Science in the Public Sphere: Greater Sage-grouse Conservation Planning from a Transdisciplinary Perspective

By Alicia Torregrosa, Michael L. Casazza, Margaret R. Caldwell, Teresa A. Mathiasmeier, Peter M. Morgan, and Cory T. Overton

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Usage Note: This report adheres to the American Ornithological Union (AOU) naming convention for the common name of *Centrocercus urophasianus*; that is, Greater Sage-grouse is shown in uppercase and hyphenated. Generic references to “sage grouse” are left in lower case and unhyphenated.

Science in the Public Sphere: Greater Sage-grouse Conservation Planning from a Transdisciplinary Perspective

By Alicia Torregrosa, U.S. Geological Survey, Michael L. Casazza, U.S. Geological Survey, Margaret R. Caldwell, Stanford Law School, Teresa A. Mathiasmeier, U.S. Geological Survey, Peter M. Morgan, Stanford University, and Cory T. Overton, U.S. Geological Survey

Abstract

Integration of scientific data and adaptive management techniques is critical to the success of species conservation, however, there are uncertainties about effective methods of knowledge exchange between scientists and decisionmakers. The conservation planning and implementation process for Greater Sage-grouse (*Centrocercus urophasianus*) in the Mono Basin, Calif. region, was used as a case study to observe the exchange of scientific information among stakeholders with differing perspectives; resource manager, scientist, public official, rancher, and others.

The collaborative development of a risk-simulation model was explored as a tool to transfer knowledge between stakeholders and inform conservation planning and management decisions. Observations compiled using a transdisciplinary approach were used to compare the exchange of information during the collaborative model development and more traditional interactions such as scientist-led presentations at stakeholder meetings. Lack of congruence around knowledge needs and prioritization led to insufficient commitment to completely implement the risk-simulation model. Ethnographic analysis of the case study suggests that further application of epistemic community theory, which posits a strong boundary condition on knowledge transfer, could help support application of risk simulation models in conservation-planning efforts within similarly complex social and bureaucratic landscapes.

Introduction

While there is a great need for rigorous scientific data in conservation planning, traditional methods of scientific information transfer, such as journal articles and scientific conferences (Björk, 2007), are often not the most effective means of informing policy makers and land-use managers who make natural-resource decisions (Jacobs, 2002; Peterson and Shriner, 2004; Stankey and others, 2006). The production of traditional scientific products, either independently by scientists or co-generated with stakeholders (McCreary and others, 2001), is often too slow for conservation decisionmakers (Koontz and Thomas, 2006; Steel and others, 2001) and the scientific concepts often require dialogue for effective exchange (Van Sanden and Meijman, 2008; Weber and Schell Word, 2001). Resource managers often need to make decisions quickly, before fully peer-reviewed results are available from a research process that includes hypothesis generation, research design and execution, examination of results, technical and editorial review, and publication (Jacobs, 2002; Peterson and Shriner, 2004). In addition, scientists are typically rewarded for publication in peer reviewed journals with little career incentive given to help resource managers apply their scientific results (U.S. Office of Personnel Management, 2006, Sonnert 1995), even when these results can significantly impact conservation (General Accounting Office, 2008; Jacobs and others, 2005; Nikolov and Zeller, written commun., see *http://www.fs.fed.us/rmc/techtransfer*; Weber and Word, 2001). Although this situation is changing it will continue to require significant systemic institutional modifications (Imperial, 1999; Jacobs and others, 2005; Koontz and Bodine, 2008).

There is general agreement that both scientific analysis and public deliberation are necessary for conservation decisionmaking (Karl and Turner, 2003; Pound and others, 2003; Turner, 2006; Lindeman, 2007); however, there is no consensus on how best to integrate the two (Koontz and Johnson 2004; Peterson and others, 2005; Torgerson, 2005), especially for a species such as the Greater Sage-grouse (*Centrocercus urophasianus*) whose habitat coincides with such a large expanse—40 million acres—of privately owned lands (Gray, 2004a). Many successful Habitat Conservation Plans (Harding and others, 2001) have been developed for species under U.S. Fish Wildlife Service (USFWS) protection with clear, measurable biological objectives, evidence that scientific information does function as a foundation for successful natural-resource planning. Investigating how scientific information is integrated into natural resource planning and decisionmaking is complicated by the social and ecological complexity of land and resource management. Combining studies of social dynamics and ecological processes transcends natural and social science disciplines and such combined studies do not easily lend themselves to the specializations under which most scientists are trained (Stankey and others, 2006; Peterson and others, 2004; Koontz and Thomas, 2006; Gibbons and others, 1994).

This project is defined as transdisciplinary because science-based solutions are being sought for a societally defined problem, both scientists and nonscientists are joint research participants, the solutions transcend both natural and social-science disciplines, and, as a result, additional criteria of economic, social, political, and cultural values are applied to judge the quality of results beyond peer review (Gibbons and others, 1994; Gibbons, 1999; Hessels and van Lente 2008; Klein, 2004; Klein and Macdonald, 2000; Nowotny and others, 2001; Pfirman and others, 2006; Stokols, 2006; Westley and Miller, 2003). The the transdisciplinary framework, developed by Pohl and Hirsch Hadorn (2008), was used to understand outcomes from our research that were strongly influenced by social components.

The transdisciplinary approach posits three levels of knowledge generation (Hirsh Hadorn and others, 2008; Pohl and Hirsch Hadorn, 2008): system knowledge, which in the case of Greater Sage-grouse conservation deals with the complexity and uncertainties of social and ecological interactions; target knowledge, which in this case study focused on causal factors related to different stakeholder response to a social-ecological model; and transformative knowledge, which in the broader field of sustainability studies seeks to improve options for societal problem solving.

Case Study

Between 1999 and 2005, a total of nine petitions were filed under the Endangered Species Act (ESA) to protect Greater Sage-grouse. It is generally agreed (Peters, 2008) that a ruling by the USFWS that the Greater Sage-grouse are endangered or threatened would significantly affect most land-use decisions across the 165 million acres of sagebrush habitat that remain from the 296 million acres of sagebrush habitat that existed prior to 1800 (Schroeder and others, 2004; USFWS Wyoming Field Office, in Federal Register, 2005). In response to petitions, the USFWS reviews existing scientific evidence and solicits additional relevant information to determine whether protection is warranted.

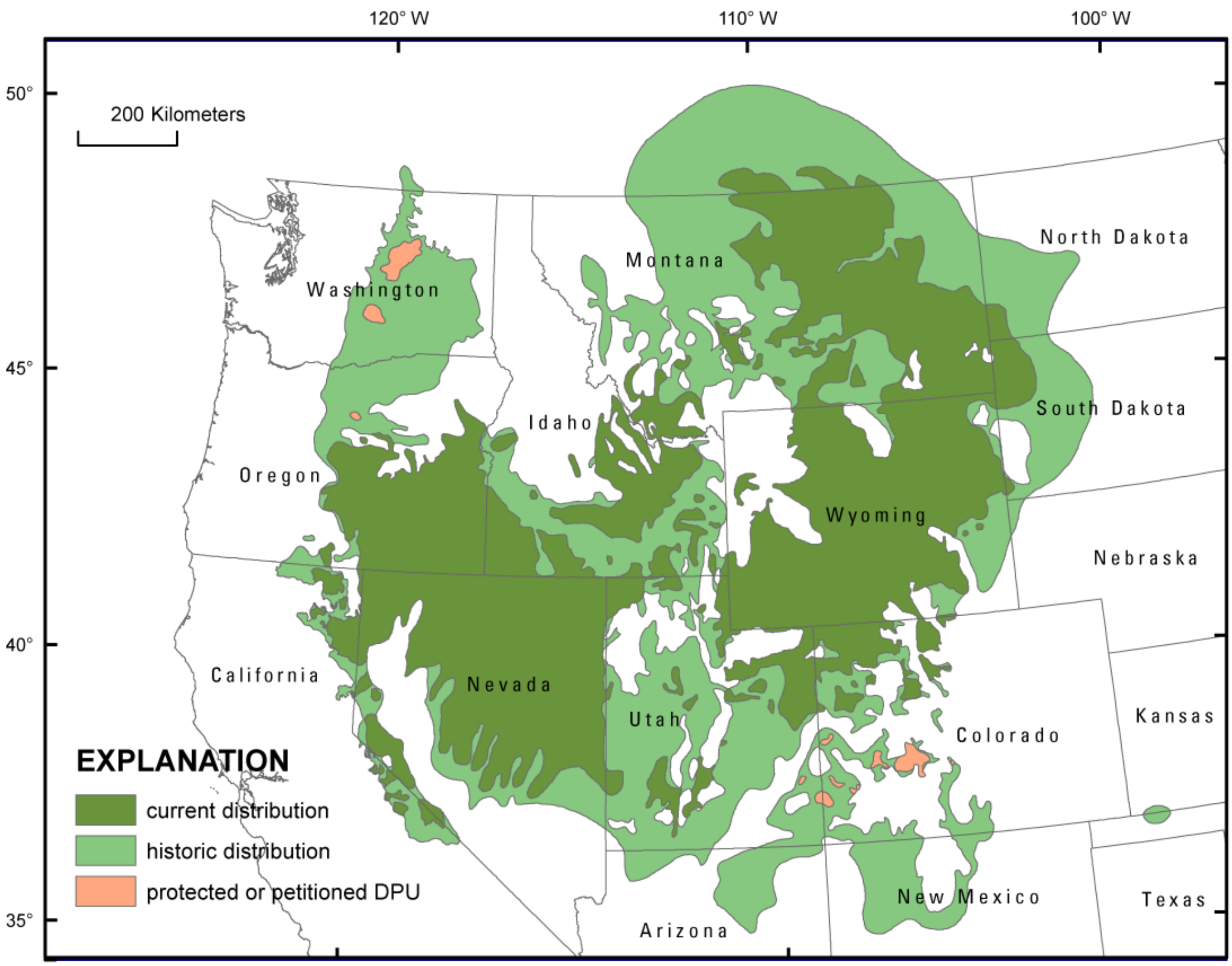

Figure 1. Distribution of Greater Sage-grouse. The historic distribution represents 296 million acres of sagebrush habitat that supported Greater Sage-grouse populations prior to 1800. The current distribution represents the estimated 165 million acres that remain (Schroeder and others, 2004; USFWS, 2005). Several populations have been defined as either distinct population units (DPU) or separate species such as the Gunnison Sage-grouse (Centrocercus minimus) which have local or state level protection (Oyler-McCance and others, 2005; Stinson and others, 2004; Lupis and others, 2006).

A significant amount of information exists regarding the Greater Sage-grouse, its habitat (fig. 1), and threats to both (Stiver and others, 2006; van Kooten and others 2004, Williams and others 2008); however, not all stakeholders agree on the value of existing data, what the data mean, or on how to use it as is evidenced by the legal appeals to the USFWS 2005 decision that the Greater Sage-grouse does not warrant Federal protection. Summarizing the current state of scientific knowledge regarding sage grouse and sagebrush habitats across the West, Connelly and others (2004) explain that "reconciling spatial and temporal resolution, collection or analysis method, incompleteness and incongruent data" Three items represent the most significant challenge to the conservation assessment of Greater Sage-grouse and sagebrush habitats. Furthermore, due to uncertainty about future conditions, the success of Greater Sage-grouse conservation planning relies upon the integration of defensible science with adaptive management (Connelly and Stiver, 2004).

The Greater Sage-grouse Conservation Plan for Nevada and Eastern California (Nevada Department of Wildlife, 2004; herein called the Conservation Plan) was submitted in response to the USFWS request for information. Its purpose was twofold—first, to detail the status of Greater Sage-grouse populations under State jurisdiction, and second, for USFWS to consider the conservation activities detailed in the Conservation Plan under the USFWS Policy for Evaluation of Conservation Efforts (PECE). PECE (Nolin, 2003) is further described in the 2001 fact sheet published by the USFWS Endangered Species Program (*http://library.fws.gov/Pubs9/esa_propolicy01.pdf*).

The Conservation Plan was developed through a local working group (LWG) process that encouraged local community involvement. Greater Sage-grouse LWG stakeholders are a diverse group of individuals—resource managers, ranchers, private landowners, community members, and scientists from a variety of organizations. These organizations are Federal, State, and local agencies that have land-stewardship responsibilities or regulatory oversight for Greater Sage-grouse or its habitat (fig. 2), advocacy groups, non-governmental agencies, and community groups with an interest in the issue.

Using existing information, the South Mono LWG, one of several groups within the Bi-State planning area (fig. 3), compiled a list of threats to the habitat and viability of Greater Sage-grouse populations in the Mono Basin region for the Conservation Plan. These threat categories (such as habitat loss, predation, and impacts from anthropogenic structures) formed the basis for conservation goals, objectives, and priorities (Appendix L, Nevada Department of Wildlife, 2004). Significant data gaps were identified in all threat categories. The uncertainty that resulted from the data gaps was a key contributing factor to the Conservation Plan recommendation that an adaptive-management approach be undertaken to implement Greater Sage-grouse conservation actions (Nevada Department of Wildlife, 2004). Other factors included the complexity of the ecological relationships, lack of mechanistic understanding of the decline of the species, wide range of quality and type of information, extreme diversity of stakeholders involved in decisions about Greater Sage-grouse management and their many levels of organization (for example, individual, group, and agency), and contentiousness of the land-use decisions. In the case of Greater Sage-grouse, contentiousness arises in part because the habitat being considered for conservation efforts affects such large areas, experiential knowledge (Brook and McLachlan, 2005) and traditional science have produced different conclusions, and values associated with the resource differ. Contentiousness also generally arises when outcomes of conservation actions are uncertain or not well established and in these situations, adaptive-management approaches are often employed (Williams, Szaro, and Shapiro, 2009).

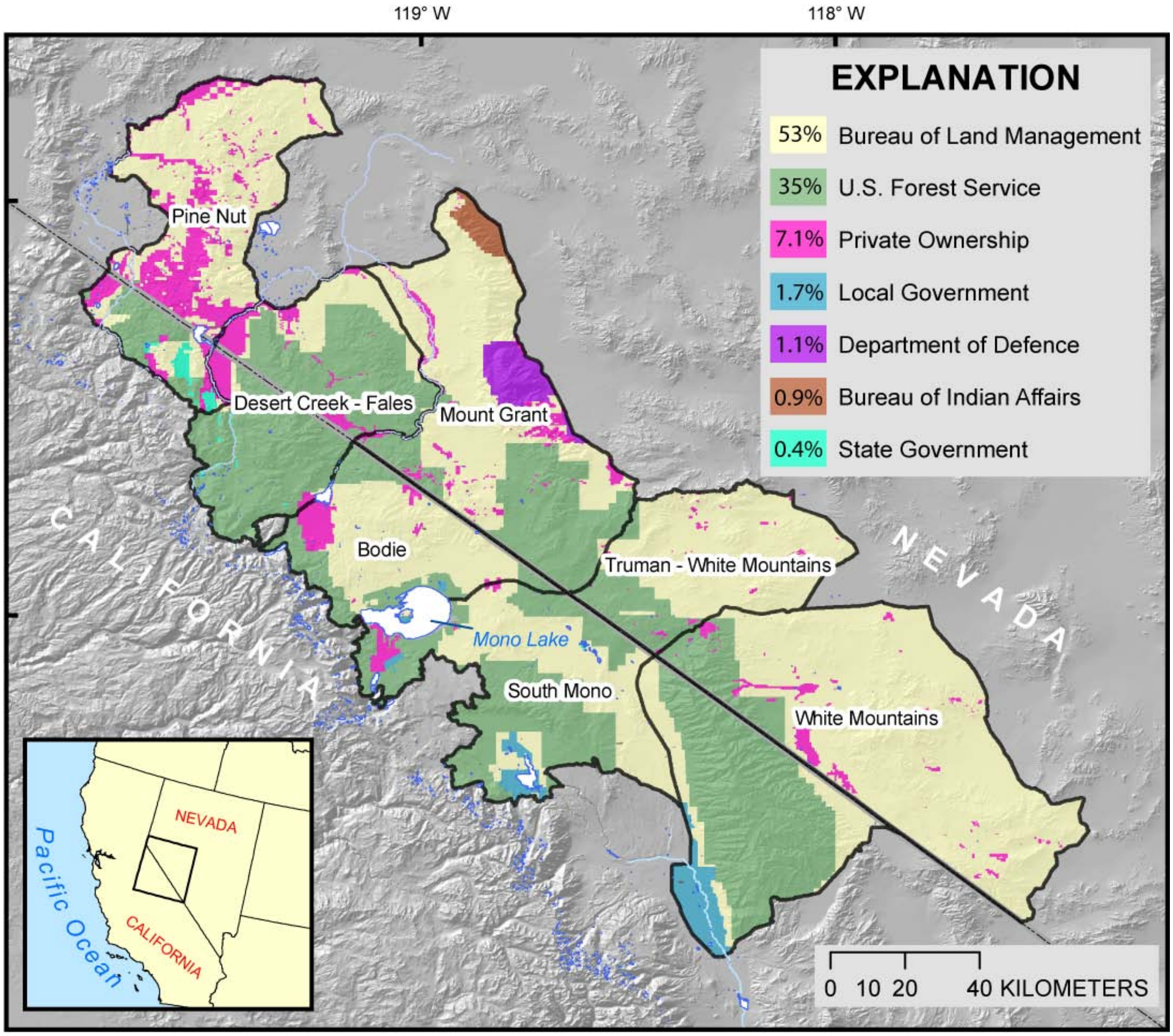

Figure 2. Land management within the Bi-State planning area is complex. Federal agencies (U.S. Forest Service, Bureau of Land Management, and Department of Defense) are the predominant stewards, with many private grazing allotments on these Federal lands. Private owners and the Los Angeles Department of Water and Power manage remaining lands. Percentages in the legend are rounded totals. Source: Bishop Field Station, Bureau of Land Management.

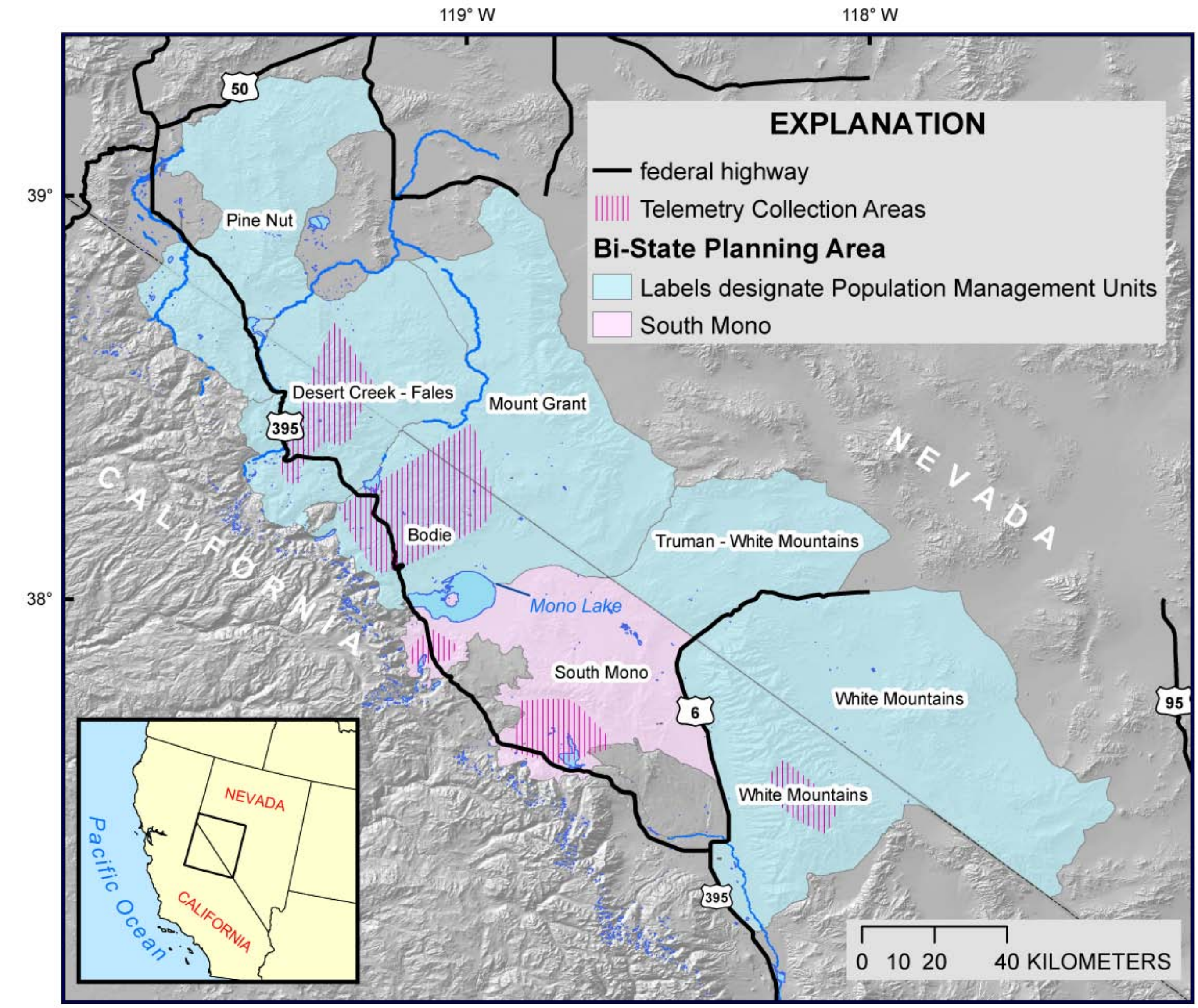

Figure 3. The South Mono local working group is one of seven, each associated with a population management unit in the Bi-State Greater Sage-grouse conservation planning area. Studies of the biology and ecology of Greater Sage-grouse populations in the Mono Basin region are being conducted through collaboration across jurisdictions. Data on bird movements, nesting success, and relationship between fecundity and vegetation parameters were being collected (in areas generally delineated by striped magenta lines on map) using radio collar telemetry, hidden mounted video cameras, and vegetation transects (Casazza and others, 2009; Kolada and others, 2009a; 2009b).

Two conservation actions in the plan focused on knowledge and knowledge transfer. The first was to “Develop additional data layers to improve decision making, and the second was to conduct public workshops “to facilitate information sharing with private landowners and provide an update of the current status of sage-grouse knowledge and research/management activities.” U.S. Geological Survey (USGS) biologists, under contract to the California Department of Fish and Game (CDFG), participated as technical experts within the LWG and collected biological and ecological data between 2003 and 2005 (fig. 3) to better understand the populations of Greater Sage-grouse (Casazza and others, 2009; Kolada and others, 2009a; 2009b) in the Mono Basin region. Analysis of the data was intended to answer basic unknowns such as, “What is the rate of nest success?” “How far do birds travel—seasonally and interannually?” and “How significant are corvids as predators?” Traditional methods of scientific information transfer were planned for the research results such as peer-reviewed publication; however, the intent was also to disseminate data as it was collected, while participating as technical advisors in the Bi-State LWG conservation-planning meetings, workshops, and fieldtrips.

The case study team’s work sought to build on the tradition of participatory approaches to joint knowledge development such as joint fact-finding, shared problem solving, and consensus building (Creighton, 1983; Eden, 1996; Shindler and Cheek, 1999; Westley and Miller, 2003; Susskind and others, 2007), tools that have been successful in mediating contentious natural resource decisionmaking. Problems that are known to occur with participatory planning processes include the difficulty of defining the problem, longer time required to reach decisions, the lack of knowledge equity among participants, and the difficulty of ensuring well-designed and effective plans (Spinuzzi, 2005; Blythe and others, 2008; Moir and Block, 2001; Koontz and Thomas, 2006).

Dynamic-simulation models are useful tools for gaining deeper scientific understanding into processes that structure complex ecological systems (Grant and Thompson, 1997; van den Belt, 2004). Collaborative development of these tools can assist in the exploration of information embedded within complex knowledge structures (Doyle and others, 2007). When data are lacking to construct a fully numerical model, using expert opinion to create a systems model (Dambacher and others, 2009; Grant and others, 1997) or a risk-assessment model (Biswas and others, 1989; Sikder and others, 2006) can guide research efforts. Hope (2006) sees promise in this approach:

“The structure of ecological risk assessment provides a common framework allowing multiple stakeholders, regulatory groups, and scientists to come to terms with the inherent difficulties of managing complex systems. (W)hat is needed are better and less contentious ways of communicating ecological risks to stakeholders.”

This report describes the results from an investigation conducted by an interdisciplinary team of biologists, geographers, legal scholars, and historian about information exchange in a conservation setting. The conservation-planning effort being undertaken by the South Mono LWG for the Greater Sage-grouse was used as a case study. The hypothesis we investigate is that the collaborative development and use of a risk-simulation model would facilitate both information and knowledge exchange and would increase the use of science for conservation planning. We define the use of science, for this study, as the rigorous application of the scientific method into the adaptive-management approach (Williams and others, 2009). A rigorous use of scientific data would incorporate an effective monitoring system. The team expected that collaborative development and implementation of a risk-simulation model would assist in the transfer of knowledge by providing scenarios that could be used to discuss assumptions about the relative impact of the various planned conservation actions. Although the study did not proceed as expected, it gave us an opportunity to collect observations of stakeholder interactions and conduct further analysis of these observations using social-science techniques.

Methods

To investigate our hypothesis within this complex biological, social, political, and scientific landscape, we drew on four distinct methodologies. They are: execution of a stakeholder analysis and user needs assessment, development and application of a simulation model, subsequent analysis of observational data of stakeholder interactions using grounded theory—an inductive social-science research method, and the use of transdisciplinary principles in which feedback from participants influences the development of research questions and ultimately alters the structure of the research study itself. Case-study model development and observations were made during an 18-month period (April 2004 – September 2005).

Stakeholder Analysis and User Needs Assessment

Several types of stakeholder analysis were conducted at different stages of the project based on evolving project needs. These included a stakeholder database that provided information on roles and relationships, an importance and influence matrix to facilitate the development of the simulation model, and a user needs assessment to be used as input for the simulation model.

The stakeholder database (fig. 4) was developed using methods suggested by Justice and Jamieson (1999) and Hermans and Taketa (2006) for interviewing participants to collect information on their perceived roles and relationships. In addition, information was compiled from archives of meeting notes, archived email, and informal notes provided by participants of the Bi-State LWG. The schematic was augmented as the project progressed from its initial introductory phase, through the model development phase, and into the analysis of results phase. From a preliminary list of 19 core stakeholders the schematic grew to include a list of 213 stakeholders (fig. 4).

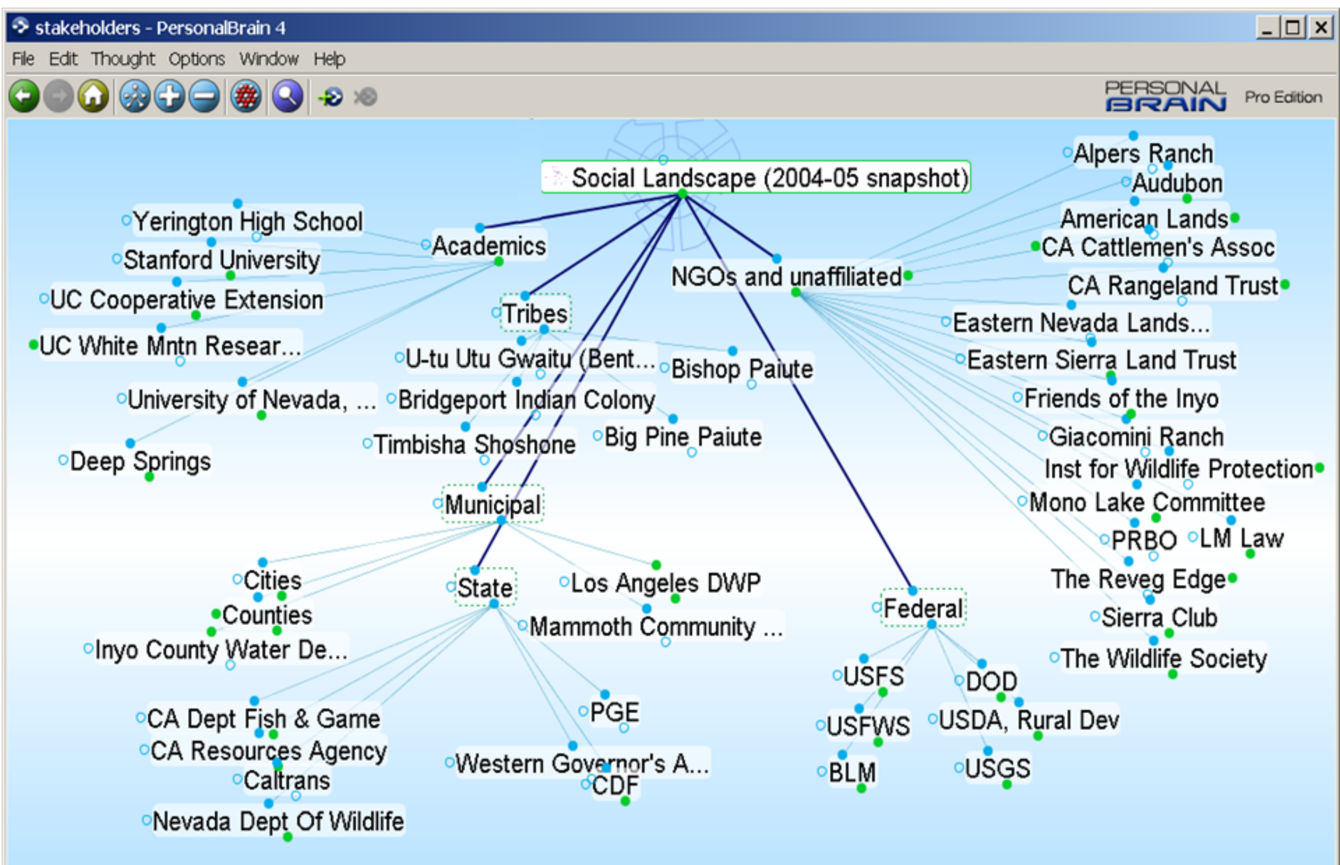

Figure 4. The knowledge management system (KMS) database used for the case study of sage grouse conservation planning. In this database all records are defined as nodes; the synonym, knowledge objects, is also sometimes used. Nodes are manually linked to any number of other nodes to form a network. The visualization function of the database application allows nodes to be collapsed or expanded to show any portion of the network. Here, the social landscape node is expanded to show two levels of links. The first

linkage level shows the major groups that stakeholders were categorized into. The second tier of links show further differentiation within each major category.

Interviews were conducted with the core group of 19 participants. As the project progressed additional participants were interviewed, in an ad-hoc manner, at LWG meetings and national conferences attended by representatives of up to 70 Greater Sage-grouse LWG from across the West. Stakeholders were defined as part of the core group if they had data or knowledge to contribute to the development of the simulation model or if they were perceived by project advisors as potential users of the model. Project advisors were an informal group of Federal, State, and local agency representatives from CDFG, Bureau of Land Management (BLM), USGS, USFWS, and the U.S. Forest Service (USFS), who were familiar with either the local socio-political conditions of the Bi-State LWG, the ESA listing process, or Greater Sage-grouse ecology. Some stakeholders were both in the core group and the advisor group. Additional information was compiled from the study team's observations of meetings, informal one-on-one interviews (in person and by telephone), and at gatherings for formal meetings such as the annual western states LWG conference.

An importance and influence matrix (Groot, 2001) was developed on a consultative basis with project advisors. Importance was defined as the potential to contribute to the model development and implementation; influence was defined as the potential to effectively disseminate opinions, attitudes, and knowledge about the model. Stakeholders were placed into four quadrants; high importance/high influence (HH), high importance /low influence (HL), low importance/ high influence (LH), and low importance/low influence (LL). When decisions about model development and implementation needed to be made, the responses from stakeholders in the HH quadrant were given more weight.

The user needs assessment was compiled predominantly from LWG documents, although some information was also added from interviews. Initially the results of the needs assessment were for use as input into the risk-simulation model and later, when the model was not implemented, they were used in the grounded theory based analysis, as described in the section entitled "Application of Social-Science Methodologies to Explain Observations."

Development of a Risk-Simulation Model for the Greater Sage-grouse

The risk-simulation model consists of two components—a geographic information system (GIS) containing spatially explicit data and a dynamic-systems model built in Stella© (software version 8.0, isee systems). The GIS data layers included base layers and specific data related to Greater Sage-grouse, its habitat, and potential threats. Base layers compiled from existing sources included land cover, parcel data, Federal grazing allotments, roads, elevation, historic fire boundaries, historic interpolated climate data, jurisdictional and administrative boundaries, and remote-sensing imagery. Some base layers needed to be generated from hardcopy sources in conjunction with expert knowledge such as landscape-wide vegetation quality (R-maps). Greater Sage-grouse specific layers included ongoing BLM and CDFG lek-count data and research results from fieldwork being conducted by USGS biologists (Casazza and others, 2009; Kolada and others, 2009a; 2009b) such as telemetry-derived movement patterns of individual radio-collared birds, nesting locations, brood size, nesting success, and vegetation survey data. These data were used to derive correlations between habitat parameters and Greater Sage-grouse demographics such as the percent cover of shrubs associated with varying levels of nest success or the relative amount of predation as a function of distance to roads. The GIS database provided spatial measures for the simulation model, such as amount of habitat or vegetation types under differing agency ownership; it also served to produce visualizations for stakeholder meetings such as three-dimensional maps of seasonal bird movements.

The dynamic-system simulation part of the model was designed to explore the risk associated with the conservation actions proposed by the H/H LWG subgroup. Risk was defined as the level of exposure to the chance of loss; high risk meant greater exposure to the possibility that the conservation action would not produce benefit to Greater Sage-grouse populations. Modeling objects from the Stella© library were linked together to form causal process flows with dynamic loops to run the process for a specified number of time intervals. Input for the model was gathered from the South Mono LWG planning documents, expert knowledge from LWG stakeholders, scientific research—both published and in-progress—and the GIS database. Details of the modeled process flows and outputs are described in the "Results" section.

The model was reviewed by LWG members and selected outside experts; observations during model development were collected during formal interviews, scheduled workshops, and informal conversations held during stakeholder gatherings held for other purposes.

Application of Social-Science Methodologies to Explain Observations

To understand the observations we made of LWG members during model development, we turned to social-science tools to elucidate the patterns of knowledge generation and information transfer across two information dissemination systems: formal and informal communications at stakeholder meetings, and collaborative risk-simulation modeling. The terms knowledge and information are used synonymously. When treated as knowledge objects, knowledge is sometimes used to connote a slightly greater cohesion to a collection of information or deeper understanding of processes associated with a collection of information. Grounded theory, a research methodology that can accommodate a dataset of social observations (Glaser and Strauss, 1967; Glaser, 1998; 2001, Strauss and Corbin, 1997; Fernández, 2005; Kelle, 2005; Fernández and others, 2007), was used during this phase. In this method, observations are first coded and then grouped and mapped to note patterns such as the frequency of recurrence of themes. Data are interpreted by identifying relationships among coded themes and patterns of response to construct a parsimonious theory to fit the situation being studied (physical and natural scientists call this technique, development of a conceptual model).

Observations of the South Mono local LWG were made during formal and informal meetings and interactions. The formal stakeholder exchanges included all interactions and activities that occurred under the auspices of the Bi-State Conservation Planning effort including (1) monthly facilitated meetings held in Bishop, Calif., or a neighboring city, (2) quarterly meetings chaired by representatives of the Governor's science committee held in Reno, Nev., (3) scheduled field trips open to all stakeholders including an all-day field trip with a group of seven nationally recognized sage grouse experts, and (4) annual national conference on conservation planning for Greater Sage-grouse attended by LWGs from across the Western states. The informal observations were compiled from notes of communications between members of the research team and LWG participants, including telephone conversations, email communication, and ad hoc meetings in the field. The reflective nature of the research, in which we, members of the research team, were also members of the LWG and likewise, members of the LWG were also considered collaborators in the research project is characteristic of Action Research (Reason and Bradbury, 2006; 2007). Our participation was guided by the principles of Action Research, which supports experimentation in which the relationships between researchers, stakeholders, and the activity outcomes change through mediated discourse and democratic dialogue (Gustavsen, 2006; Lewin and others, 1939), using the theoretical foundation developed by Luhmann and Behnke (1994) and later expanded by Luhmann and Fuchs (1994), Latour, (2000), Gray (2004b), and Leydesdorff (2006).

Observations were parsed into coded data pieces using techniques developed by Information Mapping© Inc., a protocol for breaking complex information into more basic elements (Horn, 1999).

These separate elements were then aligned along two axes to show associations between the perceived information needs of users and the categories of that information (see fig. 6 in "Results" section). Information was compiled into the PersonalBrain knowledge management system (Kroeker, 2004; Torregrosa and Aiello, unpub. data) and the dynamic visualization functions of the program were used to examine relationships and patterns among records in the database (see fig. 7 in "Results" section for an example of a pattern extracted using this procedure).

The data were structured and analyzed according to grounded theory social-science methodology. Data were grouped into collections using open coding, a technique in which the investigator refrains from using an *a priori* conceptualization of the significance of each data object (Creswell, 1998; Crotty, 1998; Sanberg, 2005). The coded groups and patterns were then woven into narratives using a recursive analysis, as defined by Luhman and Fuchs (1994) and further refined by Andersen (2003) in which the patterns and groupings are interpreted and reinterpreted through a sequential series of pairing interpretations to theory to identify and eliminate observer bias. This technique relies on comparison and coherence criteria (Strauss and Corbin, 1990; Sandberg, 2005; Thagard, 2007) to generate interpretations of the narratives. The comparison criterion is most commonly used to determine the most parsimonious conceptual model to explain the observations. The cohesion criterion is used to verify, using critical thinking, the logic connecting the interpretation of the observations into a conceptual narrative.

The final step—narrative development—is akin to a recursive literature search in which the coded data are compared and contrasted, using multiple discontinuous searches through social theory and philosophical principles in an effort to develop a stable theory (conceptual model). Marshall (2008) describes this entire research process as an emergent form that results from "an engagement with the stuff of inquiry—experience, data, and issues—within [a] larger context or field."

Transdisciplinary Analysis

As our methods for acquiring, interpreting, and understanding these data evolved, team meetings emerged as an important research activity because of the transdisciplinary synthesis they enabled. Methods were derived from examples of other transdisciplinary projects (Westley and Miller, 2003; Stokols and others, 2003; Nicholson and others, 2002), and these included generating a shared conceptual approach, distinguishing different analytical perspectives, analyzing organizational processes (Stokols, 2006), giving attention to linguistic incompatibilities (Eigenbrode and others, 2007), and applying strategic reflexive discourse (Kristiansson, 2007). This last method was important to allow the team to reflect on interactions we had with each other and with LWG participants as well as to better understand and move across our different conceptual world views for the purpose of gaining narrative insight. See Gonzalo-Turpin and others (2008) for an example of the problems encountered in implementing conservation actions when reflective discourse was not explicitly incorporated into the collaborative process. Team meetings were structured with sufficient duration (multiple sessions of 2 – 8 hours) to facilitate the philosophical dialogue required to reach across the non-convergent conceptual paradigms held among team members (Eigenbrode and others, 2007).

Results and Discussion

This social-ecological study uses observations of actors in a social network in which we continue to participate. The raw data may be, in some cases, sensitive. When ecological data are sensitive, such as location-based research on endangered species populations, some of the study details are kept undisclosed to discourage vandalism that may harm populations at risk. In documenting our results, we attempt to provide sufficient detail to allow critical review of our investigation and results without compromising the collegiality of institutional and social networks.

Exploratory conversations were conducted in June 2004 with a subset of the South Mono LWG (three identified as high influence/high importance and two with extensive modeling experience) to solicit suggestions for LWG-wide participation in the development of a dynamic-simulation model. Their strong opinion was that the LWG would not be in a position to commit time to help develop the model without a clearer understanding of what the model could do, owing to a lack of familiarity with model development in general and risk-assessment and dynamic-systems models in particular. This suggested that a prototype would be necessary.

The study team began to develop the prototype in parallel with two other South Mono LWG activities, research into Greater Sage-grouse ecology that was being conducted by the biologists on our study team and continued development of the conservation planning document by the South Mono LWG. Given the large number of knowledge gaps being identified in the conservation-planning document and the emphasis on using the adaptive-management approach to conservation actions, the study team focused on a prototype model that could incorporate knowledge gaps as a risk to conservation outcomes.

Knowledge Categories

User-needs assessment results were first categorized and coded by type of need. Several categories of information needs were identified: specific quantification of ecological information, such as Greater Sage-grouse demographics, current vegetation condition, mortality due to predation or other types of threats; specific quantification of information related to human behavior, such as locations of off-road vehicle trails and intensity of their use, expected areas of urban expansion, measures to increase stakeholder involvement, leverage points to influence political/regulatory process; information that required synthesis, such as demographic trends of Greater Sage-grouse over time, habitat suitability maps, ecological relationships between habitat and Greater Sage-grouse, effect of transmission lines on predator intensity; and predictions, such as the need to know which areas of sagebrush that sage grouse would use during extreme weather events or the predicted composition and pathway of vegetation succession after fire.

Data were also categorized and coded by how missing information would be acquired (table 1). This information was coded based on the relative ease of acquisition, such as PEC for “Participant doesn’t have information but it Exists and it is Currently available,” and RCE for “Requires Compilation of Existing knowledge.” This information helped to identify which data would require additional long-term study. Continuing with grounded-theory methodologies, coded data were then placed along various axes to enable pattern identification. In particular, these coded data were connected to stakeholders through visualizations such as that shown in figure 6, where the relationships between three sample knowledge objects are shown relative to priorities placed on that knowledge by different stakeholders. The details of this analysis and results such as “information with the greatest acquisition difficulty has the greatest range of perceived priority” are described in the next section.

Table 1. Coded categories for the new knowledge or information identified as needed by study participants.

Codes	Description of new knowledge or information needed	Example Observations
PEC	Participant doesn't have information but it Exists and it is Currently available	Facts about sage grouse life cycle, historical distribution, and diet. This category exists because existing information transfer mechanisms have been ineffective.
RCE	Requires compilation of existing knowledge	For example, Federal agency data on land treatments, currently hand drawn and notated on topographic maps, would need to be digitized into an accessible database.
MEM	Requires multi-year coordinated studies using existing methodologies	For example, seasonal use of habitat under differing weather extremes. These data were provided to stakeholders during the study.
MNM	Requires multi-year coordinated studies and development of new technology or methodologies	Many of the information needs regarding life cycle success relative to habitat quality, predator effect, or anthropogenic impact fall into this category.
ISE	Requires interpretation and synthesis of existing science	Understanding taxonomic differentiation of populations across the range. Ongoing efforts by multi-agency and academic collaborations are under funded but highly promising. This needs to include an effective communication component.
NEP	Requires inquiry with new ecological paradigms	New paradigms include improved theoretical base for including social systems and multi-scale impacts of anthropogenic effects such as climate change. Probably beyond the scope of any individual LWG.
AEK	Is best acquired through experiential knowledge	Use of scientific method to effectively monitor design. Knowing, just by looking at the range, that it is time to pull the cattle off. The epistemic community paradigm was useful for understanding the information needs within this category.

Perceived Information Needs and Priorities

The information needs and priority analysis resulted in two types of observations—first, the relationship of stakeholders to knowledge objects, and second, a list of information needs that were organized into 15 threat categories. These categories are altered fire regime, changing land use, pinyon-juniper encroachment, livestock grazing, energy development, mining, wild horse and burro, fences and transmission lines, sagebrush condition, recreational activities, predation, water management, irrigation, West Nile virus, and missing data. All these data were organized into the knowledge management system (figs. 4 and 5).

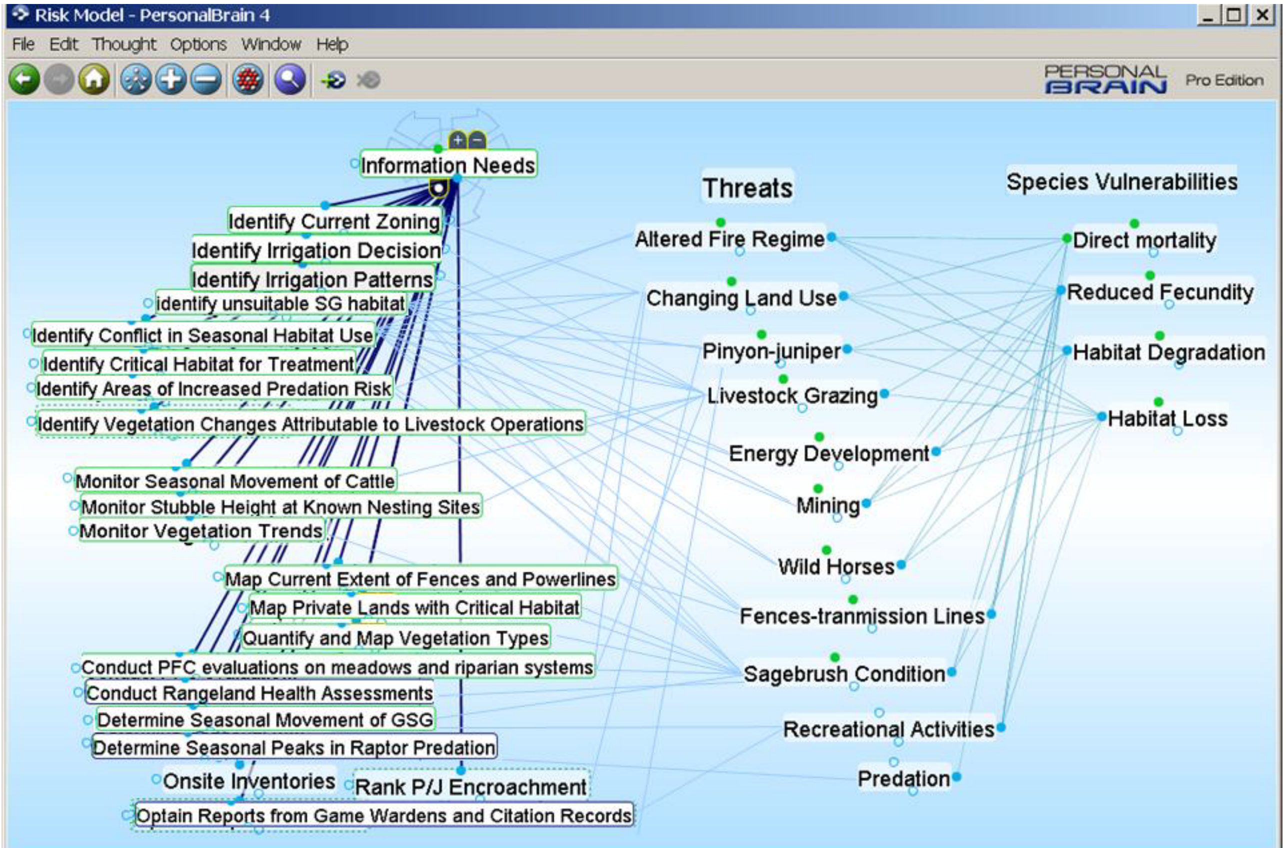

Figure 5. The Knowledge Management System (KMS) database view of three categories of records, information needs, threats, and species vulnerabilities. The KMS is a rich network of discrete records in which each record or node is linked with any number of other nodes. Each of the nodes in two of these major categories, threats and species vulnerability are also represented as reservoirs in the dynamic risk-simulation model, which is separate from the KMS database (fig. 9).

The perceived lack of conclusive information about Greater Sage-grouse conservation among stakeholders is quite high for an issue that has been studied for decades. This is due to several factors: the difficulty of determining population trends for a short-lived species with highly variable year-to-year population dynamics that respond in a generationally lagged manner to environmental conditions, the complex and multi-scale nature of the overall ecological system, the multi-jurisdictional structure of the stakeholder community, incompatibility of data collected across jurisdictions, and insufficient funding to conduct research on knowledge gaps.

All stakeholders considered gaps in knowledge to be a major risk factor that could lead to lack of success in the conservation-planning process. Although there was agreement that critical data were missing, there was a lack of agreement about what information was missing and the prioritization of needed information. The relative importance of specific information gaps was closely aligned with the perceived importance of the conservation actions for which the knowledge was required. For example, some stakeholders considered the use of off-road vehicles near breeding and nesting sites to be the greatest threat to population viability. Because they considered stopping such off-road use a necessary step for conservation, these stakeholders gave high priority to the quantification of off-road vehicle use. Other stakeholders considered West Nile Virus the greatest threat and gave high priority to research on effects, vectors, and status of the virus in the population.

The perceived importance of data is correlated with the expected use of that data and was associated with a need to know the relative quality of the data and the uncertainty associated with the data. For scientists, statistical measures of significance were necessary, for non-scientists, conclusions from experience were more informative. The result of this is that stakeholders varied in the amount and quality of information they felt was necessary before moving forward with specific conservation actions. Some stakeholders were willing to move forward with a conservation action without conducting scientific tests to confirm its effectiveness. Other stakeholders, however, were concerned about not having scientific data to back up the conservation-planning decisions. For the latter group, the greatest perceived knowledge gap was in the area of monitoring design and implementation and the need to test the hypotheses associated with each conservation action.

The responsibilities and role of a given stakeholder also related to the relative importance s/he placed on filling a particular knowledge gap. For example, professionals involved with livestock grazing identified as priorities those measures associated with rangeland improvements such as removal of pinyon-juniper, whereas those working with lands at the urban-shrubland interface first prioritized issues dealing with impacts from roads, trail, trash, or waste control.

Given that the Governor's Conservation Team (a task force appointed in 2000 by the Governor of Nevada) provided strong encouragement for the conservation-planning process to be an inclusive stakeholder process, the wide-ranging plurality of views for particular knowledge or information and their relative importance is not surprising. These varying perceptions of information needs and priorities have many implications, some of which are unexpected. Namely, consensus on conservation action does not require consensus on the expected outcome of that action. For example, both ranchers and wildlife managers agreed that reduction of pinyon-juniper forest through land treatments of prescribed burns was a high priority. Ranchers expected the burns to produce an increase in grasses, which they felt would support both sage grouse and improve grazing. The wildlife managers also supported prescribed burns, but they expected a long-term outcome of improved sagebrush stands with herbaceous understory that would improve sage grouse habitat and increase sage grouse numbers. The beneficial outcome for grazing activities would be discernable in the short term due to the annual growth pattern of grasses. The benefits for sage grouse would not be discernable for some time due both to the multi-year growth pattern of sagebrush and the difficulty of deriving statistically valid sage grouse population trend data from short-term data. Different expectations and methods for quantifying the benefit from the conservation action had little impact on the high level of support from both groups for controlled burns to reduce pinyon-juniper forest.

Perceptions regarding prioritization of filling information gaps were shaped by different ways of thinking about knowledge creation. For USGS biologists, data derived from a traditional research program (for example, theory that leads to design of experiment and peer review of results) had highest value. For some stakeholders, any data (peer-reviewed or experience-based) that was relevant to management decisions had high value. The perceived necessity of applying newly collected information to a particular conservation action affected the prioritization of information importance, as did other social considerations (such as institutional affiliations). As the difficulty of acquiring new information or knowledge increases, less cohesion about the perceived priority for that information or knowledge existed among stakeholders (fig. 6).

A set of three knowledge objects serve as an example. High-quality, scientifically defensible, seasonal-use data (in fig. 6, knowledge object 1) was perceived by stakeholder A to be of low priority relative to other needs because existing anecdotal knowledge was considered sufficient for the purpose of making land-use decisions. For stakeholder D, the determination of whether sage-grouse populations of the Mono Basin region are separate species or subspecies (knowledge object 2) was a low priority due to stakeholder D's opinion that neither the species nor the Mono Basin region populations were threatened, and, therefore, the distinction would not be useful for conservation planning.

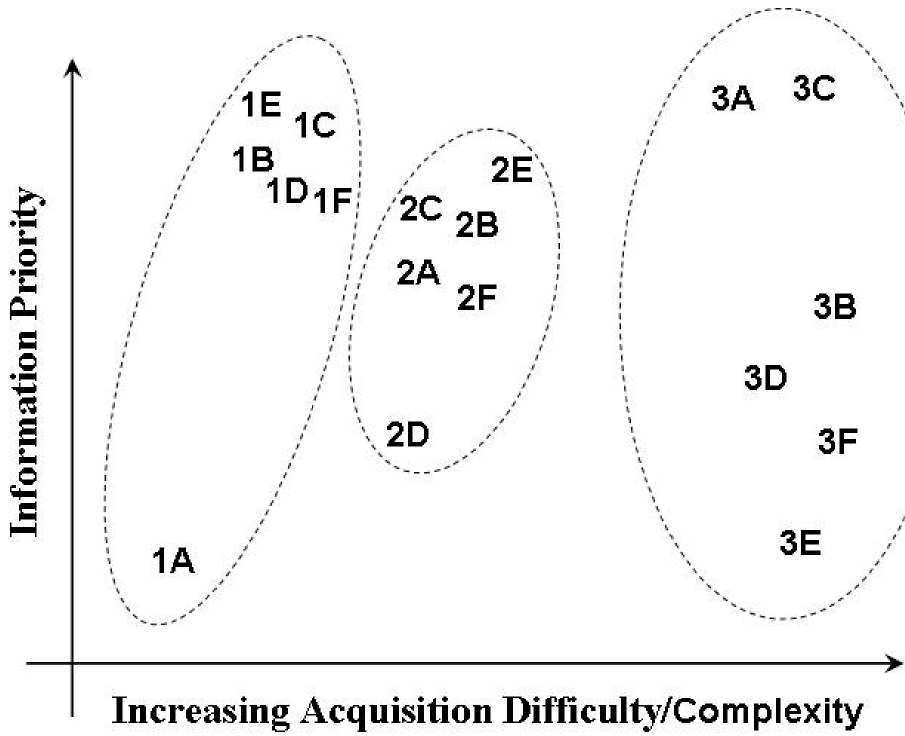

Figure 6. Schematic of the groupings and patterns found among three knowledge objects (1, 2, and 3) identified as needed by stakeholder groups (A, B, C, D, E, and F). Knowledge object 1 is the need for high-quality data on seasonal use of specific habitat areas by the Greater Sage-grouse in the Mono Basin region. Object 2 is the need to determine the genetic relationship between Greater Sage-grouse in the Mono Basin region and the rest of the species distributed across the western U.S.; Object 3 is the need to quantify the effect of anthropogenically induced predation on the Greater Sage-grouse. Knowledge with the greatest acquisition difficulty has the greatest range of perceived priority. Except for stakeholder group A, knowledge object 1, which is–relative to objects 2 and 3–easy to acquire, has a relatively high information priority rating.

The perceived value of data on the effect of predation on Greater Sage-grouse attributable to anthropogenically mediated factors (namely, increasing populations of coyotes or ravens due to transmission lines and/or trash), was similarly variable (knowledge object 3). The ecological complexity of the question and the socio-political alignment of perceived benefit of energy corridors (transmission lines) or development (waste-management facilities) was related to a broad range of opinions on its importance.

As highlighted by this example of three knowledge objects, the process of identifying and prioritizing information needs was influenced by stakeholder opinions, the complexity of the knowledge to be acquired, and the difficulty of its acquisition. Recognizing the influence of stakeholder relationships to knowledge led us to investigate the dynamics of this relationship on information transfer through the risk-simulation model.

Modeling Risks to Greater Sage-grouse: The Dynamic-Simulation Model

Developing a Prototype Model

The prototype risk-simulation model linked the three components most familiar to the LWG: threat categories described in the Conservation Plan, conservation actions intended to mitigate these threats, and relevant information or lack of information on the biology and ecology of Greater Sage-grouse populations.

These elements were converted into the Stella modeling software as four risk categories that served as an organizing framework for the simulation: population vulnerability due to direct mortality, decreased fecundity, habitat loss, and habitat degradation. The Stella software provides several basic modeling objects: reservoirs represent the amount of something (threat, habitat, or nests) that can change over time on the basis of conservation actions, regulators represent activities that change the amount in a reservoir over time, connectors link action or information to other modeling objects to create a system that can include feedback loops, and decision diamonds define an action to be taken and require the input of information. A critical rule in Stella systems modeling is to maintain consistency in the units of measure; for example, if the system is tracking currency flow and the unit of measure is the dollar, all objects in the model will be focused on what makes the number of dollars go up or down. The unit of measure in the risk-simulation model was the level of threat, an abstract unit quantified through stakeholder dialogue.

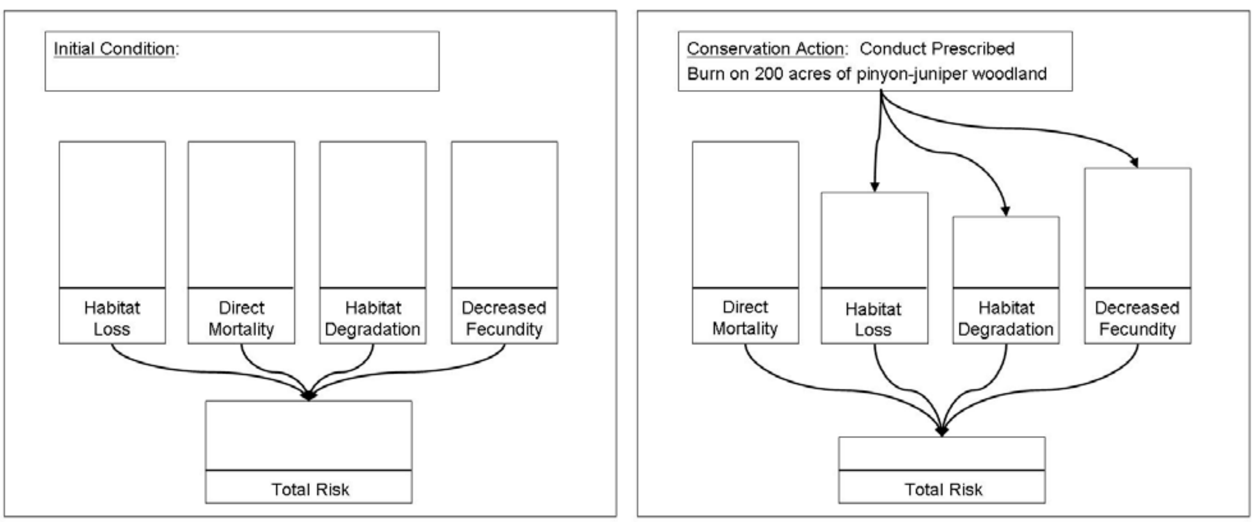

Figure 7. Schematic overview of risk-simulation model highlighting change resulting from a conservation action. Panel A represents the initial conditions where the risk of habitat loss, direct mortality, habitat degradation, and decreased fecundity are all at their maximum levels. Aggregated together, risk reservoirs flow into the reservoir describing a total risk level, which is also at its maximum. In panel B a conservation action, successful prescribed burn of 200 acres of pinyon-juniper woodland, has been implemented. This triggers a lowering of risk in three of the four risk reservoirs and a subsequent lowering of the combined total risk reservoir. A lowered reservoir level of total risk translates into a decrease in the vulnerability of Greater Sage-grouse viability over time.

The level of threat in each threat reservoir is changed as a result of conservation actions undertaken to mitigate the threat and this, in turn, changes the level of the risk reservoir. For example, removing pinyon-juniper that has encroached into sage-grouse habitat would draw down the threat of habitat degradation and habitat loss, two of the four risk reservoirs (fig. 7). Reducing each of these risk reservoirs reduces the overall vulnerability of Greater Sage-grouse in the Mono Basin by decreasing the risk of exposure to threats that affect the long-term viability of species.

Each major category of threat identified by the LWG in the Conservation Plan was modeled by linking together the conservation actions listed in the Conservation Plan to mitigate the threats, information needed to implement the conservation action (both available and missing), activities that would be conducted as part of the action, and their dependencies. For example, the conservation action "prescribed burn of pinyon-juniper" is intended to mitigate the threat of pinyon-juniper encroachment an action that has many dependencies, first critical habitat must be identified so that burn areas can be established (fig. 8). Critical habitat can only be identified if seasonal movements of Greater Sage-grouse are documented. Additionally, on-site inventories would be needed to rank the severity of the encroachment as well as provide data for the Environmental Inventory Report, a formal report required under the National Environmental Protection Act, which must be filed and reviewed prior for the action to proceed. Subroutines within the module distinguish specific landowners so that the model can keep track of acres burned by each landowner, staffing levels for this action, and other inputs that can differ among landowners.

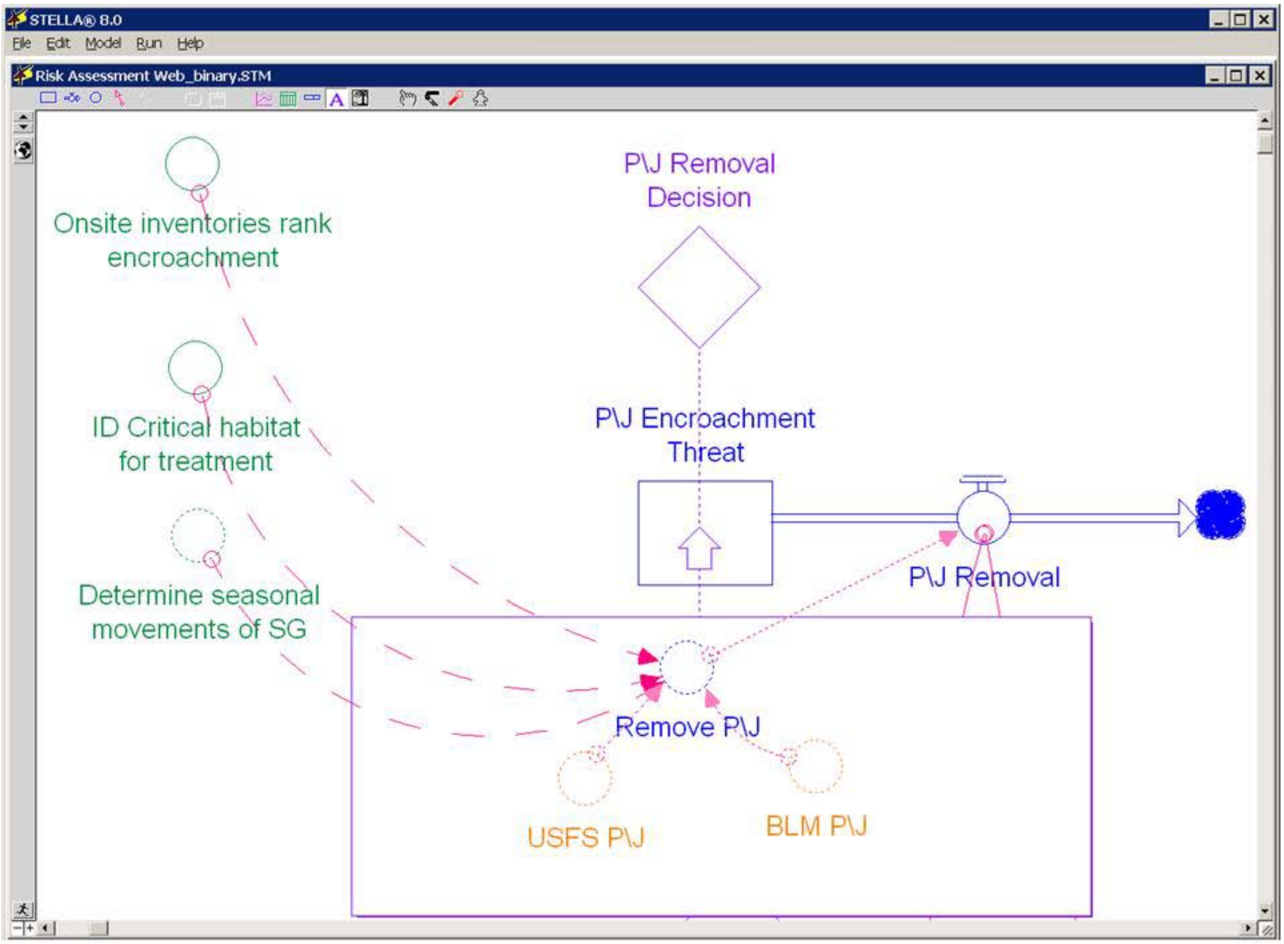

Figure 8. The pinyon-juniper subroutine, one of 15 threat subroutines in the risk-simulation model. This subroutine links the threat of pinyon-juniper encroachment with the conservation action(s) intended to mitigate the threat. The threat reservoir (blue box) is linked to the model object (labeled P/J Removal) that regulates the level of increase or decrease obtained by the conservation action. The large rectangle is an expanded view into the pinyon-juniper decision diamond (purple diamond) and includes nested subroutines that model actions taken by each of the landowners (yellow dotted circles, here labeled USFS P/J and BLM P/J) as they decide on pinyon-juniper removal. Green dotted circles represent the dependencies associated with the decision to remove pinyon-juniper.

To run a scenario, each threat and risk reservoir is assigned an initial (or maximum) value based on data within the GIS, references in the literature, or expert opinion. The model simulation begins when conservation actions are implemented and as the model progresses, the reduction in the level of threat from all the threat reservoirs are added up within the risk reservoirs they are connected to. Depending on the strength of the conservation action (as defined by either expert input or relevant data), the reservoir level of the threat is raised or lowered. These changes accumulate from the threat reservoirs into each of the four risk reservoirs and together increase or decrease the total vulnerability of Greater Sage-grouse population which impacts long-term viability. From the previous example shown in figure 7, implementing the conservation action of a prescribed fire to improve habitat by removing pinyon-juniper forest would, in the model, decrease threat in the habitat reservoir, by increasing the total acres of habitat. The decreased threat would thus reduce one component of risk to long-term sage-grouse viability. At this point in the model stakeholders are challenged to consider how much of the threat is decreased by the conservation action. Dialogue about how much of the threat is decreased, relative to all the other threats, exposes assumptions and provides a tool to focus on shared understanding of knowledge gaps. As additional actions are undertaken to reduce each threat, the model accumulates the reduction in overall risk to the species. If threat reservoirs all reach zero, all modeled threats have been either mitigated or eliminated through the simulated conservation actions. Stakeholder dialogue is the most important product of the tool. In this case, discussion about the relative level of threat posed by each threat on the their list, the timelines associated with benefits accrued from the actions, and the expected decrease in threat that accrues from conservation actions each contributes to building a shared understanding intended to more effectively implement adaptive management for Greater Sage-grouse conservation.

While the great value of the model is that it allows for simultaneous investigation of all of the system elements and their drivers, this requires quantification of the inputs—something that proved elusive during this study. Although feedback loops and the links to other threat reservoirs such as livestock grazing and sagebrush habitat condition were stated as obvious by experienced rangeland managers, these same stakeholders did not follow through on commitments to assist in the effort of reformulating their expert opinion so that it could be added as input to the model.

Application of the Model to the Greater Sage-grouse System

It became clear that it would be challenging to reach the level of stakeholder collaboration required to access, compile, transfer, select and parse the data into the model. Differences in perceived need for information, as well as a changing political landscape (namely, the species was determined not warranted for ESA protection), eventually led to collective lack of investment in the model. Collaboration, in the form of model development, would not occur within the timeframe of our study. Without parameters to model threats that were relatively simple to conceptualize, it was not possible to investigate scenarios that would uncover the more important, and less intuitive, synergistic results between threats.

Within this social context, use of the model was compromised and further model development outside the context of the LWG, would have led us away from analyzing observations that focused on the exchange of scientific information. Without a broad base of confidence in the model and lacking support from the group of high influence/high importance LWG members, there was no point in adding data to run simulations, and after much consideration, the decision was made to suspend implementation of the model.

The perceived complexity of the model was one of the deterrents to its acceptance by the stakeholders. Differences among the various stakeholder perspectives and backgrounds led to contention around the base assumptions in the model and fostered a lack of incentive to participate. Those with backgrounds in science and data management were more accepting of the model; others preferred one-on-one conversations and informal information flow. Perhaps the model was not compelling because the modeling paradigm, and its potential to quantify these relationships with a simulation, was unfamiliar. The results of subsequent inquiry to understand potential causes for the reluctance to collaborate on a risk-simulation model are addressed in the next section.

Work on the simulation model stopped just as results were published on a similar project conducted in southeastern Idaho (Pederson and Grant, 2004). The Idaho project successfully produced a working simulation model (also in Stella) to show, through scenario comparisons, the potential effects on sage grouse and sage-grouse habitat of differing levels of grazing, fire regimes, climate conditions, and synergistic interactions between these factors. The simulation model was collaboratively created over three years with extensive stakeholder participation. To overcome the problems of "lack of basic information…. such as growth rate of grass and forbs, and growth rate of sagebrush under local environmental conditions" (Pederson and Grant, 2004), the team incorporated local expert knowledge into the model. The stakeholders provided all the input and worked closely with the modeling team to define the model interactions, yet in the end the stakeholders did not accept the model or the model results.

A controversial area for the Idaho group was the level of detail incorporated into the model and the simplifications made by the modelers. Model elements that were found by the modelers to have no affect on the model outputs were discarded to improve the speed and functionality of the model, but their rejection cast suspicion on the validity of the model. Before the group could work through these issues and investigate the insights derived from the process, their collaborative modeling project was discontinued by the hosting institution, Sheep Experiment Station, Agricultural Research Service, U.S. Department of Agriculture (Pederson and Grant, 2004). The results of the Idaho project focused on a relatively simpler model than ours, and those results reinforced our decision not to pursue implementation of the risk-simulation model and instead focus on observations of information transfer.

Examining Observations in the Social Landscape

Although the simulation model was discontinued before it was fully completed, the process of its development provided valuable information. Analysis of the insights derived from observations of the LWG (from formal stakeholder meetings and informal communication between stakeholders) yielded data about information transfer.

Two pivotal associations appeared to determine the flow of information: first, the perception of importance of the information, which was influenced by the stakeholder's professional role and responsibility and by the stakeholder's perception of how that information would be used. Second, information flow was also affected by the content and complexity of information and, as a consequence, its ease of dissemination. A theoretical lens that provided the greatest coherence and cohesion (Strauss and Corbin, 1997; Sandberg, 2005) to interpret these observations was epistemic community organization theory.

The term epistemic community was first coined in 1972 by John Ruggie (quoted in Antoniades, 2003, p. 23, and Templeton, oral commun., 2007) to describe the roles and interactions within the group of actors involved around a particular episteme (Foucault, 1970). Peter Haas (1992) further developed the concept to investigate the authority and influence given to scientists during global environmental policy negotiations such as the 1987 Montreal Protocol for global ozone reductions.

The South Mono LWG stakeholders could be categorized into two main epistemic communities: professionals/experts involved in rangeland management, and those involved in peer-review dominated science. There were several stakeholders who did not fit neatly into one of these groups but these two groups encompassed the majority of the 19 South Mono LWG stakeholders as well as the larger group of 213 Bi-State LWG participants. Both of these epistemic communities have knowledge relevant for policy decisions, with authority granted to them by regulatory and political decisionmakers. Each of these groups has methods for knowledge generation that identifies and investigates causative factors relevant to their professional focus that are acceptable to their epistemic community. Similarly, each has an accepted mode for validating knowledge within their domain, especially for interpretations and conclusions brought forth in the absence of complete certainty. This last point is pivotal to the value of using the concept of epistemic communities and was well described by Knorr-Cetina in her study (1999) comparing the epistemic communities of quantum physics and molecular biology. She underscored the importance of the process for generating observations and the validation mechanisms that are used to interpret and synthesize observations into conclusions and new hypotheses. Her work highlighted how these conclusions, valid from within the epistemic community that generates them, can appear completely ad hoc and lacking in rigor to those not schooled in that discipline and therefore outside the epistemic community. An analogy would be the different conclusions made by two people looking at two barking dogs behind a dense picket fence. The fact is neither person sees more than a small part of the dogs, specifically two small parts of each dog's head and one dog leg, because the slats of the picket fence are in the way. One person who is very familiar with dogs and knows that they generally have one head per set of four legs sees beyond the missing data to conclude there are two dogs. The other person who has never encountered dogs and knows little about mammals finds it acceptable to consider a dog with two heads and demands more data before being able to agree with the findings of the first person.

The epistemic community concept was also used by Thomas (2003) to investigate collaborative biodiversity conservation policy development and implementation in California. His data showed that key high-level administrators and line managers who, in their past, were members of the conservation biology epistemic community gave strong support to conservation biologists (traditionally in lower ranks) by elevating them into positions within the complex interagency organizational structure, with sufficient authority to implement change conducive to biodiversity policy development. Managers who were not members of the conservation biology epistemic community were less likely to go beyond the traditional mission and jurisdiction of their agency to engage in collaborative behavior or give authority to their staff involved in collaborative biodiversity conservation efforts.

Analysis of epistemic communities in the Greater Sage-grouse study system goes beyond examining difference in values and perceptions. Membership in an epistemic community is closely aligned to how a person arrives at conclusions in the face of missing data. Each of these communities is a group of individuals with varying attitudes and opinions bounded by the self-reinforcing knowledge creation standards—or rationalization mechanisms—of the epistemic community to which they adhere. Indeed, differences in the perception of knowledge needs, combined with the complexity of gaps in knowledge (missing data), lead to very different understandings about how to prioritize acquisition of new data during species conservation planning. This narrative explains part of the tension between anecdotal, experiential information and peer-reviewed scientific data and how it continues to present a barrier to group decisionmaking and conservation planning for sage grouse.

Transdisciplinary Research Structure

Departing from a typical interdisciplinary USGS research project structure of physical and biological scientists, the team included legal scholars and a historian. The effectiveness of the interdisciplinary structure of the project team for this study was itself a significant research result. Duplicating this result will depend on the willingness of other project team members to engage in a transdisciplinary effort and methods described as Action Research (Reason and Bradbury, 2006; 2008; Marshall, 2008) in which researchers and research participants engage in a recursive search for solutions. The recursive practice formalized by Action Research is an explicit challenge at three different levels of research/practice. The first challenge is to foster reflection and individual assessment of the questions or practices with the goal of changing our day-to-day practice so that they better align with the team's common research goal. The second level challenge is to address interpersonal dialogue and openness to cross-disciplinary exchange to facilitate multiparty collaboration. The third level challenge is to choose dissemination venues that can impact a wider realm of participants with the research outcomes or insight. One of the epistemological results of our work was the understanding that science is a knowledge system and therefore a social construction. Although controversial among natural and physical scientists, this presupposition has a solid basis in theory (Kant, 2004 Dewey, 1998; Kuhn, 1996; Popper, 1963; Foucault, 1970; Latour and Woolgar, 1986; Chalmers, 1999 Knorr-Cetina, 1999; Gibbons, 1999; Darlaston-Jones, 2007) and facilitated our shift from a focus on scientific content to a focus on the context within which the scientific information was being generated and the mechanics of its transmittal and use.

The knowledge gained through this case study can be organized using a transdisciplinary approach into three levels—system, target, and transformative (Messerli and Messerli, 2008; Hubert and others, 2008; Hirsch Hadorn and others, 2008; Kueffer and Hirsch Hadorn, 2008).

System Knowledge

Many Greater Sage-grouse conservation research problems are system level problems in that they deal with the complexity and uncertainty of interacting ecological and social systems. Several of the ecological system uncertainties were addressed by the team members through traditional disciplinary means (Casazza and others, 2009; Kolada and others, 2009a; 2009b) and will continue to be addressed within the larger epistemic community of wildlife biologists and conservation ecologists. Several of the uncertainties related to the interactions within and between ecological and social systems were treated as objects within the risk-simulation model such as the influence of the threat of regulatory compliance on the willingness to participate in the LWG or uncertainty about expected outcomes of specific conservation actions. Observations from this case study suggest the transfer of knowledge about the social and ecological systems is a function of how individuals process information that places these case study results in the target level.

Target Knowledge

Target knowledge refers to information or research results about the goals or norms of the actors in the system (people, social groups, organization). In this case study the use of a risk-simulation model as a means for gaining deeper scientific understanding into processes that structure complex ecological systems, improve the development of adaptive management strategies, or prioritize the acquisition of new data for species conservation planning was not successful with the South Mono LWG. Many communications from stakeholders expressed appreciation for more traditional approaches to science information transfer, such as scientific presentations made at Bi-State planning meetings, which suggests a lack of shared understanding of the value of the information to be derived from the risk-simulation model contributed to its non-acceptance. Subsequent results using grounded theory further suggest that membership in different epistemic communities was a major factor differentiating stakeholder responses to risk-simulation model collaboration. Only one simulation model was tested owing to limitations in time and funding, but it has been suggested that a model that focused on a smaller part of the social or ecological relationships may have gathered more support from South Mono LWG. The results from a collaborative modeling effort focused solely on ecological relationships influencing sage-grouse populations by Pederson and Grant (2004), suggest otherwise.

Case study results further suggest that the tension that separates epistemic communities is both the strength and weakness of knowledge generation. From this premise, it could be considered an abdication of scientific responsibility if scientists did not push forward with theoretical work that may seem meaningless outside their community, just as it would be reprehensible for the ranching community to forego the benefits of experiential, anecdotal, and local knowledge passed on from neighbor to neighbor or from one generation to the next.

Evaluation of this social landscape using an epistemic community concept suggests many avenues for further investigation. What are the best indicators of epistemic community membership? How do epistemic communities influence Greater Sage-grouse policy decisions? What are the most influential attributes for knowledge generation and transfer between the epistemic communities? What are the rationalization mechanisms for knowledge validation in these communities that may inhibit effective adaptive management? Certainly, the transdisciplinary nature of this study indicates further investigation into the nature of knowledge and varying perceptions about what constitutes salient science. Only with a better understanding of the social nature of the scientific endeavor can the process of applying its findings to real-world situations be widely supported (Gonzalo-Turpin and others, 2008).

Transformative Knowledge

Knowledge that can be used to change the way scientists and nonscientists exchange information and work together to solve societal problems is categorized as transformative knowledge. Three conditions that predisposed case-study participants to undertake effective knowledge exchange were support (political, logistical, and financial in the form of facilitors, scheduling, staff, and office resource), the all-inclusive nature of the LWG participation, and the guidelines provided by the Governor's Sage Grouse Conservation Team in the form of the December 2001 report "The Nevada Sage Grouse Conservation Strategy" (unpublished but accessed September 2009 at *http://www.westgov.org/wga/initiatives/enlibra/sage_grouse.pdf*). For several members of the epistemic community most stongly associated with 'peer-review dominated science' this support was considered insufficient to overcome the barriers to effective knowledge exchange. Suggested improvements from this group included: guidelines that more clearly defined how to determine conservation action success and the level of monitoring required to document success over time, improved interagency mechanisms to work through lack of overlap between agency missions and cultures, and improved funding mechanisms to conduct needed research. For several members of the epistemic community most stongly associated with 'professional/expert rangeland management,' successful knowledge exchange was hampered by research being conducted on topics that were not seen as priorities to their community, the sense that the planning process (including the development of documentation prescribed by regulatory authority) was never-ending and resulted in the loss of a critical mass of non-agency participants, the perception that their working knowledge of the ecological system was not given as much weight as peer-reviewed knowledge, and that opportunities for conservation action were being missed. Suggested improvements from the rangeland management group included more implementation of on-the-ground actions, development of more avenues for face-to-face exchange of knowledge between LWG groups, and increased recognition for experiential knowledge.

Conclusions and Future Research

While simulation models can help guide particular aspects of conservation decisionmaking, the development and use of a risk-simulation model to aid decisionmaking requires a set of shared assumptions. Participants in this case study were not able to reach that level of congruence. Indeed, there was little interest in investing the time necessary to collaborate and participate in building computer-based risk-simulation models to better understand ecosystem interactions, prioritize conservation actions, or design monitoring efforts for those actions. However, the lack of interest to develop a trusted simulation model does not indicate that such a model would not be helpful in other conservation settings. Rather, it suggests that success in building and using such a model requires upfront commitment to the use of a model, including a shared understanding of its value.

For participants in this case study, the flow of scientific information was seen as critical to the development of a socially and ecologically successful conservation plan however the process of identifying and prioritizing science information needs was influenced by diverse, *a priori* stakeholder knowledge constructs. Collaboratively developed simulation models were seen by some participants as a means to provide a mutually trusted framework to both synthesize existing knowledge and explore the divergent stakeholder priorities for knowledge generation. Not all participants agreed and the lack of congruence led to insufficient commitment to implement the simulation model.

Evaluation of this social landscape with the epistemic community concept suggests many avenues for further investigation. What are the best indicators of epistemic community membership? How do the different epistemic communities accommodate knowledge gaps and generate conclusions in the face of missing data? What are the rationalization mechanisms for knowledge validation in these communities that may inhibit effective adaptive management? What are the most influential attributes for knowledge generation and transfer between the epistemic communities? How do epistemic communities influence policy decisions? Further exploration into how different epistemic communities accommodate knowledge gaps could help to better identify barriers to joint knowledge production and better understanding of the barriers could lead to improved mechanisms for information flow among the stakeholders.

From a transdisciplinary perspective, avenues for futher research include the exploration of more effective linkage between the three knowledge levels, specifically between systems knowledge (scientific research results about Greater Sage-grouse demographic and ecosystem dynamics), target knowledge (interactions between epistemic communities), and transformative knowledge (face-to-face presentations). The results from transdisciplinary approach to this case study of Greater Sage-grouse conservation planning suggest that further investigation into the nature of knowledge and varying perceptions about what constitutes salient science could provide a better understanding of the social nature of the scientific endeavor and, in turn, provide valuable insight into the process of applying scientific results to real-world situations.

References Cited

Andersen, N.A., 2003, Discursive Analytical Strategies: Understanding Foucault, Koselleck, Laclau, Luhmann, Policy Press, 160 p.

Antoniades, A., 2003, Epistemic Communities, Epistemes and the Construction of (World) Politics: Global Society, v. 17, no. 1, p. 21 – 38.

Biswas,G., Debelak, K.A., and Kawamura, K., 1989, Applications of qualitative modeling to knowledge-based risk assessment studies: Proceedings of the 2nd international conference on Industrial and engineering applications of artificial intelligence and expert systems, Tullahoma, Tennessee, Association for computing machinery, p.92 –101.

Björk, B.-C., 2007, A model of scientific communication as a global distributed information system: Information Research, v. 12, no. 2, paper 307.

Blythe, S., Grabill, J.T., and Riley, K., 2008, Action research and wiked environmental problems: Exploring appropriate roles for researchers in professional communication; Journal of Business and Technical Communication, v. 22, p. 272–298.

Brook, R.K., and McLachlan, S.M., 2005, On using expert-based science to “test” local ecological knowledge. Ecology and Society v. 10, no2accessed September 2009 at *http://www.ecologyandsociety.org/vol10/iss2/resp3*.

Casazza, M.L., Overton, C.T., Farinha, M.A., Torregrosa, A., Fleskes, J.P., Miller, M.R., Sedinger, J.S., and Kolada, Eric, 2009, Ecology of Greater Sage-grouse in the Bi-State Planning Area Final Report, September 2007: U.S. Geological Survey Open-File Report 2009-1113, 50 p.

Chalmers, A.F., 1999, What is this things called Science? An Assessment of the Nature and Status of Science and Its Methods: McGraw Hill, Open University Press, 266 p.

Connelly, J.W., Knick, S.T., Schroeder, M.A., and Stiver, S.J., 2004, Conservation Assessment of Greater Sage-grouse and Sagebrush Habitats: Western Association of Fish and Wildlife Agencies, unpublished report, Cheyenne, Wyoming, accessed September 2009 at *http://gf.state.wy.us/downloads/pdf/GreaterSGConservationAssessment.pdf*.

Connelly, J.W., and Stiver, S.J., 2004, Greater Sage-grouse conservation Part II—A history lesson and roadmap to the future: Grouse Partnership News, v. 5, no. 1. , accessed September 2009 at *http://www.grousepartners.org/images2/grousenews/2004/gsg1.pdf*.

Creighton, J.L., 1983, An overview to the research conference on public involvement and social impact assessment, *in* Garcia, M.W., and Priscoli, J.D., eds., Public involvement and social impact assessment: Boulder, Colorado, Westview Press, p. 1–10.

Creswell, J.W., 1998, Qualitative inquiry and research design—Choosing among five traditions: London, New Delhi, SAGE Publications, 426 p.

Crotty, M.J., 1998, The Foundations of Social Research: Meaning and Perspective in the Research Process: London, UK, SAGE Publications Ltd, 256 p.

Dambacher, J.M., Daniel J. Gaughan, D.J., Rochet, M.J., Rossignol, P.A., Trenkel, V.M., 2009, Qualitative modelling and indicators of exploited ecosystems; Fish and Fisheries, v.10, p. 305–322.

Darlaston-Jones, D., 2007, Making connections—The relationship between epistemology and research methods: The Australian Community Psychologist, v. 19, no. 1, p. 19–27.

Dewey, J., 1998, Experience and education: New York, Kappa Delta Pi, 98 p.

Doyle, J.K., Radzicki, M.J., and Trees,W.S., 2007, Measuring change in mental models of complex dynamic systems, *in* Qudrat-Ullah,H., Spector, J.M., Davidsen, P.I., eds., Complex decision making, theory and practice series—Understanding Complex Systems, Springer, 338 p.

Eden, S., 1996, Public participation in environmental policy—Considering scientific, counter-scientific and non-scientific contributions: Public Understanding of Science, v. 5, no. 3, p. 183–204.

Eigenbrode, S.D., Rourke, M., Wulfhorst, J.D., Althoff, D.M., Goldberg, C.S., Merrill, K., Morse, W., Nielsen-Pincus, M.A.X., Stephens, J., Winowiecki, L., Bosque, P., Eacute, and Rez, N.A., 2007, Employing Philosophical Dialogue in Collaborative Science: BioScience, v. 57, no. 1, p. 55–64.

Fernández, W., Martin, M.A., Gregor, S., Stern, S.E., and Vitale, M., 2007, A Multi-Paradigm Approach to Grounded Theory, *in* Hart, D.N., and Gregor, S.D., eds., Information Systems Foundations—Theory, Representation and Reality: Australian National University Press, p. 231–246.

Fernández, W.D., 2005, The grounded theory method and case study data in IS research—Issues and design, *in* Hart, D., and Gregor, S., eds., Information Systems Foundations: Constructing and Criticizing: Canberra, Australian National University, p. 43–59.

Foucault, M., 1970, The Order of Things—An Archaeology of Human Sciences: New York, Pantheon Press, 416 p.

Fuller, B., 1976, Critical Path, Boston, MA, Harvard University Press.

General Accounting Office, 2008, Natural resource management opportunities exist to enhance Federal participation in collaborative efforts to reduce conflicts and improve natural resource conditions: GAO-08-262, Washington, D.C., February 2008, accessed September 2009 at *http://www.gao.gov/new.items/d08262.pdf*.

Gibbons, M., 1999, Science's new social contract with society: Nature, v. 402, p. C81–C84.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., and Trow, M., 1994, The new production of knowledge—The dynamics of science and research in contemporary societies: London, UK, SAGE Publications, 192 p.

Glaser, B., 2001, The grounded theory perspective—Conceptualization vs. description: Mill Valley, Calif., Sociology Press, 259 p.

Glaser, B.G., 1998, Doing grounded theory—Issues & discussion: Mill Valley, Calif., Sociology Press.

Glaser, B.G., and Strauss, A., 1967, The discovery of grounded theory—Strategies for qualitative research: Chicago, Aldine Transaction, 271 p.

Gonzalo-Turpin, H., Couix, N., and Hazard, L., 2008, Rethinking partnerships with the aim of producing knowledge with practical relevance—A case study in the field of ecological restoration: Ecology and Society, v. 13, issue 2, no. 53, accessed September 2009 at *http://www.ecologyandsociety.org/vol13/iss2/art53/*.

Gray, D.B., 2004a, Doing research in the real world: London, UK, SAGE Publications, 442 p.

Gray, R., 2004b, Private lands conservation of sagebrush habitat—A voluntary approach to sage grouse conservation and recovery, *in* Western Governer's Association, Conserving the Greater Sage-grouse: A compilation of efforts underway on state, tribal, provincial, and private lands, WGA, Denver, CO., p. 94–98, accessed September 2009 at *http://www.westgov.org/wga/initiatives/grouse/sagegrouse-rpt.pdf*.

Grant, W.E., Pedersen, E.K., and Marín, S.L., 1997, Ecology and natural resource management: systems analysis and simulation: New York, John Wiley & Sons, 373 p.

Grant, W.E., Thompson, P.B., 1997, Integrated ecological models—Simulation of socio-cultural constraints on ecological dynamics: Ecological Modeling, v. 100, p. 43–59.

Groot, A.M., 2001, Stakeholder matrices—Guidelines: accessed September 1, 2009 at *http://www.icra-edu.org/objects/anglolearn/ACFegJqyr.pdf*.

Gustavsen, B., 2006, Theory and Practice: Mediating Discourse, in Reason, P., and Bradbury, H., eds., Handbook of Action Research: Concise Paperback Edition: London, UK, SAGE Publications, p. 400.

Harding, E.K., Crone, E.E., Elderd, B.D., Hoekstra, J.M., McKerrow, A.J., Perrine, J.D., Regetz, J., Rissler, L.J., Stanley, A.G., Walters, E.L., and the Habitat Conservation Plan Working Group of the National Center for Ecological Analysis and Synthesis, 2001, The scientific foundations of habitat conservation plans—A quantitative assessment: Conservation Biology, v. 15, p. 488–500.

Haas, P.M., 1992, Introduction: epistemic communities and international policy coordination: International Organization, v. 46, no. 1, p. 1–35.

Hermans, C.M., and Taketa, R., 2006, Integrating stakeholders and users into the geography discipline's research process: U.S. Geological Survey Open File Report 2006-1344.

Hessels, L.K., and van Lente, H., 2008, Re-thinking new knowledge production—A literature review and a research agenda: Research Policy, v. 37, p. 740–760, Elsevier.

Hirsch Hadorn, G., Hoffmann-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C., Wiesmann, U., Zemp, E. (eds.), 2008, Handbook of transdisciplinary research, Berlin: Springer, 448 p.

Hope, B.K., 2006, An examination of ecological risk assessment and management practices: Environment International, v. 32, p. 983–995.

Horn, R.E., 1999, Visual language—Global communication for the 21st Century: Bainbridge Island, Wash., Macrovu Inc., 270 p.

Hubert, B.H., Meuret, M., and Bonnemaire, J., 2008, Shepherds, sheep and forest fires—A reconception of grazing land management, *in* Hirsch Hadorn, G., Hoffmann-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C., Wiesmann, U., Zemp, E. (eds.) 2008, Handbook of transdisciplinary research. Berlin: Springer, 448 p.

Imperial, M.T., 1999, Institutional Analysis and Ecosystem-Based Management—The Institutional Analysis and Development Framework: Environmental Management, v. 24, no. 4, p. 449–465.

Jacobs, K., 2002, Connecting science, policy, and decision-making—A handbook for researchers and science agencies: National Oceanic and Atmospheric Association, Office of Global Programs, 30 p.

Jacobs, K., Garfin, G., and Lenart, M., 2005, More than just talk—Connecting science and decisionmaking: Environment: Science and Policy for Sustainable Development, v. 47, no. 9, p. 6–21.
Justice, T., and Jamieson, D.W., 1999, The facilitator's fieldbook (1st ed.): New York, AMACOM, 471 p.
Kant, I., 2004, Metaphysical foundations of natural science in theoretical philosophy after 1781—The Cambridge edition of the works of Immanuel Kant, Cambridge University Press, 160 p.
Karl, H., and C.E. Turner, 2003, Incorporating science into decisionmaking: Science, 24 May 2003, v. 300, no. 5624.
Kelle, U., 2005, "Emergence" vs. "forcing" of empirical data? A crucial problem of "grounded theory" reconsidered—Forum qualitative sozialforschung / Forum: Qualitative Social Research, v. 6, no. 2, art. 27.
Klein, J.T., 2004, Prospects for transdisciplinarity: Futures, v. 36, p. 515–526.
Klein, J.T., and Macdonald, R., 2000, What is transdisciplinarity?, *in* Somerville, M.A., and Rapport, D.J., 2000, Transdisciplinarity—Recreating integrated knowledge: Oxford, England, EOLSS Publishers, 272 p.
Knorr-Cetina, K., 1999, Epistemic cultures—How the sciences make knowledge: Cambridge, Massachusetts, and London, England, Harvard University Press, 352 p.
Kolada, E.J., Sedinger, J.S., and Casazza, M.L., 2009a, Nest site selection by Greater Sage-grouse in Mono County, California: Journal of Wildlife Management, v. 73, no. 8, p. 1,333–1,340.
Kolada, E.J., Casazza, M.L., and Sedinger, J.S., 2009b, Ecological factors influencing nest survival of Greater Sage-grouse in Mono County, California: Journal of Wildlife Management, v. 73, no. 8, p. 1,341–1,347.
Kootnz, T.M., and Bodine, J., 2008, Implementing ecosystem management in public agencies—Lessons from the U.S. Bureau of Land Management and the Forest Service: Conservation Biology, v. 22, p. 60–69.
Koontz, T.M., and Thomas, C.W., 2006, What do we know and need to know about the environmental outcomes of collaborative management?: Public Administration Review, v. 66, no. 1, p. 111–121.
Kristiansson, M.R., 2007, Strategic reflexive conversation—A new theoretical-practice field within LIS: Information Research, v. 12, no. 4, paper colis18, accessed September 2009 at *http://informationr.net/ir/12-4/colis/colis18.html*.
Kroeker, K.L., 2004, Seeing data—New methods for understanding information: IEEE Computer Graphics and Applications, v. 24, no. 3, p. 6–12.
Kueffer, C., and Hirsch Hadorn, G., 2008, How to achieve effectiveness in problem-oriented landscape research—The example of research on biotic invasions: Living Reviews in Landscape Research, v. 2, accessed September 2009 at *http://www.livingreviews.org/lrlr-2008-2*.
Kuhn, T.S., 1996, The structure of scientific revolutions (3d ed.): University of Chicago Press, 226 p.
Latour, B., 2000, When things strike back—A possible contribution of 'science studies' to the social sciences: The British Journal of Sociology, v. 51, no. 1, p. 107–123.
Latour, B., and Woolgar, S., 1986, Laboratory life—The social construction of scientific facts: Princeton, New Jersey, Princeton University Press, 296 p.
Lewin, K., Lippitt, R., and White, R.K., 1939, Patterns of aggressive behavior in experimentally created social climates: Journal of Social Psychology, v. 10, p. 271–299.
Leydesdorff, L., 2006, The biological metaphor of a second-order observer and the sociological discourse: Kybernetes, v. 35, no. 3/4, p. 531–546.

Lindeman, N., 2007, Creating knowledge for advocacy—The discourse of research at a conservation organization: Technical Communication Quarterly, v. 16, p 431–451.
Luhmann, N., and Behnke, K., 1994, The Modernity of Science: New German Critique, v. 61, Special Issue on Niklas Luhmann, p. 9–23.
Luhmann, N., and Fuchs, S., 1994, "What is the Case?" and "What Lies behind It?" The Two Sociologies and the Theory of Society: Sociological Theory, v. 12, no. 2, p. 126–139.
Lupis, S.G., Messmer, T.A., Black, T.A., Frey, S.N., Mitchell, D., Degirogio, J., 2006, Take Action! The past, present, and future of sage-grouse conservation in Utah; Proceedings, 11th Triennial National Wildlife & Fisheries Extension Specialists Conference, October 14 –18, 2006, Big Sky, Montana, p. 45 – 51.
Marshall, J., 2008, Finding form in writing for action research, *in* Reason, P., and Bradbury, H., eds., The SAGE Handbook of Action Research—Participative Inquiry and Practice: Los Angeles, Calif., SAGE Publications, p. 682–694.
McCreary, S., Gamman, J., and Brooks, B., 2001, Refining and testing joint fact-finding for environmental dispute resolution—Ten years of success: Mediation Quarterly, v. 18, no. 4.
Messerli, B., and Messerli, P., 2008, From local projects in the alps to global change programmes in the mountains of the world—Milestones in transdisciplinary research, *in* Hirsch Hadorn, G., Hoffmann-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C., Wiesmann, U., Zemp, E. (eds.), Handbook of Transdisciplinary Research, Berlin: Springer, 448 p.
Moir, W.H., and Block, W.M., 2001, Adaptive management on public lands in the United States—Commitement or rhetoric?: Environmental Management, v. 28, p 141 –148.
Nevada Department of Wildlife, 2004, Greater Sage-grouse conservation plan for Nevada and eastern California (1st ed.)—Prepared for Nevada Governor Kenny C. Guinn and the Sage Grouse Conservation Team: Nevada Department of Wildlife, 118 p., accessed September 2009 at *http://www.ndow.org/wild/conservation/sg/plan/SGPlan063004.pdf*.
Nicholson, C.R., Starfield, A.M., Kofinas, G.P., and Kruse, J.A., 2002, Ten heuristics for interdisciplinary modeling projects: Ecosystems, v. 5, no. 4, p. 376–384.
Nolin, C., 2003, Policy for evaluation of conservation efforts when making listing decisions: Federal Register, v. 68, no. 60, p. 15,100–15,115.
Nowotny, H., Scott, P., and Gibbons, M., 2001, Re-thinking science—Knowledge and the public in an age of uncertainty: Cambridge, England, Polity, 288 p.
Oyler-McCance, S.J., St. John, J., Taylor, S.E. , Apa, A.D. , and Quinn, T.W., 2005, Population genetics of Gunnison Sage-grouse—Implications for management: Journal of Wildlife Mangement, v. 69, p. 630–637.
Pederson, E.K., and Grant, W.E., 2004, Sage-grouse populations in southeastern Idaho, U.S.A.—Effect of sheep grazing and fire, *in* van den Belt, M., ed., Mediated Modeling—A System Dynamics Approach to Environmental Consensus Building,Washington, D.C., Island Press, p. 185–204.
Peters, K.M., 2008, Bellwether Bird, National Journal Group, accessed September 2009 at *http://www.govexec.com/features/0208-01/0208-01s1s1.htm*.
Peterson, C.E., and Shriner, D.S., 2004, Contributions of acid rain research to the forest science-policy interface—Learning from the National Acid Precipitation Assessment Program: Scandinavian: Journal of Forest Research, v. 19, no. 4, supp. 4, p. 157–165.
Peterson, M.N., Peterson, M.J., and Peterson, T.R., 2005, Conservation and the myth of concensus: Conservation Biology, v. 19, no 3.

Peterson, T.R., Peterson, M.J., and Grant, W.E., 2004, Social practice and biophysical process, *in* Senecah, S., and Depoe, S., eds.: The Environmental Communication Yearbook (1st ed.): Mahwah, N.J., Lawrence Erlbaum, p. 15–32.

Pfirman, S., Martin, P., Berry, L., Fletcher, M., Hempel, M., Southard, R., Hornbach, D., and Morehouse, B., 2006, Interdisciplinary hiring, tenure, and promotion—Guidance for individuals and institutions: Council of Environmental Deans and Directors, National Council for Science and the Environment, 32 p.

Pohl, C., and Hirsch Hadorn, G., 2008, Methodological challenges of transdisciplinary research: Natures Sciences Sociétés, v. 16, p. 111–121, accessed September 2009 at *http://www.transdisciplinarity.ch/documents/Pohl&Hirsch%20Hadorn%202008.pdf*.

Popper, K.R., 1963, Conjectures and refutations—The growth of scientific knowledge,(1st ed.): New York, NY, Routledge, 431 p.

Pound, B., Snapp, S., McDougall, C., and Braun, A., 2003, Managing natural resources for sustainable livelihoods—Uniting Science and Participation: London, U.K., IDRC Publishers, 252 p.

Reason, P., and Bradbury, H., eds., 2006, Handbook of Action Research: Concise Paperback Edition: London, UK, SAGE Publications, 400 p.

Reason, P., and Bradbury, H., 2007, The SAGE handbook of action research—Participative inquiry and practice, (2d ed.): London, SAGE Publications, 512 p.

Ruggie, J.G., 1972, Collective goods and future international collaboration: The American Political Science Review, v. 66, no. 3, p. 874–893.

Sanberg, J., 2005, How do we justify knowledge produced within interpretive approaches? Organizational Research Methods, v. 8, no. 1, p. 41–68.

Schroeder, M.A., Aldridge, C.L., Apa, A.D., Bohne, J.R., Braun, C.E., Bunnell, S.D., Connelly, J.W., Deibert, P.A., Gardner, S.C., Hilliard, M.A., Kobriger, G.D., McAdam, S.M., McCarthy, C.W., McCarthy, J.J., Mitchell, D.L., Rickerson, E.V., and Stiver, S.J., 2004, Distribution of Sage-grouse in North America: The Condor, v. 106, no. 2, p. 363–376.

Shindler, B., and Cheek, K.A., 1999, Integrating citizens in adaptive management—A propositional analysis: Conservation Ecology, v. 3, no. 1, p. 9.

Sikder, I.U., Mal-Sarkar, S., and Mal, T.K., Knowledge-based risk assessment under uncertainty for species invasion: Risk Analysis, v. 26, no. 1, p. 239–252.

Sonnert, G., 1995, What makes a good scientist?—Determinants of peer evaluation among biologists: Social Studies of Science, v. 25, p. 35–55.

Spinuzzi, C., 2005, The methodology of participatory design; Technical Communication, v. 52, p. 163–174.

Stankey, G.H., Clark, R.N., Bormann, B.T., and eds., 2006, Learning to manage a complex ecosystem—Adaptive management and the Northwest Forest Plan: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 194 p.

Steel, B., List, P., Lach, D., and Shindler, B., 2001, The role of scientists in the environmental policy process—A case study from the American west: Environmental Science & Policy, v. 7, no. 1, p. 1–13.

Stinson, S.W., Hays, D.W., and Schroeder, M., 2004, State of Wasington Greater Sage-grouse Recovery Plan: Washington Department of Fish and Wildlife, Olympia, Washington, 109 p.

Stiver, S.J., Apa, A.D., Bohne, J., Bunnell, S.D., Deibert, P., Gardner, S., Hilliard, M., McCarthy, C., and Schroeder, M.A., 2006, Greater Sage-grouse comprehensive conservation strategy: Western Association of Fish and Wildlife Agencies, 442 p.

Stokols, D., 2006, Toward a science of transdisciplinary action research: American Journal of Community Psychology, v. 38, no. 1, p. 63–77.

Stokols, D., Fuqua, J., Gress, J., Harvey, R., Phillips, K., Baezconde-Garbanati, L., Unger, J., Palmer, P., Clark, M.A., Colby, S.M., Morgan, G., and Trochim, W., 2003, Evaluating transdisciplinary science: Nicotine & Tobacco Research, v. 5, no. 6, supp. 1, p. S21–S39.

Strauss, A.C., and Corbin, J., 1990, Basics of Qualitative Research: Grounded Theory Procedures and Techniques (2nd ed.): Newbury Park, Calif., SAGE Publications, 272 p.

Strauss, A.C., Corbin, J., and eds., 1997, Grounded Theory in Practice: London, New Delhi, SAGE Publications, Inc., 288 p.

Susskind, L., Field, P., van der Wansem, M., and Peyser, J., 2007, Integrating scientific information, stakeholder interests, and political concerns, *in* Hanna, K.S., and Slocombe, D.S., eds., Integrated Resource and Environmental Management—Concepts and Practice: Cambridge, England, Oxford University Press, p. 288.

Thagard, P., 2007, Coherence, Truth, and the Development of Scientific Knowledge: Philosophy of Science, v. 74, no. 1, p. 28-47.

Thomas, C.W., 2003, Bureaucratic Landscapes—Interagency Cooperation and the Preservation of Biodiversity: Cambridge, MA, The MIT Press, 368 p.

Torgerson, D., 2005, The uncertain quest for sustainability—Public discourse and the politics of environmentalism, *in* Fischer, F., and Black, M., eds., Greening Environmental Policy: London, England, Macmillan, 221 p.

Turner, J.M., 2006, Conservation Science and Forest Service Policy for Roadless Areas, Conservation Biology, v. 20, p. 713–722.

U.S. Office of Personnel Management, 2006, Research Grade Evaluation Guide, September 2006, Washington, D.C., U.S. Office of Personnel Management, accessed September 2009 at *http://www.opm.gov/Fedclass/gsresch.pdf*.

U.S. Fish and Wildlife Service, Wyoming Field Office, 2005, Endangered and Threatened Wildlife and Plants—12 month Finding for Petitions to List the Greater Sage-grouse as Threatened or Endangered: Proposal Rules: Federal Register, v. 70, no. 8, p. 2,243–2,282.

van den Belt, M., 2004, Mediated Modeling: A System Dynamics Approach to Environmental Consensus Building, 1st ed., Island Press, 339 p.

van Kooten, G.C., Eagle, A.J., and Eiswerth, M.E., 2004, Anthropogenic and natural determinants of the population of a sensitive species—sage grouse in Nevada: Working Paper 2004-8, Resource Economics and Policy Analysis Research Group, University of Victoria, 30 p.

Van Sanden, M., and Meijman, F., 2008, Dialogue guides awareness and understanding of science—An essay on different goals of dialogue leading to different science communication approaches: Public Understanding of Science, v. 17, p. 89–103.

Weber, J.R., and Schell Word, C., 2001, The Communication Process as Evaluative Context—What Do Nonscientists Hear When Scientists Speak: BioScience, v. 51, no. 6, p. 487–495.

Westley, F.R., and Miller, P.S., eds., 2003, Experiments in Consilience: Integrating Social and Scientific Responses to Save Endangered Species (1st ed.): Washington, DC, Island Press, 361 p.

Williams, B.K., Szaro, R.C., and Shapiro, C.D., 2009, Adaptive Management—The U.S. Department of the Interior Technical Guide: Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

Williams, R.D., and Staff of the Nevada Fish and Wildlife Office, 2008, Endangered and Threatened Wildlife and Plants—90-Day Finding on a Petition to List the Mono Basin Area Population of the Greater Sage-grouse (*Centrocercus urophasianus*) as Threatened or Endangered.: Federal Register, v. 73, no. 83, p. 23,173–23,175.