PINEDALE ANTICLINE PROJECT OFFICE (PAPO)

1625 West Pine
PO Box 768
Pinedale, Wyoming 82941
Attention: Project Coordinator 307-367-5386
Eric G. Decker: egdecker@blm.gov

2016 PAPO APPLICATION FOR FUNDING

(Deadline for applicants is February 1, 2016 - use additional sheets if necessary)

1. GENERAL PROJECT INFORMATION

Project Name: Greater Sage-Grouse Conservation and Management in Wyoming:

Guiding Successful Implementation of Conservation Plans

General Location (distance and direction from nearest city/town, attach map at a scale not less than ½" = 1 mile):

Sagebrush-dominated portions of the BLM Pinedale Field Office.

Legal Location of Project (attach map at a scale not less than 1 inch = 2,000 feet).

N/A – We describe a research project focused on generating the tools necessary to effectively implement the Resource Management Plans updated by the BLM late in 2015, as well as proactive aspects of the Wyoming Core Area Protection Policy as envisioned throughout the Upper Green River Basin, Sublette County, WY.

Surface Ownership (check all that apply): Federal ___X___ State ___X___ Private___X___

**If project includes a mosaic of land ownerships (e.g., mix of federal, state and/or fee lands), provide a breakdown for each specific owner by acres and percent of total project area.

N/A – we describe a research project encompassing all sagebrush-dominated habitats in the BLM Pinedale Field Office area, SW Wyoming regardless of surface ownership.

Contact Information for Affected Parties or Agencies:

N/A – The research proposed would provide tools useful to all land managers public and private, and to wildlife management agencies.

2. APPLICANT INFORMATION

Name/Organization: Audubon Rockies (WY/CO); Attn. Alison Holloran, Executive Director

Mailing Address: 116 North College Ave., Suite 1

City: Fort Collins *State:* CO *Zip Code* : 80524

Daytime Phone # (970) 416-6931 *Fax #* (970) 416-5944

Email Address: aholloran@audubon.org

Point of Contact (if different from above)

3. PROJECT DESCRIPTION

General Project Type (check all that apply):

Land Use/Livestock X	Land Use/Recreation X
Cultural _____	Wildlife/Aquatic X
Air _____	Other Land Use/Energy Development

Describe Project Proposal (e.g., mechanical treatment, water improvement, etc.) – Sage-grouse habitat quality assessment using existing data in the BLM Pinedale Field Office area, WY. This project has the goal of providing land and wildlife managers with the tools necessary to implement the BLM's recently revised RMPs and the state sage-grouse conservation approaches. This need is critical and time sensitive given the recent USFWS decision to not list Greater sage-grouse as threatened or endangered, which was contingent on the requirement that state and federal agencies responsible for sage-grouse management demonstrate and quantify viable and effective conservation strategies. However, our abilities to effectively and efficiently evaluate conservation success remain undeveloped. The tools we propose to develop are necessary to inform proactive habitat management as well as assess the efficacy of conservation actions implemented, thus guiding effective use of limited resourced directed towards sage-grouse conservation. We have designed the approach to complement and further develop approaches outlined in the Monitoring Framework appendix in all of the Resource Management Plans updated by the BLM late in 2015.

Total Project Acres (if applicable) – N/A

Acres Indirectly Affected (if applicable, explain) – N/A

4. A. WHAT ARE THE OBJECTIVES OF THE PROJECT?

Our objective for this project is to accurately estimate the quality of sagebrush-dominated habitats for sage-grouse in the BLM Pinedale Field Office area such that the tools developed through the project can be used to inform site-level habitat management in the context of the landscapes required to support populations. The overall goal of this project is to provide land and wildlife managers with the tools and approaches necessary to effectively and efficiently implement the state and federal sage-grouse conservation plans across scales and as envisioned.

B. HOW DOES THE PROJECT MEET THE PAPO STRATEGIC PLAN GOALS? (please refer to the PAPO 2016 Ranking Score Sheet – link is on PAPO website)

The project addresses all 3 of the wildlife strategic plan goals. Goal 3 is the exact objective of this project, with the added benefit that we will estimate habitat effectiveness (or quality) across scales so that the management tools that result from the project will be directly relevant to the monitoring approaches promoted through the Habitat Assessment Framework* (HAF). The HAF is a framework which has been promoted in federal sage-grouse management plans – most recently as the Monitoring Framework appendix in all of the Resource Management Plans updated by the BLM late in 2015 – and also by the Wyoming Game and Fish Department (WGFD). But, the tools developed to implement the HAF are only as good as how those tools are used. We will work with land and wildlife managers in the Upper Green River Basin establishing approaches to using the tools we develop to prioritize conservation action (required to effectively address Goal 1) and to assess the

effectiveness of those actions through space and time (Goal 2). The approach developed to address Goal 2 – assessing conservation effectiveness through time – establishes the foundation for actually executing an adaptive management program that can be sustained and effective long-term.

* Stiver, S. J., E. T. Rinkes, D. E. Naugle, P. D. Makela, D. A. Nance, and J. W. Karl, eds. 2015. Sage-Grouse Habitat Assessment Framework: A Multiscale Assessment Tool. Technical Reference 6710-1. Bureau of Land Management and Western Association of Fish and Wildlife Agencies, Denver, Colorado, USA.

C. HOW DOES THE PROJECT MEET THE 2016 PAPO PRIORITIES? (please refer to the PAPO 2016 Ranking Score Sheet)

Our project addresses the 3rd priority listed—a research project providing tools to improve mitigation and direct monitoring. But, the tools we propose developing are critical for effectively address the 1st priority on the list for sage-grouse long-term (mitigate impacts to current high priority issues). We will provide the tools necessary for land managers to be able to prioritize proactive management actions, assess and quantify the effectiveness of those actions, and modify those actions in case they are ineffectual or conditions change. The 2015 U.S. Fish and Wildlife Service (USFWS) decision not to list sage-grouse as threatened or endangered was contingent on the requirement that state and federal agencies responsible for sage-grouse management demonstrate and quantify viable and effective conservation strategies. However, our abilities to effectively manage habitat for the species and measure conservation success remain undeveloped. The project we are proposing would address these major gaps and allow conservation planning efforts by PAPO and associated land and wildlife management agencies to be integrated with the existing habitat evaluation strategy developed through the Western Association of Fish and Wildlife Agencies, the Habitat Assessment Framework.

5. WHAT ARE THE DIRECT AND/OR INDIRECT EFFECTS ON OTHER RESOURCES?

Sage-grouse are considered both an umbrella and an indicator species for sagebrush ecosystems. An umbrella species is one that is representative of a larger suite of bird and wildlife species reliant on sagebrush habitats; an indicator species is one that is representative of critical habitat characteristics that are integral to a healthy and sustainable sagebrush ecosystem. Therefore, sagebrush landscapes capable of supporting robust sage-grouse populations are by association capable of supporting robust populations of other wildlife species reliant on sagebrush habitats year-around or seasonally (e.g., pygmy rabbits, mule deer, etc.). The tools we are proposing to develop will quantify habitat quality for sage-grouse, and as such may be useful informing the management and mitigation of other high priority wildlife in the BLM Pinedale Field Office area.

6. WHAT IS THE POTENTIAL FOR FUTURE EXPANSION OF THE PROJECT?

The long-term goal of this project is to develop a series of regional-level conservation evaluation tools throughout Wyoming from available sage-grouse lek count, seasonal habitat selection, and seasonally-specific demographic data. The processes and framework for developing tools across the state will be informed by the original investigation described here. We are initially focused in the Pinedale region because of the breadth of sage-grouse data available, and because we have focused other efforts on preliminarily compiling and generating the explanatory data set for the region required to develop the tools. We envision a progression whereby the tools that are developed in the Upper Green River Basin are used to inform the analytical process and the explanatory data needed to complete that process in other areas, thereby streamlining our ability to generate evaluation tools throughout Wyoming.

7. LIST ALL PROJECT PARTNERS/COOPERATORS, THEIR ROLES AND/OR CONTRIBUTIONS:

The organization leading the research described in this proposal will be Audubon Rockies, a 501(c)3 non-profit conservation organization that works in Wyoming and Colorado. Audubon Rockies has represented the conservation community as a voting member of the Sage-grouse Implementation Team (SGIT) appointed by the Governor of Wyoming since inception of that team in 2007. The SGIT developed and implemented the Wyoming Greater Sage-Grouse Core Area Protection policy in 2008. Processes established in this policy became the foundation for sage-grouse conservation plans adopted at state and federal levels across the species' range. Audubon Rockies has been engaged in state and regional discussions about the challenges impacting the sagebrush ecosystem for over a decade. Given their roles in these efforts, senior-level staff at Audubon Rockies (Alison Holloran [Executive Director] and Brian Rutledge [Conservation and Policy Advisor Central Flyway]) have unrivaled knowledge of the management approaches and politics surrounding the challenges of managing this species. Audubon Rockies is known for working with a broad range of stakeholders and promoting science-based conservation and management of bird populations and their habitats. Audubon Rockies' model for scientifically informing their initiatives is to coordinate teams of experts that provide high-quality technical products, and Audubon has assembled a first-rate team to address this project.

Ms. Alison Holloran (Primary Contact) is Executive Director of Audubon Rockies; **Mr. Brian Rutledge** is the Central Flyway Conservation and Policy Advisor for Audubon. Alison and Brian designed and implemented Audubon Rockies' Sagebrush Ecosystem Initiative, and have been focused on sage-grouse management and conservation in Wyoming and throughout the West for over a decade. Alison earned her master's degree studying sage-grouse in Pinedale, Wyoming in 2000. Brian is an original member of the SGIT appointed by the Governor of Wyoming to develop and implement the Wyoming Greater Sage-Grouse Core Area Protection policy. Alison will be the primary point of contact on this project, and will provide administrative oversite; Brian will provide technical assistance for this project.

For this project, Audubon has drawn on their extensive connections within the field of sage-grouse and assembled a remarkable team of experts to carry out the proposed research. The team has unparalleled experience studying sage-grouse and the conservation of sagebrush communities, and a proven track record of working collaboratively with partners and producing timely and relevant research products. Combined, the team has over 45 years studying sage-grouse (predominantly in Wyoming) and has published over 20 peer-reviewed articles within the last 10 years that address priority questions in sage-grouse ecology.

Dr. Matt Holloran is principal of Operational Conservation, LLC. Matt has over 20 years' experience researching sage-grouse, and is considered one of the leading experts on the species. Matt specializes in investigating the response of sage-grouse populations to anthropogenic activity—predominantly energy development. Matt will be the lead investigator on this project, will provide biological and statistical expertise needed to address the objectives outlined in this proposal, and will assist in project design, result interpretation, and writing.

Dr. Bradley Fedy is a professor at the University of Waterloo (a member institution of the Rocky Mountain Cooperative Ecosystem Studies Unit) and an expert in sage-grouse ecology. Brad leads a strong quantitative research lab and brings extensive expertise both in sage-grouse ecology (particularly in habitat selection and population monitoring) and data analysis; he specializes in examining factors that influence the fitness of animal populations at multiple scales—from genes to landscapes. Most of Brad's research focuses on priority conservation issues for sage-grouse and sagebrush steppe habitats and he resides in Wyoming 4 months out of

every year. Brad is the lead biometrician for this project, and will further assist in project design, result interpretation and writing.

Ms. Holly Copeland is a conservation scientist with The Nature Conservancy. Her research has focused on landscape-scale impacts of oil and gas, wind, and residential development to sage-grouse within the Rocky Mountains and the benefits of various conservation scenarios at abating these impacts. Additionally, she has been leading research on sage-grouse as an umbrella species for mule deer and has developed new statewide models in Wyoming of mule deer migration to assess overlap between sage-grouse and mule deer population needs. Holly will provide spatial analysis and modeling expertise needed to guide the project, and will assist in result interpretation and writing.

Dr. Robert Crabtree is the founder, president and chief scientist of the Yellowstone Ecological Research Center (YERC) and is a Research Professor at the University of Montana in the department of Ecosystem and Conservation Sciences. YERC is renowned as an organization generating time-varying remote-sensed covariate layers across North America and using those products developing approaches to modeling wildlife populations and monitoring ecosystem health across broad landscapes (http://www.yellowstoneresearch.org/). Bob and his staff at YERC, led by **Mr. Steven Jay**, will provide explanatory covariate GIS layers, spatial analysis and modeling expertise needed to guide the project, and will assist in result interpretation and writing.

8. PROJECT MONITORING AND REPORTING: (Describe how monitoring and reporting will be done, and how it relates to the objectives)

The project we are describing requires no direct monitoring, but would provide a framework for integrating monitoring data into a rigorous adaptive management program. In fact, this is the overall goal of this project; as described above—to provide land and wildlife managers with the tools and approaches necessary to effectively and efficiently implement adaptive management programs envisioned in state and federal sage-grouse conservation plans. Planning and the decision support tools required to plan are only the first step in long-term management and conservation. A framework for the actual implementation of a conservation strategy that is inherently able to cope with the vagaries of changing conditions and uncertain management outcomes is as critical to the landscape-scale, sustained conservation paradigm as rigorously developed conservation planning tools. The *ingest* (i.e., incorporation of monitoring data) and *repeat* (i.e., re-evaluation given monitoring data) cyclic nature of the implementation framework is mandatory for assessing whether goals are being achieved (i.e., hypothesis testing) and for adapting management prescriptions, and is the backbone of science-based management.

We will conduct periodic project management meetings with PAPO and other interested managers throughout the project. We will deliver the project as a draft and final technical report on analysis methods and findings, draft and final technical reports on tool validation methods and findings, and a full draft and final summary report describing project goals, methods, results, and implications for sage-grouse management in the Pinedale region with hard copies of relevant maps and electronic copies of all relevant shapefiles necessary to generate the maps. Upon approval of the final report, we will work with PAPO and other interested managers generating a framework for using the tools to prioritize conservation actions, and for building from these original tools an iterative process for assessing the efficacy of implemented management actions through space and time. Our goal with this project is to provide PAPO with the tools and approaches necessary to effectively and efficiently implement the state and federal sage-grouse conservation plans as intended. We will pursue publication of results in peer reviewed journals.

9. RESEARCH POTENTIAL: (Describe research potential of the project)

As mentioned above, the 2015 USFWS decision not to list sage-grouse as threatened or endangered was contingent on the requirement that state and federal agencies responsible for sage-grouse management demonstrate and quantify viable and effective conservation strategies. However, our abilities to effectively and efficiently evaluate conservation success remain undeveloped. The project we are proposing would address these major gaps and allow conservation planning efforts by PAPO and associated land management agencies to be integrated with the existing habitat evaluation strategy developed through the Western Association of Fish and Wildlife Agencies, the Habitat Assessment Framework (HAF).

The HAF is the BLM's and WGFD's chosen method for monitoring sage-grouse habitat in Wyoming, but the guidance developed by both agencies does not provide for implementing the HAF at all relevant scales for adequately managing sage-grouse over the long-term. The HAF outlines a multi-scaled approach to assessing and monitoring sage-grouse habitat suitability and quality. A fundamental concept of the HAF is that scales of habitat selection – described as orders of selection* in the document – are inherently related; the value of a location for sage-grouse as quantified at a given scale needs to be taken in the context of the value of that location as quantified across the other scales. Successful implementation of the HAF – and thereby the BLM's and WGFD's conservation plans – hinges on building sufficient detail into finer scale habitat assessments and integrating them with analyses performed at coarser spatial scales. The successful development and implementation of an approach of combining sage-grouse habitat value assessments across orders would provide a framework to help guide approaches to RMP and state conservation plan implementation across the range of the species. This could influence not just the management of sage-grouse, but as the ramifications of the recent sage-grouse listing decision start to permeate across other species and other ecosystems, with wildlife management in general.

* Habitat selection by sage-grouse is broken down into four orders: *1st-order selection*: species range; *2nd-order selection*: population areas, dispersal between sub-populations; *3rd-order selection*: home range of small/ isolated populations, subpopulations, or groups of sage-grouse associated with a cluster of leks, movement between seasonal ranges (breeding to summer); and *4th-order selection*: seasonal habitats, movement between daily use areas (feeding to roosting, nesting to feeding, feeding to loafing). See Figure 5 in Technical Reference 6710-1.

10. PERMITS AND AUTHORIZATIONS REQUIRED PRIOR TO PROJECT IMPLEMENTATION (including but not necessarily limited to the following): N/A – we will use existing sage-grouse data and remotely-sensed explanatory data to generate the tools described; given our reliance on existing data sets, no permits are required for these efforts.

PERMIT OR AUTHORIZATION	REQUIRED		SUBMITTED		APPROVED	
	Yes	No	Yes	No	Yes	No
Cultural Resource Inventory						
COE Section 404 Permit						
Cooperative Agreement(s)						
NEPA Analysis						
Pesticide Application Permit						
Private Landowner Agreement(s)						
Sensitive Species Clearance						
Surface/Ground Water Permits						

T/E Species Clearance						
Other (explain)						

11. TOTAL PROJECT COST (Attach detailed budget)

Project Planning, Design, and Reporting	$ 200,650
Project Implementation	$ 185,000
Project Operation and Maintenance	$ 34,430
Total Required	$ 420,080

12. MATCHING FUNDS ANTICIPATED IN CASH (list source & amount)

$ 175,000 – Wyoming Governor's Office

13. ANTICIPATED "IN KIND" MATCHING FUNDS (list source, valuation, valuation method) N/A

14. PERCENTAGE OF FUNDING ON HAND OR COMMITTED

22% -- $ 25,000 from Wyoming State BLM to initiate compiling and generating explanatory variable layers in the Upper Green River Basin (these funds have been spent); **$ 68,000** secured from multiple sage-grouse local working groups throughout Wyoming (reference detailed budget attached).

15. TOTAL PAPO FUNDING REQUESTED:

$ 152,080 – This amount is requested to fully fund the project assuming the anticipated funds from the Wyoming Governor's Office mentioned above are secured. A lesser amount would move us closer to full funding, but we will not be able to meaningfully initiate the project until we have secured full funding.

16. EXPECTED/ANTICIPATED LIFE OF PROJECT (LOP)

Perpetual ___X____ > 50 Years_____ 25-50 Years_____ < 25 Years_____

Explain Basis for Projected LOP:

As described in detail in #8 above, our goal is to help define and implement a process of using the tools developed through this project in a perpetually-updated, iterative evaluation of sagebrush ecosystem health. The process will ensure that the tools used to evaluate and prioritize management are constantly being updated with monitoring data and research results as those are collected, thereby establishing a dynamic and scientifically defensible management approach informed by perpetually-pertinent tools.

17. PROJECT TIMELINE AND ESTIMATED COMPLETION DATE. Explain

Phase 2 Timeline***	F16	M16	A16	M16	J16	J16	A16	S16	O16	N16	D16	J17	F17	M17	A17	M17	J17	J17
Explanatory data layer development and update (2nd and 4th order scales)																		
2nd Order habitat quality assessment modeling (lek count data)																		
4th Order habitat quality assessment modeling (telemetry data)																		
4th Order habitat quality metric developed -- across season assessment																		
Explanatory data layer development (for 3rd order from 4th order model results)																		
3rd Order habitat quality assessment modeling (4th order model results)																		
3rd Order habitat quality metric developed -- annual habitat use assessment																		
Model development and implementation across orders (2nd, 3rd and 4th)																		
Sage-grouse population monitoring metrics developed																		
Final reporting*																		
Publication submittal**																		

* Deliverable: Final Report delivered by July 1, 2017.

** Publication(s) submitted by August 1, 2017.

*** Note that this timeline assumes full funding commitment by February 2016 - the timeline can be systematically shifted to start on the date of funding is committed.

18. ATTACHMENTS AND SUPPORTING DOCUMENTATION

Map of Project _____ (at a scale not less than 1 inch = 2,000 feet)

Project Design X_____

Letters of Support _____

Management Plan _____ Long Term _____ Short Term _____ [1]

Monitoring Plan _____ Long Term _____ Short Term _____ [1]

Relevant Past Experience X_____ Other X_____ Explain: Detailed Budget

[1] Long term is defined as greater than (>) 5 years; short term is less than (<) 5 years.

19. ADDITIONAL INFORMATION FOR PAPO CONSIDERATION

See attached Project Design and Relevant Past Experience of Researchers.

20. ACKNOWLEDGEMENT: This project and requested funding is subject to approval by the Pinedale Anticline Monitoring and Mitigation Board of Directors

Signed

Alison Holloran
Printed Name

Executive Director, Audubon Rockies
Title

1/29/16
Date

DETAILED BUDGET – FEBRUARY 2016

		Cost	Budget Comment
Project Lead			
	Audubon Rockies personnel	$ 70,000	Salary plus fringe
	Overhead @ 29.5%	$ 20,650	
Principal Investigators			
	Matt Holloran (Lead Investigator; Operational Conservation LLC)	$ 37,500	Contract
	Holly Copeland (TNC)	$ 17,500	Contract
	Bob Crabtree (YERC)	$ 20,000	Contract
	Brad Fedy (Univ. of Waterloo)	$ 35,000	Contract
Support Services			
	Biometrician (model development)	$ 60,000	Contract
	Covariate development (YERC)	$ 125,000	Contract
Miscellaneous			
	Travel	$ 7,500	Reimbursed as used
	Office Expenses	$ 4,380	
Administrative			
	Audubon	$ 22,550	8% total direct cost to administer grant
TOTAL BUDGET		**$ 420,080**	
Secured Funding		$ 10,000	Upper Green LWG
		$ 15,000	Wind River/Sweetwater River LWG
		$ 16,000	Upper Snake LWG
		$ 10,000	Southwest LWG
		$ 17,000	Bates Hole/Shirley Basin LWG
		$ 25,000	WY state office of the BLM (funds spent)
Anticipated Funding		$ 175,000	WY Governor's Office
	SUB-TOTAL	*$ 268,000*	
Additional Funding Required		**$ 152,080**	

PROJECT DESIGN

Successful management and conservation of wildlife requires more than estimating habitat suitability; the demographic outcomes of that selection (survival and reproductive success) must be taken into account. Otherwise habitat suitability estimates may direct conservation to areas that are attractive, but ultimately detrimental, to sage-grouse. Habitat suitability modeling uses species-specific datasets (e.g., sightings, telemetry data, or GPS data) to define 'selected' or 'preferred' resources relative to the availability of those resources. These models are necessary to define important habitat requirements as well as risk factors associated with species distributions and habitat loss or degradation, but they are not sufficient to fully understand habitat quality. Fitness influences population growth and persistence, and habitat suitability alone can be misleading if not combined with relevant measures of demography that reflect habitat quality, e.g. classic source-sink habitat dynamics. For example, species' response to anthropogenic activity such as energy development can include both avoidance (essentially resulting in effective habitat loss) and reduced probability of survival and/or successful reproduction. Consideration of both potential responses is critical to accurately quantify the effects of that activity. Effective planning for recovery requires a direct link between habitat selection and population demographics.

Simply generating maps of sage-grouse occurrence is not enough. In order to accurately quantify the value of a given location for sage-grouse, habitat and population-level metrics must be developed that link selection and fitness measures to habitat conditions. We believe that ultimately a systematic framework that examines these metrics at each order of selection as described in the HAF represents the most robust method for understanding and quantifying habitat value for sage-grouse. We propose using distinct population metrics (lek counts, seasonal habitat selection, and individual survival rates [e.g., nest success, chick productivity]) unique to each of the four orders of selection described in the Habitat Assessment Framework (HAF)[1] to generate a set of seasonally-specific models that predict probability of success or survival given selection. Outputs at each order of selection will be combined into an overall habitat value index that expresses the multi-scale and multi-season habitat value by pixel as a pseudo-population growth (lambda) estimate. Different population metrics respond to conditions at different scales, thus by investigating multiple population metrics we are effectively assessing across the orders of selection defined in the HAF.

Habitat metrics represent habitat characteristics or attributes – both natural and man-made – that influence sage-grouse. We will base these habitat metrics on differing *orders of selection*, which represent 4 levels of spatial scale at which habitat metrics influence where sage-grouse reside and obtain resources necessary for survival and reproduction. Habitat metrics influence different sage-grouse *population metrics* that must be linked to the habitat metrics at each corresponding order of selection. In general, population-level metrics (e.g., lek counts) are influenced by and therefore are assessed at lower orders, whereas metrics associated with individual sage-grouse (e.g., seasonal habitat selection, nest success, survival) are influenced by and assessed at higher orders. We will use lek count data to estimate landscape-scale habitat quality (2nd order assessment), and telemetry data to estimate site-level habitat quality (4th order

[1] Stiver, S. J., E. T. Rinkes, D. E. Naugle, P. D. Makela, D. A. Nance, and J. W. Karl, eds. 2015. Sage-Grouse Habitat Assessment Framework: A Multiscale Assessment Tool. Technical Reference 6710-1. Bureau of Land Management and Western Association of Fish and Wildlife Agencies, Denver, Colorado. Habitat selection by sage-grouse is broken down into four orders: *1st-order selection*: species range; *2nd-order selection*: population areas, dispersal between sub-populations; *3rd-order selection*: home range of small/ isolated populations, subpopulations, or groups of birds associated with a cluster of leks, movement between seasonal ranges (breeding to summer); and *4th-order selection*: seasonal habitats, movement between daily use areas (feeding to roosting, nesting to feeding, feeding to loafing). See Figure 5 in Technical Reference 6710-1.

assessments). Results from 4th order assessments will be used to estimate habitat quality at the 3rd order of selection.

We will build population response models (PRMs) as empirically-based, spatially-explicit models of sage-grouse habitat selection (suitability) and demographic (quality) response to habitat conditions as those conditions vary annually. We propose to use Generalized Linear Mixed Modeling (GLMM) procedures to generate models. Time-varying response and explanatory variables – with the inclusion of random effects to account for within-year variability – will be used to generate models. PRMs require field data on sage-grouse (response variables) and a wide variety of data layers generated from GIS, mapping products, and remote-sensing data products (explanatory variables described in more detail below). Each model will estimate the population metric being examined as a product of applicable habitat variables quantified at a scale pertinent to that metric. Models will be developed at regional scales related to the response data sets available. Modeled estimates will be projected across the modeled regions at 30-m resolution. Given the suite of population metrics, this approach will establish a series of values for each pixel; each value representing a population metric that responds to certain habitat attributes at a certain scale. For example, the nesting habitat selection and success model will consider habitat variables known to influence that seasonal period (e.g., herbaceous cover and height; vegetative heterogeneity; distance to anthropogenic infrastructure; etc.) quantified at a scale pertinent the metric being modeled (i.e., vegetation within relatively close association of the selected nesting location). Conversely, for the models investigating lek counts we will consider habitat variables pertinent that metric (e.g., the proportion of the landscape surrounding the lek comprised of sagebrush; anthropogenic infrastructure densities; etc.) again quantified at a pertinent scale (i.e., the landscape used by a majority of the individuals breeding on that lek). Estimated values from distinct seasonal habitat models will be used to model annual survival given the suite of locations selected by an individual throughout the year to provide a habitat value estimate of mid-scale habitat attributes. In this way, each model is providing information as to the suitability and quality of a given location (pixel) based on assessments estimating the value of that location at a different scale. By combining each of these modeled estimates into a single metric of habitat value by pixel, we are truly assessing habitat quality across scales.

A recent study[2] concluded that sage-grouse abundance can be determined in large part by annual variation in resource availability. As abundance is determined by demography (e.g., survival and productivity), this conclusion suggests that annual fluctuations in vital rates are the major drivers of sage-grouse population sustainability. However, few studies to date have incorporated temporal variability in habitat into analyses. Although temporal replication is often associated with species data sets, investigators have generally focused on individual sites and averaged habitat conditions over time rather than modeling the temporally-dynamic drivers of annual variability. In the past this limitation was inevitable because sufficient explanatory data time-series could not be developed. For example, time-series of herbaceous cover estimates that matched existing sage-grouse nesting time-series were not available in a GIS. These limitations can now be largely overcome, so we will be focusing our assessment of habitat value on developing data to describe variation through both space and time.

GIS data layers such as habitat maps and validated remote-sensing data products are essential to approximate sage-grouse habitat requirements. When conducting predictive models of wildlife habitat suitability and quality, obtaining access to sufficient applicable explanatory datasets in a GIS-ready format

[2] Blomberg, E. J., J. S. Sedinger, M. T. Atamian, and D. V. Nonne. 2012. Characteristics of climate and landscape disturbance influence the dynamics of greater sage-grouse populations. Ecosphere 3(6):55. http://dx.doi.org/10.1890/ES11-00304.1.

is a primary concern. When key explanatory variables are excluded from models, outputs may be biased due to deficient models leading to erroneous conclusions and a net loss for species management. The proposed project will require sufficient data development and modification to produce the desired results. We will rely on existing data layers when available (for example NASA-derived gross primary productivity). Other habitat data will be represented through reasonable proxies (for example annual spring soil moisture as a proxy for cool season bunch grass annual production). A proxy is an indirect measure used to infer the value of a habitat metric—for example, GIS layers establishing the cover of perennial grasses do not exist across the state of Colorado; therefore we will need to investigate potential proxies that infer perennial grass cover from GIS layers that do exist at that scale (e.g., net primary productivity; aboveground herbaceous biomass; leaf area index; etc.). Other data layers will be derived from remotely-sensed data (for example natural gas infrastructure layers generated from high resolution aerial imagery).

Several years ago the Yellowstone Ecological Research Center (YERC) recognized that spatially-explicit, time-varying explanatory data sets for describing patterns in wildlife distributions and demographics were a critical data-gap to effectively informing conservation and management actions. In response, Dr. Crabtree led the design and development of the Ecological Assessment, Geospatial Analysis and Landscape Evaluation System (EAGLES; see http://www.yellowstoneresearch.org/eagles.html) mentioned above. EAGLES is a series of web-based tools developed by YERC and provided in an ArcGIS interface that allow conservationists to test hypotheses regarding landscapes or ecosystems of interest. Several of these tools (e.g., COASTER; Geospatial Data Wiki; CASA for Wetlands and Mountains; Access to Validation) focus on the generation and maintenance of temporally-dynamic geospatial covariate data sets. Many of the explanatory variables needed for the GLMM analysis are available through COASTER (www.coasterdata. net).

We are focused initially on generating a framework that relies on habitat metrics derived from remotely-sensed information (rather than relying on vegetation plots for some of the habitat metrics for example) for 2 reasons: (1) using GIS layers to assess habitat value allows us to "go back in time" so to speak. We can therefore match explanatory variables to the time-frame of the response data set which allows for an assessment of changes in habitat values through time. Temporal-variance provides the foundation for the iteration required to do adaptive management and effectively assess the response of sage-grouse populations to management actions implemented. And (2) given our scale of inference, GIS layers provide a cost-effective approach to gathering habitat information (especially those that change substantially through time) as well as standardized variables for assessment, which establishes the foundation for future monitoring and adaptation.

Our objective for this project is to accurately estimate the quality of sagebrush-dominated habitats for sage-grouse in the Upper Green River Basin of western Wyoming such that the tools developed through the project can be used to inform site-level habitat management in the context of the landscapes required to support populations. The overall goal of this project is to provide land and wildlife managers working in the Pinedale region with the tools and approaches necessary to effectively and efficiently implement the state and federal sage-grouse conservation plans across scales and as envisioned. As range-wide sage-grouse conservation approaches are finalized, it is imperative that these plans are implemented diligently and effectively to set a positive precedent for species recovery without invoking the Endangered Species Act. The effectiveness and success of these efforts will hinge not only on the management approaches

stipulated in the plans, but on how the plans are implemented. A truly science-based, adaptive approach[3] to implementation will maximize the probability of success as well as the efficiency with which limited resources are allocated and applied.

RELEVANT PAST EXPERIENCE OF RESEARCHERS

Three of the research team members are considered leading experts on sage-grouse, and have conducted some of the seminal research on the species (B. Fedy; H. Copeland; M. Holloran). Federal and state land and wildlife management agencies regularly request the assistance of these researchers for developing and vetting approaches to conservation and management of sage-grouse. For example, during the recent 2015 status review for greater sage-grouse, Dr. Fedy was the only researcher invited to both the U.S. Fish and Wildlife Service expert elicitation workshops on sage-grouse genetics and modeling. Following is a list of publications resulting from sage-grouse projects led or participated in by members of the research team within the last 10 years. These studies range from local to range-wide scales and focus on habitat and population modeling. Additional information on sage-grouse projects led by team members either on-going or not resulting in a publication is extensive, and can be found in each of the researcher's CVs (available upon request).

The research team as a whole has unparalleled experience developing and applying species distribution models using a variety of analytical software and statistical approaches—these skills are required to develop the tools described in this proposal. Members of the team are well versed in the use of ArcGIS, qGIS, Program R, STATA, Python, MARK, WinBUGS, Maxent, Zonation, RandomForest modeling, Approximate Bayesian Computation, and CircuitScape; and have used these programs and approaches to perform a myriad of spatially-explicit analyses. As examples: Dr. Crabtree developed the Ecological Assessment, Geospatial Analysis and Landscape Evaluation System (EAGLES; see http://www.yellowstoneresearch.org/eagles.html), that has the primary goal of assisting users in developing species distribution and habitat models to identify critical habitats, assessing environmental and cumulative impacts to species of anthropogenic and environmental changes (both positive and negative), and prioritizing conservation and management actions. The tool relies on Risk-Reward Spatial Capacity (RRSC) modeling procedures developed by Dr. Crabtree. Dr. Fedy led the analysis of sage-grouse telemetry data collected throughout the state of Wyoming where Resource Selection Function (RSF) models were developed using logistic regression; these RSFs were used to identify suitable seasonal habitats (nesting, summer and winter) throughout the state at a spatial resolution of 30 m (see Fedy et al. 2014 below). Dr. Holloran managed an analysis of lek count data in Wyoming where binomial mixture models were used to estimate sage-grouse abundance on leks through time; abundance estimates were used to project landscape-scale habitat condition in a spatially-explicit manner at 250-m spatial resolution across all sage-grouse core habitat in the state (see Burkhalter et al. *In Preparation* below). The experience gained through leading these large-scale efforts is directly relevant the project proposed here. Ms. Copeland led an analysis modeling future energy development scenarios and projected potential impacts to sage-grouse; different conservation and management scenarios were also examined to estimate benefits to sage-grouse (see Copeland et al. 2013 below). Expertise in scenario development is directly relevant the long-term goal of the project proposed here.

[3] Atkinson, A. J., P. C. Trenham, R. N. Fisher, S. A. Hathaway, B. S. Johnson, S. G. Torres, and Y. C. Moore. 2004. Designing monitoring programs in an adaptive management context for regional multiple species conservation plans. U.S. Geological Survey, Western Ecological Research Center, Sacramento, CA, in partnership with California Department of Fish and Game, Habitat Conservation Division, and U.S. Fish and Wildlife Service, Carlsbad, CA.

RELEVANT PUBLICATIONS BY RESEARCH TEAM in LAST 10 YEARS

Burkhalter, C., **H. Copeland, R. Crabtree, B. Fedy,** B. Rutledge, and **M. Holloran**. *In Preparation*. Assessing landscape-scale habitat condition for an imperiled avian species: the greater sage-grouse in Wyoming. Conservation Biology

Cagney, J., E. Bainter, B. Budd, T. Christiansen, V. Herren, **M. Holloran**, B. Rashford, M. Smith and J. Williams. 2010. Grazing influence, objective development, and management in Wyoming's greater sage-grouse habitat with emphasis on nesting and early brood-rearing. University of Wyoming Cooperative Extension Service report B-1203. University of Wyoming, Laramie, USA.

Copeland, H. E., K. E. Doherty, D. E. Naugle, A. Pocewicz, and J. M. Kiesecker. 2009. Mapping oil and gas development potential in the US Intermountain West and estimating impacts to species. PLoS ONE 4:e7400.

Copeland, H. E., A. Pocewicz, D. E. Naugle, T. Griffiths, D. Keinath, J. S. Evans, and J. Platt. 2013. Quantifying the benefits of the core area policy and conservation easements to sage-grouse in Wyoming. PLoS ONE 8:1-14.

Copeland, H. E., H. Sawyer, K. L. Monteith, D. E. Naugle, A. Pocewicz, N. Graf, and M. J. Kauffman. 2014. Conserving migratory mule deer through the umbrella of sage-grouse. Ecosphere 5(9):1-16.

Crabtree, R. L. and J. W. Sheldon. 2012. Monitoring and modeling environmental change in Protected Areas: Integration of focal species populations and remote sensing. *Chapter 21 in Remote Sensing of Protected Lands*, Y.Q. Wang, (ed.). Taylor and Francis, Boca Raton, FL, USA.

Doherty, K. E., J. S. Evans, P. S. Coates, L. Juliusson, and **B. C. Fedy**. *In Review*. Importance of regional variation in conservation planning and defining thresholds for a declining species: a range-wide example of the greater sage-grouse. Ecosphere.

Fedy, B. C., J. R. Row, and S. J. Oyler-McCance. *In Review*. Integration of genetic and demographic data to assess relative risk in animals with continuous distributions. Landscape Ecology.

Fedy B. C., C. P. Kirol, A. L. Sutphin, and T. L. Maechtle. 2015. The influence of mitigation on sage-grouse habitat selection within an energy development field. PLoS One 10:e0121603.

Fedy B. C., M. S. O'donnell, and Z. H. Bowen. 2015. Large-scale control site selection for population monitoring: An example assessing sage-grouse trends. Wildlife Society Bulletin 39: 700-712.

Fedy, B. C., K. E. Doherty, C. L. Aldridge, M. O'Donnell, J. L. Beck, B. Bedrosian, M. J. Holloran, G. D. Johnson, N. W. Kaczor, C. P. Kirol, C. A. Mandich, D. Marshall, G. McKee, C. Olson, A. Pratt, C. C. Swanson, and B. L. Walker. 2014. Habitat prioritization across large landscapes, multiple seasons, and novel areas: an example using greater sage-grouse in Wyoming. Wildlife Monographs 190:1-39.

Fedy, B. C., C. L. Aldridge, K. E. Doherty, M. O'Donnell, J. L. Beck, B. Bedrosian, M. J. Holloran, G. D. Johnson, N. W. Kaczor, C. P. Kirol, C. A. Mandich, D. Marshall, G. McKee, C. Olson, C. C. Swanson, and B. L. Walker. 2012. Interseasonal movements of greater sage-grouse, migratory behavior, and an assessment of the core regions concept in Wyoming. Journal of Wildlife Management 76:1062-1071.

Fedy B. C., and K. E. Doherty. 2011. Population cycles are highly correlated over long time series and large spatial scales in two unrelated species: greater sage-grouse and cottontail rabbits. Oecologia 165:915–924.

Fedy B. C. and C. L. Aldridge. 2011. Long-term monitoring of greater sage-grouse populations: the importance of within-year repeated counts and the influence of scale. Journal of Wildlife Management 75:1022–1033.

Holloran, M. J., B. C. Fedy, and J. Dahlke. 2015. Winter habitat use of greater sage-grouse relative to activity levels at natural gas well pads. Journal of Wildlife Management 79:630-640.

Holloran, M. J., R. C. Kaiser, and W. A. Hubert. 2010. Yearling Greater Sage-grouse Response to Energy Development in Wyoming. Journal Wildlife Management 74:65-72.

Johnson, D. H., **M. J. Holloran**, J. W. Connelly, S. E. Hanser, C. L. Amundson, and S. T. Knick. 2011. Influences of environmental and anthropogenic features on greater sage-grouse populations, 1997-2007. pp. 407-450 in S. T. Knick and J. W. Connelly (editors). Greater Sage-Grouse: ecology and conservation of a landscape species and its habitats. Studies in Avian Biology (vol. 38), University of California Press, Berkeley, CA, USA.

Kirol, C. P., J. L. Beck, S. V. Huzurbazar, **M. J. Holloran**, and S. N. Miller. 2015. Identifying greater sage-grouse source and sink habitats for conservation planning in an energy development landscape. Ecological Applications 25:968-990. http://dx.doi.org/10.1890/13-1152.1

LeBeau, C. W., J. L. Beck, G. D. Johnson, and **M. J. Holloran**. 2014. Short-term impacts of wind energy development on greater sage-grouse fitness. Journal of Wildlife Management 78:522-530.

Naugle, D. E., K. E. Doherty, B. L. Walker, **H. E. Copeland**, **M. J. Holloran**, and J. D. Tack. 2011. Sage-grouse and cumulative impacts of energy development. pp. 55-70 in D. E. Naugle (editor). Energy development and wildlife conservation in western North America. Island Press, Washington, DC, USA.

Row, J. R., S. T. Knick, S. J. Oyler-McCance, S. C. Lougheed, and **B. C. Fedy**. In Review. Developing best practices for linear mixed modeling in landscape genetics through landscape-directed dispersal simulations. Heredity.

Row J. R., S. J. Oyler-McCance, J. Fike., M. O'Donnell, K. E. Doherty, C. Aldridge, Z. Bowen, and **B. C. Fedy**. 2015. Landscape characteristics influencing the genetic structure of greater sage-grouse within the stronghold of their range: a holistic modeling approach. Ecology and Evolution 15. 1955-1969.