mosquito habitats and therefore probability of WNV infection.	17
	What is the current extent of conifer species (stand age, canopy cover, snag density, soil site potential, stand density, overstory species) within greater sage-grouse habitats?	4, 6
	Where are areas of future threat from encroachment of conifer species within greater sage-grouse habitats?	4, 6
	Prioritize areas where removal of piñon-juniper to enhance sage-grouse habitat is needed.	9
Herbivory Effects – Horses and burros – Habitat condition	How is sage-grouse habitat affected by free-ranging horses and burros? Mechanisms of alteration, and which (if any) most strongly affect sage-grouse and other sage-dwelling birds.	18
	Much remains to be learned of the synecology of free-ranging horses, and how their effects on other ecosystem components vary across ecological contexts and key environmental gradients (e.g., rainfall, elevation, seasonality, temperature).	18
Herbivory Effects – Horses and burros – Habitat condition – Other wildlife	What are impacts of introduced, free-ranging equids on habitat conditions for sagebrush obligates, and habitat specialists? – invertebrates (ants and other sage-grouse foods), small mammals, passerines, etc.	13
Herbivory Effects – Horses and burros – Habitat condition – Population control	Determine effects of management, culling and population control on equids; determine effects/response on ecosystem of equid control; determine effects/response of equids on sage-grouse populations/behavior/etc.	13
Herbivory Effects – Horses and burros – Habitat condition – Rangeland health	Impacts of wild/feral equids, and removal (gathers), on rangeland health and sage-grouse habitat conditions.	12, 13, 14, 17

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Change Agents – Natural Processes—Continued		
Herbivory Effects – Horses and burros – Habitat condition – Wet/mesic	Understand the effects of horses on habitat value of springs and seeps for sage-grouse and other sagebrush-obligate species; highlight equid relationships with mesic areas, research from outside the region, potential interactions (e.g., Mosquito/WNV habitats) vulnerability of different systems...	13
Invasive Species – Cheatgrass	Climate induced patterns, climate change, adaptation and plasticity of cheatgrass – potential effects on ecosystem values, fire return intervals, etc.	13
	What is the risk of increased fire and loss of existing sagebrush communities due to extensive distribution of cheatgrass, combined with its aggressiveness in replacing sagebrush?	13
Invasive Species – Control and Containment	Locations and methods (soil bacteria, chemical) to control cheatgrass and restore (seed, re-treat, etc.) the native communities.	17
	What methods can be used for early detection of new patches of invasive species before they spread?	4, 5, 6
	Develop and implement management techniques that minimize the risk of invasive plant infestation.	4, 5
	What are the best integrated invasive species control methods (e.g., grazing, mowing, seeding, herbicides) that minimize negative impacts on greater sage-grouse population and their habitats?	6
	What methods are effective for containment of existing infestations (e.g., border spraying, planting barriers of aggressive plants, grazing to minimize seed production)?	6
	What are the practices that will minimize the spread of invasive species by domestic livestock and wildlife?	6
	What are the practices that will minimize the spread of invasive species by vehicles and equipment?	6
	Cheatgrass control and restoration of valuable sagebrush-grassland ecosystem.	17
Invasive Species – Habitat condition – Ecosystem function	Ecological processes affected by/affecting weeds and range degradation – e.g., altered vegetation, nutrient cycles, topsoil, biotic crusts.	15
	Which species is the biggest problem (widespread plus negative effects)? How to effectively combat (treatment development/effectiveness)? How to strategically attack widespread distributions? How to best combat re-occurrence, including seed banks, recruitment, native health, etc.?	13
	How will annual/biennial grasses such as Japanese brome affect Northern habitats in the long run? How will fire intervene in conjunction with climate change?	18
Invasive Species – Habitat condition – Fire	Interactions between cheatgrass, disturbance (history), range condition and prob. of wildfire need better characterization, understanding of causal relationships, etc.	13
Invasive Species – Habitat condition – Food availability	Effects of noxious and invasive weeds on insect communities, which are an important food source for young sage-grouse.	9
	Which, if any, exotic invasive plants do Sage-grouse use as food?	9
Invasive Species – Habitat condition – Prioritization	Identify significant annual grass infestations in relation to SGPAs – prioritize for treatment.	16
	Conduct analyses to identify intact landscapes at high risk of conversion.	16
Invasive Species – Habitat condition	Separate and define cause-effect with regard to invasive plants, disturbance, ecosystem function and services, degradation and resilience – for improved management of sage-grouse habitats.	13
	What invasive plant species pose the greatest risk to sage-grouse and their habitats?	1, 5, 6, 10, 11, 13, 17, 18
	Establish functional links between invasive species and habitat degradation.	11, 13

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Change Agents – Natural Processes—Continued		
Invasive Species – Mapping	Map areas of exotic plant occurrence and effect zones.	13
	Inventory and map existing invasive, introduced, and noxious weed populations within and adjacent to occupied sage-grouse habitat or suspected range.	1, 4, 5, 6, 10
	Risk mapping of annual grass invasion potential and annual-induced/triggered fire potential.	17
Invasive Species – Restoration/ Mitigation	After treatment in invaded areas what are the optimal seed mixtures appropriate for the soils, climate, and landform of the area to ensure recovery of the ecological processes and habitat features of the potential natural vegetation, and to prevent the re-invasion of undesirable species?	6, 12
	Research and develop effective prevention, control, and restoration techniques for invaded landscapes.	16
	How can exotic plant invasion following fire be mitigated, and what are reasonable strategies for reducing threats of sagebrush conversion to exotic grasslands? Are there unintended negative risks to sage-grouse from management activities to reduce risk?	18
Invasive Species – Weather/ Climate	Interaction between cheatgrass and perennial species, seed banks, stability and resilience to changes in weather and climate (effects on long-term ecosystem condition and stability).	13
Mixed issues – Herbivory	Evaluate the effects of herbivores (wild and domestic) on greater sage-grouse (e.g., nest trampling, changes in behavior, also positive effects).	9
	Review effects of herbivores (wild and domestic) on sage-grouse; evaluate effects of trampling; evaluate effects on sage-grouse behavior; evaluate positive effects on habitat, predation rates, behavior.	9
	Impacts of mule deer, white-tailed deer, elk, pronghorn, bison, and free-roaming horses and burros on sage-grouse and habitats?	6
	Evaluate the effect of herbivores on the quality of sagebrush habitat (e.g., grass and forb abundance, diversity, and vegetative structure).	9
	What are the compounding and interactive effects of livestock, feral horses and other ungulates under different range conditions, fire risk and regimes, invasive species, etc.?	17
Weather/Climate – Interactions	Role of "stochastic events" in risks to sage-grouse habitats – especially wildfire, drought – as well as interactions of these factors with other management activities/goals.	13
Other wildlife – Birds	Does the stocking of pen-reared birds, such as ring-necked pheasants have potential to adversely impact wild populations of sage-grouse?	6
Other wildlife – Colocation	Which regional species are positively correlated with the abundance of sage-grouse and which are negatively correlated and how do these negative and positive correlations relate to potential management?	6
	If other species such as mule deer or elk are treated as umbrella species for sage-grouse, how are sage-grouse effected and is this effect dependent on region, habitat, or other factors?	6
	Identify how and where sage-grouse management may affect other species, i.e., Utah prairie dog, burrowing owl, sage thrasher, mule deer, pygmy rabbit, etc.	10
	Continue, expand and improve evaluation of sage-grouse and associated management of sagebrush ecosystems, as a suitable "conservation umbrella" for a variety/multitude of sagebrush obligates/inhabitants.	13
Other wildlife – Competition	What is the influence of wild ungulates on sage-grouse and their habitat?	9
Other wildlife – Guzzlers	What are the effects of gallinaceous guzzlers built to supply free water in normally arid habitats? Are benefits offset by increased competition with other species, WNV from mosquitos, or increased predation risk?	6
Other wildlife – Monitoring	Establish an inventory and vegetative monitoring schedule to quantitatively determine the extent of the effects of other wildlife in key areas.	4, 5
Other wildlife – Restoration/ Mitigation	Assess how proposed habitat improvement projects geared toward other species could impact sage-grouse.	1

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Change Agents – Natural Processes—Continued		
Predation – Behavior	Research, monitoring and evaluation activities to investigate: the behavior of predator species, the intra- and inter-specific relationships of predator populations, the impact of predators and other mortality factors on specific sage-grouse populations of concern, and on sex/age classes.	7
Predation – Control	What are the functional and/or numerical responses by predators following control programs?	9
	Experimentally implement and evaluate predator control measures in areas where predation is suspected to be limiting sage-grouse, to gain a greater understanding of the effects of this management approach on sage-grouse, specific predators, and the relationship between predator species. Both short- and long-term consequences.	1, 5, 7, 9, 10
	How do different species of predators interact with each other and how is this inter-relationship influenced by predator control?	2, 6
	Evaluate whether predator management aimed at a specific predator species is an effective management tool that increases production and recruitment of sage-grouse in local populations.	9
	Predator management has been tried within the range of sage-grouse, but sufficient evidence has not been provided to support implementing control programs over broad geographic or temporal scales.	13
	The long-term biological consequences of predator control are poorly understood and may actually be counterproductive under some circumstances.	4
	Predation Management – need to characterize levels and species (better characterize risk); determine if/when needed and effective; determine predator behaviors, e.g., foraging distances.	13
Predation – Demographics	What are the effects of current levels of predation on annual survival?	18
Predation – Effects	Effect of predation on the fluctuations and viability of sage-grouse populations.	9
	Effect of predation on the demographic structure and population fluctuations.	9
	Determine age-specific mortality and identify relative risks from avian and mammalian predation within local sage-grouse populations.	9
	Information is needed to determine the presence and possible effects of non-indigenous predators or abnormally high levels of predators on sage-grouse populations, regardless of habitat quality.	7
	How do predators impact sage-grouse populations (by life history stage)?	9, 10, 15
	How do native predators (at un-naturally high population levels) (e.g., ravens) impact sage-grouse population?	10
	Assessment of predation to determine if predation is a limiting factor.	2
	Determination of the time of day and period of incubation in which nests are most vulnerable to predation.	2
	Detection of links between female time budgets and types of successful predator encounter.	2
	Does predation impact survival in a compensatory or density-independent way?	6
	What is the level of predation of snakes on sage-grouse (and/or eggs); and is this a significant source of mortality?	17
Predation – Habitat	Does reduction in canopy cover increase predation risk?	9
	Investigate the influence of sage-grouse habitat on predation rates.	9
	Investigate how predation rates on sage-grouse are influenced by the natural temporal and spatial variability in sagebrush ecosystems (e.g., plant age class, fire intervals).	9
	Investigate the influence of habitat quality (e.g., nutrition, forb/insect quality and quantity) on sage-grouse chick vulnerability to predation.	9
	Determine the factors that affect habitat quality as it relates to the level of predation.	7
	Predator population structure * predation rates * habitat variables * landscape context (relationships and interactions).	13

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Change Agents – Natural Processes—Continued		
Predation – Habitat	Relationship between habitat management, connectivity of suitable habitats and long-term predation rates.	13
	Research methods for increasing the populations of sage-grouse, such as reducing predation through manipulation of habitat features.	3
	Review the relationship between predation and sage-grouse populations and habitat conditions, variations due to seasons, ecosystem pattern and processes, disturbance, etc.	9
	To what extent can intact habitat mitigate the effects of increasing predators?	18
	The influence of predation, interaction with habitat features, and the role of anthropogenic disturbance are not well-understood for nesting sage-grouse and information on other vital rates such as adult or juvenile survival are lacking.	18
Predation – Habitat – Human footprint	Effectiveness of removing den sites, such as abandoned farmsteads, and nesting or perching structures, such as powerlines and fences to reduce predation.	9
	Initiate studies to determine the relationships between predation, habitat fragmentation, and habitat condition.	4, 5
	Determine the effect of habitat fragmentation as it relates to the level of predation.	7
	Does the human footprint, especially infrastructure, increase predation by common ravens? Does raven control have a substantial and/or lasting effect on sage-grouse reproductive rates?	13
	Test and compare in different regions/SMZs: The human footprint can influence sage-grouse population regulation via top-down and/or bottom-up regulatory processes. Top-down human footprint effects increase the spread of synanthropic predators into areas in which they do not occur or are present only at low densities in the absence of human features.	13
Predation – Identification	Develop better methodologies to assist in identification of predator species linked to sage-grouse predation.	7
	What is the predator community influencing sage-grouse? – distributions, behavior/foraging, interactions?	13
Predation – Infrastructure	Evaluate the impact of infrastructure, powerlines, roads, and fences on predation rates in sage-grouse populations.	9
	Document the incidence and extent of avian predation on sage-grouse nest success, juvenile and adult survival in areas with extensive infrastructure and areas without extensive infrastructure.	7
	To what extent does predation from human subsidized predators limit individual sage-grouse vital rates, and overall population growth?	18
	The overall role of subsidized predation in changing landscapes regulating sage-grouse populations remains unclear.	18
Predation – Invasive Species	Investigate how invasive weed species impact predation rates on sage-grouse.	9
Predation – Methods	Identification of nest predators and their depredation sign.	2
Predation – Monitoring	Develop an effective and consistent monitoring program to determine if predation management actions are achieving desired results in sage-grouse populations.	9
Predation – Non-native	How do non-native predators impact individual sage-grouse populations?	10
Predation – Populations	Document and monitor current predator population levels in sage-grouse habitat.	9
	Investigate and evaluate the natural variability in sage-grouse predator populations.	9
	Assess population status and trends of important predator species (both native and invasive).	4, 5
Predation – Restoration/ Mitigation	Can the effects of predation be mitigated by habitat management, and would this approach be more efficient or effective than controlling predators?	6
Predation – Species interactions	Behavioral and spatial interactions of predators with sage-grouse and with other predator species.	9
	Evaluate relationships among sage-grouse predator species, including how sage-grouse predator species population levels change relative to each other.	9

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Change Agents – Natural Processes—Continued		
Predation – Species interactions	Investigate the roles of and relationships between native and nonnative predators in the sagebrush ecosystem.	9
	Determine if changing predator species (e.g., increased red fox, raven, raccoon, etc.) impacts sage-grouse productivity.	1
	Evaluate relationships among sage-grouse predator species, including how sage-grouse predator species population levels change relative to each other, and different effects in different life stages and seasons.	9
	Influence of predator trophic interactions and behavior on predation rates.	9
	Correlate changes between alternate prey species abundance and sage-grouse abundance.	1
Weather/Climate – Cycles/ Trends	What are the effects of drought cycles, ENSO-PDO-NAO, and long-term warming?	11
Weather/Climate – Demographics	How does weather at peak of hatch affect Fall populations? What is the associated prediction for climate change affecting weather at peak of hatch? Can multiple years of good/poor conditions affect long term (20 year) population numbers?	18
Weather/Climate – Fire	Examine the relationship between climate change and fire frequency in sagebrush ecosystems; will wildfire severity and frequency increase?	13
Weather/Climate – Future scenarios	What influence will climate change have on long-term conservation of sagebrush and sage-grouse?	10, 15
	Reduce uncertainty in climate projections and assess impacts of climate variability.	15
Weather/Climate – Habitat condition	Develop a system that identifies the effects of global change in the very early stages and identifies appropriate management responses.	7
	Develop new concepts of landscape scale management of rangelands to provide for adaptive management in response to climate change.	7
	Quantify possible effects of climate change on sagebrush and associated understory plant composition and distribution.	1
	Is there a relationship with the recent historic climate record and highly functional or degraded habitat areas, or population density?	18
	Which habitat characteristics or landscape features buffer populations against periodic drought and/or climate change?	18
Weather/Climate – Habitat condition – Interactions	Effects of climate (and changing climate) on composition, structure and productivity (incl. sage-grouse) of the sagebrush ecosystem; interactions of drought-grazing, drought-invasives, drought-invertebrates, etc.	17
	Correlate historical and present weather data with historical and present sage-grouse population data to determine weather impacts to sage-grouse populations and habitat.	1
	How do climate patterns/trends (esp. drought) affect sagebrush ecosystem conditions (productivity, composition, invasions…) and how are/might cycles be tied to cycles (and vulnerabilities) of vegetation and wildlife?	13
	Characterize the potential influence of climate change on sagebrush species, communities and landscape patterns – e.g., increasing temperature, atmospheric CO_2, severe weather events.	13
	Characterize the role and effects of interactions between climate and changing climate with woody expansion, drought, invasive spp., wildfire threats – and implications for sagebrush ecosystems.	13
Weather/Climate – Population	How does drought affect sage-grouse over the short- and long-term?	10, 15
	Evaluate the effects of drought and water developments on sage-grouse populations.	10
	Correlate climate data with sage-grouse population distribution.	1
Weather/Climate – Population response	Correlate, on a local level, historical and present weather data with historical and present sage-grouse population data to determine weather impacts to sage-grouse populations and habitat.	1, 10
	What are the predicted consequences of climate change to sage-grouse populations, and how does this risk vary across the species' range?	18

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Change Agents – Natural Processes—Continued		
Weather/Climate – Population response	Recent evidence from the Great Basin demonstrates that sage-grouse populations may be extremely sensitive to annual climatic variation. Does this pattern hold true range-wide, and what are the implications of these results, given future climate change?	18
Weather/Climate – Seasonal habitat	Relationship between winter and spring conditions (esp. weather/climate) and the timing/location of lek use/appearance, breeding, nesting, etc. (linear time-line, variable amongst years? Populations? Individuals?)	17
	What habitat or landscape features allow small segments of sage-grouse populations reproduce successfully during years of extreme drought? How can managers protect or improve these habitat features.	18
Socio-economics		
Coordination – Management and policy	Mechanisms for integration and coordination across range and jurisdictions.	6
Coordination – Monitoring	Encourage, inform and support (WAFWA, others) efforts to better estimate sage-grouse distributions, abundance, and trends – and importantly, link and integrate monitoring of populations with monitoring of habitat conditions, environmental patterns, etc.	14
Data Management – Monitoring	Standardization of field data collection protocols and/or the establishment of a centralized data storage system would facilitate analyses and foster closer coordination.	7
Economics – Management and policy	It is also possible that there is an economical and biological tradeoff between the uses of habitat management or harvest management for the purpose of improving populations of sage-grouse; which is more approach is more efficient or should they both be used?	6
	What are the costs and benefits of status quo, habitat loss, or habitat restoration for rangeland use and rural/urban rangeland towns, cities, and counties?	6
	What are the social and economic factors that influence human actions and decisions and their role in the persistence of sage-grouse and habitat?	6, 12
	What do we know about socioeconomic conditions of ranching that will affect sage steppe habitats? How can working landscapes and local economies, especially ranching, be integrated across a landscape to foster sage-grouse?	18
Information/Data – Management and policy	How can assembling a common database (e.g., LCMAP) be fostered across the range?	18
	Science, data and information (development and distribution).	6
Integrated management – Adaptive management – Management and policy	Develop an effective adaptive management framework for sage-grouse conservation.	14
	What long term Adaptive Management experiments can be established across the range of the Greater Sage-Grouse to foster science and management collaboration and test conceptual models about how grouse respond to climate change and habitat management?	18
Integrated management – Management and policy	Translate quantified habitat and population objectives to management objectives (practical, meaningful, attainable, etc.)	14
	What management actions (annual decisions) are being made by state and federal land managers that affect grouse? What are the local and landscape level social networks that informally implement such things?	18
	Address (numerous/all) threats and constraints rigorously and objectively to inform practices and decisions that perpetuate sage-grouse populations...	13
	Are regulatory mechanisms sufficient for long-term sage-grouse conservation?	6
Landscape planning – Management and policy	Policy and planning frameworks need science based objectives, measures and decision process for RMPs.	17
	Policy and planning frameworks need common data and regional perspectives for local and regional cumulative impacts analyses.	17
	Policy and planning frameworks need consistent measures/evaluations across jurisdictions.	17
	Policy and planning frameworks need: habitat mapping and “parcel prioritization” for connectivity, seasonal habitat value, restoration potential.	17

Appendix A. Research questions identified from a review of Federal and State sage-grouse conservation document, peer-reviewed papers, and input from the scientific community. Questions have been categorized into a hierarchical organizational structure by theme and topics addressed—Continued.

Theme/topic	Question or Issue	Citation
Socio-economics—Continued		
Landscape planning – Prioritization – Management and policy	Prioritizations for proactive, efficient allocation of limited resources (maximize biological return).	6
	Habitat Protection – need inventory, priorities; ID and protect "existing sagebrush habitat" via plans.	13
	Relative Importance (values) of landscape units for habitat(s) and uses; Landscape Scale Risk-Opportunity Assessment; Cumulative Effects Assessment; Vulnerability assessment.	13
	How can science-based research be best used to prioritize management actions and ensure efficient use of limited resources?	18
Landscape planning – Regional planning – Management and policy	How to balance wildlife and human use/needs (across the landscape and mutually desirable habitats/areas) to provide for local economies and protect public resources? (landscape conservation planning).	17
	Development of information, outlines, approaches for broad-scale, long-term conservation plans that address development including rate/level of disturbance, impact area, recovery, turn-over and accumulation of effects.	13
	Research aimed at developing decision support tools that map habitat, guide management decisions, and assess management actions would substantially benefit range-wide sage-grouse populations.	18
Social trends – Management and policy	What are the characteristics of early-adopters of good grazing and grouse management practices in different SMZs?	18

Citation Reference

1 Wyoming Sage-Grouse Working Group (2003)
2 Nevada Sage-Grouse Conservation Team (2004)
3 Stinson and others (2004)
4 Montana Sage Grouse Work Group (2005)
5 McCarthy and Kobriger (2005)
6 Stiver and others (2006)
7 Idaho Sage-Grouse Advisory Committee (2006)
8 South Dakota Department of Game, Fish, and Parks (2008)
9 Colorado Greater Sage-Grouse Steering Committee (2008)
10 Utah Division of Wildlife Resources (2009)
11 Stiver and others (2010)
12 Hagen (2011)
13 Knick and Connelly (2011)
14 Sage-grouse National Technical Team (2011)
15 U.S. Department of the Interior (2012)
16 Range-wide Interagency Sage-Grouse Conservation Team (2012)
17 Manier and others (2013)
18 U.S. Geological Survey Sage-Grouse Committee (written commun., 2013)