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Original Research

Collaborative Adaptive Rangeland Management Fosters Management-Science Partnerships☆,☆☆

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ABSTRACT

Rangelands of the western Great Plains of North America are complex social-ecological systems where management objectives for livestock production, grassland bird conservation, and vegetation structure and composition converge. The Collaborative Adaptive Rangeland Management (CARM) experiment is a 10-year collaborative adaptive management (CAM) project initiated in 2012 that is aimed at fostering science-management partnerships and data-driven rangeland management through a participatory, multistakeholder approach. This study evaluates the decision-making process that emerged from the first 4 yr of CARM. Our objectives were to 1) document how diverse stakeholder experiences, epistemologies, and resulting knowledge contributed to the CARM project, 2) evaluate how coproduced knowledge informed management decision making through three grazing seasons, and 3) explore the implications of participation in the CARM project for rangeland stakeholders. We evaluated management decision making as representatives from government agencies and conservation nongovernmental organizations, ranchers, and interdisciplinary researchers worked within the CARM experiment to 1) prioritize desired ecosystem services; 2) determine objectives; 3) set stocking rates, criteria for livestock movement among pastures, and vegetation treatments; and 4) select monitoring techniques that would inform decision making. For this paper, we analyzed meeting transcripts, interviews, and focus group data related to stakeholder group decision making. We find two key lessons from the CARM project. First, the CAM process makes visible, but does not reconcile differences between, stakeholder experiences and ways of knowing about complex rangeland systems. Second, social learning in CAM is contingent on the development of trust among stakeholder and researcher groups. We suggest future CAM efforts should 1) make direct efforts to share and acknowledge managers' different rangeland management experiences, epistemologies, and knowledge and 2) involve long-term research commitment in time and funding to social, as well as experimental, processes that promote trust building among stakeholders and researchers over time.

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Introduction

Substantial differences between the goals and methodologies of rangeland science and rangeland management have limited their integration throughout the history of the rangeland profession. Science and management are not directly comparable endeavors (Provenza, 1991), so the development of knowledge that is legitimate to managers and that scientifically supports management actions is a formidable challenge. Although there has been considerable experimental research focusing on specific aspects of grazing management, these studies have not included the decision-making and learning processes central to grazing management (Briske et al., 2008, 2011; Brunson and Burritt, 2009). Therefore, research and monitoring approaches need to document explicitly the processes of adaptive management to enrich

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☆☆ Integrated Social-Ecological Approches to Silvopastoralism (Huntsinger and Plieninger, editors).

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our understanding of successful grazing management (Brunson and Burritt, 2009; Budd and Thorpe, 2009).

Participatory research approaches that promote mutual learning through collaboration between researchers and stakeholders could create opportunities to bridge the gap between rangeland science and management (Ballard and Belsky, 2010; Shirk et al., 2012). One such approach is collaborative adaptive management (CAM), which, as implied in the name, aims to reduce uncertainty in complex ecosystem management by combining participatory and collaborative processes with adaptive management (Stringer et al., 2006; Armitage et al., 2009; Beratan, 2014). This paper first outlines and then evaluates the claims that CAM can effectively promote learning and reduce uncertainty among diverse interests in rangeland management by examining a single application of CAM, the Collaborative Adaptive Rangeland Management (CARM) experiment. CARM is a 10-yr, interdisciplinary project (initiated in 2012) conducted at the US Department of Agriculture — Agriculture Research Service (ARS) Central Plains Experimental Range, a Long-Term Agro-ecosystem Research (LTAR) network location on the shortgrass steppe of eastern Colorado.

This paper is a case study, based on qualitative social data collected from meeting notes and interview transcripts recorded in CARM. In this synthetic assessment, we explore to what extent participation in the CARM experiment enabled adaptive decision making by a group of rangeland stakeholders. The specific objectives of this study were to 1) document how diverse stakeholder experiences and epistemologies (meaning their socially constructed theories and justifications for rangeland management knowledge) contribute to the CARM project, 2) evaluate how coproduced knowledge informed management decision making through three grazing seasons, and 3) explore the implications of participation in the CARM experiment for rangeland stakeholders.

Collaborative Adaptive Management Framework

CAM is a framework to link rangeland stakeholders and scientists in a shared process of learning by doing (Stringer et al., 2006; Armitage et al., 2009; Knapp et al., 2011; Beratan, 2014). CAM explicitly incorporates experimental design in the implementation of management treatments and collaborative decision-making processes (Hopkinson et al., 2017). Conventional engagement of rangeland managers by agencies and academics often centers on extension bulletins, presentations, or popular press articles produced after research has been completed. In contrast, CAM, when implemented as participatory research, seeks to connect researchers and managers throughout the research process and empower stakeholders to develop new knowledge and take ownership of research results (Uphoff, 1986, 2002; Wilmsen et al., 2008). Next, we discuss the theoretical contributions of adaptive management, participatory research approaches, and collaborative processes to the CAM framework.

Adaptive Management To Reduce Uncertainty in Complex Systems

Adaptive management is a formal process whereby managers work to reduce uncertainty through systematic learning of system function by adapting management actions to new information learned from management outcomes (Gunderson, 2000; Jacobson et al., 2009). This approach represents an alternative to command and control management and assumes that complex natural systems cannot be effectively controlled via prescriptive actions (Holling and Meffe, 1996). Adaptive management is often discussed in a complex social-ecological systems perspective with an emphasis on the concept of "loop learning" (Petersen et al., 2014), the process by which new information is used to alter management actions (single-loop learning), revise guiding assumptions about the management context in question (double-loop learning) (Argyris, 2002), or inspire higher level reflections on the context and power of the management process (triple-loop learning) (Roux et al., 2010). Adaptive management has been celebrated as an alternative to trial and error approaches to managing complex systems, but common pitfalls in the implementation of adaptive management have been identified. These include insufficient monitoring, failure to maintain stakeholder engagement and acknowledge that managers are risk averse, and lack of institutional commitment to use learning to modify management (Allen and Gunderson, 2011; McFadden et al., 2011). Adaptive management is also restricted when academics learn among themselves rather than with external stakeholders (Fabricius and Cundill, 2014).

Participation to Increase Engagement

The collaborative aspects of CAM respond to some of the limitations of adaptive management to address complex natural resource issues in the face of uncertainty and conflict (Susskind et al., 2012). CAM employs iterative (Plummer, 2009), participatory and consensus-based decision-making frameworks that include multiple hypotheses and sources of knowledge (Bouwen and Taillieu, 2004; Leys and Vanclay, 2011; Cundill et al., 2012; Bennett, 2016). The major premise is to increase stakeholder engagement and ownership in research, as evidence suggests that stakeholders' level of engagement, and not time involved in collaborative research, is a major driver of learning outcomes (Evely et al., 2011).

Various forms of rancher participation have been included in rangeland research in the United States since the early 20th century (Sayre, 2017). However, the paradigm of participatory research gained traction in crop agriculture, health, and development fields in the 1970s and has grown to become a stakeholder engagement orthodoxy across a number of disciplines (Gow and Vansant, 1983; Uphoff, 1986; Cornwall and Jewkes, 1995), including natural resource management (Ballard and Belsky, 2010; Knapp et al., 2011). This type of research focuses on processes of change, including ongoing adaptation, evaluation, and outreach built upon collaborative relationships among managers, researchers, and/or nongovernmental organizations (NGOs; Uphoff, 1986, 2002; Wilmsen et al., 2008). Participatory research reorganizes the traditional view of science in terms of who conducts, analyzes, and presents research and for whose benefit this knowledge is produced and recorded (Cornwall and Jewkes, 1995; Cornwall, 2003). Participatory processes emphasize decentralization, transformation, empowerment, integration of local knowledge, and application of research to locally relevant management scales (Cornwall and Jewkes, 1995) and are thus a natural fit for the challenges of linking rangeland management and science across social, spatial, and temporal scales.

Collaboration to Increase Learning

A key contribution of CAM is to wed adaptive management, in which management actions are treated as experiments, with stakeholder collaboration to foster social learning. We define social learning as the processes in which individuals and groups work together to critically evaluate existing norms, values, institutions, and interests, and thereby to coproduce new knowledge, develop a shared understanding, and take collective action (Muñoz-Erickson et al., 2010; Cundill and Rodela, 2012; Nykvist, 2014). In the collaborative rangeland management context, stakeholders bring management knowledge formed through diverse management experiences to new decision-making contexts involving multiple, and seemingly contradictory, goals (e.g., grassland bird conservation and beef production). In these complex management contexts, social learning becomes a key concept to help bridge knowledge gaps among stakeholders (Fernandez-Gimenez et al., 2006; Edelenbos et al., 2011).

The collaborative and participatory aspects of the CARM project design rely on numerous examples of collaborative, participatory, and community-based agriculture, rangeland, and other common-pool resource management work conducted over the past three decades (Ostrom, 1990; Fernandez-Gimenez et al., 2006; Arnold and Fernandez-Gimenez, 2007). Advances in conceptual development of these approaches in rangeland contexts derive largely from experiences of international development (Coppock, 2016) and recent work in the

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western United States (Walker and Hurley, 2004; Rudeen et al., 2012; Hopkinson et al., 2017). This work suggests that participatory approaches provide a strong test of research hypotheses to produce knowledge that is relevant to rangeland managers but require more time and funding than conventional research approaches (Coppock, 2016). Developing successful collaborations depends on both a strong understanding of management context and careful design of the collaborative process (Walker and Hurley, 2004). Participatory research and collaborative management approaches are not a panacea and have been scrutinized for failing to be accountable to stakeholders, for overlooking the integral role of politics in collaboration, and for unequal access to participation and benefits among stakeholders from different groups (Jordan, 2003; Walker and Hurley, 2004; Long et al., 2016).

Multiple Theories of Knowledge in Complex Rangeland Systems

Our qualitative examination of decision making within the CARM experiment is informed by constructivist theory, a theory often used in qualitative social research that explains the social nature of learning and knowledge (Charmaz, 2006; Bryant and Charmaz, 2007). We consider knowledge to be more than a set of facts or information used by an individual or literature cited by an individual or organization (Blackman et al., 2004; Blackmore et al., 2007). Instead, we work from the assumption that knowledge is socially constructed or the result of ever-changing social and cultural interactions (Oeberst et al., 2016). We recognize that knowledge is "situated," meaning that it is developed and actionable in specific contexts (Schwandt, 2000; Robbins, 2006) and shaped by the ways in which it is practiced and applied (Haraway, 1988; Cote and Nightingale, 2012; Cundill and Rodela, 2012).

Our analysis also relies on the assumption that diverse social contexts and lived experiences influence managers' and researchers' epistemologies or their theories of knowledge (Cote and Nightingale, 2012). Rangeland epistemologies describe how stakeholders know what they know and how they justify, filter, and develop trust for new rangeland management knowledge (Kassam, 2008; Fernandez-Gimenez et al., 2006; Black Elk, 2016). For example, a rancher may "know what she knows" about rangeland management from her experiences in school; as a member of a ranching community and family; from cultural traditions, stories, or records from past social or weather events; and from years of observations of ecological processes in a specific working landscape (Bennett, 1971; Knapp and Fernandez-Gimenez, 2009; Wilmer and Fernandez-Gimenez, 2015). In contrast, a rangeland ecologist, studying plant-herbivore interactions in the same ecosystem, may justify his recommendations for rangeland management through his own experience within a team of researchers, through his time spent gathering and analyzing experimental evidence, and with reference to the peer-reviewed literature. Knowledge and ways of knowing are also relational and political (Bixler, 2013). One epistemology may be privileged over others in different contexts or at different scales (Cote and Nightingale, 2012), particularly where natural resource decision making involves management for multiple objectives across spatiotemporal and social scales (Harrison et al., 1998; Black Elk, 2016). We also recognize that knowledge is dynamic. Epistemologies can overlap and interact, so knowledge classification based on social categories, particularly occupation or education, is likely to oversimplify complex social relations and learning processes (Robbins, 2006).

Theoretically, CAM is an opportunity to engage multiple stakeholder epistemologies through a collaborative process that addresses complex social-ecological questions. CAM is a potential alternative to top-down regulatory approaches (Behnken et al., 2016; Gianotti and Duane, 2016) and conflict in complex rangeland management scenarios. As a result, there is heightened interest in documenting the learning and decision-making processes of diverse stakeholders acting in collaborative management contexts (Rathwell et al., 2015).

Methods

Study Site: CARM Experiment

CARM Overview and Decision-Making Guidelines

The CARM experiment is centered at the Central Plains Experimental Range (CPER), a USDA-ARS LTAR site in Nunn, Colorado, on the semiarid shortgrass steppe. In a public-private lands management scenario, 11 stakeholders collaborate with a team of interdisciplinary researchers to make management decisions on ten 130-ha pastures and a herd of yearling cattle (Fig. 1). The experimental design enables a comparison of the social and ecological outcomes of an aspirational management approach (CARM) with outcomes from paired pastures managed under traditional rangeland management (TRM), a status quo approach used widely in the local area (Bement, 1969; Hart and Ashby, 1998).

The research team members have expertise in rangeland ecology, wildlife biology, animal science, agricultural economics, and natural resource management social science. The researchers invited stakeholders to the project in 2012. This is not a random sample of stakeholders. Rather, stakeholders were purposefully selected on the basis of known interests in collaboration. These stakeholders were active in the local rangeland management community in some way and were interested in participating in a research project that would potentially help to identify new management strategies to serve multiple rangeland management objectives or quantify trade-offs in these objectives.

Stakeholders (3 women and 8 men) include representatives from three conservation NGOs: The Nature Conservancy, Bird Conservancy of the Rockies (formerly Rocky Mountain Bird Observatory), and Environmental Defense Fund. Government agency representatives joined from the USDA Natural Resources Conservation Service (NRCS), Colorado State University Extension (a seat occupied from 2012 to 2014, vacant in 2015, and filled in 2016), Colorado State Land Board (a seat created in 2015), and the USDA Forest Service. Ranchers have four seats on the stakeholder group and are all members of the local grazing association that supplies cattle to the experiment, the Crow Valley Livestock Cooperative, Inc. The CARM experiment is one of many research projects carried out at CPER with Crow Valley Livestock Cooperative cattle.

Baseline ecological data were collected in 2013, and the experimental treatments began in 2014 and have continued to present. Group decision-making rules were initially established as consensus based in 2013. In 2014 the stakeholder group recognized that a super-majority rule was needed for decisions when consensus could not be obtained in order to keep the project moving forward. At this point, the group refined quorum rules (7 of 11 stakeholders must be present to conduct any voting) and there must be a 75% supermajority of those present to pass a proposed decision. Stakeholders meet in January, April (before grazing season), and late September (near the end of the grazing season) and receive weekly email updates of monitoring results collected by ARS researchers and staff during the grazing season mid-May to early October.

Stakeholder Meeting Facilitation

With the exception of the first stakeholder meeting in 2012, meetings are facilitated by the research team and typically last 1 day. All meetings include a presentation of ecological monitoring data, seasonal weather outlooks, and general project updates by researchers. Spring and fall meetings typically involve a tour of select pastures. Following monitoring presentations, the researchers lead stakeholders in a semistructured discussion of the data and any relevant decisions, working to ensure that all voices are heard and concerns are addressed. Decision making often includes group activities, such as worksheets and small group discussion, to facilitate data interpretation and consensus building.

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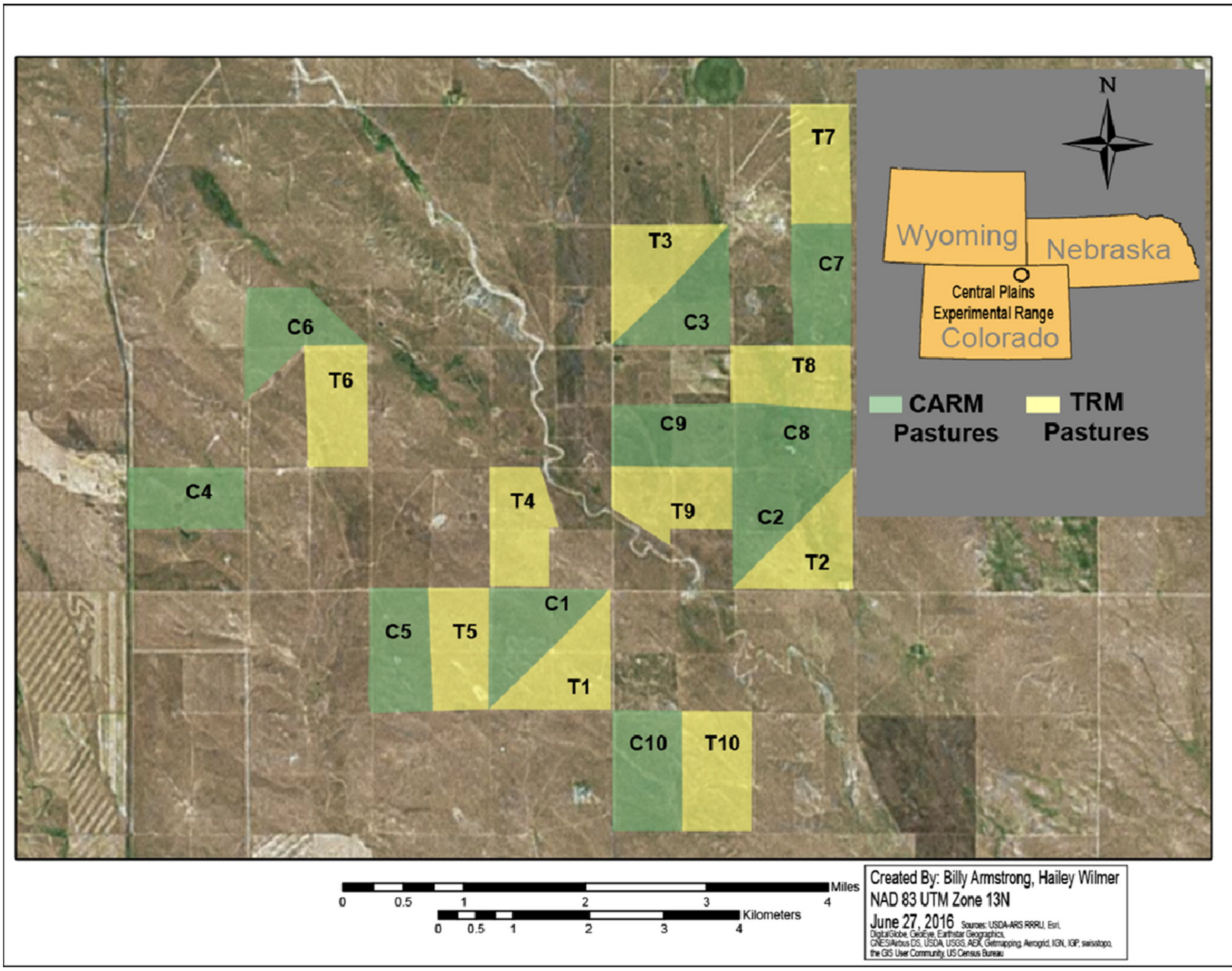

Figure 1. Ten, 130-ha collaborative adaptive rangeland management (CARM) pastures are shown in green color and denoted by "C" and a pasture number. Pastures are paired on the basis of soils, ecological sites, topography, and plant communities with ten 130-ha pastures managed under traditional rangeland management, a continuous, season-long (mid-May to early October) grazing system (yellow pastures, denoted by "T" and a pasture number) with the same moderate ranch-scale, growing season stocking rate using yearling steers. During the first three grazing seasons, stakeholders chose to rotate a single herd of cattle through the CARM pastures, moving the herd based on vegetation structure and cattle behavior monitoring triggers.

Stakeholder Goals, Objectives, and Experimental Design Constraints

In 2012 the research team and stakeholders developed the overall stakeholder goal "to manage the land in order to pass it on to future generations" and identified specific objectives related to livestock production, wildlife, and vegetation outcomes (Fig. 2). Birds that breed in grasslands of the western Great Plains have been identified as one of the most rapidly declining guilds of birds in North America (Brennan and Kuvlesky, 2005), and many are listed as species of conservation concern by federal land management agencies and state wildlife agencies in the region. Production concerns centered on livestock weight gains and the negative economic impact of drought, when cattle are removed from summer pastures early. Vegetation concerns focused on increasing diversity of plant functional groups and increasing structural heterogeneity.

In 2012, the group also established guidelines and experimental design constraints, parameters for the project based on logistical constraints and scientific research design considerations that would enable a valid comparison of traditional rangeland management (TRM) and CARM outcomes. While these parameters did limit the possibilities for adaptive management in the project, they were seen as necessary by the ecological research team to produce defensible scientific results and maintain the experiment within financial, logistical, and temporal constraints. The experimental constraints align the project with the local management context and help produce locally relevant research findings for ranchers and range managers. These design constraints are:

1) The paired-pasture design of the grazing management strategies, wherein stakeholders compare monitoring data from the pastures managed via collaborative adaptive rangeland management (CARM) to 10 paired pastures with TRM, a continuous, season-long (mid-May to early October) grazing approach typical of management approaches employed by ranchers in the local area (Bement, 1969; Hart and Ashby, 1998). CARM and TRM pastures were paired on the basis of ecological site attributes.
2) Both the CARM and TRM treatments are stocked with yearling cattle between mid-May and early October of each year (i.e., no grazing during October to mid-May). This grazing period is similar to that the USDA Forest Service negotiates with the permittees on an annual basis for the Pawnee National Grassland. Yearling cattle were used because of the long-standing agreement between ARS and cooperative ranchers supplying the cattle.
3) Stakeholder decision making includes prioritizing desired objectives, determining rules for collective decision making, altering the number of grazing animals across years, deciding on the

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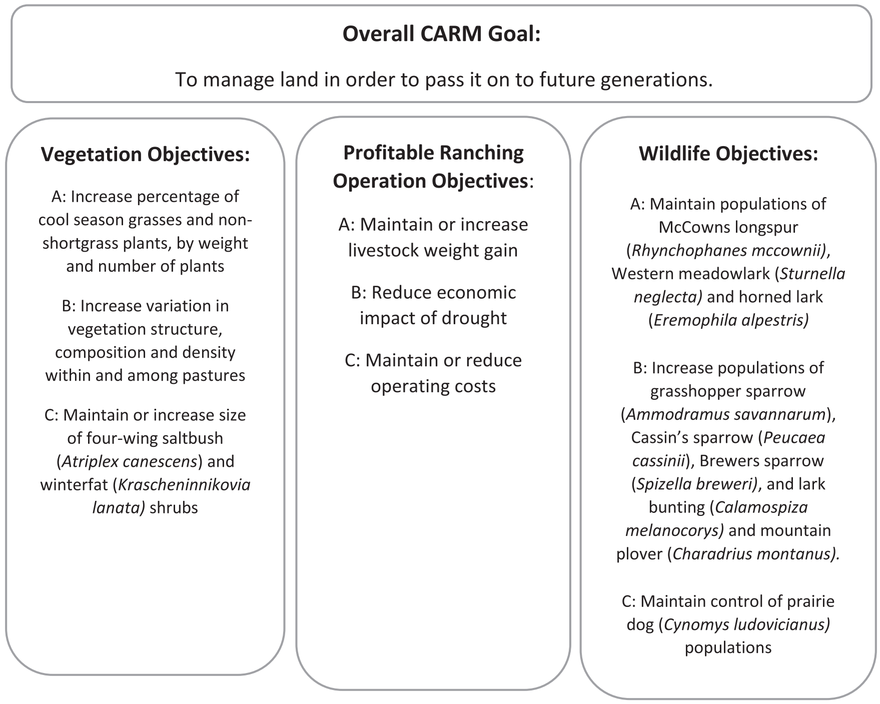

Figure 2. Stakeholders and researchers established goals and objectives in 2012. These encompass vegetation, beef production, and wildlife conservation aspects of rangeland management.

sequence of pastures used by cattle each year and whether any pastures are planned for nonuse, determining and adjusting criteria for livestock movement among pastures, and considering the application of other vegetation management treatments, such as prescribed burning and/or herbicide applications.

4) The first year (2014) of grazing treatments were based on a moderate growing-season stocking rate for the 10 pastures, as defined by NRCS ecological site descriptions and an analysis of ecological sites within each pasture using the national soil survey (SSURGO) database. After 2014, the stakeholder group could increase or decrease the stocking rate each year according to pasture conditions and seasonal weather forecasts. However, because of an existing agreement with cooperative ranchers supplying the cattle, changes > 10% may be made by October preceding the grazing season and stocking rate adjustments < 10% may be made any time between October and April preceding the mid-May start of the grazing season. More flexible within-season stocking rates would be preferable for effective, weather-adaptive rangeland management. However, the prevailing management of local ranchers (the model for the TRM treatment) does not include within-season stocking rate changes, though they do maintain some flexibility in stocking rate among seasons. If stakeholders change the CARM stocking rate, then the stocking rate of the 10 TRM pastures is also adjusted to maintain equivalent growing-season, ranch-scale stocking rates between the two treatments. This is consistent with the primary intent of the project to address the contributions of collaborative adaptive rangeland management, rather than to investigate grazing strategy.
5) Any criteria for thresholds, or "triggers," that stakeholders select for the movement of cattle among pastures must be consistent within a season, among years, and measurable in a way that could be clearly communicated among stakeholders, researchers, and technical staff. Stakeholders are volunteers who visit the research location infrequently and depend on quantitative assessments of pasture condition by the research team to determine when to move cattle.

Case Study Data Collection and Analyses

To explore to what extent participation in the CARM experiment enabled adaptive decision making by a group of rangeland stakeholders, we followed the CARM experiment for the first 4 yr (2012 − 2016), including three grazing seasons (2014 − 2016), using a qualitative case study (Yin, 2013). We conducted our qualitative social data collection and analysis in an iterative fashion (Charmaz, 2006) using stakeholder meeting data (meeting transcripts, notes, and audio recordings), semistructured stakeholder interviews, and a participatory focus group.

Stakeholder Meetings

Social scientists collaborated with biophysical scientists to document the decision-making processes of CARM stakeholders throughout the project. During meetings, audio recordings captured group discussions and decisions, while the researchers took in-depth notes about participants' activities and discussions. Interviews and the focus group were conducted by the lead author and were audio recorded and transcribed verbatim. We coded transcripts and meeting notes (Glesne, 2011a) using RQDA, a qualitative data analysis package in R (Huang, 2014) and used coded data to construct a decision-making timeline via a process-tracing method (George and Bennett, 2005; Yin, 2013). This method results in a timeline of the CARM project events, including stakeholder meetings, management action implementation, presentation of monitoring and precipitation data, and other participant actions (see Supplement A, available online at http://dx.doi.org/10.1016/j.rama.2017.07.008). During coding, we interrogated the meeting transcript data to identify patterns in stakeholder discussion of existing and experiment-produced knowledge, their decision-making processes, evidence of social learning, and existing frameworks of rangeland management.

Semistructured Stakeholder Interviews

In the spring of 2016, the lead author conducted semistructured interviews with 11 past and current stakeholders (Glesne, 2011b; Nagy Hesse-Biber, 2014) which were audio recorded, transcribed, and subject to a round of coding. We synthesized the results of this coding process

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and the resultant patterns and themes into a research memo that was then subject to peer-checking by the researchers on the CARM project. Next, themes from the interviews were used to develop a facilitation guide for a stakeholder focus group (Munday, 2014).

Focus Group

In April 2016, ten stakeholders and four researchers participated in a focus group facilitated by the lead author. This focus group explored stakeholders' experiences in the project, suggestions for improvements to research and decision-making processes, and concerns related to specific decisions and uncertainties. We coded interview and focus group transcripts in RQDA with codes related to ecological and social learning concepts. Coded data from interviews and the focus group, which we summarized in tables, were subject to negative case analysis, triangulation with observation notes and coded data from meetings, and other documents from stakeholder meetings and the project website (Morse et al., 2008).

Synthesizing Findings

To document how diverse stakeholder epistemologies contribute to the CARM project, we used a matrix to identify patterns in stakeholders' professional experience and education, and rangeland epistemologies. We used stakeholder meeting notes and the project timeline to summarize stakeholder roles and contributions to the CARM decision-making processes. We identified patterns in the matrix within and among stakeholder subgroups (ranchers, agency representatives, and conservation NGOs) in terms of the context of their rangeland management experience and epistemologies.

Next, to evaluate how coproduced knowledge informed management decision making, we analyzed decisions regarding implementation of two management practices in the CARM experiment: rotation of a single livestock herd among pastures and the use of prescribed burning. We synthesized patterns in stakeholder discussion, their reference to monitoring data, and their voting for these two management decisions for 2014 – 2015. Ecological results from the experiment are represented in this paper only as they were made available in the form of preliminary results to the stakeholders in meetings and via electronic communication (as indicated by meeting transcripts). In this study, we evaluate stakeholder interpretations of biophysical data presented at meetings to better understand how the stakeholders "made sense" of those data for decision making in the CARM project. Finally, to explore the personal and professional implications of participation in the CARM project for rangeland stakeholders, we summarized patterns in stakeholder interviews and the focus group with a matrix.

Ensuring Rigor of Analysis for Coproduced Findings

Throughout the case study, the rigor of the qualitative analysis (known as *trustworthiness* in qualitative research) and transparency in the process were enhanced through prolonged engagement with the data by the research team, who sought out evidence that contradicted initial results, engaged in reflexive, or self-reflective, writing and team meetings and maintained an audit trail (Lincoln and Guba, 1986; Merriam, 2002). We also subjected initial explanations of decision-making processes to member checking, by stakeholders, and peer checking, by the research team. Both groups provided valuable feedback on the initial findings, including alternative explanations for decision making related to fire, that were incorporated into the study results. The findings are presented as coproduced results of stakeholder and research team collaboration.

Results

Diverse Stakeholder Experiences and Epistemologies

> "I have a completely different culture than the landowners. I interact with totally different people. It's just interesting for me to sort of think of why people are advocating for what they're advocating for, because they're all getting the same data. The data are all the same, but we're different. We're not always in agreement on things."
> [—Conservation NGO representative]

This passage from a transcribed interview with an NGO representative illustrates the distinctions among CARM stakeholders' interpretations of monitoring data and voting patterns 2 yr into the project. It also hints at the complex differences in social experiences and cultures among the stakeholders. As follows, we explore how stakeholder subgroups' experiences and epistemologies contributed to contrasting adaptive grazing management decisions. Subgroups included representatives from the grazing association, government agencies, and conservation NGOs.

Interview data indicated that the four ranchers were all multigenerational ranchers with secondary or some postsecondary education. They had decades of personal experience managing extensive beef operations with public land grazing leases, primarily following a grazing approach similar to TRM. They had experiential and cultural knowledge of animal husbandry, nutrition, cattle markets, local weather, local rangeland site potential, plant species, and management and ecological history, including knowledge of drought risk. As such, they served as advisors to the project on animal husbandry questions and as gatekeepers of the profitability goals and relevant livestock condition concerns.

Interviews with representatives of conservation NGOs revealed that all had some graduate education in wildlife, rangeland science, or human dimensions of natural resources. They had experience as researchers and managers in the shortgrass steppe and in other rangeland ecosystems. Their work in these systems was influenced by recent literature about threats to avian biodiversity, ecosystem heterogeneity, and adaptive management in rangelands (e.g., Fuhlendorf et al., 2012; Hovick et al., 2015). One member of this group had experience practicing high-intensity, short-duration grazing management. Others stated that the project presented them with a steep learning curve relative to livestock production systems. Meeting transcripts indicated that these representatives were sources of wildlife and vegetation management knowledge and also provided critical evaluation of methodology, specifically questioning how monitoring data could be used to improve decision making. These stakeholders often proposed actions that would maximize wildlife and rangeland management goals and trusted other stakeholders to counter their proposals with additional information, an approach one described in his interview as "asking for the whole loaf of bread and expecting to get half." Members of this group said during their interviews that they were interested in relating to, and connecting with, other stakeholders, and so avoided overuse of scientific jargon during meeting discussion.

Interviews with government agency representatives revealed they each had a bachelor's degree or higher in rangeland ecosystem science, range management, or agriculture. These stakeholders had experience as knowledge brokers in outreach, regulation, and management of public or private rangelands and knowledge of other collaborative group processes. Two described their own ranch decision-making experience, while all three worked with ranchers professionally in the public or private lands grazing context. Meeting transcripts indicated that these stakeholders were sources of knowledge about how management decisions impact vegetation dynamics and rangeland plant communities. During stakeholder meetings, they critically evaluated the transparency and process of group decision making and often took leadership in conversations or activities that "translated" the implications of monitoring data and observations during field tours to other stakeholders.

Coproduced Knowledge Informs but Does not Drive Early CARM Decision Making

Complex Cattle Rotation Decision Making

The CARM stakeholders' decision-making processes for cattle rotation were influenced by efforts to reduce the economic impact of

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drought through grassbanking and experimental constraints on design of the CARM experiment and by stakeholders' experiences with grazing management outside of the project. To illustrate this, we outline the CARM stakeholders' grazing rotation decision-making processes, drawn from meeting transcripts and the project timeline, and then explain each influence.

During 2013, the stakeholders agreed to an initial grazing management approach that involved selecting 2 of 10 CARM pastures for complete rest each grazing season and developing an annual plan for rotating cattle among the remaining 8 pastures. Meeting transcripts and interviews suggested that the basis for this decision was the hypothesis that a key advantage of the CARM process over the TRM treatment was the ability to rest pastures. The perceived advantage of annually resting pastures was threefold. First, it would provide reserve forage that could be grazed in dry years so that livestock would not have to leave the location early (before mid-October). Second, the practice was hypothesized to improve the density of cool-season grasses. Finally, rested pastures were hypothesized to increase vegetation height, improve among-pasture heterogeneity of vegetation structure, and provide habitat for bird species requiring tall-structure habitat.

Stakeholders set triggers for cattle rotation among pastures during an April meeting each year and adjusted these triggers on the basis of reference to and discussion about previous years' monitoring data (Table 1). On the basis of these triggers, cattle could potentially graze < 8 pastures in years of above-average forage production. In the event of drought, the CARM grazing plan allowed for grazing in pastures that had been scheduled for rest. In 2014 and 2015, both relatively wet years, CARM cattle grazed 7 of 10 and 4 of 10 pastures, respectively. Monitoring data presented to the group indicated that the average daily gain (kg/steer/day) was 15 − 16% greater for steers in the TRM compared with the CARM treatment. At the same time the researchers' data presentations indicated that treatments had no negative impacts to vegetation composition and structure objectives or grassland bird habitat.

Meeting transcripts suggested that cattle performance data strongly influenced decisions regarding the timing of cattle rotation. A substantial difference in average daily gain between the two treatments was counter to the assumption expressed in meetings by some in the stakeholder group. These individuals anticipated that rotated cattle would gain more weight on an average per head basis because the movement among pastures across the grazing season would provide consistent access to "fresh" forage (Box 1, A). In 2015 and 2016, the stakeholders attempted to make their triggers for pasture rotation more responsive to ecological variability to achieve similar cattle average daily gain between CARM and TRM treatments (see Table 1). During this time, the group incorporated multiple forms of expertise to refine their monitoring and decision making to achieve this goal. For example, when the group identified gaps in cattle performance data created by limited opportunities for weight monitoring during the grazing season, they developed a new monitoring protocol. Stakeholders, researchers, and project technicians collaborated to write and implement this cattle behavior and condition monitoring protocol that technicians could use to regularly track cattle behavior. This was linked to triggers for pasture movement (see Table 1).

Monitoring data presented to the stakeholders in 2014 and 2015 indicated that diet quality (e.g., crude protein) of CARM cattle did not increase when cattle moved to a new pasture. Dietary quality remained consistently lower for the CARM cattle than TRM cattle each week during the two grazing seasons. This information, paired with preliminary cattle distribution data compiled from GPS collars, was interpreted by the stakeholders to indicate that stock density played an important role in average daily gain. They eventually concluded that stock density forced the CARM yearlings to graze in less selective patterns regardless of the amount of forage on offer and prevented them from choosing the higher-quality diet that the TRM yearlings encountered. However, the stakeholder group did not consider any proposals to alter stock density and instead focused on improving grazing rotation triggers and incremental changes in stocking rate.

Why would the stakeholder group remain committed to the one-herd, high − stock density grazing approach, even after monitoring data, and a widely recognized livestock-forage relationship, which suggested that stock density was negatively impacting cattle production objectives? Interview, meeting, and focus group transcripts provide more detail. Stakeholders hypothesized that this grazing approach would have payoffs during future drought because it provided the capacity to grassbank forage in the ungrazed pastures. Whether the financial benefits of grassbanking for drought would outweigh animal production losses in the initial wet years of the project remained to be

Table 1
The decision-making processes of the CARM stakeholder group were documented throughout the project using meeting transcripts, interviews, weekly email updates, and a stakeholder focus group.

Stakeholder decisions for CARM pastures			
Planned CARM pasture treatments			
Thresholds for cattle rotation among pastures	2014	2015	2016
1. Residual biomass thresholds (kg/ha)			
Loamy pastures	336	336	504
Mixed (Sandy/Loamy) pastures	448	448	560
Sandy pastures	504	504	616
2. Max days threshold	Set for each pasture from production estimate for average precipitation yr	No max days	24 d in each pasture; move to fresh pasture 10 d before shipping
3. Cattle behavior threshold	Codeveloped cattle behavior checklist	Cattle behavior checklist	Refined cattle behavior checklist
Rest	Plan to rest 2 pastures	Plan to rest 2 pastures	Plan to rest 2 pastures
Drought plan	Graze rested pastures	Graze rested pastures	Graze rested pastures; if ≤75% of normal precipitation by June 15, thresholds reduced
Prescribed burn	Conduct 2 burns in fall 2014	Graze burned pastures early in grazing sequence	NA
Number of steers	Moderate stocking rate (214)	2014 stocking rate + 5% (224)	2015 stocking rate + 5% (234)
Actual CARM pasture treatments			
Pastures grazed	7; all rotations based on max days threshold	4; 2 rotations based on biomass thresholds, 1 based on cattle behavior	7; 5 rotations based on max days, 1 based on biomass thresholds
Number of pastures rested	3	6	3
Prescribed burns conducted	Two burns fall 2014	No burns	N/A

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Box 1
Stakeholder uncertainties. The following quotes typify perspectives of each stakeholder subgroup related to triggers for herd movement, a dominant concern across the stakeholder group. Stakeholders struggled to find triggers that would consistently support decision making within and across years.

A. "You can't go twice through a pasture and we can't make the pastures smaller. If we could do some of those things, we could try and hit that growth curve on the vegetation, but the experimental constraints mean that you can't test that very easily. It would also be helpful to the ranchers. They are so concerned about the weight differential and from what I hear from other ranchers and from people who test things, it's not just holistic management, but people who do more intensive, quicker rotations, hit the growth curve and actually have better weight gains. Weight gain is the ranchers' main concern, and I feel like we're really constrained from trying things that may address that because we only have so many pastures, so we have to stay at least x number of time in each pasture. Testing that quicker rotation is just not possible under the constraints we have and that might address the ranchers' weight gain concerns."—*NGO representative*
B. "[The greatest uncertainties in the ecosystem are] the livestock production factors. We've seen success with our vegetation objectives. We've seen success with our wildlife objectives. We haven't seen as much success with our livestock production as we would like to. That definitely is the question. I still think it's a timing issue. We're not getting the timing right. We're not getting the triggers right. I think we need to know more about the triggers and the timing of the grazing to make all the objectives work in a reasonable way. As far as the basic, fundamental experiment, the triggers is the thing that we need to figure out a little bit more of." —*Government agency representative*
C. "Our triggers need tweaked a little bit, so they can benefit what the bird folks are after, and what the ranch folk are after, and just what the grass is after."—*Rancher*

seen by 2016. During meetings and in interviews, stakeholders expressed willingness to be patient in the face of time lags between decisions and outcomes, repeatedly citing the slow time frame for management results in this semiarid rangeland ecosystem.

The commitment to the one-herd, high — stock density approach was also influenced by the experimental design constraints of CARM project, which arose from researchers' interest in producing scientific results that would be considered valid by their peers. Researchers expressed concern that valid research findings would need data from a drought to confirm the outcomes of the one-herd approach and grassbanking. At the same time, one researcher and one stakeholder noted during meetings that while the average daily gain and total pounds of beef achieved through CARM were less than TRM, the livestock gain per unit land area was greater in CARM than TRM. These participants argued that this metric, not average daily gain per head, best captured the benefits of the CARM group's decision.

Finally, stakeholders' experience in rangeland management, as revealed in interviews, likely facilitated their ability to refine triggers for herd movement (not stock density) as a way to deal with reduced diet quality. Stakeholders were asked to describe uncertainties in the project and/or ecological system in 2016. They expressed concern over rotation speed or herd movement triggers six times more often than they expressed concern about stock density (see Box 2). This emphasis provides insight into the experiential and professional knowledge with which the stakeholders interpreted monitoring data and made management decisions, knowledge that emphasized the benefits of increased speed of cattle rotation, but deemphasized the importance of stock density in cattle diet quality.

Several stakeholders, including NGO and government agency representatives, came to the project more familiar with high-intensity, short-duration grazing systems, which emphasize faster cattle rotations. In contrast, ranchers in this area practice a traditional grazing management approach that does not involve rotation but does maintain conservative stocking rates. One rancher repeatedly argued that rotating cattle too quickly could cause unnecessary energy expenditure. However, other stakeholders indicated that a faster rotation would improve cattle access to fresh forage while increasing the rest period for vegetation. The stakeholders voted to allow the herd to move through the same pasture twice in given year at the end of 2014.

During the focus group, stakeholders discussed their perceptions of the impact of different speeds of cattle rotation on the three overarching project objectives. One conservation NGO representative pushed for consideration of a "small (pasture)/quick (duration)" system, achieved by cross-fencing existing pastures and grazing 30, rather than 10, pastures in short duration (see Box 1, A). Two stakeholders mentioned that ranchers in their social networks operating in the local area had achieved benefits from this type of grazing approach. In response to this comment, a rancher argued that the current 10 pasture rotation "was small/quick," relative to the season-long, continuous system he managed on his own ranch. Because the speed of rotation determines the timing and length of pasture rest, stakeholders also debated the merits of various speeds of rotation for shortgrass species rest and recovery, referring to agency recommendations, existing published research, rancher observations and practices, and experience of high-intensity, short-duration grazing management approaches practiced on ranches in the region.

Box 2
Learning and collaboration. CARM stakeholders reflected on learning and collaboration with these quotes in their interviews. We used a matrix to identify patterns in these perspectives and present quotes that typify perspectives from three subgroups of stakeholders.

A. "I think when we first started, everybody was kind of out for their own. I know I was. All I really cared about was cattle, cattle gains, when we first started, but after some heated conversations and getting to know all the objectives, now I look at it as I want to meet the cattle objective, but I also want to meet the bird objective and the grass objective. I've learned a lot about inter-pasture heterogeneity … and then how cows gain better because of other reasons not just cow triggers. So we have to come together and work for all those objectives."—*Rancher*
B. "I hope the major lesson that comes out of it is that collaborative, multi-stakeholder processes actually work. That you can have your cake and eat it, too. You can have three different parties with three different objectives sit down and manage something and everybody at the end of 10 years can be happy."—*NGO representative*
C. "I think maybe the biggest challenge is that the parties at the table seem so absolute opposite in their missions, so I think a huge challenge and accomplishment will be if you can get the bird folks and the cattlemen even in the same room. I think that's an accomplishment I already noticed, is some mutual respect there. I don't know if it's been there from the beginning? That, I think, is a challenge and maybe one of the neatest takeaways is just a mutual respect of the parties." —*Government agency representative*

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Decision making regarding grazing rotations illustrates how stakeholders' professional experiences, priorities for project objectives, and existing knowledge of grazing management systems are important drivers influencing their management decisions.

Burning Question Reveals Differences in Risk Perceptions

We traced stakeholder decision-making processes about the use of prescribed burns and found that CARM did produce new management knowledge in the novel management context. However, CARM did not replace or reconcile differences among stakeholders' distinct, situated knowledges and led to disagreement about the use of fire as a vegetation management tool.

During the 2014 grazing season, cattle grazed 7 of 10 pastures yielding an "extra" rested pasture compared with the pregrazing-season plan, but CARM stakeholders were also presented with the finding that individual animal gains were lower in CARM versus TRM yearlings. Meeting transcripts suggest the group recognized the need to increase dietary quality and to create short structured vegetation for two grassland bird species (mountain plover, *Charadrius montanus,* and McCown's longspur, *Rhynchophanes mccownii*). Stakeholders voted to conduct two 32.4-ha prescribed burns in two different CARM pastures in late fall 2014. Two paired TRM pastures also received 32.4-ha prescribed burns. Monitoring data presented to the stakeholders in 2015, the year following the burns, identified a reduction in prickly pear cactus *(Opuntia polycantha)* densities on burned patches; a slight increase in diet quality for yearling steers, which did preferentially graze on the burned patch in the pastures early in the spring, but not as the grazing season progressed; and the presence of mountain plovers *(C. montanus)* on the burn patches in both CARM and TRM pastures. Despite the evidence that burning was beneficial to project objectives, and following a relatively wet year and grazing rotations that left six pastures ungrazed (see Table 1), the proposal to burn in 2015 failed. In the following discussion, we examine why the benefits of fire were challenged by some stakeholders.

Qualitative data detailing prescribed burning decisions reveal differences in how the stakeholders interpreted mutually established management objectives. Stakeholders held different interpretations of how the data related to the project objectives not because the data were incomplete or ambiguous, but because the stakeholders evaluated risk (Boholm, 2009; Weber, 2009) and trade-offs between objectives differently. Rancher interpretations, which were diverse within the rancher group, were based on a different way of knowing about risk in the shortgrass system, one stemming from their individual experiences as rangeland managers, and from cultural knowledge, developed over generations. This knowledge became transparent in interviews and meetings to provide justification and rationale for their decisions and perspectives. Ranchers' experiences shaped their rangeland management practices such that they emphasized conservative forage use, spreading risk across the landscape, and excluding fire because it reduced forage availability. These concerns regarding risk aversion dominated their decision, in spite of the potential benefits of burning identified in the monitoring data.

In contrast, government and NGO stakeholders, trained as scientists and facilitators of collaborative processes, expressed a greater concern in meetings and interviews over the risk of excluding ecological processes, such as fire from the ecosystem, than over the risk of reducing forage availability through prescribed burning. This subgroup of stakeholders recognized the need for economic return in grazing but had less experiential knowledge of the financial consequences of drought on beef production systems. While rancher stakeholders hypothesized that grazing could be used in place of fire to achieve vegetation structure heterogeneity objectives, other stakeholders and the research team argued that grazing alone could not achieve suitable short-structure habitat for mountain plover (Derner et al., 2009).

An alternative explanation for these decision-making processes is that the researchers failed to set clear guidelines for stakeholders regarding expectations for collaborative decision making around all the objectives. The group's decision not to use prescribed fire in 2015 could have occurred because stakeholders were not operating under the assumption that they should strive to vote in a way that served all the CARM objectives, not just objectives that best aligned with their own interests (e.g., ranchers voting just for actions that would benefit livestock production outcomes). Stakeholders discussed this issue in the focus group in 2016 and agreed that they would strive to serve all objectives and discuss potential impacts of a decision on all objectives before voting in the future. During the focus group, many in the stakeholder group said they had been working to serve all objectives throughout their involvement in the CARM experiment, and that their ability to do this was improving as they learned different aspects of the shortgrass ecosystem (Box 2, A). This discussion highlighted the importance of setting clear rules and allowing adequate time for sharing and learning to ensure consideration of all objectives simultaneously.

Stakeholders Describe Real-Life Implications of CARM

Of 11 stakeholders interviewed in spring 2016, nine described a growing level of trust in the group and motivation to continue their involvement in the experiment. Several stakeholders acknowledged challenges in group communication, including between stakeholders and researchers, and two (one rancher and one government agency employee) described being stressed by challenges of collaboration, including the apparent trade-offs between objectives and conflict between stakeholders. These stakeholders brought to light the challenges of collaboration in complex systems for individual stakeholders who invest social and emotional capital in collaborative process that do not produce immediate shared understanding and compromise. Stakeholders in all three subgroups reported that the collaborative aspect of the CARM project is an important motivator for their participation (see Box 2). Stakeholder interviews illustrate the development of increased ability to collaborate on management decision making for multiple management objectives over time in the group. They also reflect the expectations and hopes of engaged stakeholders from different professional and personal perspectives. Stakeholders expressed optimism in the group's ability to find what one called "the sweet spot" where they could manage the landscape for vegetation, beef production, and grassland bird objectives simultaneously over the lifetime of the project at the ranch scale (see Box 2). Here we describe differences in the personal and professional implications of engagement in participatory research across stakeholder subgroups (Box 3).

Interviews suggested that in the short term, ranchers are concerned with how management strategies developed in the project might improve livestock production and economic returns on their ranches. In the next decade, ranchers in the project could provide innovative management strategies for drought planning through lessons learned from the CARM experiment. Although drought typically results in reduced grazing days or number of animals grazing, the resultant reduction in herd size and/or expenditure on alternative forage can negatively affect economic returns for many years (Ritten et al., 2010).

Ranchers told us in interviews that they had an interest in demonstrating to the public and to federal agencies that they share interests in public lands management with nonlivestock production stakeholders. Ranchers described their participation as part of an effort to maintain their culture and livelihood by demonstrating commitment to learning and collaboration. As in other studies, ranchers in the CARM experiment donate personal time away from their businesses in order to participate in the project, while other stakeholders are being paid to attend CARM meetings and tours, which take place during the day (de Loë et al., 2015). Benefits or challenges to individual rancher stakeholders may differ from perceived benefits to the livestock industry or to the local grazing association (de Loë et al., 2015). Individual ranchers may sacrifice time away from their businesses to participate, but the benefits of that participation may extend to their communities and organization.

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Box 3
Motivations. These select quotes illustrate the diverse motivations for stakeholder involvement in the CARM project.

A. "I'm certainly invested in [the experiment] at this point. I'm invested in it because I've participated. I've seen progress. I have learned things that have benefited my own job and, I think, my own agency. That's huge for me because that's part of my job in the federal agency, is making sure I hear all sides. It's huge for me as an agency person, to see both sides in this experiment, where I am not directly involved but can learn from it."—*Government agency representative*
B. "I don't want to see the old ways go away."—*Rancher*
C. "I'm really interested in seeing what the full potential of the grass is, or what the grass can do for the cattle and what the cattle can do for the grass."—*Rancher*
D. "Really maximizing heterogeneity was my number one concern [in the CARM meetings], whether that was more fires, bigger fires, heavier grazing, or less intense grazing. Those were sort of the things that drove me."—*NGO representative*
E. "That it is long term, I think, is really attractive to me because that's also rare in research, just to have a 10-year project, and that we're actually doing it."—*NGO representative*

For conservation NGO representatives, the experiment has appeal because of the scope and "real-life" management context. For these stakeholders, CARM is also an opportunity to gather data on the costs of managing for grassland birds and variance/heterogeneity in vegetation structure. The experimental nature of the project lowered the risk that these stakeholders typically face in the private lands management context, where these representatives may be "very cautious about what you would recommend to people because you realize there's a lot of their livelihood at stake." While ranchers emphasized risk aversion in decision making because these decisions influenced their livelihoods directly, representatives from conservation NGOs were interested in learning how far they could "push" the system or if they could better understand ecological thresholds in the ecosystem through the experiment (see Box 3, D). They said they were also interested in learning if the group would be able to make science-informed decisions to balance and quantify trade-offs between and among objectives. These organizations have an interest in mitigating threats that shortgrass steppe ecosystems face from land conversion, understanding how management practices affect bird habitat, and incorporating historic disturbance processes such as fire into the landscape (see Box 3, D and E).

Interview data suggested that the project provided government agency representatives the opportunity to engage with rancher, researcher, and conservation NGO partners and to test underlying assumptions of current grazing management approaches that they might promote or regulate in their professional lives (Box 3, A). One described this as an unprecedented opportunity to have "immediate input into research to respond to immediate needs." CARM also holds promise in providing a suite of lessons learned for managing public rangelands for multiple goals and objectives (Cheng and Sturtevant, 2012). In the long term, the project could provide a reference with which to guide structured, collaborative decision making to reduce conflict in the public lands grazing context (see Box 2, C).

Discussion

Our comparison of stakeholder subgroups and grazing decision-making processes reveals that stakeholders' distinct experiences, epistemologies, and existing rangeland management knowledge greatly influenced the outcomes of the initial years of the CARM experiment, specifically in decisions regarding grazing rotations and the use of fire as a vegetation management tool. While concern for other objectives (e.g., drought management) and experimental design constraints influenced grazing rotation decisions, our analyses suggest that the decisions made in the early years of CARM were driven by stakeholders' existing and dynamic knowledge, constructed and justified in contexts outside of the CARM project. Distinct interpretations of the risks and benefits of prescribed burning, as well as their assumptions regarding triggers for cattle herd movement among pastures, cannot be attributed fully to coproduced knowledge and their CARM experiences (Cote and Nightingale, 2012). These differences in stakeholder perceptions of the use of prescribed fire illustrate why a season of monitoring data, coproduced as it was, was unlikely to alter stakeholder perceptions of existing rangeland management strategies, a proven way of thinking for ranchers in this semiarid rangeland ecosystem embedded in deeper cultural contexts. Three years of meetings were unlikely to build a working body of knowledge around simultaneous grassland bird and beef production goals across a group of diverse stakeholders who had little or no experience making management decisions within the CARM context.

The hypothesized role of learning in collaborative adaptive management is to develop a common understanding of complex systems among a diverse group of collaborators that, in turn, enables collective action. However, results from the CARM project suggest that this process is more complex. In CARM, social learning made the epistemologies of stakeholders more transparent. However, our data do not suggest that the CARM process reconciled differences in stakeholder knowledge or led to management decision making wholly informed by monitoring data. Stakeholder epistemologies and their socially constructed knowledge for rangeland management interacted with, but were not replaced by, coproduced knowledge from CARM. Rangeland managers' capacity to make adaptive decisions may not change as a result of participation in CARM alone, particularly during the early phases of a CARM project (Blackmore et al., 2007; Reed et al., 2010; Leys and Vanclay, 2011; Fabricius and Cundill, 2014; Oeberst et al., 2016).

Increased trust and engagement among stakeholders and between stakeholders and researchers is an early outcome of the CARM project. Despite the complexities and challenges of adaptive decision-making processes, stakeholder interviews and the focus group data suggested a high level of stakeholder engagement and investment in the CARM project. Engagement, ownership of data, and reflective experiences are critical to learning outcomes in participatory research projects (Evely et al., 2011). We interpret CARM stakeholder engagement to be motivated by an interest in learning and the potential benefits of participation. The experimental framing of the CARM project reduces risks to participants but may also reduce benefits of learning compared with a working ranch context. Stakeholders described participating in the project based on an understanding that not collaborating has risks for their respective real-world objectives for rangeland management, especially on public lands. Stakeholders said the project was a potential model for future collaborative projects in rangeland management and that they appreciated being able to work together in an experiment to make decisions with resulting outcomes on ranch scales over a long (10-year) time frame. The importance of participatory processes in facilitating the development of trust among stakeholder group members, as well as between stakeholders and researchers, is a key aspect of project success.

Many other examples of CAM have emerged from nonexperimental settings to deal with more controversial management issues under more complex institutional constraints than those at play in the research-based CARM project. The challenges of integrating multiple disciplines and stakeholders' experiential knowledge and management objectives in long-term CAM processes are well documented (Hopkinson et al. 2017; Susskind et al., 2012). Our findings are consistent with previous recommendations that CAM projects employ strategies to facilitate shared learning and fact-finding processes over the long term and to

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adapt and improve CAM processes and procedures over time (Susskind et al., 2012; Beratan, 2014; Hopkinson et al., 2017). The design of CARM as a research project removes some of the political and social complexities at play in other CAM projects but reveals social learning processes and potential personal and professional benefits of stakeholders' engagement in greater detail.

While our qualitative analytical approach documents social learning and decision making, it is based on initial results from a single case study and precludes generalization to CAM processes for decision makers with greater levels of uncertainty or risk outside of an experimental setting. The stakeholders in this group were intentionally selected at the exclusion of others who may have been less willing to collaborate or compromise. The amount and breadth of ecological monitoring data provided by the researchers to stakeholder decision makers could also be cost prohibitive in other contexts. Conversely, the availability of substantial amounts of monitoring data that required nuanced interpretation, and that led to differing conclusions regarding the role of fire in rangeland management, showcases how improving the amount and quality of monitoring in CAM will not necessarily resolve uncertainty in a linear, consistent manner.

Implications

Key lessons learned from the CARM experiment can inform future CAM projects attempting to link rangeland researchers and managers through the coproduction of actionable rangeland research and knowledge. First, the CAM process makes visible, but does not reconcile differences between, stakeholder knowledge and ways of knowing about complex rangeland systems. On the basis of our observations of stakeholder decision making, particularly related to cattle rotation and prescribed fire decisions, a complete collective understanding of a system among diverse stakeholders is unlikely using experimentally derived information alone. A more realistic expectation may be to use CAM, in part, to build awareness and appreciation for the diverse ways of knowing about rangeland management. We recommend CAM practitioners facilitate explicit discussion and consideration of different reasoning for management actions and include stakeholders in project design and monitoring data collection and presentation. Best practices include frequent discussions of the rationale for decisions, presentations of multiple information sources, and focus groups or tours that encourage sharing participants' ways of knowing and experiences. This process increases the probability of making the decisions on the basis of the broadest range of available information, rather than exclusively using scientifically derived knowledge. Increased awareness of differing stakeholder perspectives may also enable project coordinators to address data gaps or identify testable hypotheses. It may also contribute to the long-term development of management-relevant knowledge that is founded on a shared recognition for the diversity of ways of being and knowing and interests in multiple rangeland management outcomes that exist among participants.

Second, our data suggest that the development of trust among stakeholder and researcher groups may improve social learning in CAM by increasing the transparency of unique stakeholder experiences and epistemologies. Building new, actionable management knowledge for multiple rangeland objectives may take a great deal of time, as well as ongoing efforts to sustain stakeholder engagement and celebrate project successes (Cheng and Sturtevant, 2012). In the case of the CARM experiment, interviews indicated that the development of stakeholder trust over time facilitated engagement and commitment from stakeholders and researchers to work toward a common goal. The building of trust among group members is necessary for the CAM process to effectively facilitate adaptive management (Cheng and Mattor, 2010; Cheng et al., 2011), especially when diverse stakeholders are required to interpret multiple forms of data to support multiple management options. We recommend that CAM project timelines extend beyond typical (3- to 5-yr) research funding cycles and include long-term commitment from researchers. We also suggest that CAM projects provide funding to support the participation of self-employed producers to offset an inequality in cost for attendance at meetings within diverse stakeholder groups. CAM efforts should also plan for adequate time to develop stakeholder trust through attention to stakeholder concerns and personal needs and limitations.

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References

Allen, C.R., Gunderson, L.H., 2011. Pathology and failure in the design and implementation of adaptive management. Journal of Environmental Management 92, 1379–1384.
Argyris, C., 2002. Double-loop learning, teaching, and research. Academy of Management Learning Education 1, 206–218.
Armitage, D.R., Plummer, R., Berkes, F., Arthur, R.I., Charles, A.T., Davidson-Hunt, I.J., Diduck, A.P., Doubleday, N.C., Johnson, D.S., Marschke, M., McConney, P., Pinkerton, E.W., Wollenberg, E.K., 2009. Adaptive co-management for social-ecological complexity. Frontiers in Ecology and the Environment 7, 95–102.
Arnold, J.S., Fernandez-Gimenez, M., 2007. Building social capital through participatory research: an analysis of collaboration on Tohono O'odham tribal rangelands in Arizona. Society and Natural Resources 20, 481–495.
Ballard, H.L., Belsky, J.M., 2010. Participatory action research and environmental learning: implications for resilient forests and communities. Environmental Education Research 16, 611–627.
Behnken, J.A., Groninger, J.W., Akamani, K., 2016. Institutional constraints to collaborative ecosystem management within a wetlands conservation partnership. Journal of Contemporary Water Research Education 158, 19–33.
Bement, R.E., 1969. A stocking-rate guide for beef production on blue-grama range. Journal of Range Management 22, 83–86.
Bennett, J.W., 1971. Northern plainsmen: adaptative strategy and agrarian life. Transaction Publishers, New Brunswick, NJ, USA, p. 334.
Bennett, N.J., 2016. Using perceptions as evidence to improve conservation and environmental management. Conservation Biology 30, 582–592.
Beratan, K.K., 2014. Summary: addressing the interactional challenges of moving collaborative adaptive management from theory to practice. Ecology and Society 19. http://dx.doi.org/10.5751/ES-06399-190146.
Bixler, R.P., 2013. The political ecology of local environmental narratives: power, knowledge, and mountain caribou conservation. Journal of Political Ecology 20, 273–285.
Black Elk, L., 2016. Native science: understanding and respecting other ways of thinking. Rangelands 38, 3–4.
Blackman, D., Connelly, J., Henderson, S., 2004. Does double loop learning create reliable knowledge? The Learning Organization 11, 11–27.
Blackmore, C., Ison, R., Jiggins, J., 2007. Social learning: an alternative policy instrument for managing in the context of Europe's water. Environmental Science Policy 10, 493–498.
Boholm, Å., 2009. Speaking of risk: matters of context. Environmental Communities 3, 335–354.
Bouwen, R., Taillieu, T., 2004. Multi-party collaboration as social learning for interdependence: developing relational knowing for sustainable natural resource management. Journal of Community Applied Society Psychology 14, 137–153.
Brennan, L.A., Kuvlesky Jr., W.P., 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management 69, 1–13.
Briske, D.D., Derner, J., Brown, J., Fuhlendorf, S., Teague, W., Havstad, K., Gillen, R.L., Ash, A.J., Willms, W., 2008. Rotational grazing on rangelands: reconciliation of perception and experimental evidence. Rangeland Ecology Management 61, 3–17.
Briske, D., Sayre, N.F., Huntsinger, L., Fernandez-Gimenez, M., Budd, B., Derner, J., 2011. Origin, persistence, and resolution of the rotational grazing debate: integrating human dimensions into rangeland research. Rangeland Ecology Management 64, 325–334.
Brunson, M.W., Burritt, E.A., 2009. Behavioral factors in rotational grazing systems. Rangelands 31, 20–25.
Bryant, A., Charmaz, K. (Eds.), 2007. The Sage handbook of grounded theory. Sage, London, England, p. 623.
Budd, B., Thorpe, J., 2009. Benefits of managed grazing: a manager's perspective. Rangelands 31, 11–14.
Charmaz, K., 2006. Constructing grounded theory: a practical guide through qualitative research. Sage, London, England.
Cheng, A.S., Danks, C., Allred, S.R., 2011. The role of social and policy learning in changing forest governance: an examination of community-based forestry initiatives in the U.S. Foreign Policy Economy 13, 89–96.

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Cheng, A.S., Mattor, K.M., 2010. Place-based planning as a platform for social learning: insights from a National Forest landscape assessment process in western Colorado. Society of Natural Resources 23, 385–400.
Cheng, A.S., Sturtevant, V.E., 2012. A framework for assessing collaborative capacity in community-based public forest management. Environmental Management 49, 675–689.
Coppock, D.L., 2016. Cast off the shackles of academia! Use participatory approaches to tackle real-world problems with underserved populations. Rangelands 38, 5–13.
Cornwall, A., 2003. Whose voices? Whose choices? Reflections on gender and participatory development. World Development 31, 1325–1342.
Cornwall, A., Jewkes, R., 1995. What is participatory research? Social Science & Medicine 41, 1667–1676.
Cote, M., Nightingale, A.J., 2012. Resilience thinking meets social theory: situating social change in socio-ecological systems (SES) research. Progress in Human Geography 36, 475–489.
Cundill, G., Cumming, G.S., Biggs, D., Fabricius, C., 2012. Soft systems thinking and social learning for adaptive management. Conservation Biology 26, 13–20.
Cundill, G., Rodela, R., 2012. A review of assertions about the processes and outcomes of social learning in natural resource management. Journal of Environmental Management 113, 7–14.
de Loë, R.C., Murray, D., Simpson, H.C., 2015. Farmer perspectives on collaborative approaches to governance for water. Journal of Rural Students 42, 191–205.
Derner, J.D., Lauenroth, W.K., Stapp, P., Augustine, D.J., 2009. Livestock as ecosystem engineers for grassland bird habitat in the western Great Plains of North America. Rangeland Ecology & Management 62, 111–118.
Edelenbos, J., van Buuren, A., van Schie, N., 2011. Co-producing knowledge: joint knowledge production between experts, bureaucrats and stakeholders in Dutch water management projects. Environmental Science Policy 14, 675–684.
Evely, A.C., Pinard, M., Reed, M.S., Fazey, I., 2011. High levels of participation in conservation projects enhance learning. Conservation Letters 4, 116–126.
Fabricius, C., Cundill, G., 2014. Learning in adaptive management: insights from published practice. Ecology Society 19, 29.
Fernandez-Gimenez, M.E., Huntington, H.P., Frost, K.J., 2006. Integration or co-optation? Traditional knowledge and science in the Alaska Beluga Whale Committee. Environmental Conservation 306–315 null.
Fuhlendorf, S.D., Engle, D.M., Elmore, R.D., Limb, R.F., Bidwell, T.G., 2012. Conservation of pattern and process: developing an alternative paradigm of rangeland management. Rangeland Ecology & Management 65, 579–589.
George, A.L., Bennett, A., 2005. Case studies and theory development in the social sciences. MIT Press, Cambridge, MA, USA, p. 325.
Gianotti, A.G.S., Duane, T.P., 2016. Learning to listen: how collaborative dialogue in regulation influences landowner adoption of best management practices on unregulated lands. Environmental Plan. C: Policy Space 34, 320–339.
Glesne, C., 2011a. Becoming qualitative researchers: an introduction. 4th edition. Longman, White Plains, NY, USA.
Glesne, C., 2011b. Becoming qualitative researchers: an introduction. 4th ed. Pearson, Boston.
Gow, D.D., Vansant, J., 1983. Beyond the rhetoric of rural development participation: how can it be done? World Development 11, 427–446.
Gunderson, L.H., 2000. Ecological resilience—in theory and application. Annual Review Ecology Systems 425–439.
Haraway, D., 1988. Situated knowledges: the science question in feminism and the privilege of partial perspective. Female Studies 14, 575–599.
Harrison, C.M., Burgess, J., Clark, J., 1998. Discounted knowledges: farmers' and residents' understandings of nature conservation goals and policies. Journal of Environmental Management 54, 305–320.
Hart, R.H., Ashby, M.M., 1998. Grazing intensities, vegetation, and heifer gains: 55 years on shorgrass. Journal of Range Management 51, 392–398.
Holling, C.S., Meffe, G., 1996. Command and control and the pathology of natural resource management. Conservation Biology 10, 328–337.
Hopkinson, P., Huber, A., Saah, D.S., Battles, J.J., 2017. A word to the wise: Advice for scientists engaged in collaborative adaptive management. Environmental Management 69, 752–761.
Hovick, T.J., Elmore, R.D., Fuhlendorf, S.D., Engle, D.M., Hamilton, R.G., 2015. Spatial heterogeneity increases diversity and stability in grassland bird communities. Ecology Applications 25, 662–672.
Huang, R., 2014. RQDA: R-based qualitative data analysis, R package version 0.2-7. ed. Available at: http://rqda.r-forge.r-project.org/ March 1, 2016.
Jacobson, C., Hughey, K.F.D., Allen, W.J., Rixecker, S., Carter, R.W., 2009. Toward more reflexive use of adaptive management. Society for Natural Resources 22, 484–495.
Jordan, S., 2003. Who stole my methodology? Co-opting PAR. Global Society for Education 1, 185–200.
Kassam, K.-A., 2008. Diversity as if nature and culture matter: biocultural diversity and indigenous peoples. International Journal of Diverse Organizations, Communities, and Nations 8, 87–95.
Knapp, C.N., Fernandez-Gimenez, M.E., 2009. Knowledge in practice: documenting rancher local knowledge in northwest Colorado. Rangeland Ecology & Management 62, 500–509.
Knapp, C.N., Fernandez-Gimenez, M., Kachergis, E., Rudeen, A., 2011. Using participatory workshops to integrate state-and-transition models created with local knowledge and ecological data. Rangeland Ecology & Management 64, 158–170.
Leys, A.J., Vanclay, J.K., 2011. Stakeholder engagement in social learning to resolve controversies over land-use change to plantation forestry. Regulatory Environmental Change 11, 175–190.
Lincoln, Y.S., Guba, E.G., 1986. But is it rigorous? Trustworthiness and authenticity in naturalistic evaluation. New Directions for Program Evaluation 1986:73–84. http://dx.doi.org/10.1002/ev.1427.
Long, J.W., Ballard, H.L., Fisher, L.A., Belsky, J.M., 2016. Questions that won't go away in participatory research. Society for Natural Resources 29, 250–263.
McFadden, J.E., Hiller, T.L., Tyre, A.J., 2011. Evaluating the efficacy of adaptive management approaches: is there a formula for success? Journal of Environmental Management 92, 1354–1359.
Merriam, S.B., 2002. Qualitative research in practice: examples for discussion and analysis. Jossey-Bass, San Francisco, CA.
Morse, J.M., Barrett, M., Mayan, M., Olson, K., Spiers, J., 2008. Verification strategies for establishing reliability and validity in qualitative research. International Journal of Quality Methods 1, 13–22.
Munday, J., 2014. The practice of Feminist Focus Groups. In: Nagy Hesse-Biber, S. (Ed.), Feminist research practice: a primer. Sage, Thousand Oaks, CA, USA, pp. 233–263.
Muñoz-Erickson, T.A., Aguilar-González, B., Loeser, M.R.R., Sisk, T.D., 2010. A framework to evaluate ecological and social outcomes of collaborative management: lessons from implementation with a Northern Arizona Collaborative Group. Environmental Management 45, 132–144.
Nagy Hesse-Biber, S., 2014. Feminist approaches to in-depth interviewing. In: Nagy Hesse-Biber, S. (Ed.), Feminist research practice: a primer. Sage, Thousand Oaks, CA, USA, pp. 182–232.
Nykvist, B., 2014. Does social learning lead to better natural resource management? A case study of the modern farming community of practice in Sweden. Society for Natural Resources 27, 436–450.
Oeberst, A., Kimmerle, J., Cress, U., 2016. What is knowledge? Who creates it? Who possesses it? The need for novel answers to old questions. In: Cress, U., Moskaliuk, J., Jeong, H. (Eds.), Mass collaboration and education. Springer, Cham, Switzerland, pp. 105–124.
Ostrom, E., 1990. Governing the commons: the evolution of institutions for collective action. Cambridge University Press, Cambridge, England.
Petersen, B., Montambault, J., Koopman, M., 2014. The potential for double-loop learning to enable landscape conservation efforts. Environmental Management 54, 782–794.
Plummer, R., 2009. The adaptive co-management process: an initial synthesis of representative models and influential variables. Ecology Society 14, 24.
Provenza, F.D., 1991. Viewpoint: range science and range management are complementary but distinct endeavors. Journal of Range Management 44, 181–183.
Rathwell, K., Armitage, D., Berkes, F., 2015. Bridging knowledge systems to enhance governance of environmental commons: a typology of settings. International Journal of Commons 9, 851–880.
Reed, M.S., Evely, A.C., Cundill, G., Fazey, I., Glass, J., Laing, A., Newig, J., Parrish, B., Prell, C., Raymond, C., Stringer, L.C., 2010. What is social learning? Ecology and Society 15 (4): r1 [online] URL: http://www.ecologyandsociety.org/vol15/iss4/resp1.
Ritten, J.P., Frasier, W.M., Bastian, C.T., Gray, S.T., 2010. Optimal rangeland stocking decisions under stochastic and climate-impacted weather. American Journal of Agricultural Economy 92, 1242–1255.
Rudeen, A.K., Fernandez-Gimenez, M.E., Thompson, J.L., Meiman, P., 2012. Perceptions of success and the question of consensus in natural resource collaboration: lessons from an inactive collaborative group. Society and Natural Research 25, 1012–1027.
Robbins, P., 2006. The politics of barstool biology: environmental knowledge and power in greater Northern Yellowstone. Geoforum 37, 185–199.
Roux, D.J., Stirzaker, R.J., Breen, C.M., Lefroy, E.C., Cresswell, H.P., 2010. Framework for participative reflection on the accomplishment of transdisciplinary research programs. Environmental Science Policy 13, 733–741.
Sayre, N.F., 2017. The politics of scale: a history of rangeland science. University of Chicago, Chicago, IL, USA.
Schwandt, T.A., 2000. Three epistemological stances for qualitative inquiry: interpretivism, hermeneutics, and social constructionism. In: Denzin, K., Lincoln, Y. (Eds.), Handbook of qualitative research. Sage Publications, Thousand Oaks, CA, USA, pp. 189–214.
Shirk, J.L., Ballard, H.L., Wilderman, C.C., Phillips, T., Wiggins, A., Jordan, R., McCallie, E., Minarchek, M., Lewenstein, B.V., Krasny, M.E., 2012. Public participation in scientific research: a framework for deliberate design. Ecology Society 17, 29.
Stringer, L.C., Dougill, A.J., Fraser, E., Hubacek, K., Prell, C., Reed, M.S., 2006. Unpacking "participation" in the adaptive management of social–ecological systems: a critical review. Ecology Society 11, 39.
Susskind, L., Camacho, A.E., Schenk, T., 2012. A critical assessment of collaborative adaptive management in practice: collaborative adaptive management. Journal of Applied Ecology 49, 47–51.
Uphoff, N., 2002. Agroecological innovations: increasing food production with participatory development. Earthscan Publications, Ltd., London, p. 306 Routledge, NY, USA.
Uphoff, N.T., 1986. Getting the process right: improving irrigation water management with farmer organization and participation. Cornell University, Ithaca, NY, USA, p. 135.
Walker, P.A., Hurley, P.T., 2004. Collaboration derailed: the politics of "community-based" resource management in Nevada County. Society and Natural Resources 17, 735–751.
Weber, E., 2009. Explaining institutional change in tough cases of collaboration: "ideas" in the Blackfoot watershed. Public Administration Review 69, 314–327.
Wilmer, H., Fernandez-Gimenez, M.E., 2015. Rethinking rancher decision-making: a grounded theory of ranching approaches to drought and succession management. Rangeland Journal 37, 517–528.
Wilmsen, C., Elmendorf, W., Fisher, L., Ross, J., Sarathy, B., Wells, G., 2008. Partnerships for empowerment: participatory research for community-based natural resource management. Earthscan, London, England.
Yin, R.K., 2013. Case study research: design and methods. Sage Publications, Thousand Oaks, CA, USA, p. 153.

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