

DISSERTATION

CATTLE RANCHING ON THE WESTERN GREAT PLAINS: A STUDY OF ADAPTIVE
DECISION-MAKING

Submitted by

Hailey Wilmer

Department of Forest and Rangeland Stewardship

In partial fulfillment of the requirements

For the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Fall 2016

Doctoral Committee:

Advisor: Maria E. Fernandez-Gimenez

Justin D. Derner

Paul Meiman

Peter Taylor

Copyright by Hailey Wilmer 2016

All Rights Reserved

ABSTRACT

CATTLE RANCHING ON THE WESTERN GREAT PLAINS: A STUDY OF ADAPTIVE DECISION-MAKING

Ranching social-ecological systems (SESs) in the semi-arid, western Great Plains persist under highly variable inter- and intra-annual weather conditions and globally influenced markets. Ranch spatial scales and manager decision-making processes have traditionally been excluded from conventional grazing experiments, leading to considerable debate between scientists and land managers about grazing strategies to achieve both beef production and biodiversity conservation outcomes on rangelands. In this dissertation I use collaborative, interdisciplinary methodologies to link rangeland and grazing management decision-making processes and learning with ecological outcomes in the semi-arid rangeland social-ecological systems (SESs) of Wyoming and Colorado.

Chapter 2 analyzes relationships between ranchers and rangeland ecosystems, inspired by the rise of adaptive management discourses in the natural resource management literature and informed by post-colonial and feminist scholarship. Rancher decision-making processes during and after drought can be understood through an ethic of care, as ranchers try to reduce social and ecological vulnerability through adaptation, learning, and respect over long-term (generations-long) time frames. Chapter 3 follows a participatory grazing research project, the Collaborative Adaptive Rangeland Management (CARM) experiment, for four years (2012-2016). I track the social learning processes of a group of 11 stakeholders representing 3 groups: ranchers, conservation NGOs, and public agencies. These stakeholders manage 10 experimental pastures in the shortgrass steppe with comparison to the traditional grazing management practice. These pastures are managed to maintain or improve a viable cattle

operation, grassland bird diversity, and rangeland vegetation structure, composition, and cover. Decisions by the stakeholder group about grazing and prescribed burning illustrate the complex role of existing management knowledge in social learning and the outcomes of participatory rangeland research.

In Chapter 4, I use repeated interviews and ecological monitoring on 17 family-owned and operated ranches in eastern Colorado and eastern Wyoming to categorize different grazing management strategies and compare plant species composition outcomes across those different strategies, accounting for environmental factors. After accounting for environmental influences, using non-metric multidimensional scaling and linear mixed models, I found a reduction of perennial cool-season grasses on ranches in higher grazing stocking rates and on cow-calf/yearling operations compared to cow-calf operations, but no significant differences in plant species composition on ranches with different grazing rotation strategies or different planning styles (tacit vs. explicit planners). I classified ranches into adaptive cycle trajectories to interpret ranch decision-making in terms of ranch SES-scale resilience. In Chapter 5, I review critical social literature to reflect on my positionality as a researcher, as well as the importance of consent and respect in social-ecological research.

Findings in this dissertation provide useful information for understanding the adaptation of ranch-scale rangeland SESs. Future research or outreach projects seeking to engage with rancher stakeholders may be improved by considering complex decision-making processes, caring practices, and the stewardship ethic of ranchers. Future efforts to bring multiple public-lands stakeholder groups with different management perspectives together for adaptive management will be improved if they consider the important role of stakeholder practices and experiences with rangeland management in social learning, and commit to building trust

and knowledge through engagement that extends beyond the typical 3-5 year window for grazing research projects. My investigation of ranch-SES adaptive processes illustrates diverse decision-making strategies on different ranches. More research is needed on stocking rate decision-making, including around the social and political contexts of stocking rate decisions. This work suggests that a resilience lens can contribute to existing theory on ranch adaptive decision-making. Outreach and education efforts are likely to be more successful if they consider that one size does not fit all for ranch grazing management strategies.

ACKNOWLEDGEMENTS

This research was sponsored by ARS-USDA, grants from USDA AFRI award 2009-04442; USDA ARFI award 2012-38415- 20328; Colorado Agricultural Experiment Station project COLO0698; and the Center for Collaborative Conservation fellows program.

This was truly a collaborative effort. Emily Kachergis established the ranch visit case study project in 2012 and mentored me in social and ecological research. Pam Freeman was the lead biological technician on the ranch visit study and contributed invaluable support with data collection and entry. Matt Mortenson, Jeff Thomas, and Melissa Johnston, were lead biological technicians on the CARM project, and Nick Dufek and David Smith provided incredible input. Savannah Warwick, Tamarah Plechaty, Tanner Craigmile, Thadd Strom, Ahmad Alamad, Alicia Meyers, Elisa Dolan, Laina Baltic, Maggie Gannon, Matt Mortenson, Shakota Dilley, Ian Blackburn, Averil Reynolds, Grace Woodmansee, Tanner Large, and Andrew Mainini, and others contributed excellent field data collection and research assistance. Kyler Sherry always knew where we were. John Wendt organized data and inspired everyone. Nick Dufek's weekly email updates informed process tracing for Chapter 3. Jeff and Jake Thomas and Craig Lawrence taught me all I know. Nicole Kaplan conducted data management and kept the good tunes rolling. Billy Armstrong lent GIS expertise. Jen Ackerfield assisted with plant identification. NRCS soil and range gurus Clark Harshbarger and Josh Saunders volunteered their time to train the crew. The Crow Valley Livestock Cooperative and Weld County Livestock Association also supported this project. Randy Reichert at the Forest Service supported field work and volunteered his time for project outreach.

At the Colorado State Rangeland Social-Ecological Systems Lab, Shayan Ghajar gave me the idea for Chapter 2. Tungaa Ulambayar, Khishig Jamiyansharav, Crystal and John Tipton,

Chantsaa Jamsranjav, Kevin Jablonski, Aramati Casper, Arren Mendezona Allegretti, and Chris Dickey provided friendship and all-round social-ecological support. Jen Timmer helped me stay sane. Retta Bruegger reminded me to go crazy once in a while.

Sincere thanks to Madeleine Lecocq. Natalie Anderson taught me how to write loops and almost throw loops. Buck Crockett taught me to self-support. Thanks also to Octavius Jones for valuable feedback and Namu Temanju for her optimism and for reviewing a draft.

Thanks to Ken Tate and Leslie Roche for feedback on conference presentations and posters. From CSU faculty, Robin Reed set the bar high, Roy Roath provided wisdom, Monique Rocca taught me R, Louise Jennings and Caridad Souza pushed me to become a better qualitative researcher. Peter Taylor and Paul Meiman challenged me to think about methods, power, reciprocity, and grazing exclosures. And Phil Turk is just an incredible guy.

Thanks for love and support from my MT crew: my Red-neck Ants Pants parents, Julie and Bill Kennedy, Art Wilmer, tight-wad cattle-trader and nail straightener Brad Palmer and his wife Deb. Ben O. Williams (a Leopold in his own right) gave us two, yes, two big-runnin' Brittany puppies just to keep me busy. Thanks for support from Caroline Lamar, and the Rams Horn Hotshots, particularly barstool biologist Kayla Mount. Thanks also to my husband Sam Cannon for being on my team, trading his copy of *Orientalism* for my torn-up copy of *The Monkey Wrench Gang*, and taking care of Thunder while I wrote. And for deleting all those commas.

The project could not have been possible without the collaboration of 17 ranching families and 11 stakeholders (identities confidential), including those who welcomed me into their families (even if that meant I got teased for not wearing flip flops). Thanks to those who

challenged the stereotypes, who lived in multiple worlds and even in multiple centuries, and to those who know that *everything is better with some cows around*.

Thanks also to the fellow Western Montana Democrat who shared with me countless hours of great conversation at that Waffle House by I-25. And thanks to Hector for waiting in the car the whole time.

Any young scientist would be so lucky to be surrounded by mentors and scholars as the ones who have welcomed me into “Team AGM.” Thank you to David Briske for venturing into the social sciences; Justin Derner for letting me use a drip torch, asking tough comp exam questions and taking on a green-broke horse at the Hub; famous ecologist David Augustine for arguing with me about science and knowledge, and for asking random people he meets “What is your relationship with rangelands?” Many thanks to Lauren Porensky for incredible leadership, methods help, and insight into collaborative research. Thank you to my advisor, Maria Fernandez-Gimenez, a “transdisciplinary woman warrior,” poet, shepherd, pioneer, and boundary spanner who has been a patient and inspiring bulldozer for the last four years.

This dissertation is dedicated to the memory of the old timers: Walt Stebbins, Bill Kennedy Sr., and Nelson Starkweather; and to the short-timers: Kip Rand, Carol Brawner, and Hunter Bossler.

Great thanks are also due to Leif Anderson for building this L^AT_EX document class, allowing me to meet the graduate school formatting requirements with no effort on my part.

TABLE OF CONTENTS

ABSTRACT	iv
ACKNOWLEDGEMENTS	vii
Chapter 1. Introduction	1
Chapter 2. “Sometimes there’s no good answer, sometimes it’s half-way in-between:” Human-Nature Relationships in Complex Ranching Systems	9
2.1. Introduction	9
2.2. Literature Review	15
2.3. Methods	23
2.4. Findings	26
2.5. Discussion	35
Chapter 3. Building Management-Science Partnerships through Collaborative Adaptive Rangeland Management	46
3.1. Introduction	46
3.2. Methods	50
3.3. Results	55
3.4. Discussion	71
3.5. Conclusion	74
Chapter 4. Adaptive Ranch Decision-Making In Resilient Rangeland Systems: A Social-Ecological Case Study from the North American Great Plains	76
4.1. Introduction	76

4.2. Methods	85
4.3. Results	96
4.4. Discussion	107
4.5. Conclusion	113
4.6. Recognition of Support.....	114
Chapter 5. The Problem of Speaking for Ranchers: Reflections on Methods and Subjectivity	115
5.1. The problem of Speaking for Others.....	118
5.2. Am I an Insider? An Outsider?	119
5.3. Conclusion	122
Chapter 6. Conclusion	123
REFERENCES	128

CHAPTER 1

INTRODUCTION

“Researchers and managers attempt to understand and better manage creative relationships among soil, plants, herbivores and human beings, but we have become increasingly separated from one another in our endeavors.” -
(Provenza et al., 2013, p. 6)

Cattle ranching is an agro-ecological livelihood and industry through which individuals and communities interact with and manage native and restored rangeland ecosystems and mixed crop/rangeland systems. In the North American Great Plains, native rangeland ecosystems are the diverse, but increasingly limited, extents of semi-arid northern mixed-grass prairie and shortgrass steppe (Epstein et al., 1998). These rangelands are highly grazing resistant due to a long evolutionary history of grazing (Milchunas et al., 1988). It was here that Euro-American capitalists made their largest investments in cattle ranching in the late nineteenth and early twentieth centuries (Dale, 1930). As geographer Nathan Sayre has documented, ecology and rangeland science arrived in the North American Great Plains not long after these cattle herds arrived in my study area, and the discipline grew up beside, and with input from, the federal public lands management agencies (Sayre, 2006, 2008, 2015).

I often wonder what science historian and philosopher Thomas Kuhn would think today if he could turn his attention to the field of rangeland science (Kuhn, 2012). What would he find if he located, in the scientific record, the innovative ways that rangeland science has built a body of knowledge around the role of large domestic herbivores as secondary producers on rangelands, and more recently, the ability of these animals and their human managers to engineer rangeland structures and ecological processes through grazing practices (Derner et al., 2009; Sayre et al., 2012)? In the time since the first “successful” grazing

management experiment (Sayre, 2015), (elements of which trace directly to this dissertation) rangeland science has been a part of 1) the rise and fall of the “golden era” of Extension at the Land Grant Universities (McDowell, 2001), 2) a massive colonial project and land ownership transfers through the Homestead and Dawes Acts (Deloria, 1969; Brewer et al., 2016), 3) continent-scale ecological and financial crisis and the establishment of the Taylor Grazing Act (Sylvester & Rupley, 2012; Huntsinger, 2016; Holleman, 2016), 4) post-war productivism (Wilson, 2001) and 5) the increasingly complex challenges of “The New West” (Kittredge, 1996; Sheridan, 2007). In this New West, rangeland science finds itself in era of altered climatic regimes (Joyce et al., 2013), globalizing commodity markets and shifting rural/urban demographics, and political environments characterized by heightened urgency around issues of biodiversity conservation (Valdez, 2015), ecosystem management for the provisioning of multiple goods and services (Huntsinger et al., 2010; Huntsinger & Oviedo, 2014), and conflict over public land use (Sheridan, 2007; Alagona, 2013).

If Kuhn were to examine rangeland science, he might note that the methodology of choice for scholars of plant-herbivore interactions and outcomes over the years has been the grazing experiment (Milchunas et al., 1994; Manley et al., 1997; Milchunas et al., 1998; Hart, 2001; Derner et al., 2008; Augustine et al., 2010, 2012; Irisarri et al., 2016; Porensky et al., 2016). Advancement in our understanding of complex, adaptive processes in diverse rangeland systems has been no small task, particularly given the behind-the-scenes complications that limit long-term experimental ecological research: limited long-term and stable funding for scientists and agencies, especially where decades can be needed to observe vegetation changes (Porensky et al., 2016; Irisarri et al., 2016), short-term (2-5 year) time frames for projects and graduate students, the challenges of achieving power and required replication for statistical

differences, and the topographic, ecological, and climate variability across treatments in heterogeneous ecosystems.

Kuhn might also find, somewhat apart from grazing research in the broad universe of academia, a small group of anthropologists, sociologists, economists, social psychologists, and historians busy in their own research, documenting and describing the cultures, decisions, and innovations of land managers, farmers, and ranchers (Bennett, 1971; Smith & Martin, 1972; Robbins, 2006; Brunson, 2012; Rimbey et al., 2015). Their methods have been largely observational, or based on questionnaires, and more recently, advanced economic modeling (Rimbey et al., 2015; Hamilton et al., 2016). These social scientists have contributed to our understanding of agricultural economics, community-based natural resource management, and Extension and technology transfer theory (Fernandez-Gimenez et al., 2006; Brunson & Huntsinger, 2008; Knapp & Fernandez-Gimenez, 2009; Brunson & Burritt, 2009; Brunson, 2012; Lubell et al., 2013; Fernández-Giménez et al., 2015; Roche et al., 2015b; Hamilton et al., 2016).

Even more rare in the scientific record, Kuhn would occasionally read the voices of the producers and managers themselves (Grissom & Steffens, 2013; Goodloe, 2013; Budd & Thorpe, 2009; Wilmer & Fernández-Giménez, 2016), but more often, those voices are hard to find, like those of the first cowboys, black slaves in New Spain, who developed horseback roping techniques and established the grazing ecology of continent's earliest cattle ranches (Sluyter, 2012). Who is to say what impact all this rangeland research has had on the daily lives of rangeland decision-makers: those working on and with the land as producers of food and fiber, stewards of natural resources, managers of wildlife habitat and clean water, consumers of rural lifestyle amenities, and as politicians and advocates for their communities?

If Kuhn went back through the papers and conferences, he would notice debates throughout the history of the field: through the 1950s, as rotational grazing practices gained popularity (Sampson, 1951; Heady, 1961), the late 1990s as Maria Fernandez-Gimenez and Mark Brunson began to teach and research in rangeland social science (Fernandez-Gimenez et al., 2005), and the late 2000s-present, in the latest iteration of the rotational grazing debate (Briske et al., 2008, 2011b; Provenza et al., 2013) and a focus on management practices that promote rangeland heterogeneity (Augustine et al., 2010; Fuhlendorf et al., 2012; Twidwell et al., 2013). In these debates, Kuhn would find disagreements about the proper way to interpret and apply experimental knowledge among scientists, and between scientists and managers. Sometimes practical and sometimes epistemological, these debates reflected the progress and complex growth of an applied ecological field. In addition, they mark adaptations of science to contemporary, and increasingly challenging and complex, research questions (Boyd & Svejcar, 2009).

Today, in the context of a complex, globalized world where conflict over resources emerge from multiple ecosystem management goals desired by society, grazing experiments and social observational studies working apart from one another cannot address our need for new rangeland management knowledge (Knapp et al., 2011; Kachergis et al., 2013). As Chapters 2 and 4 outline, recent debates concerning the efficacy of rotational grazing have revealed key gaps in our understanding of adaptive management in complex social-ecological systems (SESSs). Conventional grazing experiments have failed to account for management processes and time frames greater than a decade, whereas social methods have often over-emphasized innovation adoption and failed to account for complex, relational social processes (Briske et al., 2011b; Teague et al., 2013). With the need to understand rangelands as coupled social

and ecological systems, rangeland science has found itself in an almost classic Kuhnian crisis, with misaligned methods and research questions (Roche et al., 2015a).

Thus, rangeland science has taken up the task of identifying adaptive decision-making and research processes that link scientists and managers—cattle ranchers, conservation NGOs, government agencies and other decision makers—through shared opportunities for learning, listening and collaboration. The ability of rangeland researchers to capture the opportunities of this “post-normal” shift in methodology has important implications for rangeland ecosystems and for the humans who depend on them (Francis & Goodman, 2010; Bestelmeyer & Briske, 2012). While the development of the bricolage that is rangeland science has been slow in human terms, on the time scale of the prairies—measured in evolutionary and geologic terms—these ecosystems have undergone massive transformations overnight (Lauenroth & Burke, 2008).

The following chapters are an attempt to develop collaborative, adaptive rangeland science that responds to these challenges. Chapter 3 highlights early lessons of one such approach. Collaborative Adaptive Management (CAM) is a participatory, transdisciplinary approach that links diverse stakeholders in a formal, science-based processes of “learning by doing” (Susskind et al., 2012; Beratan, 2014a). As this case study of the Collaborative Adaptive Rangeland Management (CARM) experiment on the shortgrass steppe of Colorado illustrates, the CAM framework holds promise for creating novel contexts for social learning in contexts where multiple stakeholders have seemingly divergent goals for wildlife species and habitat, rangeland vegetation communities and structure, and soil diversity, and livestock (beef, sheep, bison, etc.) production. But like any decision-making or research framework, CAM is not

without limitations, including the same logistical challenges all grazing research faces, and the added dimensions of human relations and learning.

On-ranch social-ecological (mixed-methods) research is another tool for collaborative rangeland science. Research that involves both interviews and ecological monitoring can create opportunities for relationship building between scientist and manager communities, and challenge rangeland scientists to listen and, perhaps, even to hear, manager perspectives. Chapters 2 and 4 present data from a mixed-methods case study of 17 ranches in eastern Colorado (10) and eastern Wyoming (7)

Chapter 2 provides an in-depth analysis of ranchers' relationships with nature, inspired by the rise of adaptive management approaches in natural resource management. The chapter considers a parallel discussion of the role of humans in shaping ecosystem wildness in post-colonial and feminist scholarship. In this chapter, I review theoretical developments in natural resource management, and use repeated interview data collected during and after the flash drought of 2012 to interpret ranchers' decision-making processes as an ethic of care. This chapter traces specific management actions ranchers used to reduce social and ecological vulnerability through adaptation, learning, and respect over generations-long time frames.

Chapter 4 illustrates how a mixed-method, collaborative approach is capable of examining ecological outcomes of ranch management at temporal and spatial scales unattainable in conventional grazing experiments. In this chapter, I document the adaptation of ranch social-ecological systems at multiple scales, including broad spatial scales, across groups of ranches along a climatic gradient, and over long temporal scales, covering the lifetime of family ranches. I compare rangeland species composition outcomes of different management strategies, including tacit and explicit planning styles, grazing strategies (rotation), grazing

intensity (stocking rate), and operation type (cow-calf vs. yearling operations), and examine the adaptive trajectories of different ranches through qualitative analysis. This approach is complicated by the dynamic social processes of qualitative research, the constructions of human memory, and methodological contradictions that stem from working across multiple disciplines that tend to have different standards for scientific validity, objectivity, and generalizability.

Chapter 5 is my personal reflection on methodology and positionality. Social-ecological research is shaped by research subject position and human relationships. Part of the influence of social, including feminist, methodologies in my work is the need for ongoing reflexivity and a reconsideration of my own biases, goals, and interpretations of the data.

The concepts of participatory and collaborative research are not new (Uphoff, 1986). I have had the privilege to be mentored by scientists who have dedicated their careers to collaborative and participatory processes (Fernandez-Gimenez et al., 2006), as well as learning beside ecologists, economists, and stakeholders engaging with these ideas for the first time. The need for this collaboration is more important than ever. As I was conducting data quality assurance/control and analyzing the data for this dissertation in 2016, a group of people, some of whom presented themselves as “ranchers,” staged an armed standoff on a federal wildlife refuge in Oregon, motivated at least in part by their interpretation of recent conflict between public rangeland stakeholders (Gallaher, 2016). Social media and news reports of the standoff painted a very different image of public lands stakeholders than the attitudes and management choices reflected in my data. But as one rancher in my study noted, *“Folks who are trying to work together never make the news.”* The following chapters reflect what I hope can be a collaborative turn in rangeland science, an effort by scientists to find methods

to listen, learn, and contribute to the advancement of rangeland management knowledge in a way that builds bridges between diverse stakeholders and their desired goals and objectives.

CHAPTER 2

“SOMETIMES THERE’S NO GOOD ANSWER, SOMETIMES IT’S HALF-WAY IN-BETWEEN:” HUMAN-NATURE RELATIONSHIPS IN COMPLEX RANCHING SYSTEMS

2.1. INTRODUCTION

The ability of cattle ranchers to navigate dynamic human-nature relationships has implications both for the function of rangeland ecosystems and the viability of rural communities. In the semi-arid Western Great Plains of North America, ranchers manage extensive beef production operations under high levels of complexity and uncertainty. Here, ranchers rely on forage from biologically diverse, native short- and mixed-grass prairies, restored rangeland and mixed irrigated cropping and rangeland systems, held through a patchwork of public (state and federal) and private ownership. In these water-limited and highly erratic precipitation environments, cattle production outcomes are affected by extreme weather events, such as drought, and by variability in the amount, timing, and intensity of precipitation within and among years (Reeves et al., 2013). Ranchers must also consider the influence of socio-cultural and economic relations on their rangeland resources, communities, and largely family-owned businesses that drive changes in cultural and economic understandings of human-nature relationships across spatial and temporal scales (Huntsinger et al., 2012; Brunson, 2012). These relationships involve wildlife and public lands regulation (Huntsinger et al., 2012; Charnley et al., 2014), changing social demands for meat production and globalization (Easdale & Domptail, 2014), market integration (MacDonald & McBride, 2009; Thornton, 2010), oil and gas development (Allred et al., 2015; Kreuter et al., 2016), shifting land uses towards amenity

ranching, non-production uses, and urbanization (Gosnell et al., 2006), and climate change (Joyce et al., 2013).

This chapter addresses the idea that rangeland management practices embody complex human-nature relationships in highly complex rangeland landscapes (Boyd & Svejcar, 2009). Following an introduction to adaptive decision-making in rangeland ecosystems that justifies a grounded study of ranchers' perceptions of human-nature relationships, the chapter reviews existing efforts to deconstruct human/nature dualisms, including social-ecological systems (SES) theory. In the second section, I present data collected from repeated interviews with managers on six ranches in the western Great Plains of the US during and after the flash drought of 2012. These findings challenge academic conceptualizations of command and control and adaptive management as incomplete and over-simplified representations of human-nature relationships as lived by ranchers in complex rangeland SESs.

2.1.1. THE NEED TO UNDERSTAND RANCHERS' RELATIONSHIP TO NATURE. Natural resource management (NRM) scholars have acknowledged the interconnectedness of humans and their environments, and have turned their efforts toward identifying and supporting the capacity of managers to adapt (Brown, 2014; Bestelmeyer & Briske, 2012; Fernández-Giménez et al., 2015; Marshall & Smajgl, 2013). Adaptive management, often discussed within SES theory, has been offered an alternative to a "command and control" management paradigm (Holling & Meffe, 1996; Holling & Sundstrom, 2015). Rather than engineering inflexible management prescriptions and attempting to control variability in ecosystems, a complex adaptive systems approach recognizes, "works with," and learns about complexity and heterogeneity across spatiotemporal scales. While adaptive management was originally

developed as a technocratic solution to incorporating complexity into NRM, a more soft-systems approach (Reed et al., 2010; Cundill et al., 2012) that emphasizes social processes of learning and adaptation may inform rangeland management across spatiotemporal scales and groups of diverse stakeholders. The adaptive capacity literature provides a useful framework for understanding and promoting adaptation in rangeland systems, such as the ranches and ranching communities of the western Great Plains, where we recognize humans and ecological systems as interdependent and coupled (Glaser, 2006). Adaptation is a set of actions and decisions that enable people (whether individuals or groups) to persist in the face of current or future changes and shocks (Adger, 2006; Agrawal, 2010). The capacity to adapt is often analyzed in terms of Agrawal’s framework which considers management actions for adaptation (mobility, storage), the adaptation of assets (diversification, communal pooling), and institutional opportunities for adaptation (reciprocity and exchange) (Agrawal, 2010). Adaptive processes are interconnected because they co-evolve in SESs and are mutually reinforced (Fernandez-Gimenez et al., 2012; Fernández-Giménez et al., 2015). Social networks strengthen social capital and enable resource managers to spread risk across space, time, and asset class (Fernández-Giménez et al., 2015).

Marshall and colleagues examined graziers’ adaptations to climate risk and uncertainty at the level of the individual manager’s ability to adapt to change with four dimensions: 1) perceptions of risk and managing uncertainty, 2) planning, 3) learning and strategic skills, 4) flexibility and interest in change (Marshall & Smajgl, 2013; Marshall & Stokes, 2014). A survey of 240 cattle producers in Australia identified occupational identity, employability, networks, strategic approach, environmental awareness, dynamic resource use, and use of

technology to correlate with some aspect adaptive capacity. In addition, place attachment was negatively correlated with adaptive capacity (Marshall & Stokes, 2014).

Briske et al. (2015) have extrapolated Marshall's framework to the Western US, noting that the importance of risk management in terms of drought is reportedly quite low among US producers. The authors emphasized the importance of learning, enterprise reorganization, and emotional flexibility for beef producers as climate changes across the country, and highlighted that strategies such as conservative stocking rates, drought planning, changes in livestock breeds and species, changes in operational structure, and relocation are possible ways to adapt to climate change on rangelands. They also predicted continued changes in the national herd and livestock industry infrastructure through a feedback loop where fewer resources are available for adaptation as shifts in production undercut regional infrastructure and less flexible managers are left in one area while more adaptive producers relocate. This shift may accelerate as producers take advantage of favorable conditions created by climate change in different regions (Briske et al., 2015). Briske et al. (2015) also discussed the possible implications of the failure of adaptation, taking Marshall's lead in framing the discussion at the individual ranch level.

This turn in the NRM literature from framing the human-nature relationship as one of a struggle for control towards one of "learning to live with change" has coincided with a discussion of the gap between grazing research and manager experiences (Brunson & Burritt, 2009; Briske et al., 2011b). For example, one common point of agreement across the many papers and perspectives that have debated the appropriate application of rotational grazing is that adaptive decision-making is an important determinant of success in grazing management (Provenza et al., 2013; Teague et al., 2008).

While some have argued for increased control over grazing systems via precision grazing practices (Laca, 2009), researchers increasingly recognize the importance of managing for complexity (Provenza et al., 2013; Grissom & Steffens, 2013), through formal and informal processes of monitoring and learning. Briske et al. (2011b) note that “human dimensions” were not accounted for in grazing experiments, and it is possible that the adaptive management aspects of management frameworks (e.g. Holistic Resource Management) result in positive manager experiences and perceived ecological benefits (Briske et al., 2011a; Sherren et al., 2012; Briske et al., 2014). A number of ranchers and range managers have emerged in the borderlands between rangeland science and management with important insights into rancher practical knowledge of system complexity (Grissom & Steffens, 2013; Brunson & Burritt, 2009; Budd & Thorpe, 2009). Because rangeland science is primarily a biophysical field, and has emphasized ecological processes and functions, efforts to explain the gap between scientific recommendations for management and manager experiences have either lacked empirical data and appropriate social science theoretical framings entirely, or have over-generalized findings and policy recommendations (Briske et al., 2014).

During fieldwork for a larger study, the nuances of this science-management gap in ranch decision-making became hard to ignore. I repeatedly observed contradictions among the rangeland and NRM literature, my own experience, and initial findings from interviews I conducted with Colorado and Wyoming ranchers. In these interviews, ranchers explained how their practical knowledge and actions were poorly explained by scientific findings. They frequently contrasted their own experiences with information or advice they had been given by researchers or other technical sources which was, in their view, not applicable to their specific management contexts. Ranchers told me they were constantly adapting to biophysical and

cultural changes in their ranch management, even in day-to-day decision-making scenarios. As evidence of this adaptation, many of these ranches had been continuously managed by multiple generations of the same family.

Ranchers also relayed to me their concern for environmental stewardship, sometimes quoting American conservationist Aldo Leopold. Of particular interest was Leopold's discussion of the concept of community in his essay "The Land Ethic," whereby "...a land ethic changes the role of *Homo sapiens* from conqueror of the land-community to plain member and citizen of it. It implies respect for his fellow members and respect for the community as a whole." (Leopold, 1966, p. 203). At the same time, ranchers I interviewed said that the scientific community failed to understand their desire to earn a profit. They argued that their identities and life's work, and the function of ecological and cultural processes, were dependent on the financial viability of their respective operations. A sort of frugal risk-intolerance is celebrated in the traditions of ranching communities within highly variable ecological regions. For multigenerational ranching families, where one bad decision can mean a loss of the entire ranch, high risk-reward approaches such as operational diversity and flexible stocking rate, are not commonly embraced. This conservatism may not conform to traits desired for innovation and technology transfer (Rogers, 2010; Trauger et al., 2010) or fit within the economic modeling framework to optimize net returns (Torell, 2010).

This experience taught me that the "science-management" divide in grazing and rangeland research so often acknowledged in the literature and at conferences is more than a matter of miscommunication or different definitions of success. It is an epistemic and cultural distinction that requires careful, ethnographic attention (Fischer & Burton, 2014). This study documents the intersection of ecological complexity and ranchers' adaptive decision-making

processes from a grounded approach that considers how ranchers construct and act upon their understanding of complex rangeland systems (Schwandt, 2000; Boyd & Svejcar, 2009). My objectives for this study were to use repeated interviews with managers on 6 ranches in eastern Colorado (2) and eastern Wyoming (4) to 1) complicate human/nature dualism through an examination of rancher decision-making processes during drought, and 2) describe a framework for on-ranch management grounded in an empirical examination of rancher narratives.

2.2. LITERATURE REVIEW

2.2.1. DECONSTRUCTING HUMAN/NATURE DUALISMS.

“How simple our relationship with nature would be if we only had to choose between protecting our natural home and destroying it.”- Shepard (pg 63).

At the heart of discussion about how humans can best manage rangeland agroecosystems are tensions in the relationship between humans and their natural environments. While experimental data has helped to identify the factors that predict specific livestock or vegetation production outcomes from grazing systems (Derner et al., 2008), the specific contexts of ranch management culture and practices offer insight into working knowledge of grazed systems (Roche et al., 2015b). Rancher motivations and management paradigms can be understood as knowledge of how humans relate to nature in specific cultural ways. Rancher actions (from daily decisions and to strategic planning and cultural practices) embody that knowledge. This working knowledge informs how managers act in complex systems, and how complexity (via social relations and biophysical drivers) shifts system processes relative to manager goals.

The human-nature relationship has been subject to much theoretical development in the humanities, particularly from decolonial critics and feminist methodologists. Contemporaneous with the “adaptive turn” in NRM literature, postcolonial and feminist scholars have re-imagined theories of human-nature relationships by deconstructing the persistent Western forms of dualism that, they argue, maintain distorted views of difference so as to separate human and natural systems. In this section, I identify attempts to problematize or deconstruct human/nature dualisms with an emphasis on NRM. This review informs my empirical analysis of rancher interviews through a theoretical framework that complicates human/nature dualisms in particular ways. I consider Latour’s description of ‘Two Great Divides’ between humans, their environment and “Others”; postcolonial criticisms of ‘conservation as control’; mapping human power relations on landscapes; and feminist epistemologies and care ethics, which challenge rational/emotional and male/female dualisms. I also consider efforts of SES theory to better interpret human actors in complex systems so as to understand gaps in the theory that may be informed by my empirical analysis.

2.2.1.1. *One and the Other in many forms.* Ecology has long recognized the role of humans in shaping our natural environment (Vitousek et al., 1997; Hobbs, 2013), and this discussion has been enriched by the conceptualization of the “Anthropocene” and climate change (Sayre, 2012). But the discussions of how humans fit into ecosystem processes, or how SESs should be examined, also have a rich tradition in the humanities and philosophy, where human-nature relationships are considered as relations of power and knowledge. For example, Latour (1993) conceptualizes the Western vision of the human/nature dichotomy as “The Two Great Divides’ achieved through a process he refers to as ‘purification.’ The first (internal) great divide, “The Modern Partition,” splits culture and nature. The second

(external) great divide distinguishes this modern “us” from the premodern “them,”—those who cannot distinguish between nature and culture. Modernism, then, promises to free Westerners from the constraints of nature (via the first great divide) and from each other (via the second divide).¹ As Smith (1999) and Plumwood (2003) have noted, the human/nature dualism privileges human spheres (associated with reason) and treats non-human difference as inferior. By excluding and “othering” (Said, 1979) nature, emotion, women, and “primitive” peoples, this dualism takes many forms, from reason/emotion and mind/body divides to male/female, One/Other, West/East, objective/subjective and science/society (Willems-Braun, 1997; Cameron, 2003; Haraway, 2008).

There are several forms of othering within NRM discourses, particularly agricultural producers. This is a form of the human/nature dichotomy which perpetuates false rational/irrational or like us/like them categorizations, often between rural/urban, age or conservation/production borders (Stephenson, 2003). This includes the innovator/laggard split, which falsely divides managers with the resources and risk tolerance to adopt desirable practices from those who “fail to innovate” (Federico, 2005; Roux et al., 2006; Rogers, 2010). The old-timer/new generation distinction has risen out of concern for aging farming and ranching populations (Chiswell & Loble, 2015; Fischer & Burton, 2014) and research showing a correlation between age (and other factors) and innovation or conservation program adoption (Peterson & Coppock, 2001). The profit-oriented vs. amenity- and/or conservation-oriented dichotomy suggests that ranchers can either try to make a living or conserve rangeland

¹ Latour also describes the process of ‘mediation,’ or the creation of hybrids (quasi objects, or Haraway’s cyborgs) of nature and culture such as domesticated species. The problem is that modernist systems of knowledge and inquiry are so purified into distinct social and biophysical sciences, that the processes that create quasi objects (mediation) are ‘invisible, unthinkable, unrepresentable,’ (Latour, 1993, p. 34) even as it becomes apparent that modernism has not emancipated humans from the limits of our environment (or that ‘We have never been modern’ as Latour’s title suggests).

ecosystem and/or consume ranch amenities, (e.g. landscape aesthetics and rural lifestyles) (Gosnell et al., 2006; Abrams et al., 2012).

2.2.1.2. *Against conservation as control.* Decolonial scholars have spoken out against conservation and NRM approaches that control or simplify wild, complex systems, pointing out that human/nature dichotomies have been used to maintain both exploitive and preservation-oriented management paradigms and discourses around the world (Willems-Braun, 1997; Adams, 2003). This work has criticized “wilderness” as a concept that separates humans from place, challenged management paradigms of “conservation as control,” and celebrated the “wildness” and unpredictability of biophysical systems (Cameron, 2003). This thinking runs parallel to critique of “fortress conservation” (Hartter & Goldman, 2011; Duffy, 2016) and Fuhlendorf’s argument for a heterogeneity-based rangeland management paradigm which rejects efforts to simplify and homogenize complex and surprising rangeland systems through fire suppression and grazing management that promotes uniform vegetation structure across landscapes (Fuhlendorf et al., 2012). Dominant forms of ecological knowledge and approaches to NRM and conservation are products of violent colonial processes that artificially separated humans from their environments (Smith, 1999; Plumwood, 2003). Plumwood argues that human-centric approaches to understanding place (place includes landscapes and the relationship of various agents to those landscapes) deny intentionality and subject position of non-humans, limiting our understanding of the meaning of place (Plumwood, 2003, p. 69). Given the increased concern for environmental degradation and climate change Cameron (2003) asks if it is possible to motivate ecologically responsible decision-making based not on fear of ecological collapse, but on daily experiences, a love of place and the recognition

that experience of place is conditioned through intersecting social relationships of race, class, gender, sexuality, colonial position, age, and ability.

2.2.1.3. *Mapping human-nature relations.* Another approach to deconstructing false human/nature dichotomies (particularly science/society and native-landscape/non-native divides) is to demonstrate how human power relations shape and are shaped by landscapes and biophysical processes. Engel-Di Mauro (2014) has suggested ways to document the role of human power relations in pedology. Van Dyke (2015) similarly suggested that human-nature relations be mapped by connecting narratives of human relations to biophysical state-and-transition (STM) models. STM models identify multiple potential stable states of a given system and pathways and thresholds between those states (Bestelmeyer et al., 2003), but have conventionally only included human elements in terms of management actions (Van Dyke, 2015).

Sluyter (2002, 2012) has provided a more comprehensive mapping of human-nature relationships in his work on colonial processes in the tropical lowlands of Veracruz. He examined how elements of the system (native, non-native, and landscape, which are both material and conceptual) related through distinct, reciprocal conceptual and material process. He distinguished his approach from both environmental and culturally deterministic approaches defining “natives” apart from “landscape,” and describing the agency of each element (Sluyter, 2002). He discusses how colonial grazing ecology, informed by slaves’ animal husbandry and grazing knowledge, reshaped the landscape, and the diets, land use practices, and social relations of native and colonialists (Sluyter, 2002, 2012). Though Sluyter’s work stands out with specific consideration of beef production systems, contemporary consideration of colonialism and class struggle in shaping human-nature relationships is limited (Yeh, 2015)

but does occur across a number of fields and methodologies, particularly through the interaction of geography, political economy, and other biophysical sciences (Rocheleau et al., 2013; Meinzen-Dick & Zwartveen, 1998; Walker, 2005; Mortimore & Turner, 2005; Liao et al., 2014).

2.2.1.4. *Ways of Knowing and Ethics of Care.* The emotional/rational, body/mind conceptualization of the human/nature dichotomy is addressed by epistemologists concerned with the justification of knowledge. Growing interest in knowledge as social construction (Oeberst et al., 2016) has re-framed knowledge as a situated, embodied practice (Haraway, 1988). Feminists have recognized the role of every day experience and wisdom, and empathy, in intellect and decision-making (Haraway, 1988; Collins, 2002; Harding, 2006). Jaggar (2008) argues that the false dichotomy between “rationality” and “emotion” serves to separate us from our own senses and perceptions, from the knowledge that our emotions can help to produce, and in turn, from one another. In this vein, Kassam (2008) challenges whether conventional statistical methods are capable of measuring concepts such as biodiversity and language diversity because of the methods’ inherent tendency to homogenize diversity.

The embodied, place-based, and emotional knowledge farmers and ranchers practice, particularly in relationship with livestock, has also been documented (Fernandez-Gimenez, 2015; Herman, 2015). Scholars have recognized the distinct role of rural and agricultural livelihoods in shaping knowledge of natural systems (Harrison et al., 1998), and biological processes (Knapp & Fernandez-Gimenez, 2009; Bruegger et al., 2014), and that ranchers understand their relationships with livestock and their environments through a symbiotic stewardship (Ellis, 2013). Research on rancher local knowledge reflects a growing recognition of epistemology and methodology throughout practical ecology and conservation fields,

though researchers still struggle with concepts of epistemology and ontology, particularly in interdisciplinary research (Simberloff, 2004; Robbins, 2006; Yeh, 2015).

Feminist ethics of care have emerged from feminist and ecofeminist discussion of the links between the oppression of women and the oppression of nature and animals. Care ethics focus on relationships (Flanagan & Jackson, 1987; Herman, 2015; Larsen, 2016). This ethical framework emphasizes the role of connections over rules in morality, and relationships over individual moral judgement and principles (Gilligan, 1977). Care ethics have been used in discussions of a number of diverse topics, including human diet, environmental stewardship, and international relations (Curtin, 1991; Larsen, 2016). Tronto (1999, 2001), for example, identifies four phases of care, including caring about (recognizing a need for care), caring for (or assuming responsibility to care), caregiving (material tasks of care), and care receiving (response of the cared-for to such care).

2.2.2. THE RESILIENT DUALISMS OF SES. Another attempt to dismantle human/nature dualisms has emerged from SES theory and resilience thinking (Berkes et al., 2000b; Agrawal & Chhatre, 2011). Much of the popularity of this theory in practical ecology and natural resource management fields can be attributed to overt efforts to include humans in conceptualizations of ecosystem change (Berkes et al., 2000b), though human/nature dualisms persist.

SES theory attempts to deal with problematic human/nature dichotomies by raising a form of social, though not political, consciousness in two theoretical ways: 1) through the assertion that human systems are inextricably linked to ecological and biophysical systems, (Armitage et al., 2009), effectively inserting humans into ecological science in an unprecedented way; and 2) through a focus on resilience-based management that enhances the ability of systems

to cope with change (or disturbances) without shifting into undesirable states (Agrawal, 2010; Armitage et al., 2008, 2009; Marshall & Smajgl, 2013; Fernández-Giménez et al., 2015).

As Holling & Meffe (1996) have argued, much of SES adaptive capacity comes from the inherent variability within the system itself. They described the “pathology of natural resource management,” whereby managers, when surprised by system complexity, respond by trying to control unpredictability and to remove, to the extent possible, variability in the system. The result, Holling & Meffe (1996) asserted, is unforeseen consequences, such as a loss of biodiversity, more human conflict, and an overall loss of resilience. The alternative to this “command and control” approach is their “golden rule of natural resource management”: “managers should strive to retain critical types and ranges of natural variation in resource systems in order to maintain their resiliency” (Holling & Meffe, 1996, p. 328). The heart of this argument is that ecosystems (and interdependent social systems) are best able to face uncertainty and change when they are characterized not as homogenous and predictable, but as diverse and heterogeneous (Pickett et al., 2012).

SES theory has enabled important advances for conservation and ecological research to include human dimensions in research on complex systems (Berkes et al., 2000b). But SES theory fails to reject human/nature dualisms in two ways. First, SES theory remains politically unconscious. While SES holds that social, economic, and ecological changes occur on different spatiotemporal and social scales and at different speeds in integrated, “self-organizing” and “adaptive” ways, the capacity of both of human and non-human actors to take agency is not clear, particularly when resilience is framed as an inherent system property (Olsson et al., 2015; Yeh, 2015). Second, the management paradigm associated with resilience thinking and SES theory–adaptive management– can reinforce human/nature dualisms if trust, knowledge,

and power are not considered (Beratan, 2014a). While adaptive management can include stakeholder development of management objectives, models, alternatives, monitoring planning and decision-making, the process of uncertainty reduction is framed through formal scientific method with little overt discussion of other ways of knowing (Berkes et al., 2000a), and so reverts to a modernist divide between humans and nature, manifested this time as a dichotomy between society and culture (again, emotive, subjective) and science (rational, objective), that SES attempts to avoid (Armitage & Johnson, 2006; Crane, 2010; Cote & Nightingale, 2012; Stone-Jovicich, 2015).

Based on this review of the literature, my aim was to explore ranchers' adaptive decision-making processes from a grounded approach that considers how ranchers construct and act upon their understanding of complex rangeland systems (Schwandt, 2000; Boyd & Svejcar, 2009). My objectives were specifically to complicate human/nature dualism through an examination of rancher decision-making processes during drought and to describe a framework for on-ranch management grounded in an empirical examination of rancher narratives.

2.3. METHODS

2.3.1. METHODOLOGY AND RESEARCH SUBJECT POSITION. This study is informed by constructivist grounded theory and feminist oral history and ethnography methodologies. Constructivist grounded theory (Charmaz, 2006) is an updated grounded theory methodology that provides a systematic method for qualitative data collection and analysis based on the premise that knowledge and meaning are constructed through social processes. Feminist methodologies inform my approach to conducting interviews and shaping research findings (Opie, 1992). Feminist oral histories seek to understand rather than control oral histories and cultural knowledge. They apply specific methodological tools for recognizing the role of the

researcher and subject position in knowledge construction, addressing the ethical concerns of representing or speaking for others, and considering the transformative potential of research for both participants and researchers (Geiger, 1990).

Small sample size is justified because my aim is not to identify the statistical distribution or probability of particular actions or decisions, but to gather deep and nuanced qualitative information about ranchers' experience of social phenomena. The generalizability of the findings is purposefully limited to theoretical applications.

By placing authority to some extent in the hands of the informant, feminist oral history methodology seeks to disrupt the traditional participant-researcher relationship (Geiger, 1990). The majority of the data collection and analysis were conducted by me, though the a rancher collaborator co-produced a portion of the analysis. Allowing participants to shape their narratives, my method selection served to record insights into rancher decision-making that may not have been accessible through more structured questionnaires. However, this approach may create tensions in interpreting and presenting research findings because of researcher-participant relationships and the motivations of the broader research project (Geiger, 1990). In-depth interviews were enhanced by researcher reflexivity and reflection on my own motivations and dynamic subject positions (Geiger, 1990).

2.3.2. CASE SELECTION AND DATA COLLECTION. This study included extensive beef cattle operations that rely on forage from northern mixed-prairie in eastern Wyoming or shortgrass steppe in eastern Colorado for at least part of the year. Ranchers were invited to participate through a snowball sampling method that took advantage of existing research contacts. Participants self-identified as “ranchers” and were reliant on income from selling a calf crop, yearlings, or custom grazing (renting pasture to other ranchers), though they

received some income from farming, energy development, hunting revenue, or off-ranch income (Kachergis et al., 2014). The ranches ranged in size (including privately-owned land and public and private leases) from 1200 ha to 10,000 ha (5,000 ha average, though ranch size changed with various leases throughout the study). All operations included some public grazing leases, and three [Ranches 1,2,4] were highly dependent on their leases. All ranchers in the study were raised on ranches and completed some post-secondary education. Five of the six had operated at their current location for multiple generations. In 2012, interviewees on these ranches were all male and were ranch primary operators, though by 2015 two ranches were managed by co-operators (including one woman and her husband and a father/son team) and a third ranch was actively seeking a successor through a formal mentorship program (see Table 2.1).

2.3.3. DATA COLLECTION AND ANALYSIS. Data were collected under Colorado State University human subjects approval protocol 12-3381H. Semi-structured interviews were conducted with ranch managers in the summers of 2012 and 2014-2016. In 2012, ranchers were asked to describe their ranching operations, grazing management planning, responses to drought, management priorities, and definitions of success. In 2014 through 2016, managers were asked to describe any changes in management and the context and outcomes of those changes since their last interview. Participants were also asked to describe their relationships with nature as they would for a non-rancher audience. Additional supporting data included management plans, news articles, email correspondence, and field notes from participant observation, which occurred throughout the study. I audio recorded and transcribed interviews, took notes during the interviews and analyses, and kept an audit trail of research data and analysis during the study (Lincoln & Guba, 1985, 1986).

TABLE 2.1. Repeated interviews (2012, 2014 through 2016) were conducted with six ranchers in Colorado and Wyoming. Ecotypes: Northern Mixed-Prairie (NMP) or Shortgrass-Steppe (SGS).

Number	Ecotype	Public land dependence	Operation type	Multi-generational?	Heir?	Dependence on Haying
1	NMP	High	Cow/Calf, yearling	Yes	Yes	High
2	NMP	High	Cow/Calf, yearling	Yes	No	High
3	NMP	Low	Custom grazing	Yes	Yes	Low
4	SGS	High	Cow/Calf	Yes	Yes	Low
5	SGS	Low	Cow/Calf	No	No	Low
6	NMP	Low	Cow/Calf	Yes	No	High

While I was collecting data, I began initial coding (in RQDA), which involved labeling chunks of data for information that described ranchers’ relationships to nature and adaptive actions during drought (see Figure 2.1). I synthesized initial findings in a memo which received peer feedback from other rangeland and social scientists. I collaborated with a rancher to develop a conceptual model of ranch decision-making. Once all interviews were completed, I coded for analytic themes related to major changes in management, perceptions of success, decisions made during and after drought, as well as the social, economic, and cultural context of the ranch operation. I compared patterns from codes across the six ranches over time using a table and synthesized these patterns into a conceptual model, which I also compared to the original interviews for negative examples. Ranchers who had not participated in the study reviewed the conceptual framework and I made appropriate revisions based on their critiques.

2.4. FINDINGS

Analysis of repeated rancher interviews reveals the diverse perspectives of interviewees regarding their relationships with rangeland ecosystems, climate, socio-cultural, and economic dynamics. These perspectives were dynamic relative to drivers of system conditions during and between interviews.

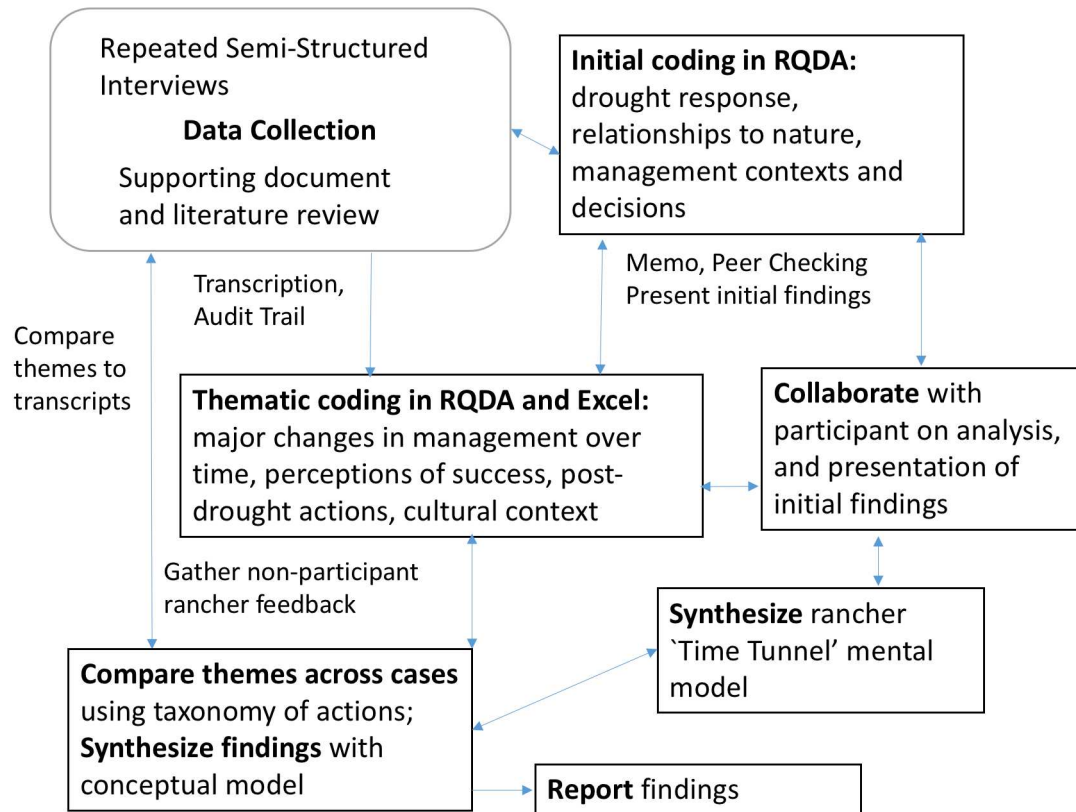


FIGURE 2.1. Iterative steps of qualitative data analysis.

I synthesize the results of the narrative analysis in two parts. First, I use rancher narratives of decision-making during and following drought to complicate the controlling/adapting dichotomy often discussed in NRM literature. Second, I describe the ethic of care, a conceptual framework that provides an alternative lens through which to understand rancher decision-making approaches. After describing the ethic of care as presented in rancher narratives, I illustrate the concept with a conceptual model developed in collaboration with one rancher in the study.

2.4.1. CONTROLLING NATURE VS. ADAPTING TO NATURE. Rancher narratives complicate the controlling vs. adapting dichotomy presented in the NRM literature. Ranchers

described understanding their management as decision-making within constraints of precipitation, wildfire, cattle health, wildlife behavior, topography, and variation in production, available water, vegetation species composition, and structural heterogeneity of ecological sites. The narratives demonstrate constraints on ranchers' abilities and need to control nature for the sake of their livelihoods. This need was expressed in terms of grazing management and the control of specific species.² Narratives of control that centered on grazing management emphasized the importance of managing cattle distribution to promote desired rangeland species composition, provide high quality forage, and limit time and labor required to gather or handle livestock. Ranchers who use intensive rotational grazing management (characterized by frequent cattle rotations, higher density of livestock, longer periods of rest and a larger number of pastures) reported benefiting from their ability to control cattle distribution and utilize forage species more evenly across broad areas of their ranches.

One Colorado rancher [Ranch 4] described his relationship with nature as one constrained by precipitation:

“Mother Nature sets our life. Whatever Mother Nature does is what we have to abide by, whether it's rain, snow, wind, hail, whatever, we have to adjust our lives around Mother Nature. That's been, we've had to do that forever. The old, old-timers, they learned about Mother Nature, blizzards coming in and they didn't have any hay stockpiled. They thought on the open range their cattle were fine. Well, they lost thousands of cattle. Mother Nature tells you exactly what to do. If it don't rain, you don't have grass for cows. You try to conserve or plan ahead, but you're conserving some so you can stay in business, but without Mother Nature you don't have a life. I don't care whether you're farming, ranching, living in town with a garden or what.”

²Species specifically included elk in Wyoming and prairie dogs and grasshoppers in Colorado, though one rancher, who received income from hunting, also noted the benefits of his grazing management to elk on his ranch.

This rancher’s narrative illustrates a theme found across the rancher interviews: a recognition of how little agency ranchers had in managing system variability, particularly in the timing and amount of precipitation. This vulnerability in turn shaped both a need for reduced uncertainty through learning and a management paradigm of adaptation. Across the interviews, ranchers acknowledged that their livelihood strategies might strain rangeland resources, but tried to limit where and how often they “pushed” the rangeland ecosystem for beef production objectives. As one said [Ranch 3], “The philosophy is to not push it on an average [precipitation] year.” Ranchers also described efforts to learn and to facilitate “healing” following periods of stress and shock such as drought and/or overgrazing (see next section). Thus, actions that might “command and control” nature in order to improve short-term profit are culturally constrained by an understanding of potential long-term change.

2.4.1.1. *Drought and Recovery.* Ranchers described striking a balance between controlling and adapting to system variability. In this section I illustrate this complexity by describing diverse management responses across the interviews.

In dry years, ranchers dealt with trade-offs between selling their cattle at depressed prices or buying expensive hay. In describing his deliberation in 2012, one Wyoming rancher [Ranch 2] referred to the perceived resilience of the rangeland ecosystem, as well as the value of the culture and genetics of his mother cows. He settled on a course of action that balanced the most limited cull possible, some overgrazing, and limited hay purchase:

“You can’t just say ‘Oh yeah we’re going to leave 50 percent of the grass.’ There are a lot of years we’ve got to use 70 or 80 percent. Or you go buy some extra land or ship your cows to Kansas. You’ve got to find a way to [maintain] financial [viability], and you know sometimes, just like buying two hundred ton of hay or keeping the cows? That’s one of those tough ones where you lay awake at nights going... and sometimes there’s no good answer, and sometimes its half-way in-between. Which is kind of what I’m

planning, not buy as much hay, but we're going to have to buy some. Cull the cow herd down but we've got to have enough cows to pay the mortgage payment a year from now. But you always, on the good years, you think well, just like my Dad saying we've got to rest the deeded land north of the Forest because it carried us through the last drought. Well, that paid off, and I can see that, so now next year or the year after, I'm going to give it a rest."

In 2013, this rancher acted on a heuristic that the ranch should heal after drought, a philosophy developed during years of experience and time spent learning and managing the ranch with his father. He leveraged opportunities to lease a second ranch and rest his own private land and public land lease for an entire growing season.

Over the course of the study, another Wyoming rancher [Ranch 3] re-organized his business from a cow-calf operation to a high intensity, short duration custom grazing business. He settled into an operation with more yearling cattle than mother cows and little need for winter feeding or hay production. He described the constraints of winter feeding and buying winter forage inherent in maintaining his own cow-calf herd and the increased control he had over his time, grazing management, and overhead expenses provided by his new system. The change in his operation was enabled by support from his social networks, but triggered by limited forage availability following a wildfire and extended drought. He described observing indicators that his approach allowed his pastures to recover from grazing such as the development of below-ground biomass and natural re-seeding. He said his management had improved the resilience of the beef operation to drought because he was able to cull less deeply during severe droughts than the previous generation had done.

Other ranches coped with drought by relaxing efforts to control grazing distribution. In 2012, one Wyoming ranch [Ranch 1] was a high intensity-short duration operation that leased yearling pasture to other ranchers. By 2014, the same ranch was being operated by a sibling

of the 2012 interviewee. The new operator simplified the grazing management, moved away from high intensity short duration grazing on irrigated hay meadows and re-aligned livestock distribution with topographic and forage species variation across the landscape. The rancher attributed this shift to the slow decline of ranch profitability during long-term drought in the mid-2000's, the increased complexity of management under the high intensity system, and a poorly timed investment in yearling cattle preceding a drop in the cattle market. In 2014 and 2015, the ranch re-purchased haying equipment sold prior to drought, moved calving locations and timing to limit calf mortality, and began to experiment with changes in the timing of weaning and shipping of calves. These ranchers emphasized the limitations of intensive management of cattle distribution in rugged topography under highly variable precipitation.

In 2012, one Colorado rancher [Rancher 5] was among the most intensive grazing managers in his local grazing association, attributing his approach to interest in improving species composition on his shortgrass pastures. In 2012 and 2013, drought, grasshoppers and low cattle prices strained this approach, and the rancher coped with forage deficits by moving towards season-long grazing, selling many of his mother cows, putting calves on foster mothers, and relying more on forage crops. This rancher's approach to management was proactive heading into late summer 2012, and included detailed descriptions of his attempts to prepare for drought and swings in the cattle market. In 2014 and 2015 interviews, his descriptions of proactive decision-making, however, shifted to a narrative of coping and humility in the face of "Mother Nature".

As these examples illustrate, the ranchers' narratives of control are nested within complementary, even contradictory, discussions of coping and adaptation to weather, livestock behavior and biology, and rangeland productivity. Ranchers described their relationship

with nature as interdependent and intimate. Their ability to maintain their livelihoods and identities was linked to management actions that took full advantage of resource opportunities while mitigating weather and market risks through conservation strategies and actions. As such, these narratives suggest that the command and control vs. adaptive dichotomy often discussed in NRM discourse is an inappropriate framework to understand the actions of ranchers in our study. Instead, ranchers' descriptions of their decision-making during and following drought reveal an overt recognition of system complexity, and a cultural emphasis on learning and adaptation, balanced with a need to control some aspects of the ranch system at specific times.

2.4.2. THE ETHIC OF CARE: HOW THESE RANCHERS RELATED TO RANGELAND SYSTEMS.

If ranchers' decision-making cannot be fully understood through a comparison of control or adaptive paradigms, an alternative framework is needed to describe rancher relationships to nature. This framework must account for the knowledge and principles that guide their decisions in these complex SESs. I coded repeated interviews for ranchers' perceptions of success, statements about their goals and objectives, and descriptions of actions they tried to avoid. I also coded for ranchers' descriptions of their management philosophies and tracked qualitative change in these statements over time.

I synthesized thematic coding results as an ethic of care (see Figure 2.2), a conceptual framework for rancher decision-making whereby managers navigate livelihood decisions through responsive and responsible actions that reduce the vulnerability of SESs. Specifically, the ethic of care involves: 1) a systems-based approach to learning about and respecting the interrelationships of components of ranch landscapes, 2) taking actions to care for these components, i.e. facilitating the function of social and ecological aspects of rangelands and

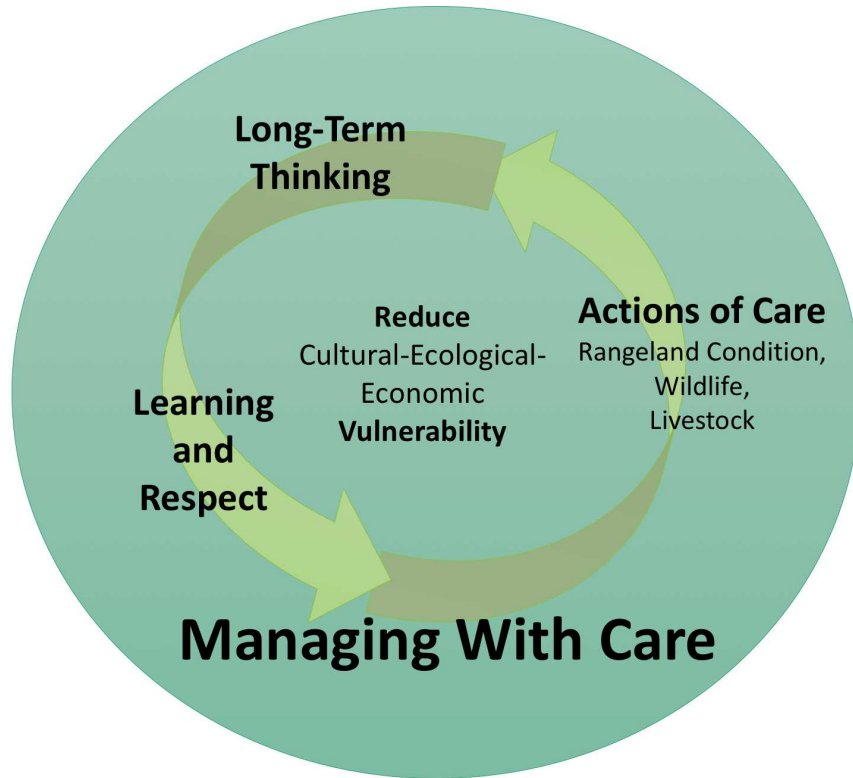


FIGURE 2.2. Conceptual diagram of Ethic of Care, a framework by which to understand rancher perceptions of decision-making processes developed from repeated interviews of managers on 6 ranches in NE Colorado and SE Wyoming.

ranching and 3) framing decision-making within long planning horizons (over generations). I illustrate the ethic of care on a specific ranch through a discussion of “The Time Tunnel,” one rancher’s conceptual framework of his ranch decision-making processes, which demonstrates the ethic of care on a specific ranch.

2.4.2.1. *Learning and Respect.* Learning and respect constitute the first component of the ethic of care. Ranchers described their management decisions in relation to the variability and function of interconnected components of rangeland ecosystems—vegetation composition, rangeland hydrology, and plant-herbivore interactions. The concept of respect here implies a systems-thinking approach that stems from a recognition of system complexity and a sense of place.

The ranchers said they had spent years, even lifetimes, learning about the variability and potential of the landscapes they manage. As one Wyoming [Ranch 2] rancher said: “I’ve been manager-in-training, and I have two brothers and a sister, but I’m the one that always stayed. I’ve been training for this job since I was five.”

Ranchers described planning for disturbance by imagining potential decision-making scenarios. They emphasized flexibility in strategic plan creation and implementation, preparing to gain new information and adapt quickly in response to drought, fire, flood, or livestock health scenarios. Ranchers also described gathering lessons, heuristics, and cultural practices from older generations, and adapting these practices to contemporary management decision-making processes. Notably, rancher narratives described this learning as cultural and multi-species; learning the land is a social process for individuals, families, communities and livestock. This learning process enables ranchers to adapt to complexity, but also to exert agency and control over components of ranching systems when necessary. Take for example one rancher’s [Ranch 3] discussion of how he sees his livestock handling at branding, a traditional rope-and-drag method, as a “teaching moment” for calves that grow to be large, powerful animals capable of injuring ranchers and other livestock:

“I guess one thing I like about branding livestock in that way [rope-and-drag], like these heifers here, and bulls particularly, they grow a deep respect for a horse. You can work them cattle with a horse with no problems. You take cattle that have never been roped and drug and when they grow up, they have no respect. You can find yourself in a lot of trouble with cows or a bull coming after your horse. [Branding is] a teaching moment for them, in a way.”

Ranchers contrasted their knowledge of rangeland systems and drivers of change with scientific or technocratic management recommendations or the practices of other generations or types of ranchers. This suggests that ranchers recognize the specific and unique aspects of

TABLE 2.2. Rancher Actions and Perceived Benefits

Concern	Specific actions [Described by whom]	Perceived Limitations	Perceived ecosystem benefit	Perceived social, economic benefit
Livestock wellbeing	Move calving date [1,3]; move calving location or build infrastructure for calf safety [1,5]; Build shelters from recycled materials [5]; maintain body condition during winter months[1:6]	Seasonal climate; market strategy; forage	Reduced death and suffering for livestock	Reduced financial loss, rancher stress
Livestock stress	Implement technologies that reduce stress (e.g. chute and corral design); [1:5]; low-stress handling techniques[3,4]; frequent contact with livestock[2,3,4,6]; steps to reduce time for handling[1:6]; design grazing rotations to reduce travel [2,3,6]	Cost efficiency; labor	Reduce duration of stress on livestock	Maintain networks and traditions; reduce labor/time
Wild ungulates	Use grazing plan to limit ungulate competition [3]; provide water developments for wildlife [3:5]	Wildlife competition with livestock; destroy fences	Landscape connectivity and forage for elk, pronghorn, mule-deer	Maintain ecosystem aesthetics; hunting revenue; mutual benefits to livestock
Grassland bird species	Use grazing management to create variable structure[3,4,6]; collaborate with public lands agencies in grazing planning [1,4,5]; use rest to promote diverse species composition [1:5]; avoid grazing specific areas during nesting [5]; consider birds during infrastructure development[5]	Regulation; liability; cost in forage, time	Support bird populations	Enjoy wildlife viewing, sense of conservation; hunting revenue
Plant community	Change timing of grazing and rest to promote palatable grasses, shrubs and subshrubs [1:3,5,6]; use targeted grazing to reduce invasive cool-season grasses [1,3,6], use rest to store forage and reduce overgrazing in drought	Forage quality and availability; precipitation	Support diverse plant species composition, vigor	Improves forage availability and quality, financial resilience to drought

their relationships to rangeland landscapes and ranching operations compared to other ways of knowing and ranch practices.

2.5. DISCUSSION

2.5.1. HOW CARING RANCHERS MAKE “BAD” DECISIONS.

2.5.1.1. *Actions of Care.* Caring actions are the second component of the ethic of care. Ranchers described specific actions they took to reduce system vulnerability through simultaneous attention to profitability and environmental stewardship (see Table 2.2). The specific actions ranchers took to reduce vulnerability considered specific limitations: cost, labor, and seasonal climate limitations. For example, ranchers described their efforts to promote diverse rangeland species composition through rest or rotational grazing management as beneficial to plant diversity for its own sake, particularly if the landscape needs to “heal” following drought

or overgrazing, and to the resilience of ranching operations to drought. These management actions must also be understood within the context of ranchers' perceptions of specific limiting factors, such as interaction with public lands management agencies, precipitation, learning, and cost efficiency. One Wyoming rancher [Ranch 6] described the tensions between his financial needs and his goals for rangeland management:

“My goals are still to leave the ranch in better shape than I found it. I don't want to go to the touchy-feely, tree hugger part of it, [but I'm trying to] make the ranch more environmentally sound, and just make it easier really. I mean it's about money in the long run. Foremost you've got to make your payments and then once you can do that then you start making decisions on do I want to grub [heavily graze] the pasture out because I can or maybe we'll let the turkeys grow in there? The hard thing is when you're young you can't afford to do those things. When you're old, you could maybe afford to but you're too tired to enjoy it. So it's a balance, I think. To me sustainability is you've got things balanced in your life and in your environment so that you can continue the ranch for the next generation, it's not about Agenda 21. Sustainability is just being able to continue, and so hopefully 50 or 75 years from now, if I was able to come back and look at the ranch, it would still be a nice place that somebody might want to live and make money.”

Specific cattle handling practices, such as traditional horseback handling at community brandings, were thought to promote livestock wellbeing, cultural traditions, and economic outcomes. In another example, ranchers considered grassland bird diversity in their decision-making processes. One Colorado rancher [Rancher 5] described his view that he is responsible for maintaining plant and animal diversity:

“It's our responsibility to keep [the bird species] from going on the Endangered Species List, because if they go on the Endangered Species List we're not doing our conservation....And as far as I'm concerned, if we don't have diversity of plants, diversity of wildlife, we go to a monoculture, we're going to be gone.”

Throughout repeated interviews with this rancher, he discussed his responsibility to produce high quality beef (“our food”) and wildlife habitat (“their food”) and his specific decisions, including cattle movements, pesticide use, and water developments, to support grassland bird species.

2.5.1.2. *Long-Term Thinking.* The final aspect of the ethic of care is the long time span (planning horizon) on which ranchers consider the implications of their management decisions. In these narratives, successful rangeland management and ranching operations sustain viable economic and ecological systems for future generations. This theme was described across all ranches in the study, specifically around concerns for rangeland condition as it relates to long-term profitability. For example, a Wyoming rancher [Ranch 3] described how he believed grazing management and yearling program development had improved resilience to drought and the implications of these improvements for his son:

“If you don’t look to improve, you are also then counting the day short on how many generations longer we will actually be able to live here and if we have another drought, you know, I feel pretty good about the fact I was still able to run the numbers I was through last year.”

All ranches in the study had some uncertainty about their succession plans; two of three that lacked biological heirs were working towards alternative succession plans (mentoring programs and conservation easements), one ranch had recently transferred generations, two ranches had heirs (one had already passed some responsibility to that heir). Despite this uncertainty, the ranchers we spoke to consistently emphasized generations-long time frames for their decisions. One rancher [Ranch 2] discussed a specific aspect of his stewardship approach:

“I ask myself, do I want to spend time and money on a tree that I will never see? It won’t save a calf in a storm in my lifetime. I have been planting trees up there in this meadow for 20 years and there are a few to show for

it. I thought I could stick cows in here in the storm and they would be protected, but it is not coming true very fast. There's something to good stewardship that just says, you save it for future generations.”

2.5.1.3. *One rancher's decision-making framework: The Time Tunnel.* The ethic of care describes a framework for conceptualizing rancher decision-making based on 1) learning and respect; 2) caring actions; and 3) long-term thinking that are perceived to help reduce system vulnerability. To illustrate how the ethic of care may be employed in ranch decision-making, we present a conceptual model of ranch decision making developed by one rancher in the study [Ranch 5] whose aim was to communicate his ethical approach to non-rancher audiences (see Figure 2.3). During repeated interviews, this rancher described a proactive, collaborative approach to management and resistance to the industry status quo, though drought in 2012 affected his forage availability and financial decision-making processes.

The rancher's diagram (Figure 2.3) illustrates the relationship he observed between the multiple “dimensions” of ranching he addresses in his decision-making as elements of a holistic, dynamic, self-adjusting system or “tunnel.” The shape of the tunnel implies connectivity and interdependence between system elements and system drivers, “The Five Dimensions of Ranching.” These dimensions are: 1) Location (including landscape, topography, precipitation); 2) Genetics (his general term for all livestock health, genetics and wildlife conservation elements); 3) Forage (year-round forage, plant diversity, recovery from drought); 4) Time (including fluctuations in cattle markets, weather, and broader economic cycles); and 5) The Unexpected (unforeseen events including weather disasters, disease, increased regulation). To detect and adapt to change and manage for stochastic events, he sought out long-term climate, financial, rangeland monitoring and dendrochronology data. The rancher maintained a list of principles, which accompany the diagram (see Table 2.4.)



Dimensions of a Ranching Business

1: Location

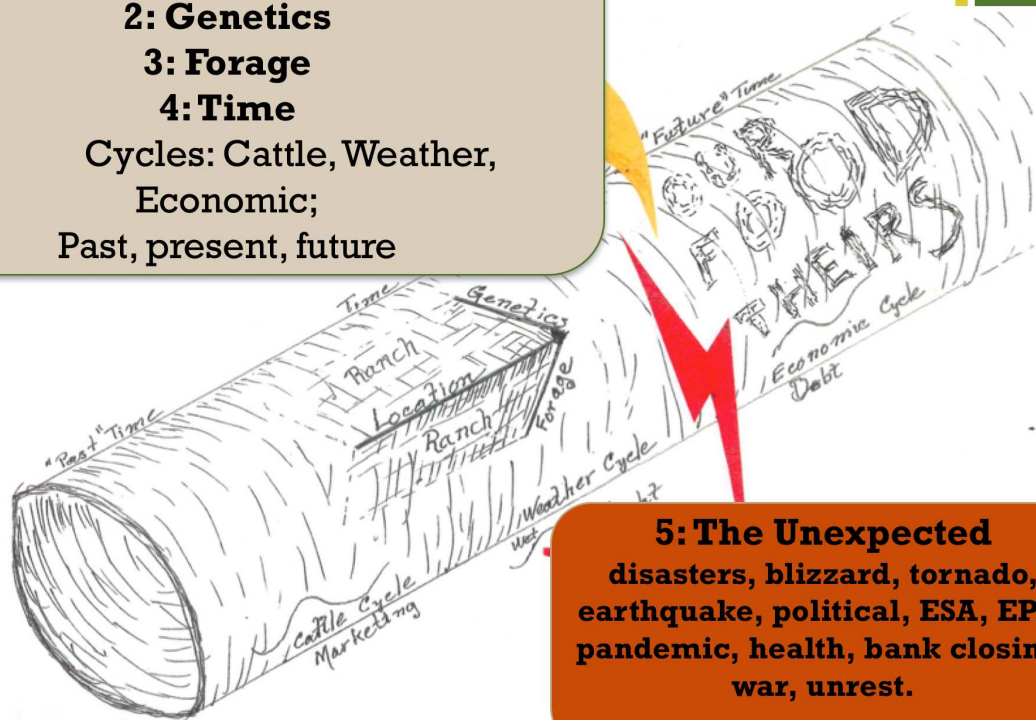
2: Genetics

3: Forage

4: Time

Cycles: Cattle, Weather,
Economic;

Past, present, future



5: The Unexpected
disasters, blizzard, tornado,
earthquake, political, ESA, EPA,
pandemic, health, bank closing,
war, unrest.

FIGURE 2.3. One rancher [5]’s conceptual model of ranch decision-making is a holistic, self-organizing system, or “time tunnel” incorporating five dimensions. ‘ESA’ refers to Endangered Species Act and ‘EPA’ refers to the Environmental Protection Agency.

The time tunnel and associated ethical framework can be understood as an individual rancher’s mental model of his decision-making processes within a complex system. However, it does incorporate the learning, respect, systems thinking, adaptive actions, and time frames that the other ranchers in our study described in their interviews.

This analysis provides insight into how interviewed ranchers perceived their decision-making processes and stewardship approaches, echoing previous work documenting the knowledge and caring actions of producers and natural resource managers (Fernandez-Gimenez et al., 2006; Knapp & Fernandez-Gimenez, 2009; Fernandez-Gimenez, 2015).

- Produce safe and wholesome beef that will provide an enjoyable eating experience . The beef will come from cattle that have been properly protected and cared for from conception to consumption.
- Be socially responsible with environmental stewardship of all natural resources.
- Maintain and enhance wildlife and plant community biodiversity is through appropriate grazing management.
- Protect the human and his rights of usage on the property through due diligence.
- Maintain economic viability.

FIGURE 2.4. Principles of a rancher accompany mental model of ranch decision-making.

However, these findings do not imply that rancher decisions and actions of care result in ecological benefit. Brunson & Huntsinger (2008) and Talbert et al. (2007) have argued that ranches and private/public rangeland management partnerships, such as those maintained by some ranchers in this study, are important tools for rangeland conservation in the Western US. Others have criticized public lands grazing strategies for degrading biodiversity in these semi-arid environments (Donahue, 1999). An evaluation of ecological conditions of the rangelands these ranchers managed is beyond the scope of this study. While this paper does not evaluate the ecological outcomes of rancher decisions, it is important to consider how these managers might make “bad” decisions, or how they might fail to balance resource use and conservation. A Wyoming rancher [Ranch 6] addressed this in his 2015 interview. In the quote below he described his efforts to improve the ecological condition of his ranch, but acknowledged the potential for ecological degradation when ranchers “make mistakes” or approach an economic threshold for leaving the business:

“The way I would explain it, and that is exactly that missing ingredient in academia, what they would term as ‘emotional attachment to the land,’ and

I guess that's as good a term as any... After you've spent your whole life on a piece of land, you respect it. I think most people would rather leave the land better than they found it. That's my goal. I could sell [the ranch] and make more money than I will if this [plan to find a successor through a mentorship program] works out. So, I just don't see people [knowingly degrading the rangeland]. I do see people, young inexperienced people, that make mistakes. We all make mistakes. But to intentionally do that, the only time that I know of that we've done environmental damage was when cattle prices were so bad that you're on the razor's edge of failing and selling out. I don't know, to me that's failure. As you start making more money you feel like you can put a little more back, or fix that problem that the drought did so many years ago, or a mistake that your ancestors made. I can see environmental damage, it wasn't intentional."

Like the man quoted above, the ranchers in this study noted that a globalizing livestock industry, high weather uncertainty, changing rural opportunities, and regulatory concerns all constrained the success of their efforts to manage with care. But they also explained that good ranch management implies doing the best one can for both social and ecological aspects of ranching operations. In 2016, these ranchers were (with one exception of turnover between siblings) operating the same ranches we visited in 2012 and were seeking opportunities for succession and ranch continuity.

2.5.2. BEYOND THESE GREAT DIVIDES. In this study, I examined rancher narratives for evidence that complicates the controlling/adaptive dichotomy in the NRM literature. These findings may be generalized on a theoretical, not statistical, basis, and do not reveal the extent of the ethic of care as a qualitative, epistemological framework across ecotypes or ranching communities, where specific contexts matter for decision-making processes (Roche et al., 2015a). However, they illustrate the complexity of interviewees' decision-making processes and constraints, particularly during drought, and the intimate relationship ranchers

maintain with highly variable ecological and weather conditions. The adaptive vs. controlling dichotomy is but one form of the human/nature dichotomy in ranch management discourse.

Rancher narratives challenge the innovator/laggard split, which falsely divides managers with the resources and risk tolerance to adopt (socially or scientifically) desirable practices from those who “fail to innovate.” Rancher narratives instead emphasized constant adaptation and learning, though biophysical and financial constraints may place adaptation rates and actions outside of “innovative” categorization by the standards of the innovation-diffusion literature (Rogers, 2010). Many of the attributes associated with laggard behavior (e.g. risk intolerance and inflexibility) can be understood in ranching culture as determination, resilience, and frugality.

These narratives challenge the old-timer/new generation split, which assumes that ranchers are either tied to traditional ranching practices or prepared to fully reorganize ranch operations (Brunson & Huntsinger, 2008). The ranchers we interviewed respected and used many traditional practices (from roping and horses to more ranch specific systems of management), acknowledging the practical knowledge gained by older generations through trial and error (all ranches had inter-generational influences in their decision-making processes). At the same time, all the ranchers we interviewed described efforts to experiment with new management systems and paradigms. One in Wyoming, for instance, departed from generations of tradition when he sold his cows and leased out pastures, and noted, “I do not have to own cows to be happy.” This rancher carefully explained that he still saw himself as a “traditional” rancher because he used horses to work livestock.

The extent to which ranchers are profit-oriented or amenity and/or conservation-oriented has been of interest since Smith & Martin (1972) identified ranchers' limited profit motivation (Torell et al., 2001; Gosnell et al., 2006). Profit/conservation categorization suggests ranchers can either try to make a living or conserve rangeland ecosystem and/or consume ranch amenities, (e.g. landscape aesthetics and rural lifestyles). As in other studies (Rowe et al., 2001), ranchers described their continued efforts to sustain viable businesses and functioning rangeland ecosystems, while enjoying their livelihoods and taking pride in their work (see Wilmer and Fernandez-Gimenez, forthcoming). Cultural, financial, and ecological sustainability are thus interconnected and interdependent processes.

The emotional/rational dichotomy excludes experience and relational ethics from the justification of knowledge. Repeated interviews with ranchers suggest caring, an ethic based on connections and relationships, frequently contributed to the “art” of adaptive ranch management under high levels of social and ecological variability. The caring stewardship ethic described by ranchers in their relationship to wildlife, livestock, rangeland ecosystems and human communities echo discussions by Leopold (1966) and care ethics scholars who orient moral practice as responsiveness to other actors within a community (Gilligan, 1977).

As rangeland problems become more complex (Boyd & Svejcar, 2009) and involve more diverse stakeholders, scientists are seeking ways to engage with natural resource managers, like ranchers, and their knowledge (Sayre, 2004; Cheng & Sturtevant, 2012). The particular ways that rancher narratives documented in this study deconstruct false dichotomies between humans and nature, and a deeper look at ranchers' relationships to rangeland environments have implications for future collaborative efforts, including collaborative adaptive, participatory, and technology transfer work (Susskind et al., 2012). Relevant collaborations are

more likely to be successful if they are developed with a consideration of rancher's complex understandings of rangeland systems and knowledge of caring practices (Resnik et al., 2006). My findings contribute to our current understanding of ranch management by pointing out that management embodies knowledge of how humans relate to nature.

This study also identifies how conceptualizations of rancher decision-making processes are likely to over-simplify human-nature relationships as they are navigated by ranch managers across different spatiotemporal scales. These oversimplifications are evident in ranchers' insistence on the difference between their knowledge and framing of success and framings of success from technical scientific ways of knowing, and on the role of profit motivation in their rangeland management decisions. Theory and research related to producer motivations, decision-making and adaptation continue to develop (Didier & Brunson, 2004; Lubell et al., 2013; Wilmer & Fernández-Giménez, 2015). Findings from this study on rancher perceptions of their relationship with nature may help locate common ground between diverse interests in rangeland conservation and management.

2.5.3. CONCLUSION. Academic interest in rancher adaptive capacity is growing because of important links between manager decisions and stewardship of rangeland ecosystems and food system viability (Roche et al., 2015b; Briske et al., 2015). Ranchers managing extensive rangeland-dependent ranches operate under high levels of social and ecological complexity and uncertainty. Documenting ranchers' perceptions of their relationships to these complex natural environments informs theories of producer decision-making. Through repeated interviews with ranchers, we find that ranch management has an adaptive component derived from ranchers' perceptions of their relationships with rangeland ecosystems, and that this adaptive management is characterized by efforts to reduce perceived vulnerability to

social and ecological aspects of complex systems through continual learning, respect for place, multi-generational time-frames and specific actions of care. Ranchers' lived experiences of decision-making involve both adaptation and controlling actions, but their perception that they are attempting to reduce system vulnerability through caring actions provides insights into their motivations that will inform future collaborative efforts between scientists and ranchers.

CHAPTER 3

BUILDING MANAGEMENT-SCIENCE PARTNERSHIPS THROUGH COLLABORATIVE ADAPTIVE RANGELAND MANAGEMENT

3.1. INTRODUCTION

Substantial differences between rangeland science and management have presented barriers to their integration throughout the history of rangeland science. Science and management are not directly comparable endeavors (Provenza, 1991), and so meaningful knowledge development is a formidable challenge to the rangeland profession. Although there has been considerable experimental research focusing on specific aspects of grazing management, the single largest factor for rangeland science, these studies have not addressed dynamic interactions within adaptively managed ecosystems, nor have they included a consideration of decision-making and learning processes central to grazing management (Briske et al., 2008; Brunson & Burritt, 2009; Briske et al., 2011b). Therefore, research and monitoring approaches need to document explicitly the contribution of adaptive management to promote a more comprehensive understanding of successful grazing management (Brunson & Burritt, 2009; Budd & Thorpe, 2009). Methods that promote mutual learning through collaboration between scientists and managers could create a mutually beneficial situation for the profession through new opportunities for diverse rangeland stakeholders to participate in rangeland management research relevant to their production and conservation objectives.

Participatory grazing research holds promise to link management and science in a shared process of learning by doing (Knapp et al., 2011). Conventional engagement of rangeland managers often centers around extension bulletins, presentations, or popular press articles

produced after research has been completed. In contrast, participatory research seeks to connect scientists and managers throughout the research process. It aims to empower stakeholders to shape and practice new knowledge and to take ownership of research results (Uphoff, 1986).

Participatory research gained interest from agriculture, health, and development fields in the 1970s and has grown to become an engagement orthodoxy across a number of fields (Gow & Vansant, 1983; Uphoff, 1986; Cornwall & Jewkes, 1995). Participatory research focuses on processes of change, including ongoing adaptation, evaluation and extension built upon collaborative relationships among managers, scientists, and/or non-governmental organizations (Uphoff, 1986). Participatory frameworks reorganize 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 & Jewkes, 1995; Cornwall, 2003). It does this through decentralization, transformation, empowerment, integration of local knowledge, and application of research to relevant local management scales (Cornwall & Jewkes, 1995).

Collaborative adaptive management (CAM) provides a framework to link rangeland stakeholders and scientists through participatory research (Stringer et al., 2006; Beratan, 2014b). Adaptive management is a formal process whereby managers use the scientific method to adapt to new information (Gunderson, 2000; Jacobson et al., 2009). This approach to management is a response to command and control management paradigms and assumes that complex natural systems cannot be controlled via prescriptive actions (Holling & Meffe, 1996). Adaptive management emphasizes the concept of “loop learning” (Petersen et al., 2014), the process by which new information is used to alter management actions (single-loop learning), alter the 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). CAM emphasizes participatory and consensus-based decision-making frameworks that include multiple hypotheses and sources of knowledge. Stakeholder participation enables “social learning,” whereby collaborative stakeholders develop a shared understanding and collective action (Muñoz-Erickson et al., 2010; Cundill & Rodela, 2012; Cundill et al., 2012; Rodela, 2013; Nykvist, 2014). The resultant “co-produced” knowledge to addresses management uncertainties, and links diverse stakeholders and divergent objectives through a process of learning (Fernandez-Gimenez et al., 2006; Edelenbos et al., 2011).

This study evaluates CAM as a framework for building stakeholder capacity to make decisions that respond to system complexity for multiple rangeland management objectives. The Collaborative Adaptive Rangeland Management (CARM) Experiment is a ten-year, interdisciplinary endeavor involving social and ecological research on rangeland management decisions made by an 11-person group of rangeland stakeholders. The experiment takes place on the shortgrass steppe of eastern Colorado, which evolved under a long history of grazing by native ungulates (Milchunas et al., 1988), and is characterized by highly variable inter- and intra-annual precipitation (Lauenroth & Burke, 2008). In this complex social-ecological system, stakeholders may have divergent production and conservation management objectives, and the CAM framework is challenged to facilitate meaningful learning that leads adaptive management.

Before the participatory CAM approach can be evaluated as a mechanism for rangeland decision-making and learning, we must define our conceptual framework for knowledge and social learning. The adaptive management literature has addressed the concept of social

learning and ways to improve learning processes in diverse natural resource management contexts (Bouwen & Taillieu, 2004; Cheng & Mattor, 2010; Cundill et al., 2012; Leys & Vancley, 2011; Reed et al., 2010). For this study, we rely on a conceptual framework that holds that knowledge is more than a set of facts or information used by an individual, or literature cited by an organization (Blackman et al., 2004; Blackmore et al., 2007). Instead, we consider knowledge to be a social construction, or the result of ever-changing social and cultural interactions (Oeberst et al., 2016). We recognize that knowledge is situated, or that it develops in specific contexts (Schwandt, 2000; Robbins, 2006), and is also shaped by the ways in which it is practiced and applied (Haraway, 1988; Cundill et al., 2012; Cote & Nightingale, 2012).

Diverse social contexts and lived experiences influence stakeholder knowledge systems, or how stakeholders justify their rangeland management knowledge (Black Elk, 2016), or how they know what they know, and how they filter, construct, and develop trust for new knowledge as management contexts change (Kassam, 2008; Knapp & Fernandez-Gimenez, 2009). We recognize the relational and political aspects of knowledge (Bixler, 2013). One justification for knowledge may be privileged over others in different contexts, particularly where natural resource decision-making involves management for multiple values and objectives across spatiotemporal and social scales in coupled SESs (Harrison et al., 1998; Black Elk, 2016). We also recognize that different ways of knowing can overlap and interact, and that knowledge classifications based on class or education may over-simplify complex social relations and learning processes (Robbins, 2006).

In the public rangelands management context, stakeholders bring knowledge formed through diverse management experiences to new decision-making contexts involving multiple,

and seemingly contradictory, goals, e.g. for simultaneous wildlife conservation and beef production. In these complex management contexts, social learning becomes a key concept to help bridge knowledge gaps between stakeholders. We adopt Cundill et al. (2012)’s definition of social learning as a process of collective action and reflection for individuals and groups who work together to critically evaluate existing norms, values, institutions, and interests in an effort to understand social and ecological systems. Because social learning brought about through the CAM framework is a potential alternative to conflict in complex rangeland management scenarios, it is important to understand how stakeholders with different rangeland management experiences and knowledge learn and make decisions in a novel management context like the CARM experiment (Rathwell et al., 2015).

We followed the CARM participatory research project for the first four years (2012-2016) and documented learning opportunities and group decision-making through meeting notes, observation, semi-structured interviews, and a focus group. The goal of this study was to explore to what extent participation in the CARM experiment enabled adaptive decision-making of a group of rangeland stakeholders. The specific objectives of this study were to: 1) document how stakeholder experience and knowledge (their knowledge systems) contributed to adaptive grazing management decisions; 2) evaluate how co-produced knowledge informed rangeland management decision-making in the CARM project through two grazing seasons (2015 and 2015); and 3) explore the implications of participation in an experimental collaborative adaptive management project for rangeland stakeholders.

3.2. METHODS

3.2.1. THE CARM EXPERIMENT. The CARM experiment is centered at the Central Plains Experimental Range (CPER) in Nunn, Colorado, a USDA-ARS facility that is also

a site in the Long-Term Agroecosystem Research (LTAR) network. In a mock public-private lands management scenario, 11 stakeholders (ranchers, state, and federal agency representatives, and non-governmental conservation organizations; 3 women and 8 men) are responsible for the decision-making on 10, 130 ha pastures and a herd of yearling cattle (see Figure 3.1. The stakeholder group was formed in 2012 via invitation from the research team. 2013 was used as a year for baseline data collection. The experimental treatments began in 2014 and are continuing for ten years.

An interdisciplinary group of researchers with expertise in rangeland ecology, wildlife biology, animal science, agricultural economics, and natural resource management social science worked with the stakeholders to develop the overall stakeholder goal “to manage the land in order to pass it on to future generation”), and specific objectives related to livestock production, wildlife, and vegetation outcomes (see Figure 3.3).

Experimental treatments began in 2014, with the annual grazing season at CPER beginning mid-May and concluding in early October. While the scientist team worked year-round to monitor and interpret indicators of project outcomes, CARM stakeholders met in January, April (prior to grazing season), and late September (near the end of the grazing season) from 2012-current, and received weekly email updates of monitoring results during the grazing season. With the exception of the first stakeholder meeting, meetings were facilitated by the scientist team, and typically involved the presentation and discussion of monitoring data, proposal and voting on upcoming management decisions, field tours, and group activities related to possible management scenarios or data interpretation.

Before the experiment began, the scientists and stakeholders drew on scientific and professional knowledge to establish base-line rules and scientific side-boards, determined in

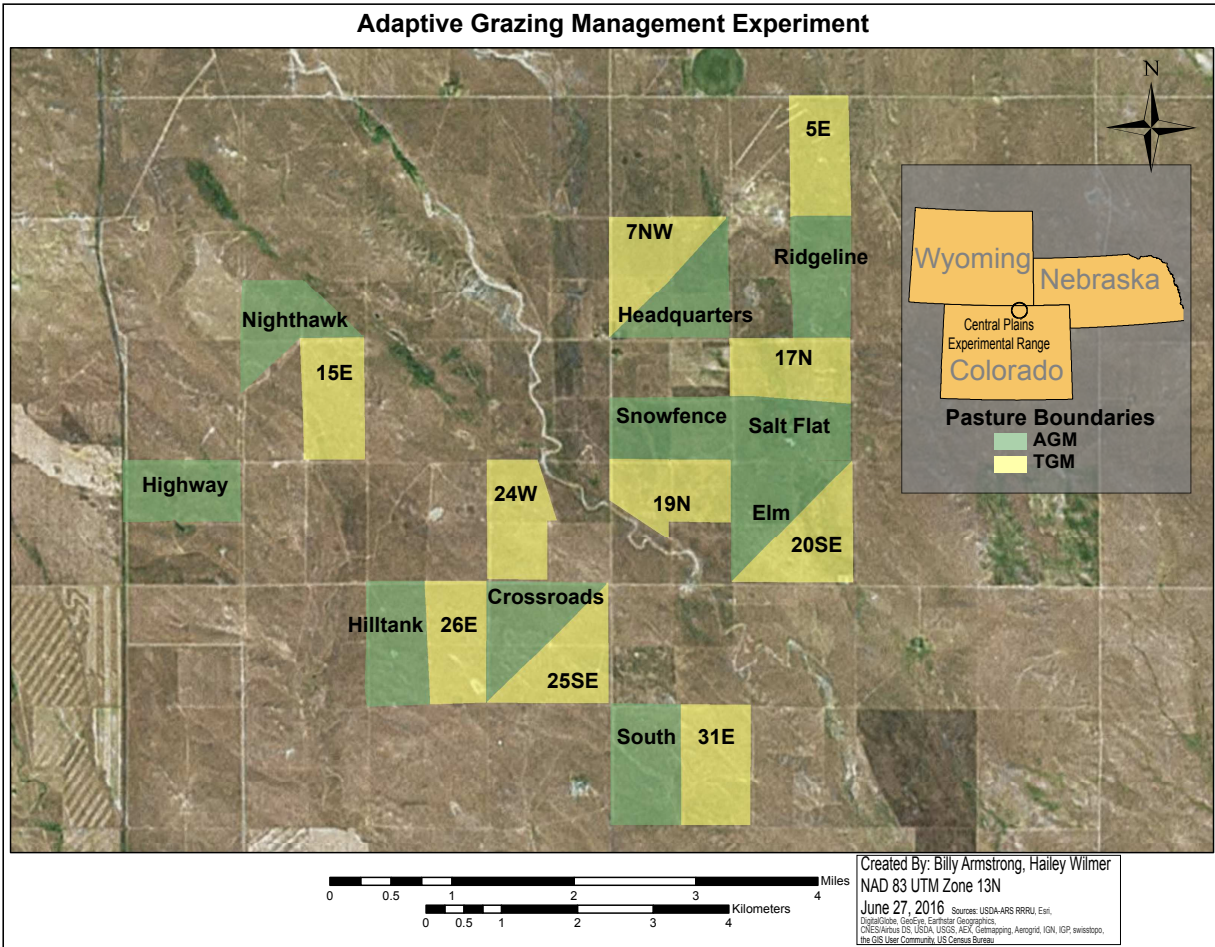


FIGURE 3.1. Ten, 130 ha pastures managed by a stakeholder group through collaborative adaptive management, known as Collaborative Adaptive Rangeland Management (CARM) pastures (green color), are paired based on soils, ecological sites, topography and plant communities with another 10, 130 ha pastures managed under Traditional Grazing Management (TGM), a season-long (mid-May to early October) continuous system (yellow pastures) with the same moderate stocking rate using yearling steers. During the first two 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.

part by logistics and in part by scientific research design considerations. These included the paired-comparison design of the grazing management strategies, wherein stakeholders compared monitoring data from the pastures managed via collaborative adaptive rangeland management (CARM) to 10 paired pastures grazed under traditional grazing management

(TGM) which is 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 & Ashby, 1998). The stakeholder group agreed to keep the stocking rate (but not density) of TGM pastures the same as AGM pastures to prevent confounding of experimental design, to use yearling steers as the grazing animals, not to allow two grazing periods in one pasture in a year and to graze pastures at different times in consecutive years, and to rest two pastures on average precipitation years. Stakeholder decision-making responsibility included prioritizing desired ecosystem services, altering the number of grazing animals across years, determining and adjusting criteria for livestock movement among pastures, and other management decisions, including the use of prescribed burning.

3.2.1.1. *Stakeholder participants and decision-making rules.* Group decision-making rules were initially established as consensus-based in 2013, but in 2014 the stakeholder group refined quorum rules (7 of 11 stakeholders needed present to conduct any voting) and allowed a 75 percent super-majority for decision-making. Non-governmental conservation organizations include representatives of The Nature Conservancy, Bird Conservancy of the Rockies (formerly Rocky Mountain Bird Observatory), and the Environmental Defense Fund. Government agency representatives were from the USDA Natural Resources Conservation Service, Colorado State University Extension (a seat vacant after 2014), Colorado State Land Board (a seat created in 2015) and the US Forest Service. Ranchers, all members of the local grazing association which supplies research cattle to the experiment, the Crow Valley Livestock Cooperative, Inc., had four votes on the stakeholder group.¹

¹The CARM Project is just one in a long line of collaborative research projects carried out at CPER with Crow Valley Livestock Cooperative cattle. During this study, two members of the stakeholder group have cattle involved in the project, while the other two ranchers do not.

3.2.2. QUALITATIVE COLLECTION AND ANALYSES. Data collection and analysis were conducted in an iterative fashion. Social scientists collaborated with biophysical scientists to document the decision-making processes of CARM stakeholders throughout the project. We documented stakeholder meetings, held 3-4 times each year, using transcripts, notes, and audio recordings. We then coded transcripts and meeting notes (Glesne et al., 1992) 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 (Yin, 2013; Becker, 1998).

During coding, we interrogated the meeting transcript data for stakeholder discussion of existing and experiment-produced knowledge, their decision-making processes, evidence of loop learning, and existing frameworks of rangeland management.

In the spring of 2016, the lead author conducted semi-structured interviews with 11 past and current stakeholders (Glesne et al., 1992; Nagy Hesse-Biber, 2014), which were audio recorded, transcribed, and subject to a round of coding. A synthesis of initial themes and meeting/stakeholder metadata was used to create a list of questions for a stakeholder focus group (Munday, 2014). In April 2016, stakeholders and scientists participated in a focus group, which 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 learning and social learning code categories. 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). The research team

had prolonged engagement with the data, and synthesized findings were subjected to peer checking by the research team and stakeholders (Lincoln & Guba, 1986).

3.3. RESULTS

3.3.1. STAKEHOLDER KNOWLEDGE AND EXPERIENCE CONTRIBUTE TO THE CARM EXPERIMENT.

“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 is all the same, but yet we’re different. We’re not always in agreement on things.”- AGM Stakeholder, NGO representative.

We present a comparison of stakeholder sub-groups (ranchers, agency representatives, and conservation NGOs) in terms of the context of their rangeland management experience and knowledge systems, and respective contributions to the decision-making processes. This comparison highlights overlap and distinctions between the sub-groups, and illustrates the complex and diverse systems of knowledge that emerge even in a CAM project conducted at a relatively small spatial scale (2590 ha). Then, we specifically examine how stakeholders grappled with two decision-making opportunities to illustrate the complexities of social learning in the project.

The four beef producers on the stakeholder group were all multi-generational ranchers. They had secondary or some post-secondary education. They had decades of personal experience managing extensive beef operations with public land grazing leases primarily following a grazing approach similar to the TGM approach. They had experiential knowledge of animal husbandry, nutrition, cattle markets, local weather, local rangeland site potential, species, and management and ecological history, including knowledge of ecological thresholds

and risks of drought. While rancher participants had experience working on other ranches, none had extensive experience ranching outside of the shortgrass ecosystem. As such, they served as advisors to the project on animal husbandry questions and as gate-keepers of the profitability goals and relevant livestock condition concerns.

Representatives of conservation NGOs all had some graduate school or more education in wildlife, rangeland science, or human dimensions of natural resources. They had experience as scientists and managers in the shortgrass steppe and in other rangeland ecosystems. Their work in these systems was influenced by contemporary discourse about threats to avian biodiversity, heterogeneity, and adaptive management in rangelands (Fuhlendorf et al., 2012; Hovick et al., 2015). One member of this group had some experience practicing high intensity, short duration grazing management. Others described that the project presented them with a steep learning curve relative to livestock production systems. These representatives were sources of wildlife and vegetation management knowledge and also provided critical evaluation of methodology, specifically questioning how monitoring data related to specific decisions. 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 as *“asking for the whole loaf of bread and expecting to get half.”* Members of this group were interested in relating to, and connecting with, other stakeholders, and thus talked about avoiding over-use of scientific jargon during meeting discussion.

Government agency representatives had a bachelors 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 had ranch decision-making experience and a third worked with ranchers professionally in the public lands grazing context. These stakeholders were sources of knowledge about how management decisions impact vegetation dynamics and rangeland plant communities. They also critically evaluated the transparency and process of group decision-making, and they often took leadership in conversations or activities that “translated” the implications of monitoring data to other stakeholders.

3.3.2. HOW DOES CO-PRODUCED KNOWLEDGE INFORM CARM DECISION-MAKING?

In the following subsections we trace the process of two types of decisions to characterize and evaluate the learning of the CARM stakeholder group. These processes were framed around the stakeholder-produced overarching goal of the experiment: “To manage the land in order to pass it on to future generations” (see Figure 3.3) and specific objectives related to beef production, vegetation, and wildlife. These objectives, decision-making processes, and management actions are outlined on the project timeline (see: Figures 3.3 and 3.2).

Our analysis of grazing management decisions related to when to rotate cattle illustrates that social learning can be incomplete and non-linear as it emerges from collaborative processes. Social learning can be influenced by time-lags in the outcomes of decisions and path dependency, and it interacts with existing stakeholder knowledge. The second decision-making process we analyzed, related to prescribed burning, illustrates how different stakeholders evaluate the perceived benefits of management practices differently and suggests that participation in the creation and application of new, co-produced knowledge is not enough to re-organize stakeholder’s existing paradigms of rangeland management in the short term.

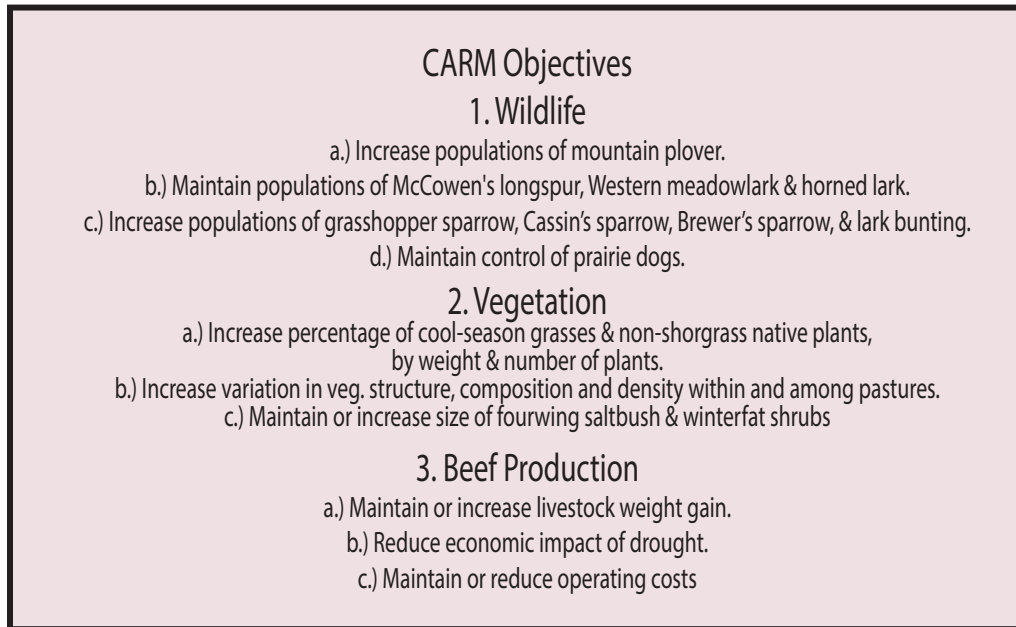


FIGURE 3.2. Stakeholder-established objectives encompass wildlife, vegetation and beef production aspects of rangeland management.

3.3.2.1. *Rotational grazing decision-making.* Stakeholders set triggers for cattle rotation among pastures during an April meeting each year. For the 2014 grazing season, these triggers included biomass thresholds set to leave 300lbs/acre in pastures dominated by loamy ecological sites (loamy pastures), 448 kg/ha in pastures with mixed sandy and loamy ecological sites (mixed pastures), and 504 kg/ha in pastures dominated by sandy ecological sites (sandy pastures). The group included a threshold for the maximum number of days calculated from a model for biomass on an average precipitation year, cattle behavior triggers, and a rule that pastures should contain at least 112 kg/ha above their threshold to allow for a minimum of 7 days of grazing. For the 2015 grazing season, biomass thresholds and cattle behavior thresholds remained the same, but the maximum days threshold was removed by the stakeholder group. The group voted to increase the number of yearlings by 5 percent. For the

movement among pastures. The stakeholder group also raised the number of yearlings by 5 percent from the previous year.

In 2014 and 2015, both relatively wet years, the monitoring data indicated that the average daily gain (kg/steer/day) was 15-16 percent greater for steers in the TGM pastures compared to CARM, though progress was being made toward vegetation composition and grassland bird habitat objectives. The reduction in average daily gain was counter to the assumption of many in the stakeholder group that rotated cattle would gain weight at a greater rate because the movement among pastures across the grazing season would provide consistent access to “fresh” forage. Ranchers in the study repeatedly stated the position that they were not “fans of rotational grazing” and that rotational systems are not profitable in semi-arid shortgrass systems. Based on this information, the stakeholders focused on changing their pasture movement triggers.

For 2015 stakeholders voted based on a new assumption that their 2014 rotations had not been responsive to ecological variability, but could be adjusted to track vegetation growth and herbivory more closely. While the 2014 pasture movements were based on thresholds for standing biomass, cattle behavior, and maximum days in each pasture established from ecological site-based predictions of forage in that pasture, above average rainfall resulted in the cattle moving through seven, not eight, pastures, each time based on the maximum number of days thresholds. In 2015, the stakeholders removed the maximum day thresholds and set new triggers to the weekly measurements of standing biomass and cattle behavior, with special stipulations so that prescribed burned areas (see below) would be grazed early in the spring. The group also increased the stocking rate by five percent for 2015 due to

the favorable growing season in 2014 and high residual forage remaining at the end of that grazing season.

During this time, the group incorporated multiple forms of expertise to refine their monitoring and decision-making. The group recognized that they had no formal indicators of animal performance that could be documented on a weekly basis. Cattle weights were collected at start and end of the grazing season, and opportunistically during the grazing season, and analysis of fecal samples for diet quality had a 2-4 week lag time in processing that would prevent the data from informing grazing decisions in real-time. Scientists, technicians, and ranchers worked together to develop and refine animal behavior monitoring and movement triggers that included observations of cattle behavior, forage selection, and cattle distribution within pastures across the grazing season.

Due to exceptional forage growth resulting from well-above average spring precipitation in 2015, it proved difficult to reach standing biomass triggers for cattle movement, and the cattle rotated through just four of the planned eight pastures (Figure 3.3). Data presented at stakeholder meetings suggested that the group had maintained progress toward wildlife and vegetation objectives, but that the CARM cattle gained 16 percent less on an average daily gain basis compared to the TGM herd. The crude protein of the diet that CARM cattle were consuming was consistently lower than TGM, with a notable decline following three weeks of grazing in a given pasture. This decline corresponded with a change in cattle behavior with animals exhibiting greater tendencies to test fences. These data informed the 2016 triggers set by the group, whereby stakeholders worked from a new assumption that the cattle needed to rotate faster through the pastures to improve average daily gains.

For 2016, the stakeholders refined their triggers for movement based on cattle behavior monitoring, raised minimum biomass thresholds (by 50 percent for loamy pastures, 25 percent for mixed loamy/sandy pastures, and 20 percent for sandy pastures and established another set of triggers in case of drought). In an effort to close the average daily gain between TGM and AGM herds, the group re-established a maximum number of days the cattle could graze each pasture, setting a universal 24 day maximum across the CARM pastures. Stocking rate was again increased by 5 percent due to the abundant residual biomass.

Interview, meeting, and focus-group transcripts reveal complexity in the pattern of decision-making related to triggers for pasture movement. Specifically, the above narrative of learning ignores important pieces of data. In 2014 and 2015, the diet quality of CARM cattle did not spike when cattle moved to a new pasture (unless that pasture had been burned). Instead, dietary quality was consistently lower for the CARM herd than TGM cattle each week during 2014 and 2015. This information, paired with preliminary cattle distribution data compiled from GPS collars, suggested that stock density played an important role in average daily gain. As a result, the group drew inferences that stock density forced the CARM yearlings to graze in less selective patterns, and prevented them from choosing the higher-quality diet that the TGM herds enjoyed.

The stakeholder group remained committed to their one-herd, high stock density grazing approach for several reasons.² First, stakeholders and scientists alike made the point that their grazing management decisions would have pay-offs during a (yet to come) drought because the single-herd, high density approach allowed for storage of ungrazed forage that could be carried as a “grassbank” into the next year. Whether the financial benefits of grassbanking in drought would outweigh losses in the initial, wet years of the project remained to be seen by

²In early CARM meetings, one and two herd proposals had been suggested.

2016. Scientists agreed to avoid conversations at the stakeholder meeting about splitting the herd into two or more groups (reducing stock density) so as to encourage the stakeholders to see the current system through at least one drought cycle. Scientists acted on the concern that their research would need data from a drought to confirm the benefit of grass banking.³ Stakeholders expressed willingness to be patient in the face of time lags between decisions and outcomes, citing the slow time frame for management results in this semi-arid rangeland ecosystem.

Second, with steady progress towards (or at least a lack of negative impacts on) vegetation and wildlife objectives, the beef production outcomes became a singular draw-back to the overall grazing approach. Path dependency entrenched the group further into their one-herd approach over time as they sought ways to improve beef production, without negatively impacting other objectives. Rancher interviews and focus group data suggest that rancher stakeholders were concerned that the CARM project was meeting all but production objectives, something one described as “beating up on the rancher a little bit.”

At the same time, one scientist noted that average gain per unit land area was greater in CARM than TGM, and argued that this metric, not average daily gain per head, best captured the benefits of the CARM group’s decision (tall structured habitat for grassland birds as well as grassbanking for drought)

Finally, stakeholders’ existing frameworks for rangeland management pushed them to focus on refining triggers for herd movement (not stock density) as a way to deal with reduced diet quality intake. During interviews conducted in Spring 2016, stakeholders were asked to describe uncertainties in the project and or ecological system. Stakeholders were six times

³The scientist team initiated a number of side experiments designed to test the relationship between stock density and weight gain in 2016.

Stakeholders reflect on the complexities of learning and grazing decision-making, specifically related to triggers for cattle movement.

"You can't go twice through a pasture, 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

"[The greatest uncertainties in the ecosystem are] the 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 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

"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

FIGURE 3.4. Text box illustrates quotations from interview transcripts with stakeholders that typify perspectives of each stakeholder subgroup related to triggers for herd movement.

more likely to express concern over rotation speed or herd movement triggers than about stock density (see Box 3.4). 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 de-emphasized the density/diet quality issue.

Several stakeholders, including NGO and government agency representatives, came to the project more familiar with high intensity-short duration grazing systems, which emphasize

Lessons learned for CAGM Stakeholders:

"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 stuff. 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

"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

"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

FIGURE 3.5. Stakeholders reflect on learning and collaboration.

faster rotations. In contrast, ranchers in this area practice a traditional grazing management approach that does not involve rotation but does maintain conservative stocking rates. During meetings and the focus group, one rancher repeatedly argued that rotating cattle too quickly could cause unnecessary energy expenditure. At the same time, other stakeholders expressed concern 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. When a 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, this same rancher replied 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 herd 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, knowledge from the scientist team, rancher local knowledge, and knowledge of high intensity-short duration grazing management approaches practiced on ranches in the region.

This example illustrates that stakeholders’ professional experiences, priorities for project objectives, and existing knowledge of grazing management systems are important drivers in the adjustment of their management actions. In this case, the double loop learning, or ability to develop a better understanding of the ecosystem and adjust their management decision-making based on a reconsideration of their guiding assumptions, was shaped by several factors. These included the experiments’s scientific side-boards, path dependence (or privileging the objectives the group made progress towards first), and the experiential and professional knowledge stakeholders use to interpret new information and management contexts.

3.3.2.2. *The burning question.* Tracing stakeholder decision-making processes around the use of prescribed burns suggests that the systems of knowledge with which stakeholders evaluate the risks and benefits of management actions are situated and contextual. Though the stakeholders did participate in a collaborative process that developed learning and new knowledge, this new knowledge did not disrupt their existing paradigms of rangeland management.

CARM stakeholders had an extra rested pasture and excess forage residual remaining after the 2014 grazing season, but were presented that livestock gains were lower in CARM yearlings than TGM yearlings on an average daily gain basis. The group also recognized the need to increase dietary quality and the need for short structured vegetation for grassland bird (mountain plover) habitat. Stakeholders voted for and carried out 4, 32.4 ha prescribed fires on 2 pairs of CARM and TGM pastures in late fall 2014. Monitoring data presented to the stakeholders during 2015 showcased the outcomes of the burns: a reduction in prickly pear cactus (*Opuntia polyacantha*) 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 the grassland bird mountain plover (*Charadrius montanus*) on the burn patches in both CARM and TGM pastures.

The prescribed burning decisions reveal tensions in how the stakeholders interpreted mutually-established management objectives in a novel management context. 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 et al., 2014) 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 developed from generations of experiential knowledge of the social and ecological implications of drought and practiced by these individuals during their lifetimes. Ranchers' experiences shaped their rangeland management practices that emphasized conservative forage use, spread risk across the landscape, and excluded the use of fire because of the perceived risk to forage availability.

Government and NGO stakeholders, trained as scientists and as facilitators of collaborative processes, had a greater concern for the risk of excluding ecological processes from the ecosystem. This sub-group of stakeholders recognized the need for economic return in some rangeland management but had less experiential knowledge of the financial effects of drought on beef production systems and did not prioritize profit maximization. These differences in stakeholder perceptions of decisions to use prescribed fire help illustrate why a season of monitoring data, co-produced as it was, was unlikely to alter traditional rangeland management strategies, a proven way of thinking for ranchers in this semiarid rangeland ecosystem. At a broader scale, three years of meetings were unlikely to build a working body of knowledge around simultaneous wildlife and beef production goals across a group of diverse stakeholders who had little or no experience managing for these objectives simultaneously.

3.3.3. EARLY OUTCOMES OF PARTICIPATION FOR STAKEHOLDERS. Despite these challenges, data from stakeholder interviews and the focus group suggest a high level of stakeholder engagement and investment in the project. We interpret this engagement to be motivated by an interest in learning and by the potential benefits of participation (see Box 3.5). Despite the experimental framing of the research, which reduces risk and benefits to all involved compared to what might be possible in a “real-life” CAM process on public land, it does provide the ranchers, conservation NGOs, and government agencies with potential benefits. First, the project serves as a model for future CAM processes involving these stakeholders. Second, stakeholders made real decisions with resulting outcomes on a real landscape within a scientific context.

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 scientists, and two were distressed by challenges regarding collaboration and the trade-offs between objectives, and conflict between stakeholders. Stakeholders in all three subgroups reported that the collaborative aspect of the CARM project is an important motivator for their participation (see Box 3.5). They also 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 landscape scale.

The implications of engagement in participatory research differs across stakeholder subgroups. In the short-term, ranchers are concerned with how management strategies developed in the project might improve their livestock production and economic returns. In the next decade, ranchers in the project could provide innovative management strategies for adaptation to drought through lessons from the CARM experiment's drought contingency planning. 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).

The ability of ranchers to demonstrate shared interests in public lands management with non-livestock production objectives could provide contemporary approaches for multiple use management on these grazing lands. Participation by ranchers can be understood as an effort to maintain their culture by demonstrating commitment to collaboration and learning for multiple-use management of public rangeland. As in other studies, ranchers in the CARM Experiment donate personal time away from their businesses, while other stakeholders are being paid to attend meetings and tours, which take place during the day (de Loë et al., 2015).

Stakeholder motivations link to “real-life” rangeland management contexts:

“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

“I don’t want to see the old ways go away.”-Rancher

“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

“Really maximizing heterogeneity was my number one concern [in the CAGM meetings], whether that was more fires, bigger fires, heavier grazing, or less intense grazing. Those were sort of the things that drove me.” –NGO

“That it is long-term, I think, is really attractive to me because that’s also rare in research, just to have a ten-year project, and that we’re actually doing it.” –NGO

FIGURE 3.6. CARM lessons have implications for stakeholders outside of the experiment.

Thus, 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).

For conservation NGOs, the experiment has appeal because of the scope and “real-life” aspects of the management context and as an opportunity to gather data on the costs of managing for grassland birds and variance 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 conservatism in decision-making and risk, representatives from conservation NGOs were interested in learning about where the thresholds are for system resilience (see Box 3.6), and if the group can 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 rangeland ecosystems face from land conversion, management practices that negatively affect bird habitat, and a lack of fire in the landscape.

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. It also holds promise in providing a suite of lessons learned for public rangeland management for multiple goals and objectives, which could inform future public lands management (Cheng & Sturtevant, 2012). In the long-term, the project could provide a model for structured, collaborative decision-making to reduce conflict in the public lands grazing context.

3.4. DISCUSSION

Producing meaningful management knowledge through rangeland science has been an ongoing challenge throughout the history of rangeland science. Despite a large body of experimental evidence focusing on ecological mechanisms and grazing management tools, this work has only recently considered decision-making and learning processes central to grazing management, particularly in the public lands grazing context (Briske et al., 2008; Brunson & Burritt, 2009; Briske et al., 2011b; Kachergis et al., 2014; Lubell et al., 2013; Roche et al., 2015a). Research that documents the contribution of adaptive management to promote a more comprehensive understanding of successful grazing management (Brunson & Burritt,

2009; Budd & Thorpe, 2009) can also provide opportunities for rangeland stakeholders to participate in knowledge creation and application for production and conservation objectives. The CAM framework links rangeland managers and scientists through a participatory process focused on adaptive management through collaborative, social learning.

To understand social learning in the participatory grazing management experiment, we traced the processes of two specific decisions related to triggers for herd movement and prescribed burning. In the case of the triggers for herd movement, the group was in consensus on what actions they thought should lead to specific outcomes, but these outcomes were not achieved with the implemented rangeland management strategies. They had to adjust their assumptions about grazing management practices over time. This series of decisions suggests that double-loop learning can be non-linear and incomplete, as it is shaped by other experiential and professional knowledge and by trade-offs between scientific and management-informed ways of learning.

Given these lessons, we recommend that participatory grazing research processes seek ways to be explicit about the challenges created by data ambiguity, data-to-decision time-lags, and experimental side-boards. We also suggest that participatory grazing research be open to the evolution of roles of researchers and stakeholders throughout the project. Collaborative processes of social learning are likely to reshape existing social relationships and assumptions about the system but may be different and incomplete across a group of participants (Cundill & Rodela, 2012). Stakeholders and scientists in the CARM experiment have already identified and implemented a number of specific activities aimed at improving learning by addressing shortcomings in communication and meeting facilitation, though we have identified time as a barrier to these efforts.

In the case of prescribed burning decisions, data on the outcomes of the management decision in question were interpreted differently by different members of a relatively small group of stakeholders. The lesson from this process was that while CARM stakeholders were part of a process that developed new knowledge, that knowledge was still interpreted through the systems of knowledge practiced by stakeholders in other contexts (Cote & Nightingale, 2012; Hinchliffe, 2007).

These two examples illustrate that rangeland managers' capacity to make adaptive decisions may not be improved by participation in the production of new knowledge alone, as that new knowledge is applied through existing knowledge systems early in a participatory adaptive management project (Fabricius & Cundill, 2014; Leys & Vanclay, 2011; Reed et al., 2010; Blackmore, 2007; Oeberst et al., 2016). We emphasize the importance of long-term commitment from researchers and attention to stakeholder needs, limitations, and concerns in the participatory grazing research framework (Huang et al., 2015; Cheng et al., 2011; Cheng & Mattor, 2010; Cheng & Sturtevant, 2012). Participatory grazing researchers should consider the role of existing experiences and perceptions of risk across stakeholder groups and find ways to build trust among group members to mitigate limitations of the scientific process in facilitating CAM (Cundill & Rodela, 2012; Cundill et al., 2012), especially when data could be interpreted to support multiple management options (Brugnach & Ingram, 2012). Building new, actionable management knowledge for multiple rangeland objectives takes a great deal of time as well as ongoing efforts to assess stakeholder engagement and to celebrate project successes (Cheng & Sturtevant, 2012).

3.4.1. LESSONS LEARNED AND IMPLICATIONS FOR FUTURE RESEARCH. This study presents findings from qualitative analysis of the learning and engagement of stakeholders

participating in an experimental collaborative adaptive rangeland management project in the first four years of the project. While this qualitative analysis provides nuanced, in-depth documentation of social learning and decision-making processes, our research focuses on a single case study and thus provides limited generalization to collaborative adaptive management processes with greater levels of uncertainty or risk for decisions-makers outside of the 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 be cost-prohibitive in other contexts. This study also largely excludes motivations and contributions of the scientific team to the decision-making and learning processes.

Future research should explore whether stakeholders who participate in an experimental CAM project apply new skills or decision-making capacity to rangeland management outside of the project. Additional work could also explore how the group addresses trade-offs between multiple stakeholder objectives at various spatial and temporal scales, time-lags between interpretation data and decision-making processes, and whether increased stakeholder leadership in data collection and interpretation promotes social learning. Additional research is needed to understand how the subject position and motivation of an interdisciplinary team of scientists, who can actually be seen as stakeholders, drives social learning, and how other power dynamics within the CARM Experiment influence rangeland management.

3.5. CONCLUSION

This study provides insight into the learning and engagement of stakeholder participants in an experimental grazing management project. Our qualitative analysis suggests that

existing stakeholder systems of knowledge are under-appreciated drivers of decision-making in the CAM framework and that these systems drive the capacity of the group to interpret and apply co-produced knowledge. The importance of participatory processes in facilitating the development of trust among group members, and among stakeholders and scientists, should not be underestimated in developing future participatory grazing research. Stakeholder subgroups act upon an understanding that not collaborating has risks for their respective real-world objectives for rangeland management, especially in a public lands context. These lessons can inform future efforts within the CAM framework to link rangeland scientists and managers through the co-production of usable grazing research.

CHAPTER 4

ADAPTIVE RANCH DECISION-MAKING IN RESILIENT RANGELAND SYSTEMS: A SOCIAL-ECOLOGICAL CASE STUDY FROM THE NORTH AMERICAN GREAT PLAINS



FIGURE 4.1. View of hay meadows, upland pasture, and homeplace on Wyoming ranch. Courtesy of an anonymous rancher, 2016

4.1. INTRODUCTION

Ranch decision-makers in the North American Great Plains manage rangeland grazing systems which are subject to high levels of weather and market variability within and among years. The ability of ranching social-ecological systems (SES) to persist in these conditions, and under rapidly changing demands for rangeland ecosystem services, depends upon the

adaptive decision-making of family ranch organizations (Marshall & Smajgl, 2013; Wilmer & Fernández-Giménez, 2015). This decision-making has been of interest to social scientists (Brunson & Burritt, 2009; Lubell et al., 2013; Ellis, 2013; Kachergis et al., 2014; Roche et al., 2015b) but excluded from traditional grazing management experiments (Roche et al., 2015a). Rangeland scientists increasingly recognize that ecological outcomes of grazing management decisions often manifest over time scales of one to several decades, but traditional grazing management experiments rarely occur at these time scales (Milchunas et al., 1994; Porensky et al., 2016).

In this paper, we refine and build upon current theory of ranch adaptive decision-making to better understand the links between rancher decision-making processes and ecological outcomes across broad temporal scales (Marshall & Smajgl, 2013; Lubell et al., 2013). After outlining this theory, we identify gaps in our knowledge of ranch adaptive decision-making processes. We trace how the exclusion of decision-making processes and the short temporal scale of traditional grazing experiments (typically less than five years) has led to debate across management and academic communities regarding grazing strategies to achieve multiple use goals on rangelands through flexible and adaptive management (Teague et al., 2008; Briske et al., 2011b; Provenza et al., 2013; Briske et al., 2014; Badgery et al., 2016).

We argue that a resilience framework and the concept of the adaptive cycle make important contributions to existing ranch adaptive decision-making theory presented by Lubell et al. (2013), which recognized ranches as complex SESs and incorporates concepts from innovation-diffusion theory and social psychology. We use a mixed-methods nested case study to track decision-making processes on 17 family ranch operations in eastern Colorado and eastern Wyoming and evaluate ranch SES level, and management strategy adaptation and the

resulting ecological outcomes. Our findings refine and build upon the framework outlined by Lubell et al. (2013) by documenting the links between three scales. These are: 1) adaptation on working ranches; 2) from the long-term ranch SES level; and 3) to management decision-making and ecological outcomes (Holling & Gunderson, 2002).

4.1.1. THEORETICAL DEVELOPMENTS IN RANCH DECISION-MAKING. Recent developments in theory related to ranch decision-making have been spurred by interest in rancher's learning and adaptation, their participation in conservation programs and their use of various grazing management strategies (Didier & Brunson, 2004; Sayre, 2004; Kachergis et al., 2014; Wilmer & Fernández-Giménez, 2015). An important theoretical development was Lubell et al. (2013), a framework that drew upon a number of approaches, including innovation-diffusion, the theory of planned behavior, social network analysis and social-ecological systems theory to evaluate California ranchers' participation in conservation programs (see Figure 4.2). This work provided a needed consideration of adaptive feedbacks between social and ecological processes across spatial and temporal scales. The authors recognized, in the tradition of research on rangeland and pastoral systems, that the management processes of learning about, and adaptation to, dynamic social and ecological conditions can be influenced by individual's values and beliefs and the context of a manager's access to information through social networks.

It has been argued that benefits of particular management strategies, particularly rotational grazing practices, stem from managers' increased ability to respond to both ecological and social dynamics in complex rangeland systems (Brunson & Burritt, 2009; Teague et al., 2013; Sherren et al., 2012; Grissom & Steffens, 2013). For example, Teague et al. (2008) note that *"Many ranchers who have practiced multi-paddock grazing management for decades are*

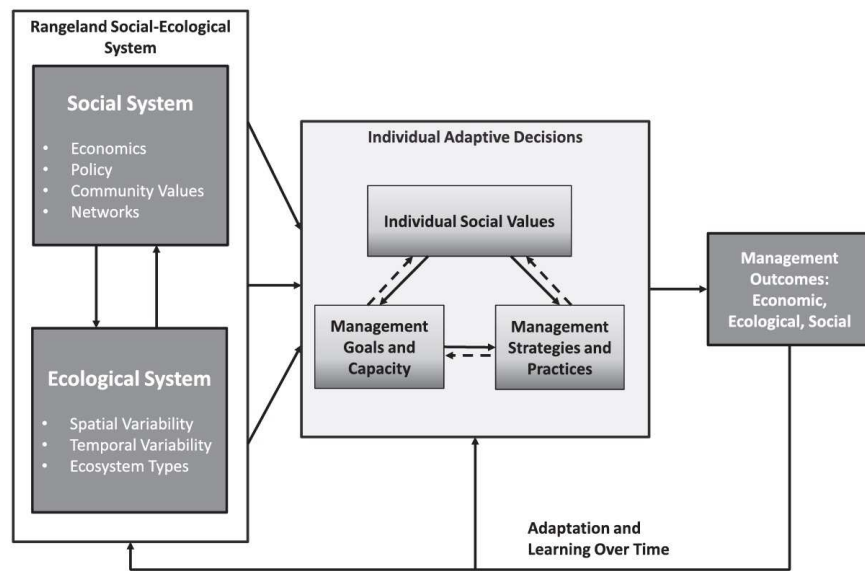


FIGURE 4. Adaptive decision making for rangeland management

FIGURE 4.2. Lubell et al's (2013) conceptual framework for adaptive rangeland management.

very satisfied with economic results and improvement to the ecosystem, as well as the change in management lifestyle and social environment of their ranch business" (pg. 2). This point reveals a gap in our knowledge of the relationships among ranch-scale adaptation processes, management strategies, and ecological outcomes (Bennett, 1971; Ellis, 2013; Marshall & Stokes, 2014).

Roche et al. (2015a) identified rancher grazing management strategies and the social and ecological contexts that influence the use of those strategies in California and Wyoming. In line with other research, they found decisions about specific management strategies could be predicted by a number of social and ecological variables across scales, including operator characteristics (goals, risk tolerance, networks and attitude toward experimentation), operation characteristics (including types, kinds, and scale of land and livestock) and the ecoregional location of the ranch. In contextualizing grazing management decision-making this way, Roche et al. (2015a) noted that these operation/operational variables have not

been previously incorporated into grazing management research. Roche et al. (2015a) cited mismatches between manager experiences and grazing research in terms of both timescale and the indicators of success or management objectives, and highlight the need for research that captures broader spatiotemporal scales and metrics of ecological outcomes (Roche et al., 2015a). There remains a need to document and evaluate adaptive decision-making processes for complex ranch social-ecological systems at long time scales (from one to many decades over the lifetime of a ranch business) in a manner that accounts for rancher goals and objectives and for the adaptation and learning suggested in the framework of Lubell et al. (2013).

4.1.2. A DEBATE REVEALS GAPS IN GRAZING RESEARCH. Rotational grazing allows managers to control the distribution of grazing pressure in space and time by managing how often, how intensely, or how uniformly grazing animal defoliate rangeland plants (Briske et al., 2011b; Teague et al., 2008). Diverse rotational grazing approaches provide a number of grazing management benefits, including control over plant response to grazing (Goodloe, 2013; Teague et al., 2008). Briske et al. (2011b) suggest that the rotational grazing debate goes back as early as the 1950s, when rangeland scientists began to wrestle with recommending practices to maximize production and/or rangeland vegetation outcomes in grazed rangeland systems. Rotational systems were examined in the early 20th century by early rangeland management experts in the United State (Stoddart et al., 1955; Sayre, 2015), and though experimental justification for its promotion was lacking (Briske et al., 2008, see), a number of rotational grazing approaches have remained a widespread management strategy for private and public lands grazing managers across the world. Recent interest in the rotational grazing debate has focused around key papers and reports by Briske and colleagues (Briske et al., 2008, 2011a,b) where analysis of the outcomes of rotational grazing research indicate that

rotational grazing does not enhance plant species composition, forage production, or livestock production. For example, while experimental evidence suggests that stocking rate can have an important impact on species composition (documented in 71 percent of stocking rate studies evaluated) (Briske et al., 2011a), 81 percent of surveyed grazing experiments indicated no difference in species composition for continuous vs. rotational grazing systems (Briske et al., 2011a). Seventeen of 19 (89 percent) studies surveyed reported no difference for plant production/standing crop between rotational and continuous grazing, controlling for stocking rate, and 57 percent of surveyed studies reported no difference for animal production per head between the two systems (Briske et al., 2011a, p. 29).

In the North American Great Plains, rangeland plant species and functional group composition are important indicators of rangeland condition (biodiversity, hydrologic function, and productivity) that are influenced by management, environmental variability, and evolutionary history of grazing and have economic implications for ranching operations. Milchunas and co-authors' (Milchunas et al., 1988) generalized model of plant response to grazing predicts impacts of grazing on grassland diversity, including a relatively moderate decline in species diversity in semi-arid rangelands with a long evolutionary history of grazing (Milchunas et al., 1988; Milchunas & Lauenroth, 1993). In our study area, spring precipitation (Lauenroth & Sala, 1992), catena position, grazing (Milchunas et al., 1989), soil texture, and temperature (Epstein et al., 1997) shape the relative abundance of plant species and rangeland production. Under heavy grazing, cool-season perennial grasses have a reduced ability to respond to variability in precipitation in northern mixed prairie (Irisarri et al., 2016).

Heavy grazing intensity can lead to a reduction in rangeland productivity via replacement of cool-season perennial grasses with (less productive) warm-season grass species (Milchunas

et al., 1994; Hart & Ashby, 1998; Derner et al., 2008) and moderate increases in bare ground (Augustine et al., 2012). Long-term grazing experiments in the northern mixed prairie indicate that heavy-grazing induced shifts in cool-season perennial grasses to short warm-season perennial grasses (*Bouteloua spp.*) were slow, continuous, and directional, and resulted in distinct plant communities that were not stable (Porensky et al., 2016). Because grazing experiments, including grazing intensity studies, have largely excluded ranch decision-making processes, including modifications in stocking rate and rotational grazing made by adaptive decision-making, key gaps remain in our understanding of the links hypothesized by Lubell et al. (2013) between management strategies and ecological outcomes at ranch relevant time-scales, from one to several decades.

4.1.3. RESILIENCE CAN CONTRIBUTE TO RANCH DECISION-MAKING THEORY. Lubell et al. (2013)’s framework hypothesizes long-term ranch scale adaptation in social-ecological systems (see section 4.2) as learning and transformative processes that connect management outcomes to socio-cultural and ecological sub-systems. Taking the family-owned ranches as a unit of analysis requires simultaneous consideration of social and ecological components (Gunderson, 2001). We argue for a more explicit consideration of social-ecological (SES) theory (Berkes et al., 2000b), via a resilience lens and more specifically through the concept of the adaptive cycle, to Lubell et al. (2013)’s framework (Darnhofer et al., 2016).

Resilience theory, which already informs Lubell et al. (2013)’s framework, has been discussed relative to rangeland management or ranch management processes (Bestelmeyer & Briske, 2012), particularly around climate adaptation (Marshall & Smajgl, 2013; Marshall & Stokes, 2014; Briske et al., 2015) and the adaptive cycle (Gunderson, 2000, 2001) has been used to evaluate change in family farms more generally (Darnhofer, 2010; Darnhofer

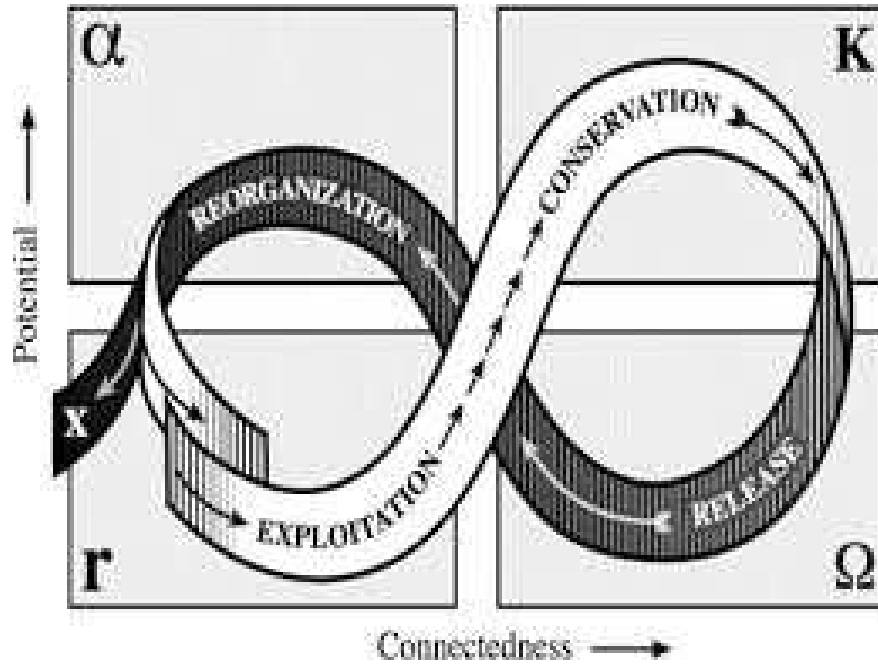


FIGURE 4.3. The adaptive cycle is often described through a ecological succession metaphor. A rangeland, for example, may experience an incremental phase of growth and accumulation (moving from the exploitation phase into the conservation phase as it becomes a mature plant community with few dominant individuals). Then, it may enter a more rapid phase of disturbance (the release phase) and renewal (the reorganization phase) after a fire or other ecological disturbance transforms landscape (Gunderson, 2001; Holling & Gunderson, 2002).

et al., 2016). Resilience is a concept drawn from non-equilibrium ecology that describes how systems retain their structure, function, and identity in the face of perturbations (Holling & Meffe, 1996; Holling & Gunderson, 2002; Gallopín, 2006). Resilience is often defined in SES literature as the amount of change a system can absorb without altering its essential structure and function (Berkes et al., 2000b; Walker & Salt, 2012).

In this study we consider the adaptation of individual ranches, acknowledging that the concepts of resilience and adaptive capacity are often applied at the community level in the community-based natural resource literature (Armitage, 2005), though both scales of analysis have limitations (Armitage & Johnson, 2006). Adaptive capacity is the ability to cope with environmental contingencies and to improve its condition in relation to the

(social and ecological) environment, or to extend the range of environments in which it is adapted (Gallopín, 2006, p.300) through learning and innovation (Smit & Wandel, 2006). Adaptive capacity is often associated with forward-looking, proactive measures (Smit & Wandel, 2006; Fernández-Giménez et al., 2015) where decision-makers create opportunity for learning, renewal, and transformation, and learn to live with uncertainty (Armitage, 2005).

Processes of adaptation for SESs have been conceptualized through the adaptive cycle (see Figure 4.3), whereby the system experiences stages of reorganization and adaptation, from longer periods of growth or exploitation (r) and conservation (K), and faster periods of release or collapse (Ω) and reorganization (α) that create opportunities for novel recombinations of sub-system interactions and assemblages (Holling & Gunderson, 2002). The adaptive cycle is often illustrated with an ecosystem succession metaphor. A rangeland, for example, may experience an incremental phase of growth and accumulation (moving from the exploitation phase into the conservation phase as it becomes a mature plant community with few dominant individuals). Then, it may enter a more rapid phase of disturbance (the release phase), and renewal (the reorganization phase) after a fire or other ecological disturbance influences ecological structure and function (Gunderson, 2001).

The application of ecological concepts to SES and social processes of change is not without limitations (Olsson et al., 2015; Darnhofer et al., 2016). Resilience theory is often applied with great emphasis on institutional rule-making (Berkes et al., 2000b; Ostrom, 1990) and has faced criticism for an underutilization social theory and recognition of power (Adger, 2000; Cote & Nightingale, 2012). Darnhofer et al. (2016) note that conceptualizations of SES change on family farms can be one-sided, in that they can either emphasize manager agency and ability to control system dynamics, or ecological determinants of system dynamics.

Darnhofer et al. (2016) call for research that focuses on emergent, context specific relations between humans and their environment and on resilience as a process.

We interpret the above review of recent theoretical developments in research on adaptive ranch decision-making and insights from the rotational grazing debate to suggest gaps in our knowledge of adaptive ranch decision-making. First, debate lingers as to the apparent disconnect between experimental and ranchers' experiential evaluation of different management strategies and the resultant ecological outcomes at long time scales greater than 2-5 years, relevant to ranch decision-makers. Second, ranch adaptive processes have not been evaluated at the ranch SES scale.

We address these gaps by examining social and ecological data from 17 ranches in eastern Colorado and eastern Wyoming. Our research question to evaluate ranch decision-making processes and the resultant ecological outcomes were: Do ecological indicators of plant species and structural (including plant functional groups and non-plant cover types) group composition differ among management types after accounting for environmental variation? Our specific research questions to evaluate ranch SES scale adaptation: What adaptive trajectory is each ranch in? What transformation does the ranch SES experience over time? Where is the ranch SES coming from, and where is it going? In doing so, we aim to evaluate ranch SES adaptation on multiple temporal scales.

4.2. METHODS

4.2.1. METHODOLOGY. We chose a case-study methodology with a sampling approach that accounts for the diversity of decision-makers, across gender and generation, at the family ranch level (Pannell & Vanclay, 2011). We used a repeated semi-structured interview protocol

to track decision-making processes across broad temporal scales (an overview of methods, including data collection and analysis are provided in Figure 4.5).

We conceptualized family-owned cattle ranches as complex, social-ecological systems involving dynamic and interdependent relationships among social entities (families or individual ranchers and their communities), ranching agro-ecosystems (including many types of land, livestock, and natural resources), and business operations (involving agricultural and non-agricultural production) (Fulton & Vanclay, 2011). Prolonged engagement with rancher collaborators during field work situates our findings within localized contexts and enables us to document decision-making processes in depth, though case selection methods limit our ability to generalize to broader ranching populations in a statistical manner. In this way, we aim to contribute to current middle-range theory on rangeland adaptive decision-making (George & Bennett, 2005).

4.2.2. CASE SELECTION. We selected 17 beef cattle operations distributed across a latitudinal gradient in the North American Great Plains ranging from approximately 39.882000 to 42.821000 ° N and from -102.150000 to -105.217000 ° W (See Figure 4.4). The study area is characterized by a north-south gradient in mean annual temperature (7 – 11° C) and a weak east-west gradient in mean annual precipitation (339-460 mm). Native plant communities within the region are dominated by warm-season shortgrasses (primarily *Bouteloua gracilis* and *Bouteloua dactyloides*), cool-season mid-grasses (*Pascopyrum smithii*, *Hesperostipa comata*) and cool-season sedges (*Carex spp.*) with increasing dominance of cool-season graminoids in the northern, cooler portion of the study area and dominance of warm-season shortgrasses in the southern, warmer portion of the study area (Lauenroth et al., 1999; Lauenroth & Burke, 2008).

TABLE 4.1. Summary of concepts evaluated in this study. We used mixed-methods to evaluate ranch SES-level adaptations, specific management strategies and the resultant ecological outcomes.

Concept	Adaptive Trajectories	Management Strategies	Ecological outcomes
Scale of analysis	Ranch SES-level adaptation	Specific ranch management decisions	Three pastures/ranch
Research Questions	What transformation does the state of the SES experience over time? Where is the ranch SES coming from, where is it going?	What is each ranch’s grazing strategy (3 levels); operation type (2 levels); grazing intensity (2 levels); planning style (2 levels)?	Do ecological indicators (species and structural group composition) differ among management types after accounting for environmental variation?
Data	Repeated interviews	Repeated interviews	Relativized, transformed species composition, structural group composition (2014-2015); climate and soil data
Analysis	Thematic and analytic coding	Variables created from interviews and used in statistical analysis to compare ecological outcomes across groups of ranches.	Unconstrained (NMDS) ordination on species composition, linear mixed models; pairwise comparison of structural composition dissimilarity.
Strengths	Narratives document management in depth, over large scales of time and space.	Management treatments evaluated over longer time scale than typical range research and account for “real-life” management constraints faced by ranchers	Plot types link to ranchers’ subjective interpretation of their management outcomes, plots located along environmental gradient.
Limitations	Study focuses on “successful” cases, no opportunity to observe ranch SES state shift.	Rely on narratives (accuracy).	Limited number of variables analyzed, small sample size.

Our study ranches were distributed relatively systematically across north-south gradient with seven in Wyoming and ten in Colorado. Cases were all family-owned cow-calf and/or yearling ranches. Potential participants were identified through a snowball sampling method from a pool of operators known to the researchers and their social networks. Based on pilot conversations with potential participants, we invited a group of ranchers into the study who

spanned a spectrum of grazing management strategies from season-long continuous grazing with few pastures and greater than 30 day grazing duration, moderate (30 days) grazing durations with many pastures, and high density, short-duration grazing with short (few day) grazing durations. Roche et al. (2015a)'s recent analysis survey of Wyoming ranchers considered number of pastures, number of livestock herds, duration of grazing, livestock density, and timing of rest from grazing, and identified three grazing strategies in the state. These included 53 percent of respondents using rotational grazing with ≤ 5 pastures, 35 percent used rotational grazing with 6+ pastures, and 12 percent used high-density, short duration grazing, with the majority of these ranchers reporting short (few days) grazing durations.

4.2.3. SOCIAL DATA COLLECTION AND ANALYSIS. Repeated, audio recorded rancher interviews took place in 2012, and 2014-2016. Members of seven families in Wyoming and two in Colorado were interviewed in 2012, and 10 more Colorado operations were added in 2014. Initial semi-structured interviews focused on questions about the structure, goals, definitions of success, grazing management approaches, and annual decision-making points for each ranching operation. In subsequent interviews, ranchers were asked to describe major changes in their grazing management practices and other decisions on the ranch, and to describe their perspectives of social, economic, and ecological outcomes of those decisions relative to fluxes in market, climatic and social change. Interviews were conducted in person on-ranch, with the exception of two phone interviews. A total of 30 ranchers were interviewed (17 men, 13 women). All members of ranching families were invited to participate in interviews. Interviews involved one to five people, ages from mid-20s to mid-80s, two generations in four cases (including couples and their children in 3 cases and a father/daughter ranching team),



FIGURE 4.4. Map of study area: study ranches were distributed relatively systematically across north-south gradient with 7 in Wyoming and 10 in Colorado and had been operating for at least 10 years. Cases were all family-owned cow-calf and/or yearling ranches.

couples in five cases, and individual primary decision-makers in seven cases (five men and two women). Interviewees were all white. Ranchers who participated in the study for three years were provided with a cash honorarium in 2016. This study was approved by Colorado IRB protocol 12-3381H and participation in the study was confidential.

We took steps to ensure the validity of the qualitative data, including peer debriefing, prolonged engagement with the data, and member checking, whereby we gathered feedback on our initial findings with rancher participants at subsequent interviews. We maintained a data audit trail (including clear documentation of raw data and descriptions of decisions about data reduction and synthesis), triangulation of the data with researcher field notes and documents (including rancher-conducted research and monitoring results) provided by ranchers, as well as ongoing activities of researcher reflexivity (Lincoln & Guba, 1985; Creswell, 2013).

4.2.3.1. *Grazing Management Variables.* We categorized each ranch into ranch-scale grazing management categories based on ranchers' reported management of the ranch in the last decade (though, with two exceptions, all the ranchers in the study had been in operation for twenty or more years) (see (see 4.1). Grazing strategy was based on average duration of grazing in each pasture, total number of herds and pastures, and period of rest. This factor had three levels, 1= Few pastures, long duration (several weeks to months); 2= Many pastures, moderate duration (a few weeks); and 3= Many pastures, short duration grazing, (a few days to a week), thus following the typology of Roche et al. (2015a). Planning style (two levels) was assigned based on the extent to which managers engaged in explicit or tacit grazing management planning. Explicit planning involved development and re-evaluation of goals, explicit grazing planning, record keeping, and adjustment of grazing practices between and within years based on documented events or new information. Tacit management planning

included unwritten or unspoken traditions, lack of documentation of grazing planning or records, and adjustments to management without documented rationale. Cases were assigned high or low grazing intensity based on the study-wide median (ten ha) maximum grazeable landbase managed to support an animal unit equivalent year-round (excluding irrigated cropland). Operation type included cow-calf operations and cow-calf/yearling operations.

4.2.3.2. *Ranch Adaptive Trajectories.* Coding of rancher interviews allowed us to document management change over time, and account for decades and generations-long term change from narratives. We tracked this change in a spreadsheet and linked key themes to raw data with RQDA (Glesne et al., 1992). To categorize ranchers into adaptive cycle trajectories, we coded interview data for ranch history, goals and objectives, recent adaptations to social and ecological disturbances, other major management changes and challenges, and rancher identified definitions of success. We also coded for actions or choices ranchers said they avoided. Ranch level adaptation was examined by categorizing ranches into four trajectories in the adaptive cycle. Trajectory categories indicate the directional change and ranch-system transformation. They included: 1) Exploitation-to-Conservation ($r-K$); 2) Conservation-to-Release ($K-\Omega$); 3) Release-to-Reorganization ($\Omega - \alpha$); and 4) Reorganization-to-Exploitation ($\alpha-r$) (Gunderson, 2001; Holling & Gunderson, 2002).

4.2.4. ECOLOGICAL DATA COLLECTION AND ANALYSES. We measured ecological conditions on three locations (plots) on each ranch. Two plot locations were determined by ranchers, who were asked to identify pastures on relatively loamy soil where one pasture represented the “best” outcomes of their management and the other pasture represented the area with the “most room for improvement.” We established a third plot in a random location on the each ranch. We verified the ecological site based on site characteristics including depth,

TABLE 4.2. Species code key for relative rangeland basal cover, including corresponding structural (plant functional and non-plant cover type) group category. AF=Annual forb, BOBU=*Bouteloua* warm season grasses, PF=Perennial Forb, PGWS=Palatable perennial warm-season grasses, PGCSNP=Unpalatable perennial cool-season grasses, S=Shrub/Subshrub

Code	Scientific name	Authority	Common name	Functional Group
ANRO	<i>Antennaria rosea</i>	Greene	rose pussytoes	PF
ARCA	<i>Artemisia cana</i>	Pursh	silver sagebrush	S
ARFR	<i>Artemisia frigida</i>	Willd.	fringed sagewort	S
ARLO	<i>Aristida longiseta</i>	Steud.	red threeawn	PGWS
BOGR	<i>Bouteloua gracilis</i>	(Willd. ex. H.B.K.) Lag. ex. Steud.	blue grama	BOBU
BRTE	<i>Bromus tectorum</i>	L.	cheatgrass	AGCS
BUDA	<i>Bouteloua dactyloides</i>	(Nutt.) Engelm.	Buffalograss	BOBU
CAEL	<i>Carex eleocharis</i>	Bailey	needleleaf sedge	PGCS
CAFI	<i>Carex filifolia</i>	Nutt.	threadleaf sedge	PGCS
CHVI	<i>Chrysopsis villosa</i>	(Pursh) Nutt.	hairy goldenaster	PF
CRMI	<i>Cryptantha minima</i>	Rydb.	plains cryptantha	AF
GUSA	<i>Gutierrezia sarothrae</i>	(Pursh) Britt. & Rusby	broom snakeweed	S
KOPY	<i>Koeleria pyramidata</i>	(Lam.) Beauv.	prairie junegrass	PGCS
LEMO	<i>Leucocrinum montanum</i>	Nutt. ex. Gray	common starlily	PF
OPPO	<i>Opuntia polyacantha</i>	Haw.	plains prickly pear	S
PASM	<i>Pascopyrum smithii</i>	(Rydb.) A.Love	western wheat grass	PGCS
PHHO	<i>Phlox hoodii</i>	Richards	hoods phlox	PF
PLPA	<i>Plantago patagonica</i>	Jacq.	woolly plantain	AF
POSE	<i>Poa segunda</i>	J. Presl	sandberg bluegrass	PGCS
SIHY	<i>Sitanion hystrix</i>	(Nutt.) J.G. Sm.	bottlebrush squirreltail	PGCSNP
SPCO	<i>Sphaeralcea coccinea</i>	(Nutt.) Rydb.	scarlet globemallow	PGCS
SPCR	<i>Sporobolus cryptandrus</i>	(Torr.) Gray	sand dropseed	PGWS
STCO	<i>Heterostipa comata</i>	Trin. & Rupr	needle and thread	PGCSNP
VUOC	<i>Vulpia octoflora</i>	(Walt.) Rydb.	sixweeks fescue	AGCS

surface and subsurface soil texture and cover of rock fragments by volume. In 2014 and 2015, the field team measured basal cover using the line-point intercept method (Godínez-Alvarez et al., 2009) with measurements (see Table 4.2) taken every 0.91 m along two 45.72 m transects on each plot following a modified NRCS Natural Resources Inventory protocol (U.S. Department of Agriculture, 2014). We determined rangeland plant species, liter, moss/lichen, biological soil crust and abiotic (soil, rock, and dung) basal cover percentages by years.

We collected a 20cm soil core and measured soil clay content using the hydrometer method averaged across 1-10 and 10-20 cm depths for samples at each plot (Bouyoucos, 1962). We

measured the latitude and longitude of the center of each plot, and used the coordinates to sample precipitation and temperature data at from Parameter-elevation Relationships on Independent Slopes Model (PRISM) datasets (Daly et al., 2008). We sampled long-term precipitation data for the growing season months (April-August) from PRISM’s 30-year normal product (1981-2010) at 800m resolution. We calculated the proportion of growing season (April-August) precipitation falling during the spring (April and May). We derived elevation, slope, and aspect from 1-arc second resolution ASTER global digital elevation models.

We performed all ecological data transformations and analyses in R (R Core Team, 2016). We calculated species composition by averaging and relativizing 2014 and 2015 basal cover data for each plot (see 4.5). We removed rare species occurring on fewer than 5 percent of plots, checked for outliers based on a nearest-neighbor criterion using the R library ‘dave’ (McCune et al., 2002; Wildi, 2010), and transformed the relative species composition data ($+1 * \log 2$) to down-weight dominant species. We derived rangeland structural group data to untransformed, relativized basal cover (including rare species), and grouped plant functional groups and non-plant groups (bare ground, dead plants, litter, moss/lichen, biological soil crust, rocks, and dung). Plant functional groups were determined by growth habit, photosynthetic pathway, and palatability, and included: shrubs/subshrubs, palatable cool-season perennial grasses, unpalatable cool-season perennial grasses, shortgrass (*Bouteloua*) species, other warm-season grasses, annual grasses, annual forbs, and perennial forbs.

We computed non-parametric statistics using the R package *vegan* (Oksanen et al., 2016). To interpret the influence of environmental drivers and management categories on rangeland species composition, we performed a Non-Metric Multi-Dimensional Scaling (NMDS)

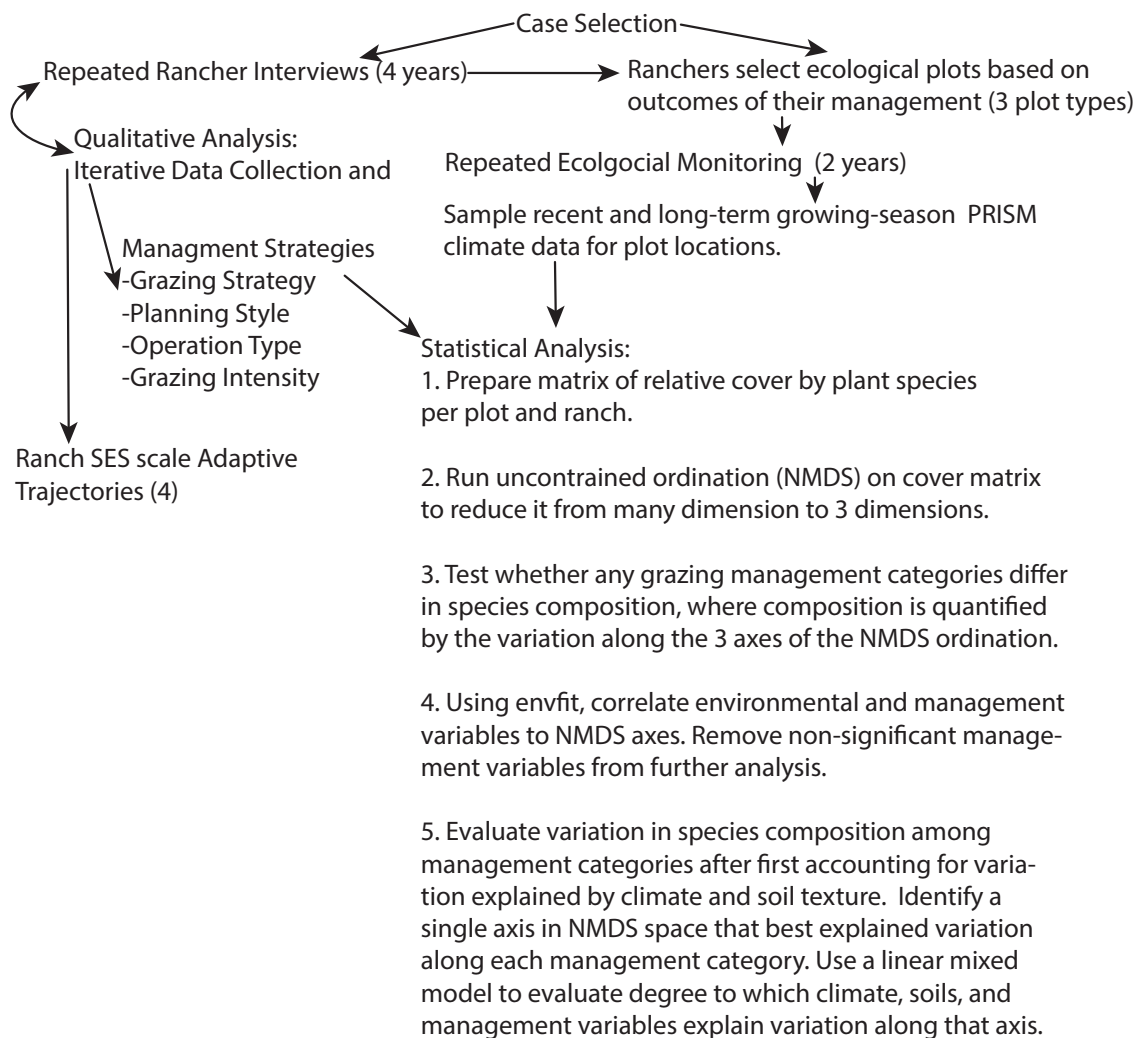


FIGURE 4.5. Flow chart of social and ecological data collection and analyses.

ordination using the Bray-Curtis dissimilarity (Kruskal, 1964). NMDS is an unconstrained ordination technique chosen because of the method's ability to handle non-linear species responses to environmental gradients (McCune et al., 2002). NMDS finds coordinates for multidimensional data in reduced k-dimensional ordination space by optimizing the difference between the ranked distances between response variables (species) in higher dimensional space and the distance between them in the reduced (k) dimensional space. Stress— the distance between community dissimilarity and ordination distances, is used as a goodness of

fit measure and interpreted from a Shepard plot. Based on stress, Shepard plot outputs and convergence behavior k was chosen to be 3.

For exploratory analysis, we used the function ‘envfit’ (permutations=999 in vegan) to correlate management categories and environmental variables with NMDS axes, and displayed scaled significant ($p < 0.05$) environmental variables as vectors on the ordination plots. We compared the centroids of management categories and plot types in envfit using ellipses covering 95 percent confidence intervals. Categories that were not significantly correlated with the NMDS ordination and had overlapping confidence intervals were excluded from further analysis.

To understand the relationship between NMDS axes and management groups, while accounting for environmental variables, we first rotated the NMDS ordination with the first dimension parallel to significant management categories (we conducted one rotation for grazing intensity and another for operation type) and extracted the site scores for the respective axis. We fit linear mixed models (LMMs) using the lme4 package in R (Bates et al., 2014) to predict the site scores on each rotated NMDS axis. For the NMDS axis rotated parallel with grazing intensity, fixed effects included long-term growing season mean temperature, long-term growing season precipitation, soil clay content, and grazing intensity group as fixed effects and ranch as a random effect.

For the NMDS axis rotated parallel with operation type, soil clay content and operation type were fixed effects and ranch was a random effect. We calculated marginal R^2 (the proportion of the variance explained by fixed effects) and conditional R^2 (the variance explained by fixed and random effects) (Nakagawa & Schielzeth, 2013) using the piecewiseSEM package in R (Lefcheck, 2016). We used the simper function in vegan (Oksanen et al., 2016)

to calculate the overall contribution of rangeland structural groups to the Bray-Curtis dissimilarity of management groups.

4.3. RESULTS

4.3.1. ECOLOGICAL OUTCOMES OF RANCH MANAGEMENT STRATEGIES. The NMDS ordination (stress=0.138, k=3, non-metric $R^2 = 0.98$) did not show distinct clustering of species composition for ranch grazing strategy, plot type (“best”, “most room for improvement,” or randomly identified plot), or planning style management groups (see Figure 4.6 and Table 4.4). These categories were not significantly correlated with the NMDS ordination (grazing strategy: axes 1 and 2, p=0.224 axes 2 and 3 p=0.635; planning style: axes 1 and 2 p=0.272, axes 2 and 3 p=0.268, plot type: axes 1 and 2 p=0.933, axes 2 and 3 p=0.978).

Distinct clustering patterns did appear for grazing intensity (Figure 4.7) and operation type groups (Figure 4.8) on the NMDS ordination plots. Long-term growing season mean temperature and precipitation, soil clay content and grazing intensity accounted for 57 percent of the variance, and the full model with ranch as a random effect accounted for 63 percent of the variance in relative species composition along the NMDS axis rotated to parallel with grazing intensity (see Axis 1 on Figure 4.7 and Table 4.3). This axis separated low grazing intensity sites with a greater abundance of perennial cool-season grasses and sedges (*P. smithii*, *P. segunda*, *Carex spp.*, *H. comata*, *E. elemoides*), perennial forbs (*Astragalus/Oxytropis*, *S. coccinea*), subshrub species *C. villosa*, *A. frigida*, and annual forbs (*P. patagonica*, *L. montanum*) from the high grazing intensity sites with a greater abundance of annual cool-season grasses (*B. tectorum*, *V. octoflora*), unpalatable perennial warm-season grasses (*A. longisteta*), cacti (*O. polyacantha*), and palatable warm-season grasses (*B. dactyloides*, *S. cryptandrus*).

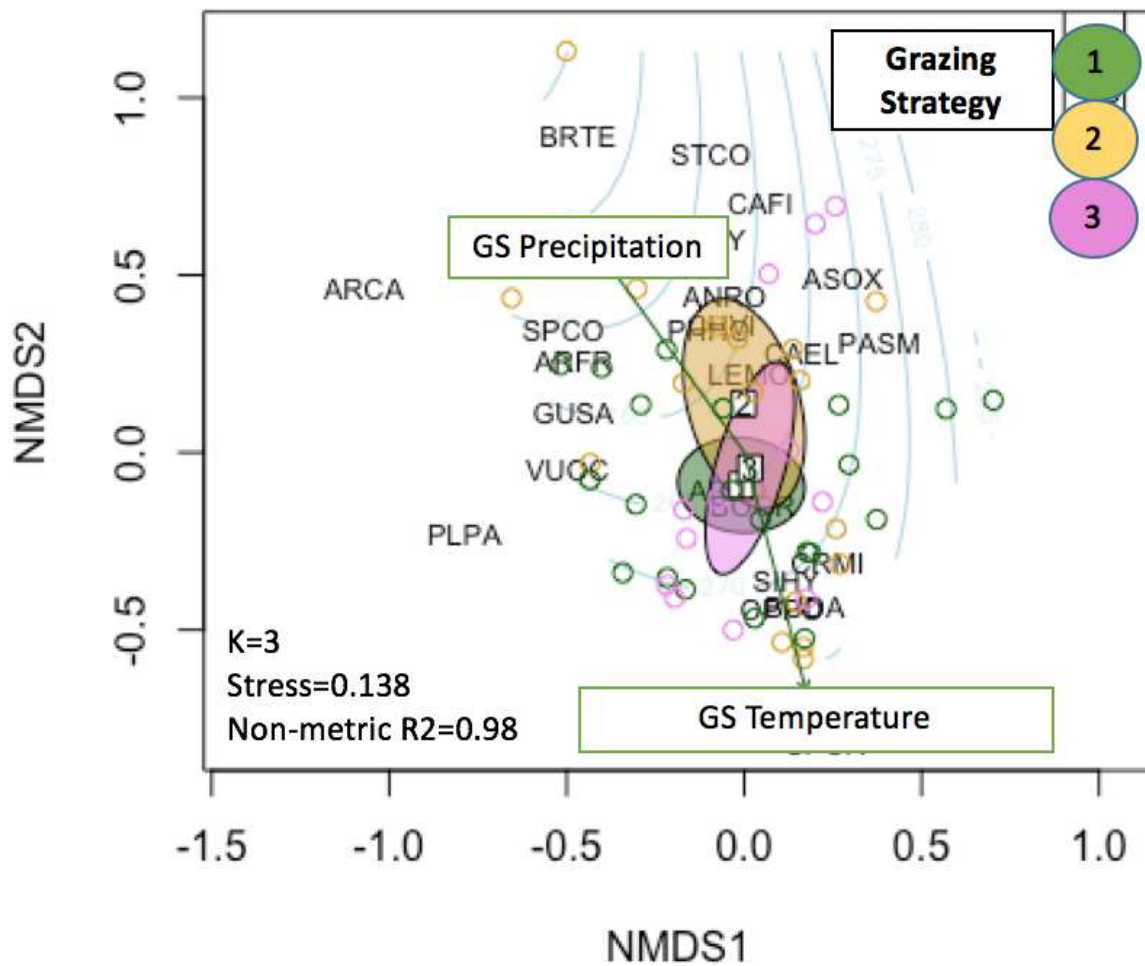


FIGURE 4.6. NMDS ordination plot shows the comparison of species composition (points) by ranch grazing strategy (not rotated). The centroid of each management group is enclosed in a 95 percent confidence ellipse. 4-letter codes are species. Plots found closer to species codes have more relative abundance of that species in reduced-dimensional space. Contours are long-term spring precipitation as a proportion of total growing season precipitation. Vectors are significant ($p < 0.05$) environmental variables correlated with the NMDS ordination. Vectors are scaled to their level of significance and point in the direction of their correlation. Grazing strategy was not significantly correlated with species composition in the study. Contours are long-term average growing season precipitation (mm).

Soil clay content and operation type accounted for 46 percent of the variance in species composition along the NMDS axis rotated parallel to operation type, and the full model with ranch as a random effect accounted for 80 percent of the variance in species composition

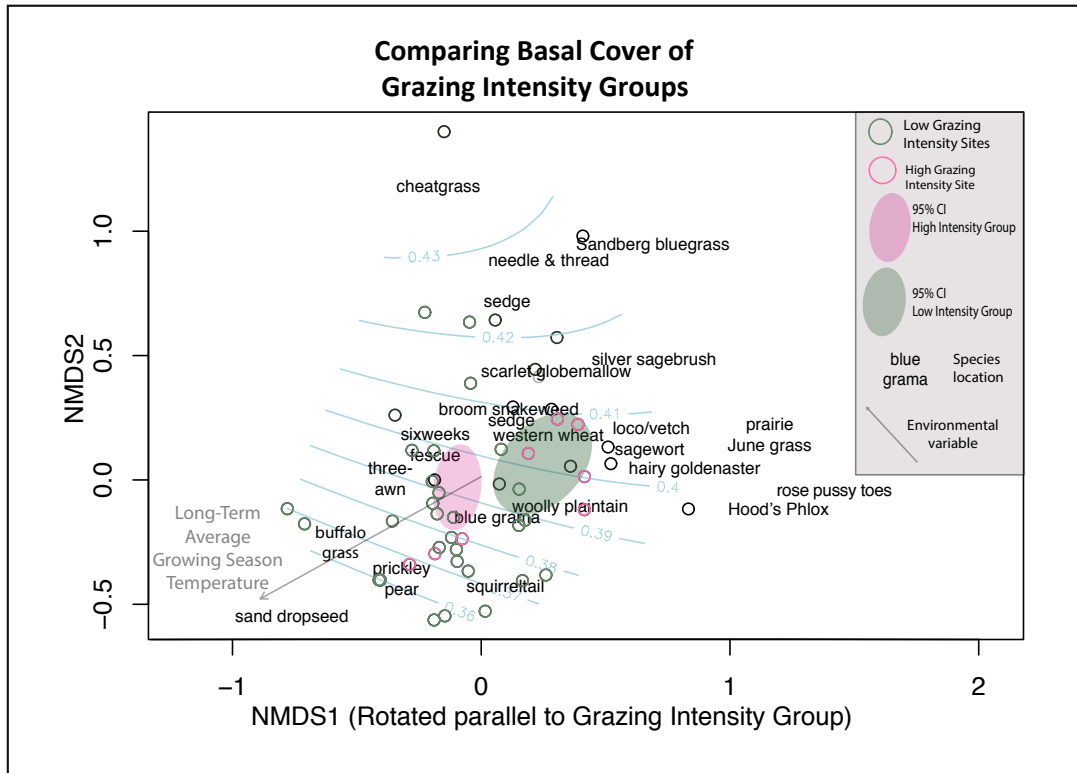


FIGURE 4.7. NMDS ordination plot shows the comparison of species composition by grazing intensity group, with axis 1 rotated parallel to grazing intensity. The centroid of each grazing intensity group is enclosed in a 95 percent confidence ellipse. Contours are long-term spring precipitation as a proportion of total growing season precipitation.

(see Axis 1 on Figure 4.8 and Table 4.3). This axis separates cow-calf operations with a greater abundance of cool-season perennial grasses (*P. smithii*, *P. secunda*) and perennial forbs (*Astragalus/Oxytropis*), from cow-calf/yearling operations with a greater abundance of subshrubs (*A. frigida*, *G. sarothrae*), annual cool-season grasses (*B. tectorum*, *V. octoflora*) and annual forbs (*P. patagonica*, *L. montanum*). Pair-wise comparison of (absolute, untransformed) rangeland structural group contributions to overall Bray-Curtis dissimilarity between management groups indicate that litter, *Bouteloua* shortgrass species, bare ground, annual cool-season grasses, dead plants, and palatable perennial cool season grasses account for 83 percent of the dissimilarity between cow-calf and cow-calf/yearling operations (see Figure

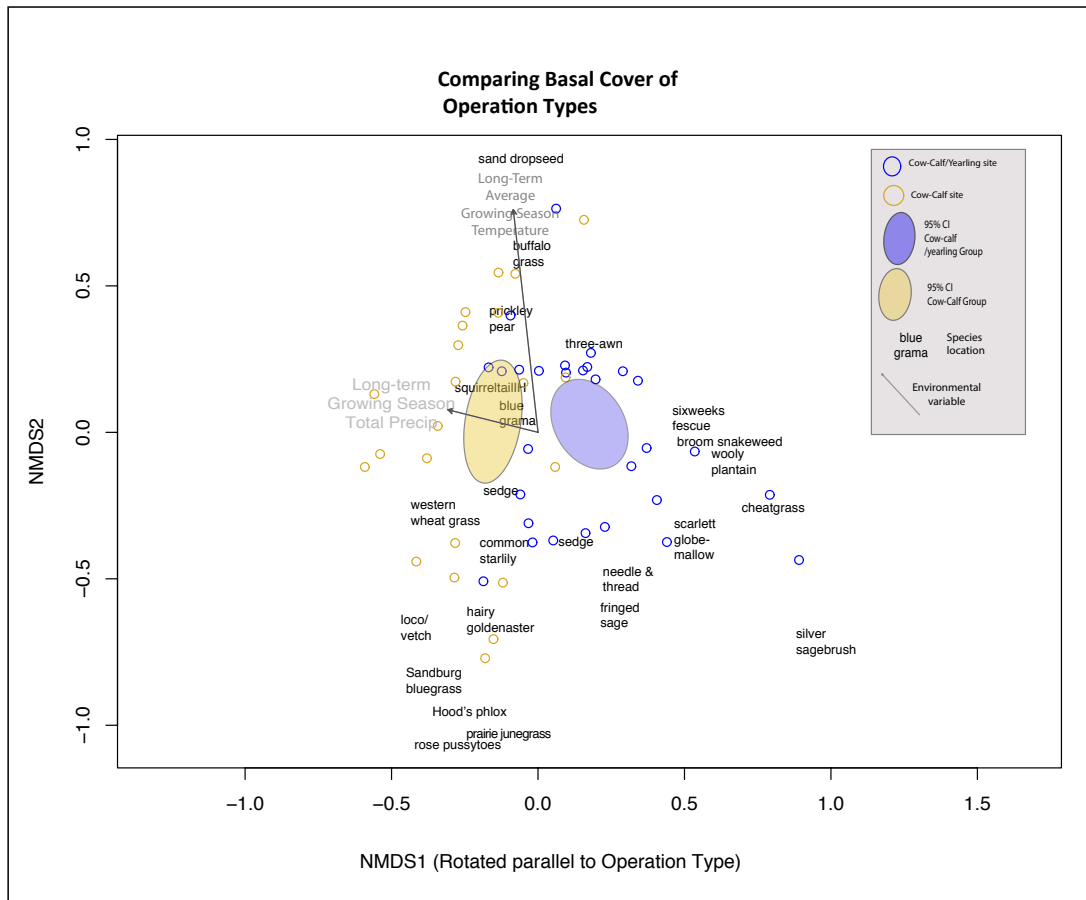


FIGURE 4.8. NMDS ordination plot shows the comparison of relative basal cover for cow-calf and cow-calf/yearling operations, with axis 1 rotated parallel to operation type. The centroid of each grazing intensity group is enclosed in a 95 percent confidence ellipse. Contours are long-term spring precipitation as a proportion of total growing season precipitation.

TABLE 4.3. The NMDS ordination was rotated twice, once to so that the first dimension was parallel to the operation type variable (cow-calf vs. cow-calf/yearling), and once so that the first dimension was parallel to the grazing intensity variable. Linear mixed models (LMMs) fitted to predict site scores (relative basal cover), on each axis with ranch as a random effect.

Response Variable		Value	Std.Error	DF	t-value	p-value
Cow-Calf vs. Cow-Calf/Yearling NMDS axis	Intercept	0.023	0.095	32	0.247	0.807
	Soil Clay	-0.006	0.002	32	-3.207	0.003
	Cow-calf/yearling	0.356	0.087	32	4.104	0.000
Grazing Intensity NMDS axis	Intercept	1.050	0.641	31	1.637	0.112
	Long-term Growing Season Precip	0.006	0.002	31	3.369	0.002
	Long-term Growing Season Mean Temp	-0.161	0.034	31	-4.692	0.000
	Soil Clay	-0.004	0.002	31	-1.966	0.058
	Low grazing intensity	0.197	0.092	5	2.146	0.049

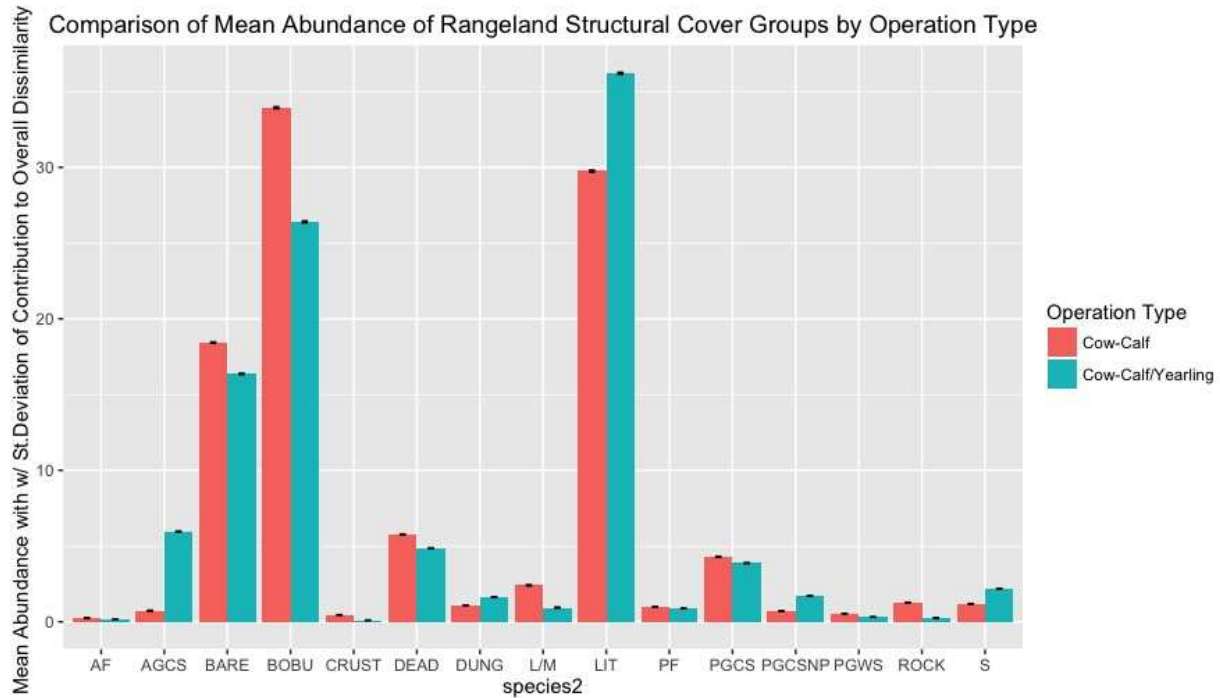


FIGURE 4.9. Pairwise comparisons of mean cover of rangeland structural group by operation type. Error bars are standard deviation of the structural group’s average contribution to the overall dissimilarity between operation types. Litter (LIT), shortgrasses (BOBU), bare ground (BARE), annual cool-season grasses (AGCS), dead (DEAD) and palatable perennial cool-season (PGCS) grasses account for 82 percent of the dissimilarity between operation types. AF=annual forbs, CRUST= biological soil crust, DUNG= feces, L/M=lichen and moss, PF=perennial forbs, PGCSNP= unpalatable perennial cool-season grasses, PGWS= perennial warm season grasses, ROCK= rock fragments, S=shrubs and subshrubs.

4.9) and 78 percent of the dissimilarity between low and high grazing intensity groups (see Figure 4.10).

4.3.2. RANCH ADAPTIVE TRAJECTORIES.

4.3.2.1. *Exploitation-to-Conservation (r-K)*. The 7 (4 in Colorado) ranches in the exploitation-to-conservation trajectory of the adaptive cycle are characterized by movement from a rapid period of growth and change to slow-changing, stable business and family structures that were well adapted to local ecological contexts. The planning processes of these ranches employed multigenerational local ecological knowledge and traditional social and political networks to

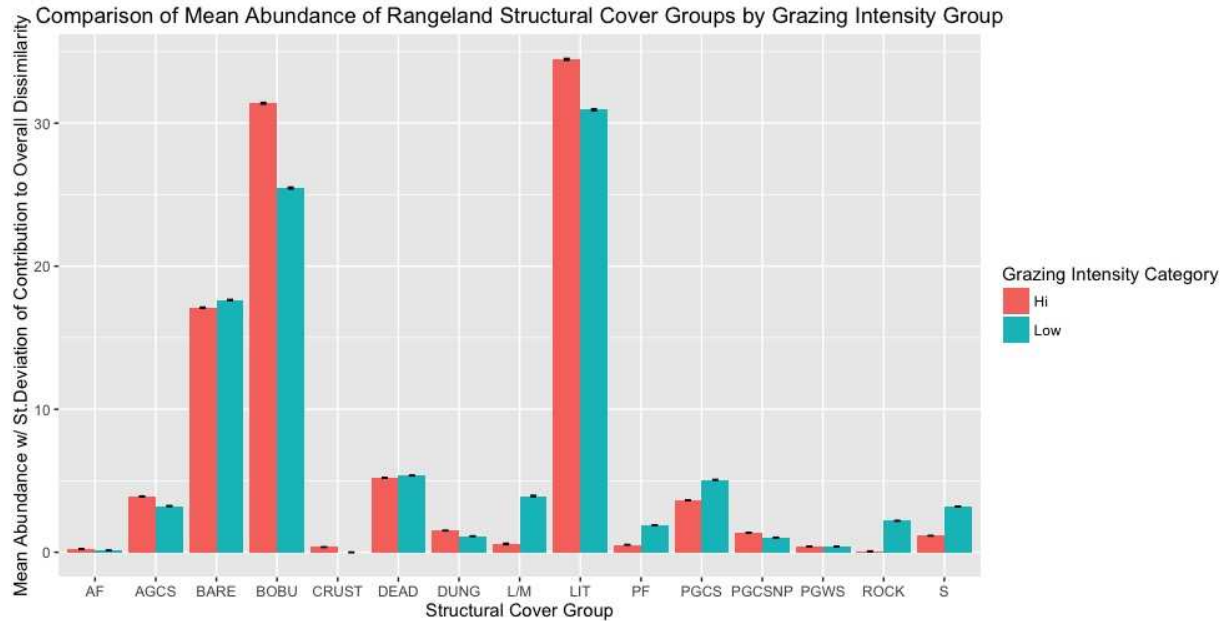


FIGURE 4.10. Pairwise comparisons of mean cover of rangeland structural group by grazing intensity group. Error bars are standard deviation of the structural group’s average contribution to the overall dissimilarity between grazing intensity groups. Shortgrass (BOBU), litter (LIT), bare ground (BARE), dead (DEAD), annual cool-season grasses (AGCS) and palatable cool-season perennial grasses (PGCS) accounted for 78 percent of the dissimilarity between intensity groups. AF=annual forbs, CRUST= biological soil crust, DUNG= feces, L/M=lichen and moss, PF=perennial forbs, PGCSNP= unpalatable perennial cool-season grasses, PGWS= perennial warm season grasses, ROCK= rock fragments, S=shrubs and subshrubs.

mitigate ecological and financial risk. These operations had a high potential for a change of a trajectory based on operator age but expressed satisfaction that years of work toward their goals were starting to lead to conservation and financial benefits.

To illustrate an example of this trajectory, we provide qualitative data from an interview with a Wyoming ranch family (2014) that included a mother, father, and two sons (see the full discussion Figure 4.11). When asked to describe the trajectory of the ranch, the discussion turned to retrospective learning about rangeland management, fires, and ranch operations. The younger generation reflected on bringing their college experiences home to the ranch. Finally, the mother brought up “the elephant in the room”: the two sons’ desire to upgrade

TABLE 4.4. Statistics from envfit function, which correlates environmental and management variables onto NMDS ordination of relative basal cover. NMDS axes shown here with first dimension rotated parallel to grazing intensity.

NMDS of relative species cover, rotated to grazing intensity groups								
					Envfit			
	Axis 1	Axis 2	R^2	P-value	Axis 2	Axis 3	R^2	P-value
Environmental Variables								
Long-term Spring Precip (proportion)	0.36	0.93	0.36	0.001	0.93	0.38	0.37	0.001
Long-term Growing Season Precip	0.30	-0.95	0.05	0.266	-0.61	-0.79	0.10	0.090
Long-term Growing Season Temp	-0.88	-0.48	0.55	0.001	-0.99	0.10	0.26	0.001
Soil clay content	-0.13	-0.99	0.01	0.894	-0.16	0.97	0.11	0.049
Management Strategies								
Intensity			0.11	0.005			0.11	0.006
<i>Low (below median)</i>	-0.24	0.07			-0.03	0.01		
<i>High</i>	-0.10	-0.03			0.07	-0.04		
Operation Type			0.06	0.067			0.17	0.001
<i>Cow-Calf</i>	0.05	-0.13			-0.13	-0.19		
<i>Cow-Calf/Yearling</i>	-0.03	0.10			0.10	0.14		
Grazing Strategy			0.03	0.272			0.03	0.635
1	-0.06	-0.07			-0.07	0.03		
2	0.12	0.09			0.09	-0.03		
3	-0.09	-0.01			-0.01	0.00		
Planning Style			0.03	0.272			0.03	0.268
<i>Tacit</i>	0.03	-0.06			-0.06	-0.03		
<i>Explicit</i>	-0.04	0.09			0.09	0.04		

their haying operation from traditional loose stacking to baling, which would require the purchase of additional equipment. This light-hearted conversation illustrates the slow, yet adaptive, change of the ranch in this trajectory as the sons' joke that they are plotting to find a way to convince their mother to pressure their father to buy a baler.

4.3.2.2. *Conservation-to-Release (K-Ω)*. The repeated interviews lead to a unique opportunity to document transition from a stable management phase into the beginning of a release phase (characterized by a marked shift in operation characteristics and management) by two ranches in the study (one in each state). On these operations, aging multi-generational ranchers without heirs began to plan for ranch turn-over by finding younger people to take

Son 1: "You can't get to where you think you need to do things the same way every year, you've got to always be reevaluating, looking, trying to think what why you are doing what you're doing. Can it be improved?"

Son2: "In a lot of ways we went off to college and to learn these things to find out just how smart Dad really was."

Father: "Yeah well weather is such a big factor, the amount of rain and moisture you get. You can change some things, and some things like the weather, it's completely out of your hands. You're at the mercy of Mother Nature, and you have to deal with it. It's not always what you want to do or the way you want to do it."

Mother: "Well I think Dad has been good about letting the boys try some things you know, you're not going to change the whole system overnight but there's little things that they wanted to try, but I think that we've let you.. The biggie I'll bring it up, it's the elephant in the room, every time this time of year is we put up all of our hay loose and that's what [my husband] wants to do and that's not what the boys want to do."

Researcher: "Okay good thing I didn't ask and you brought it up."

Mother: "So you know they've been vocal about that and there's reasons to go both ways and I try to stay in the middle although [one of my sons] told me the other day that they are not going to fix the air conditioner in my tractor because they're going to fry me into submission."

Son 2: "Into guilting Dad to agree to get a baler."

Mother: "Getting a baler [laughing] so I won't have the job of raking."

Son 1: "Happy wife, happy life."

Son 2: "We're going to cook Mom on there."

[Everyone laughing.]

Mother: "So I think from an objective standpoint, in our lifetime it will go to baled hay [My husband] says over his dead body, but you know we're talking lifetime."

[Everyone laughing]

Son1: "On the way home from your funeral we're going to stop at the tractor dealership."

FIGURE 4.11. A discussion between members of a Wyoming ranch family provides a light-hearted illustration of slow, adaptive change on their multigenerational ranch, in the Exploitation-to-Conservation (r-K) trajectory.

over their ranches. In both cases, early interviews documented these ranchers describing high levels of motivation to continue managing for the foreseeable future. In 2016, these ranchers both analyzed the benefits and draw backs of their plans to ensure their ranches remained agricultural businesses, including potential ecological and social changes and a decrease in control over daily decision-making.

To illustrate this trajectory, we present the discussion of one Wyoming rancher from his 2016 interview (see Figure 4.12). He described the traditional knowledge of older ranching generations and the challenges ranchers face communicating across generations. This text brings unique insight into the experience of ranchers grappling with succession issues and facing possible change of ownership or loss of the family ranch.

4.3.2.3. *Release-to-Reorganization* ($\Omega - \alpha$). Three cases (two in Colorado) followed a trajectory from organizational release to reorganization, characterized by rancher efforts to adjust to set-backs from drought and failed business endeavors via shifts in operation type, grazing strategy, and even decision-making responsibilities. Ranchers in this trajectory described planning processes, including frequent instances of experimentation relative to grazing strategy, and diversification of ranch income streams designed to benefit multiple generations on the ranch. Ranches in this trajectory made frequent, rapid adjustment to operation decisions based on both proactive and re-active assessment of weather variability. These ranchers expressed concern that they might cycle back into release, and described options for their own professional and financial futures if this occurred. They often described themselves as unlike other ranchers in their area in terms of operational characteristics and decision-making styles.

"I think that is just a real key, is that the older generations have got huge amounts of knowledge, that's maybe not tapped into in the right way, because grandpa can't explain it. Grandpa don't even know himself the difference between the science of what he's doing, and the tradition of it. Tradition is as important as the science, a lot of times, but it may not be financially. I'm a really traditional guy. We do almost everything horseback, we've got land that people can't run with 4-wheelers. It's still good grassland. It's scenic, which I like. That's the traditional part, but yet there's still grass there. The science of it is how many AUMs is there? To me, it's a mix of those things, and I think that's where we all have troubles communicating. How do you value tradition versus science? All of those things, it just is everywhere. Grandpa don't get it, and he really don't care. He just knows that, "We always run yearlings," and he can't articulate – Why cows and calves don't work. It's like ... He may have even forgot some of those reasons, that the pastures may have poisonous plants in them, or why the winters are hard calving or all of that stuff. He's come down with, "We run yearlings because I say so." No, there's reasons.

"The next generation, the first answer out of their mouths is, "Why? Why can't we do that? I want to do that." If he could explain that, maybe they would follow him. Maybe they're just rebellious enough they're going to try ... We all try new stuff. That's what makes life fun, but some stuff's stupid. You shouldn't crawl in the grill pit when you're 4 years old, should you? There's reasons for some of that stuff. I think instead of a template on how to do it, it should be a template on how to communicate. Communication is what it's all about.

"Yeah, both [generations' perspectives] are important, but if the kids get so frustrated they leave because grandpa is too cranky about it, grandpa's not happy when they leave, either. He had visions of generations taking on forever. It's sad for him, but yet he got where he was doing what he did. He's got reasons." - Wyoming rancher, 2016.

FIGURE 4.12. A Wyoming rancher in the Conservation-to-Release (K-Ω) trajectory described ranching traditions and the difficulties of communicating between generations in his 2016 interview.

We present data for this trajectory from a couple in Wyoming, see Figure 4.13. This couple had been involved with the family ranch for years, but assumed full operating responsibility right as a harsh winter storm hit their area. In their 2014 interview, they described the first day of their tenure, January 1, as a herd health disaster. This discussion is indicative of the fast moving, often reactive decisions of ranchers managing ranch SESs in this group. These

Wife: "Do you want me to tell you about our first year? January 1, we lost 70 head of calves. The storm came in. We had been doing okay. Then things got sick."

Husband: "We doctored."

Wife: "New Year's Day we had this horrible, horrible storm coming in, freezing cold, they were sitting, all these calves were sitting up here, and they just started, they just started dropping like flies. They just started dying. We are pretty sure it was water toxicity and pasteurella all together. That was about a third of the calves that we had. So that's how we started it."

Husband: "That's how we started our business."

Wife: "It was a very hard place to start our as, I mean we had been doing it, we been doing it on the ranch and we'd bought yearlings and stuff and ran yearlings on the ranch, but that year was when it first became totally ours, and we had a small little herd of 30 head. When it totally come on us, that's how we started our year."

Husband: "That's how we started our business."

FIGURE 4.13. A couple, operating a ranch in the Release-to-Reorganization trajectory in Wyoming, describe the fast moving, reactive nature of their early days in ranching.

ranchers often took over roles and responsibilities on operations without stable traditions or well-adapted management practices.

4.3.2.4. *Reorganization-to-Exploitation (α -r)*. The remaining four ranches (two in each state) demonstrated a trajectory from reorganization to exploitation. This was characterized by a slowing of infrastructure and grazing decision-making changes and a maturing of operator confidence in ecological and business expertise as new opportunities were envisioned and captured. These managers expressed long-term financial and ecological goals, but largely said they had achieved many of the major changes they had set out to accomplish earlier in their careers, including expanding their herds or feeding programs, and their land-bases and ranch infrastructure.

To illustrate this trajectory, we provide a quote from a Colorado rancher who described a stabilizing adaptation process 13 years into his ranching career (see Figure 4.14). He noted

that he was still looking to expand his herd and pasture area, and described how he built flexibility into his operation through diversified income streams, including corn production. This rancher, like others in this trajectory, had emphasized infrastructure development and land purchases early in his career, and leased pastures from absentee owners or purchased land from other operations that had gone out of business.

"I'd say probably last year and this year, we've been out here 13 years now, last year and this year are probably the first two years, granted, our checkbook doesn't necessarily look like it, that feel like one or two bad years in a row there's going to be an auction. We have enough depth probably in our cows. We've got our fall calving cows, those ones out there. If like, shoot, we're going into the fall and corn's really bad and we just don't think we're going to have enough money, those girls can go pretty easily and we still have our spring herd. Or, this year here we've got ... We have such good grass, one pasture we're going to use across the river, that's in the river bottom, it was under water all the way until the end of June, but we have such good grass elsewhere that heifers we artificially inseminated, we're ready to put them out with our other cows. Then there's so much grass there, no worries about not having enough to get them through. "-Colorado Rancher, 2016

FIGURE 4.14. A Colorado rancher reflects on his stabilizing ranch operation. This rancher also described diversified ranching income and enjoyment from family time spent on the ranch as benefits of his operation trajectory.

4.4. DISCUSSION

This case study documented the decision-making of 17 qualitatively different family ranching operations at two levels: at the broader ranch SES level, and in terms of ecological outcomes of management strategies over decades long time scales. We did not find significantly different species composition on pastures identified by ranchers as “best” and “most room for improvement” by ranchers, or across groups of ranches employing different grazing

strategies and grazing planning styles. Grazing intensity groups and operation types did have significantly different species composition.

Our categorization of ranch adaptive trajectories illustrated the various phases of growth, conservation, release and reorganization through which ranch SESs may transform during generations-long time scales. Thus, this study demonstrates: 1) an apparent resilience of the ecological system; 2) the limited influence of grazing decision-making strategies on ecological conditions employed by ranchers with important implications for perennial cool-season grasses; and 3) the resilience of ranch SESs documented through ranch adaptive trajectories.

4.4.1. ADAPTIVE MANAGEMENT AND ECOLOGICAL OUTCOMES. Repeated interviews with ranchers about their grazing management brings context to the “one size does not fit all” concept by highlighting diverse, successful approaches across our study. Ranchers employed a suite of management strategies (and actions within strategies) to maximize flexibility in their grazing and forage management decisions. Our interviews documented rancher decisions related to rotational grazing that enabled ranchers to manage livestock health, vegetation composition, and labor concerns in their specific social, natural resource, and economic contexts.

For example, one ranch in Wyoming organized grazing rotations seasonally around consideration of elevation and precipitation gradients across heterogeneous topography, plant species phenology, livestock nutrition and reproductive requirements, family labor constraints, and to better cope with severe late-winter and spring storms during their calving period. Another, in Colorado, developed a high intensity-short duration system that he said simultaneously allowed him to manage a complex breeding program, reduce time needed to check and gather cattle, and manage specific pastures to produce desired vegetation

conditions (including to improve perennial cool-season grasses, and reduce cacti and bare ground cover). While we documented variability in grazing strategies on the two ranches, one with a moderate grazing strategy and one a short duration strategy, managers of each were alike in their descriptions of proactive and adaptive planning and efforts to specifically adjust grazing management to local contexts. Both explicitly described their understanding of species composition and rangeland ecosystem dynamics in their planning and identified potential mitigation strategies for the effects of drought.

It has been suggested that more intensive rotational grazing strategies enable more explicit, adaptive management that is both proactive and able to cope with unexpected events and new information (Briske et al., 2011b). Membership in the short duration, high intensity grazing strategy group was not necessary for the more explicit planning style in our study, which was detected across grazing strategies and among managers with little or no exposure in high intensity short duration or holistic management paradigms. Plots managed under explicit grazing planning styles were not significantly different in species composition than those managed by ranchers who used tacit management styles. This is further evidence that there is not one “best” grazing system, and that stocking rate is the primary factor influencing vegetation and livestock outcomes (Briske et al., 2008, 2011b). Qualitative patterns in grazing planning style were linked to manager personality, learning style, and to different professional and educational experiences.

Stocking rate decisions for ranches in this study were complex, and are expected to pose continued economic challenges for producers adapting to shifting climatic conditions across central North America in the next century (Mu et al., 2013). Ranchers described these decisions as slow, path-dependent management choices, linked in space and time to recent

political, climatic, topographic and ecological conditions, labor and infrastructure, and herd health considerations (Wilmer & Fernández-Giménez, 2015). Ranchers we interviewed often referred to a historical stocking rate for their operation, a number connected to important thresholds for family income and operating costs, but then discussed factors limiting this number, including ongoing re-stocking processes from drought throughout the 2000s, reduction in numbers permitted on public grazing permits, and the trend toward larger-sized individual cattle (Scasta et al., 2015).

Our data indicate significant differences in species composition between cow-calf and cow-calf/yearling operations, with yearling operations having less cover of palatable, perennial cool-season grasses. This is potentially the result of historically grazing at the same time each year in a set of pastures, and historically higher grazing intensity on yearling operations linked to their ability to restock quickly following drought by retaining calves or purchasing animals. Cow-calf operators described a limited resilience to effects of de-stocking in drought, and restocked slowly by retaining heifers or purchasing mother cows. Cow-calf operators typically reached their full stocking potential three to four years following heavy culling in drought, while yearling operators we interviewed achieved restocking by retaining their calves or purchasing animals in one to two years. Because of the limited flexibility with stocking rates, cow-calf ranchers described creative means to cope with limited forage during dry times, including using social networks to access additional forage or rangeland, storing hay, and “banking” grass via planned resting or limited use of some pastures on the ranch.

The resilience of the rangelands in our study area to livestock grazing, and the importance of precipitation, temperature, and soil texture in the production of rangeland plant species, have been documented (Milchunas et al., 1998; Epstein et al., 1998, 1999; Derner et al.,

2008; Reeves et al., 2013, 2015). Evaluation of the economic returns of stocking management for rangeland condition over the long-term suggests that maintaining rangeland in higher vegetation states come at an opportunity cost to ranchers (Dunn et al., 2010). Recent research indicates that species composition change in our study area is a slow, continual processes, and that significant reduction in palatable cool-season grasses is the result of very long term grazing (over 30 years) at heavy (33 percent above NRCS recommended) stocking rates (Porensky et al., 2016).

While much research exists on the financial and ecological implications of grazing intensity decision-making on these rangelands (Bement, 1969; Holechek, 1988; Hart, 1993; Torell et al., 1991; Derner et al., 2008; Dunn et al., 2010; Mu et al., 2013; Reeves et al., 2013; Turner, 1993; Hamilton et al., 2016), our understanding of on-ranch grazing decision-making in this area is limited (Rowan et al., 1994; Grissom & Steffens, 2013; Kachergis et al., 2014) and has been cited as anecdotal observation (Dunn et al., 2010). Perhaps the rotational grazing debate has distracted from a more important discussion of stocking rate decision-making, including choices that increase flexibility in stocking rate within and among years (Hamilton et al., 2016), and the relationship of the ranch and ranch managers to the market. Because stocking rate decisions are linked to managers' relationships well beyond the family or ranch scale (Turner, 1993), including to sophisticated, integrated commodity markets, technological developments, regulations, and broader geographic shifts in agricultural industries, further research on managers' capacity to make adaptive and flexible stocking-rate decisions will require multiple-scale comparisons of social, economic, and political dynamics.

4.4.2. RANCH SES RESILIENCE. This study follows a body of work developed to interpret rangeland managers' decision-making, especially processes that lead to specific strategies

(such as high intensity-short duration grazing management or participation in conservation programs). While these decision-points may be of great importance to rangeland scientists, policy makers, and funders of conservation projects, our experience with rancher collaborators indicates that the emphasis on these practices is mis-aligned with manager goals in rangeland management systems. Ranchers in the study almost invariably described their overarching goal as an effort to minimize what SES scholars refer to as an undesirable state shift in the SES (Gunderson, 2001). They said they wanted to maintain or improve upon an existing ranch system in the long-term (beyond the current generation) and that they recognized that system as comprised of interdependent, dynamic, and often surprising cultural, economic, and ecological sub-systems.

Ranchers' overarching goal is not well interpreted from responses to questionnaires that rank individual ecosystem goods and services (e.g. livestock production, recreation or soil health), but can be examined through a resilience theory framework that considers adaptive change in SESs (Crane, 2010; Brown, 2014). Ranchers in this study described broad goals, including a desire to respond constructively to variability and change in ranching systems so as to avoid a state shift, possibly out of family-owned ranching operations into management by larger absentee owners, or into urban or non-agricultural development.

The application of resilience theory, specifically the adaptive cycle, to existing ranch decision-making theory accounts for manager-relevant scales of resilience. But this approach is not without notable conceptual limitations. Specifically, borrowing a theory from ecology and applying it to the explanation of ranch-level human decision-making processes denies consideration of cross-scale relationships between socio-economic and political dynamics that interact with ranch-level decision-makers at broader scales (Olsson et al., 2015; Darnhofer

et al., 2016). Ranchers in this study recognized the role of global processes, including globalization and urbanization, in shaping the ranching industry and their own SES decision making, but our study did not evaluate these larger scale processes.

4.5. CONCLUSION

The exclusion of adaptive decision-making processes from conventional grazing research has left gaps in our understanding of ranch management at multiple spatial and temporal scales (Briske et al., 2008, 2011a,b; Brunson & Burritt, 2009; Lubell et al., 2013). In this study, we built upon Lubell et al. (2013)’s existing conceptual framework for ranch decision-making. We examined the ecological outcomes (species composition and rangeland structural composition) for 17 family ranches in eastern Colorado and eastern Wyoming with different planning styles, grazing strategies, grazing intensities (stocking rates), and operation type characteristics (cow-calf or cow-calf/yearling), and interpreted these ecological results relative to ranchers’ adaptive decision-making processes and broader adaptation trajectories. Based on these findings, we recommend greater attention to the implications of stocking rate decision-making processes (with special attention to regulatory, political, and economic contexts) across scales in regional rangeland systems, and for interpretation of ranch decision-making in a way that accounts for management to sustain family ranches at the generational scale. A resilience framework and the application of the concept of adaptive cycle trajectories can enhance our understanding of ranch adaptive decision-making by accounting for ranch-scale learning and transformation over longer time frames.

4.6. RECOGNITION OF SUPPORT

We thank rancher participants and Pam Freeman, Emily Kachergis, Aramati Casper, Phil Turk, Monique Rocca, Lauren Porensky, Kyler Sherry, Tanner Craigmile, and Randy Reichert and seasonal field technicians. Funding for this study was provided by the USDA-ARS, USDA AFRI award 2009-04442 and 2012-38415-20328; and Colorado Agricultural Experiment Station project COLO0698.

CHAPTER 5

THE PROBLEM OF SPEAKING FOR RANCHERS: REFLECTIONS ON METHODS AND SUBJECTIVITY

I started grad school in 2012. It was an exciting time to get into the field of rangeland science because in 2012 in Colorado that age-old question of how to link rangeland research with rangeland managers had again emerged as an important question among those who care about the future of rangelands (Fuhlendorf et al., 2012; Briske et al., 2011b). For researchers, this question means that we are critically examining the role of humans in range landscapes. And this is made more complex by multiple, contradictory social demands for the use of these lands. As Holmes and others have noted, rapid changes in policies (Holmes, 2002; Wilson, 2001), ideologies and production systems have created multifunctional rural landscapes where



FIGURE 5.1. Traditional rope-and-drag brandings are community events.
Photo: J.Kennedy

food production interests coexist with other landscape uses, including cultural landscapes, heritage and biodiversity (Huntsinger et al., 2012; Gosnell et al., 2006; Chapin et al., 2011; Brunson & Huntsinger, 2008). We see this with the increased discussion of issues like simultaneously managing rangelands for grassland birds and beef production (Fuhlendorf et al., 2012), how managers will adapt to climate change (Carolan & Stuart, 2014; Briske et al., 2015; Marshall & Smajgl, 2013), and what the future holds for ranchland conversion and the agricultural way of life (Sayre, 2006; Brunson & Huntsinger, 2008; Darnhofer et al., 2016).

In this context, the old question of how to link rangeland science and management has evolved into a discussion of social science methods—how can we move from translational research to transformational research?—as Robin Reid might ask. New research questions are emerging: how do we understand rangeland manager decision-making processes in new ways where survey-based demographic or innovation adoption studies fall short in explanatory power (Sayre, 2004)? Looking back at 2012, I was right to be excited. It seemed that the time had come; the academy had realized that they needed to listen to managers, and I was the lucky masters student who got to do the listening.

I remember my first interview with a rancher. I remember opening the door to his truck, digital recorder in hand, and peering in at him over a panting blue heeler.

He asked me, “Are you a ranch kid?”

I grimaced. That question, again. It seemed like everybody liked to ask me if I had grown up on a ranch before we started talking about my research. This has nothing to do with the research! “No,” I said, with doubt, hoping my answer wouldn’t get me another lecture about

the futility of meat grown in a petri dish or how important it is to always close the gate. I ammended my answer in hopes that it would it bring me some credibililty with the rancher.

“Well, it’s complicated. I know which end the hay goes in.”

This was true. But much to my surprise, it was the “no” that he’d been fishing for. “Good,” he said. “Ranch kids never listen to anything I have to say. You see, I don’t do things... traditional.”

I breathed a sigh of relief. This rancher wanted to make sure I wasn’t going to compare him to all the old-timers because he liked to break tradition. He didn’t want me to compare him to any of his neighbors or peers, or to any image of a “good rancher” I might have in my head. Realizing I was in the clear, I smiled at the blue heeler, and turned on my recorder.

Since then, I’ve conducted over 50 interviews with ranchers. And I have come to realize that that question, “where do you come from?”, the question I thought had nothing to do with my research, actually has everything to do with my research, because it is important that the field of rangeland science continue to listen to and partner with ranchers so that we can, together, find working solutions for working rangelands across Western North America. But I argue that in order to do this, we need to be more self-critical and chose our methods carefully to avoid the pitfalls of so many who have gone before us.

This essay discusses problem of speaking for ranchers, which is the problematic adademic representation of people’s views (Said, 1979; Alcoff, 1991; Opie, 1992), and insider/outsider research, which deals with our subject position as researchers (Smith, 1999; Khan, 2005).

Questions of how those who are “not one of us” are represented and re-presented in social research methodology issues that are commonly discussed in critical, decolonial and feminist methodology, but that are rarely brought to the forefront in rangeland social science (though

not without exception, (Qin, 2016)). One of the reasons these ideas are so important is that they were brought to light by a number of feminist scholars, scholars of color, and historians and ethnographers from colonized and marginalized communities, who raised their voices to reimagine social scholarship methodologies through critical dialogue. These ideas are reflected in Deloria (1969); Said (1979); Spivak (1988); Smith (1999); Khan (2005). A review of this work suggests that limiting how we speak for others, and recognizing our power and influence inside and outside of the communities we work in can improve the quality of our work, whether we are rangeland social or biophysical scientists.

5.1. THE PROBLEM OF SPEAKING FOR OTHERS

What is the problem of speaking for ranchers (Alcoff, 1991)? It is the representation of manager needs and views with limited reference to actual data, in ways that assert knowledge of, and thus power over, other people. It is saying what is needed or good for ranchers without careful, rigorous presentation of their actual voices. This can easily happen in a field where scholars may move between scientific and management roles in their professional and personal lives. This is also a problem in the media and even across the ranching community—the idea that someone who is not like me is *The Other* (Said, 1979; Opie, 1992).

Linda Alcoff, from whom I borrow the title of this essay, recognizes that the problem of speaking for others involves a tension in social research between making knowledge claims that inappropriately represent the experiences of others, including research participants, and thus dominate and oppress them, and the limitations of only speaking for oneself (Alcoff, 1991). Researchers must ask, For whom can I speak? How are subject voices represented, privileged or silenced in my work? Am I speaking for others or about others? Ann Opie outlines tools for minimizing ‘appropriation of the Other,’ which is, in her view, an inevitable

result of social research. These practices include careful analysis and presentation of data (including quotes) in research findings and recognition of the limits of knowledge (Opie, 1992). She asks researchers to build empowerment into the research process and to question who is an “authentic” research participant.

The problem of speaking for others prompts range social scientists to reconsider “what we know” about rancher behavior based on the voices of a sub-set of politically active managers, social survey research conducted on (male) primary-decision makers, or information gathered through our own experiences in rangeland communities. As a qualitative researcher studying rancher decision-making, I have struggled to find new ways to “hear” rancher voices, resist the impetus for over-generalization where possible, and co-present research findings with participants while striving for critical analysis and objectivity. The problem of speaking for ranchers is a continual issue for qualitative work positioned within the context of a field that is biophysical at its core.

5.2. AM I AN INSIDER? AN OUTSIDER?

The second problem is that of insider/outsider research which relates to position and objectivity (Smith, 1999; Bhavani, 1993). The traditional scientific approach is to be an objective observer, an outsider, looking in, who can see the forest for the trees and examine a social research question without letting personal experiences, relationships, or bias get in the way of the research. But what if nobody wants to talk to me because I’m not from around here?

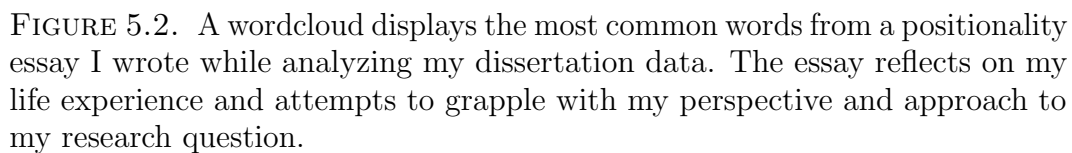
An insider, on the other hand, might get a foot in the door because of her existing experiences or relationships. She might be better able to explain cultural phenomena and experiences, and leverage her networks to improve research. She is never really an insider if

she is an academic and not dependent on the rainfall for her paycheck, she has a fundamentally different relationship with rangeland knowledge and resources (Khan, 2005). And then, of course, there's the ever-present question: Does she like these cute old ranchers too much?

Naples (1996) rejects the bipolar insider/outsider distinction, arguing that it denies the interactions that shape the research process between researcher and research participants. She argues that ethnographers are never fully inside or outside our study areas or communities; we are constantly negotiating our relationships with the communities we study in our every-day interactions, and communities themselves are always changing. We all have multiple identities, and can relate to people from a number of different angles.

I have to ask myself: How do I recognize that I am the instrument of my research and best position myself to do ethical research? How do I understand the impact of my identity and relationships to my work? Rangeland scientists with connections to the communities we study must find new ways to problematize both outsider approaches to research that claim neutrality and objectivity, and insider approaches that assume depth and nuance is made available to those with an intimate knowledge of ranching communities (Khan, 2005). Rangeland social scientists may have multiple ways of being insiders and outsiders (Smith, 1999). And as Maria Fernandez-Gimenez reminds me, respect and consent are continual processes that take work and commitment to maintain.

Another part of the insider/outside question is that of consent. My relationships to ranching individuals and communities, and their consent to participate in my work, is a dynamic process subject to fluxes in trust and respect. Smith (1999) argues for social researchers to practice localized forms of respect and consent. It is not as simple as getting



5.2.1. REFLEXIVITY. Reflexivity, the process of addressing the context of research, including a researcher's subjectivity, is an important tool for social researchers in negotiating power relationships and insider/outsider perspectives (Opie, 1992; Smith, 1999). I think of reflexivity as the process of learning where I'm coming from and being honest with myself, and my research, about that view. I have relatives and friends who ranch, and have worked on ranches, and since I started my masters, my mother and step-father have begun to ranch

through the mentoring of an older rancher who befriended our family. Sometimes that life experience and a general interest in ranching systems can help me connect with my research participants and better interpret my data. (My time as an agriculture teacher, ability to use fencing pliers, and willingness to put up with riding kids' horses doesn't hurt, either.) Feminists call this experiential knowledge.) But at other times, that experience can shape how I interact with the data in particular ways that I struggle to recognize. My view is a view from somewhere, but I have to take active steps to understand that somewhere (Wilkinson, 2015). For example, I keep an audio journal after my interviews, write about my research experience, and bounce my ideas off of ranchers who are not in my PhD study, and with other social researchers and extension folk.

5.3. CONCLUSION

We're at a point in our field where we do have a chance to listen to rangeland managers. We have to try to do it well. We can work towards methods and methodologies that recreate our research as a tool for social-ecological stewardship through transformation and healing of rangeland systems (Morales, 1998). Problematizing the claims of rangeland science to knowledge of manager needs and views requires a careful, reflexive reexamination of power, voice, and representation. I have tried to argue that it is important for rangeland researchers to take an interest in sharing power, strive to avoid speaking for others, work to build respect and consent, and acknowledge strengths and limitations of our own positions inside and outside of manager communities. While these problems, questions, and tools are not often discussed in rangeland science praxis, they will become increasingly important as rangeland scientists engage with diverse stakeholders in multifunctional rangeland systems.

CHAPTER 6

CONCLUSION

“So debates over nature and environmental uncertainty cannot be seen as simple rhetoric or ideology, but rather as more deeply contested truths, that people form and defend based on highly variable personal, idiosyncratic, experience. In that way, there are actually no “hunters” “environmentalists” or “ranchers” at work in this struggle, not in any essential sense...”-(Robbins, 2006, p. 198)

The fundamental idea behind adaptive management is the adaptation– responsive learning that leads to the adjustment of our actions based on reflection and reconsideration of guiding assumptions and beliefs. Here, positivist biophysical science and post-modern social science find common ground in the effort to *“question everything.”*

This dissertation is the result of approaches to rangeland research that respond to a need for increased participation and collaboration across groups of scientists and rangeland decision-makers. It challenges the assumption that clear distinctions exist between adaptation and command and control, humans and nature, learning and stagnation, scientists and stakeholders, and between social and biophysical disciplines. It outlines lessons learned from efforts to build bridges across these seemingly divergent categories, including between stakeholder groups and diverse interests. It reflects a commitment to listening and shared learning about adaptive management of complex rangeland social-ecological systems for multiple goals and objectives.

These lessons have implications for the continued adaptation and responsiveness of rangeland science to current and future needs for rangeland management knowledge. Specifically, in Chapter 5, I provided examples of research reflexivity that helped me deal with my own subject position. I described efforts to recognize the continued challenges of gaining respect

and consent in ranching communities where I may be perceived as both an insider and outsider. I wrote this chapter to work through my own biases, but also to present specific tools and concepts from the critical social sciences that can improve social-ecological research through processes of reflexivity.

The complexity of ranch decision-making is likely impossible to fully understand until one is standing in the boots of a producer in a drought and faced with the choice between buying expensive hay and selling valuable mother cows. In Chapter 2, data from repeated rancher interviews complicate the human/nature dichotomies often perpetuated in natural resource management or rangeland science, especially dichotomies that frame human-nature relationships as either situations where humans have complete agency (a struggle for control), or are at the mercy of nature (environmental determinism). The broader contributions of this chapter are to decolonial and rural studies discourses on the intersection between human decision-making and our environments. Future rangeland science collaborations and management interventions can be informed by a consideration of ranchers' decision-making experiences. As an important note, in recognizing ranchers' ethic of care and the specific practices they described to reduce social and ecological vulnerability, I also recognize that there may be important disconnects between this ethic and the condition of rangeland ecosystems.

In Chapter 3, I present the lessons learned from the Collaborative Adaptive Rangeland Management experiment, a long-term social-ecological research project on the shortgrass steppe in Nunn, Colorado. Data from this project highlight the contributions of rangeland stakeholder knowledge and experiences to collaborative adaptive management, and describe the “real-life” implications of participation for these ranchers, NGO and public lands agency

stakeholders. While this chapter presents data from the early years of this project, the CARM experiment holds promise in providing a model for collaborative adaptive management in public land management scenarios where stakeholders have diverse objectives and a shared interest learning.

In Chapter 4, I link multiple scales of ranch social-ecological adaptation through repeated interviews and ecological monitoring. These mixed social-ecological methods and a resilience framework build upon and refine existing theories of adaptive ranch decision-making. From this analysis, I did not find statistically different rangeland species composition among grazing strategies or planning styles, though rancher interviews helped interpret why different strategies were needed on different ranches. These findings indicate that one-size does not fit all in terms of management strategies and planning styles across heterogeneous landscapes.

Statistically significant species composition differences among groups of ranches with different grazing intensities, and between cow-calf and cow-calf yearling operators, speak to the importance of stocking rate and timing of grazing decisions. Stocking rate decisions have been examined in the grazing and economic literature, but on-ranch studies of these decision-making processes are sorely needed. Future research should consider complex cross-scale dynamics of social, cultural, economic and ecological systems in stocking rate decision-making.

The broader context of ranch decision-making processes and ecological outcomes can be understood through the adaptive trajectories of family ranches. These trajectories inform our understanding of ranch adaptive processes at a scale that is relevant to ranchers' goals for resilience, and take into account generations-long timescales. While the limited statistical power of this case study prevented me from examining the ecological outcomes

of different trajectories, the trajectories do offer insights into potential decision triggers for ranch succession, ranch land-use conversion, and rangeland fragmentation.

The chapters in this dissertation reflect a commitment to collaboration and learning between scientists and rangeland decision-makers, but as the limitations of the study suggest, challenges remain ahead for rangeland science. Science-management partnerships must continue to seek out approaches that adapt to the complexity of rangeland systems and recognize the multiple relationships human communities have with these systems, including that:

- Rangelands provide vital ecosystem services (Yahdjian et al., 2015; Huntsinger et al., 2010; Huntsinger & Oviedo, 2014). We are learning to sustain these natural resources for future generations.
- Rangelands are complex systems (Boyd & Svejcar, 2009). We are learning to live with their wildness (Fuhlendorf et al., 2012; Adams & Mulligan, 2003).
- Rangelands shape and are shaped by diverse pastoral livelihoods and cultures (Kassam, 2008). We are learning to recognize the important role of management in maintaining these lands and to hear the voices of these peoples (Reid et al., 2014).
- Rangelands are largely common lands. We are learning to share. (Ullambayar et al., 2016).
- Rangelands have intrinsic worth. They are biologically diverse. They are cathedrals, sacred places. We are learning to respect them (Snyder, 2010).
- Rangelands are marginalized lands, with high potential for conversion to other, more profitable, land uses (Sayre et al., 2013). They are “in-between” lands, but they are

the lands that hold the rest of the world together (Box, 2005). We are learning to value them.

These lessons will surely be complex and slow to emerge as we learn to work together across methods, ideologies, knowledge systems, and rangeland management objectives. We must continue to adapt, not for the sake of science, but because, as Canadian singer-songwriter Corb Lund reminds us, *this is our prairie, this is our home*.

REFERENCES

- Abrams, J., Gill, N., Gosnell, H., & Klepeis, P. (2012). Re-creating the rural, reconstructing nature: An international literature review of the environmental implications of amenity migration. *Conservation and Society*, 10, 270. URL: <http://www.conservationandsociety.org/text.asp?2012/10/3/270/101837>. doi:10.4103/0972-4923.101837.
- Adams, W. M. (2003). Nature and the colonial mind. In *Decolonizing nature: strategies for conservation in a post-colonial er* (pp. 16–50). London: Earthscan.
- Adams, W. M., & Mulligan, M. (Eds.) (2003). *Decolonizing nature: strategies for conservation in a post-colonial era*. London: Earthscan.
- Adger, W. N. (2000). Social and ecological resilience: are they related? *Progress in human geography*, 24, 347–364.
- Adger, W. N. (2006). Vulnerability. *Global environmental change*, 16, 268–281.
- Agrawal, A. (2010). Local institutions and adaptation to climate change. *Social dimensions of climate change: Equity and vulnerability in a warming world*, (pp. 173–197).
- Agrawal, A., & Chhatre, A. (2011). Against mono-consequentialism: Multiple outcomes and their drivers in social–ecological systems. *Global Environmental Change*, 21, 1–3.
- Alagona, P. S. (2013). *After the grizzly: endangered species and the politics of place in California*. Univ of California Press.
- Alcoff, L. (1991). The problem of speaking for others. *Cultural critique*, (pp. 5–32).
- Allred, B. W., Smith, W. K., Twidwell, D., Haggerty, J. H., Running, S. W., Naugle, D. E., & Fuhlendorf, S. D. (2015). Ecosystem services lost to oil and gas in North America. *Science*, 348, 401–402.
- Argyris, C. (2002). Double-loop learning, teaching, and research. *Academy of Management Learning & Education*, 1, 206–218. URL: <http://amle.aom.org/content/1/2/206>.

short.

Armitage, D. (2005). Adaptive capacity and community-based natural resource management. *Environmental management*, 35, 703–715.

Armitage, D., & Johnson, D. (2006). Can resilience be reconciled with globalization and the increasingly complex conditions of resource degradation in Asian coastal regions? *Ecology and Society*, 11.

Armitage, D., Marschke, M., & Plummer, R. (2008). Adaptive co-management and the paradox of learning. *Global Environmental Change*, 18, 86–98. URL: <http://linkinghub.elsevier.com/retrieve/pii/S0959378007000490>. doi:10.1016/j.gloenvcha.2007.07.002.

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. URL: <http://doi.wiley.com/10.1890/070089>. doi:10.1890/070089.

Augustine, D. J., Derner, J. D., & Milchunas, D. G. (2010). Prescribed fire, grazing, and herbaceous plant production in shortgrass steppe. *Rangeland Ecology & Management*, 63, 317–323. URL: <http://www.bioone.org/doi/abs/10.2111/REM-D-09-00044.1>. doi:10.2111/REM-D-09-00044.1.

Augustine, D. J., Terrance Booth, D., Cox, S. E., & Derner, J. D. (2012). Grazing intensity and spatial heterogeneity in bare soil in a grazing-resistant grassland. *Rangeland Ecology & Management*, 65, 39–46.

Badgery, W., Mitchell, D., Millar, G., Broadfoot, K., Michalk, D., Cranney, P., & Brown, W.

- (2016). Designing a grazing systems experiment for variable native pastures and flexible lamb production systems. *Animal Production Science*, 56.
- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2014). Fitting linear mixed-effects models using lme4. *arXiv preprint arXiv:1406.5823*, .
- Becker, H. S. . (1998). *Tricks of the trade: how to think about your research while you're doing it*. University of Chicago Press.
- Bement, R. E. (1969). A stocking-rate guide for beef production on blue-grama range. *Journal of Range Management*, (pp. 83–86).
- Bennett, J. W. (1971). *Northern Plainsmen: Adaptive Strategy and Agrarian Life*. New Brunswick: Transaction Publishers.
- Beratan, K. K. (2014a). Summary: Addressing the interactional challenges of moving collaborative adaptive management from theory to practice. *Ecology & Society*, 19.
- Beratan, K. K. (2014b). Summary: Addressing the Interactional Challenges of Moving Collaborative Adaptive Management From Theory to Practice. *Ecology and Society*, 19. URL: <http://www.ecologyandsociety.org/vol19/iss1/art46/>. doi:10.5751/ES-06399-190146.
- Berkes, F., Colding, J., & Folke, C. (2000a). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological applications*, 10, 1251–1262.
- Berkes, F., Folke, C., & Colding, J. (2000b). *Linking social and ecological systems: management practices and social mechanisms for building resilience*. Cambridge University Press.
- Bestelmeyer, B. T., & Briske, D. D. (2012). Grand challenges for resilience-based management of rangelands. *Rangeland Ecology & Management*, 65, 654–663.
- Bestelmeyer, B. T., Brown, J. R., Havstad, K. M., Alexander, R., Chavez, G., & Herrick,

- J. E. (2003). Development and use of state-and-transition models for rangelands. *Journal of range management*, (pp. 114–126).
- Bhavani, K.-K. (1993). Tracing the contours: feminist research and feminist objectivity. *Womens studies international forum*, 16, 95–104.
- Bixler, R. P. (2013). The political ecology of local environmental narratives: Power, knowledge, and mountain caribou conservation. *Journal of Political Ecology*, 20, 273–285. URL: <http://www.academia.edu/download/38266170/Bixler.pdf>.
- 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. URL: <http://www.emeraldinsight.com/doi/abs/10.1108/09696470410515706>. doi:10.1108/09696470410515706.
- Blackmore, C. (2007). What kinds of knowledge, knowing and learning are required for addressing resource dilemmas?: a theoretical overview. *Environmental Science & Policy*, 10, 512–525. URL: <http://linkinghub.elsevier.com/retrieve/pii/S1462901107000500>. doi:10.1016/j.envsci.2007.02.007.
- 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. URL: <http://oro.open.ac.uk/40332/1/SLIMeditorialFeb16.pdf>.
- Boholm, Å. (2009). Speaking of risk: Matters of context. *Environmental Communication*, 3, 335–354. URL: <http://www.tandfonline.com/doi/full/10.1080/17524030903230132>. doi:10.1080/17524030903230132.

- 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 Social Psychology*, *14*, 137–153. URL: <http://doi.wiley.com/10.1002/casp.777>. doi:10.1002/casp.777.
- Bouyoucos, G. J. (1962). Hydrometer method improved for making particle size analyses of soils. *Agronomy Journal*, *54*, 464–465.
- Box, T. (2005). Holding the world together-our life and our place. *Rangelands*, *27*, 46–47.
- Boyd, C., & Svejcar, T. (2009). Managing complex problems in rangeland ecosystems. *Rangeland Ecology & Management*, *62*, 491–499.
- Brewer, J. P., Hiller, J. G., Burke, S., & Teegerstrom, T. (2016). A primer: Extension, Indian land tenure, and rangeland limitations. *Rangelands*, *38*, 16–22.
- Briske, D. D., Ash, A. J., Derner, J. D., & Huntsinger, L. (2014). Commentary: A critical assessment of the policy endorsement for holistic management. *Agricultural Systems*, *125*, 50–53.
- 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. D., Derner, J. D., Milchunas, D. G., & Tate, K. W. (2011a). An evidence-based assessment of prescribed grazing practices. *Conservation benefits of rangeland practices: assessment, recommendations, and knowledge gaps*. Washington, DC, USA: USDA-NRCS, (pp. 21–74).
- Briske, D. D., Joyce, L. A., Polley, H. W., Brown, J. R., Wolter, K., Morgan, J. A., McCarl, B. A., & Bailey, D. W. (2015). Climate-change adaptation on rangelands: linking regional

- exposure with diverse adaptive capacity. *Frontiers in Ecology and the Environment*, *13*, 249–256.
- Briske, D. D., Sayre, N. F., Huntsinger, L., Fernandez-Gimenez, M., Budd, B., & Derner, J. (2011b). Origin, persistence, and resolution of the rotational grazing debate: integrating human dimensions into rangeland research. *Rangeland Ecology & Management*, *64*, 325–334.
- Brown, K. (2014). Global environmental change ia social turn for resilience? *Progress in Human Geography*, *38*, 107–117.
- Bruegger, R. A., Jigjsuren, O., & Fernández-Giménez, M. E. (2014). Herder observations of rangeland change in mongolia: Indicators, causes, and application to community-based management. *Rangeland Ecology & Management*, *67*, 119–131.
- Brugnach, M., & Ingram, H. (2012). Ambiguity: the challenge of knowing and deciding together. *Environmental Science & Policy*, *15*, 60–71. URL: <http://linkinghub.elsevier.com/retrieve/pii/S1462901111001559>. doi:10.1016/j.envsci.2011.10.005.
- Brunson, M. W. (2012). The elusive promise of social-ecological approaches to rangeland management. *Rangeland Ecology & Management*, *65*, 632–637. URL: <http://www.bioone.org/doi/abs/10.2111/REM-D-11-00117.1>. doi:10.2111/REM-D-11-00117.1.
- Brunson, M. W., & Burritt, E. A. (2009). Behavioral factors in rotational grazing systems. *Rangelands*, *31*, 20–25. URL: <http://linkinghub.elsevier.com/retrieve/pii/S019005280950020X>. doi:10.2111/1551-501X-31.5.20.
- Brunson, M. W., & Huntsinger, L. (2008). Ranching as a conservation strategy: can old ranchers save the New West? *Rangeland Ecology & Management*, *61*, 137–147.
- Budd, B., & Thorpe, J. (2009). Benefits of managed grazing: a manager’s perspective.

Rangelands, 31, 11–14.

Cameron, J. (2003). Responding to place in a post-colonial era: An Australian perspective.

Decolonising nature: Strategies for conservation in a post-colonial era, (pp. 172–196).

Carolan, M., & Stuart, D. (2014). Get real: climate change and all that ‘it’ entails. *Sociologia*

Ruralis, 56, 74–95.

Chapin, I. F. S., Power, M. E., Pickett, S. T., Freitag, A., Reynolds, J. A., Jackson, R. B.,

Lodge, D. M., Duke, C., Collins, S. L., Power, A. G. et al. (2011). Earth stewardship: science for action to sustain the human-earth system. *Ecosphere*, 2, art89.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative research*. London: Sage.

Charnley, S., Sheridan, T. E., & Nabhan, G. P. (2014). *Stitching the west back together: conservation of working landscapes*. University of Chicago Press.

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. *Forest Policy and Economics*, 13, 89–96. URL: <http://linkinghub.elsevier.com/retrieve/pii/S1389934110001462>. doi:10.1016/j.forpol.2010.09.005.

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 & Natural Resources*, 23, 385–400. URL: <http://www.tandfonline.com/doi/abs/10.1080/08941920802178198>. doi:10.1080/08941920802178198.

Cheng, A. S., & Sturtevant, V. E. (2012). A framework for assessing collaborative capacity in community-based public forest management. *Environmental Management*, 49, 675–689. URL: <http://link.springer.com/10.1007/s00267-011-9801-6>. doi:10.

1007/s00267-011-9801-6.

- Chiswell, H. M., & Lobley, M. (2015). A recruitment crisis in agriculture? A reply to Heike Fischer and Rob JF Burton's understanding farm succession as socially constructed endogenous cycles. *Sociologia Ruralis*, 55, 150–154.
- Collins, P. H. (2002). *Black feminist thought: Knowledge, consciousness, and the politics of empowerment*. Routledge.
- Cornwall, A. (2003). Whose Voices? Whose Choices? Reflections on Gender and Participatory Development. *World Development*, 31, 1325–1342. URL: <http://linkinghub.elsevier.com/retrieve/pii/S0305750X0300086X>. doi:10.1016/S0305-750X(03)00086-X.
- 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.
- Crane, T. A. (2010). Of models and meanings: cultural resilience in social-ecological systems. *Ecology and Society*, 15, 19.
- Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches*. Sage.
- Cundill, G., Cumming, G. S., Biggs, D., & Fabricius, C. (2012). Soft systems thinking and social learning for Adaptive Management. *Conservation Biology*, 26, 13–20. URL: <http://doi.wiley.com/10.1111/j.1523-1739.2011.01755.x>. doi:10.1111/j.1523-1739.2011.01755.x.

- 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. URL: <http://linkinghub.elsevier.com/retrieve/pii/S030147971200429X>. doi:10.1016/j.jenvman.2012.08.021.
- Curtin, D. (1991). Toward an ecological ethic of care. *Hypatia*, 6, 60–74. URL: <http://onlinelibrary.wiley.com/doi/10.1111/j.1527-2001.1991.tb00209.x/full>.
- Dale, E. E. (1930). *The Range Cattle Industry*. University of Oklahoma Press.
- Daly, C., Halbleib, M., Smith, J. I., Gibson, W. P., Doggett, M. K., Taylor, G. H., Curtis, J., & Pasteris, P. P. (2008). Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States. *International Journal of Climatology*, 28, 2031–2064.
- Darnhofer, I. (2010). Strategies of family farms to strengthen their resilience. *Environmental Policy and Governance*, 20, 212–222.
- Darnhofer, I., Lamine, C., Strauss, A., & Navarrete, M. (2016). The resilience of family farms: Towards a relational approach. *Journal of Rural Studies*, 44, 111–122.
- Deloria, V. (1969). *Custer died for your sins: An Indian manifesto*. University of Oklahoma Press.
- Derner, J. D., Hart, R. H., Smith, M. A., & Waggoner, J. W. (2008). Long-term cattle gain responses to stocking rate and grazing systems in northern mixed-grass prairie. *Livestock Science*, 117, 60–69.
- 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. URL: <http://www.bioone>.

org/doi/abs/10.2111/08-008.1. doi:10.2111/08-008.1.

- Didier, E. A., & Brunson, M. W. (2004). Adoption of range management innovations by utah ranchers. *Journal of Range Management*, 57, 330–336.
- Donahue, D. L. (1999). *The western range revisited: removing livestock from public lands to conserve native biodiversity* volume 5. Norman: University of Oklahoma Press.
- Duffy, R. (2016). War, by conservation. *Geoforum*, 69, 238–248.
- Dunn, B. H., Smart, A. J., Gates, R. N., Johnson, P. S., Beutler, M. K., Diersen, M. A., & Janssen, L. L. (2010). Long-term production and profitability from grazing cattle in the northern mixed grass prairie. *Rangeland Ecology & Management*, 63, 233–242.
- Easdale, M., & Domptail, S. (2014). Fate can be changed! Arid rangelands in a globalizing world—a complementary co-evolutionary perspective on the current ‘desert syndrome’. *Journal of Arid Environments*, 100, 52–62.
- 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. URL: <http://linkinghub.elsevier.com/retrieve/pii/S1462901111000530>. doi:10.1016/j.envsci.2011.04.004.
- Ellis, C. (2013). The symbiotic ideology: Stewardship, husbandry, and dominion in beef production. *Rural Sociology*, 78, 429–449.
- Engel-Di Mauro, S. (2014). *Ecology, Soils, and the Left: An Ecosocial Approach*. Springer.
- Epstein, H., Lauenroth, W., & Burke, I. (1997). Effects of temperature and soil texture on ANPP in the US Great Plains. *Ecology*, 78, 2628–2631.
- Epstein, H. E., Burke, I. C., & Lauenroth, W. K. (1999). Response of the shortgrass steppe

- to changes in rainfall seasonality. *Ecosystems*, *2*, 139–150.
- Epstein, H. E., Lauenroth, W. K., Burke, I. C., & Coffin, D. P. (1998). Regional productivities of plant species in the Great Plains of the United States. *Plant Ecology*, *134*, 173–195.
- Fabricius, C., & Cundill, G. (2014). Learning in adaptive management: Insights from published practice. *Ecology and Society*, *19*, 29.
- Federico, G. (2005). *Feeding the world: an economic history of agriculture, 1800-2000*. Princeton: Princeton University Press.
- Fernandez-Gimenez, M. (2015). “A shepherd has to invent”: Poetic analysis of social-ecological change in the cultural landscape of the central Spanish Pyrenees. *Ecology and Society*, *20*.
- Fernandez-Gimenez, M. E., Batkhishig, B., & Batbuyan, B. (2012). Cross-boundary and cross-level dynamics increase vulnerability to severe winter disasters (dzud) in Mongolia. *Global Environmental Change*, *22*, 836–851.
- Fernández-Giménez, M. E., Batkhishig, B., Batbuyan, B., & Ulambayar, T. (2015). Lessons from the dzud: Community-based rangeland management increases the adaptive capacity of mongolian herders to winter disasters. *World Development*, *68*, 48–65.
- 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*, *null*, 306–315. URL: http://journals.cambridge.org/article_S0376892906003420. doi:10.1017/S0376892906003420.
- Fernandez-Gimenez, M. E., McClaran, S. J., & Ruyle, G. (2005). Arizona Permittee and Land Management Agency Employee Attitudes Toward Rangeland Monitoring by Permittees. *Rangeland Ecology & Management*, *58*, 344–351. URL: <http://www.bioone.org/>

- doi/abs/10.2111/1551-5028%282005%29058%5B0344%3AAPALMA%5D2.0.CO%3B2. doi:10.2111/1551-5028(2005)058[0344:APALMA]2.0.CO;2.
- Fischer, H., & Burton, R. J. (2014). Understanding farm succession as socially constructed endogenous cycles. *Sociologia Ruralis*, 54, 417–438.
- Flanagan, O., & Jackson, K. (1987). Justice, care, and gender: The Kohlberg-Gilligan debate revisited. *Ethics*, 97, 622–637. URL: <http://www.jstor.org/stable/2381183>.
- Francis, R. A., & Goodman, M. K. (2010). Post-normal science and the art of nature conservation. *Journal for Nature Conservation*, 18, 89–105. URL: <http://linkinghub.elsevier.com/retrieve/pii/S1617138109000272>. doi:10.1016/j.jnc.2009.04.002.
- 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.
- Fulton, A., & Vanclay, F. (2011). Enabling change in family farm businesses. *Changing land management. Collingwood, Victoria, Australia: CSIRO*, (pp. 95–106).
- Gallaher, C. (2016). Placing the militia occupation of the Malheur National Wildlife Refuge in Harney County, Oregon. *ACME: An International Journal for Critical Geographies*, 15, 293–308.
- Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. *Global environmental change*, 16, 293–303.
- Geiger, S. (1990). What's so feminist about women's oral history? *Journal of Women's History*, 2, 169–182.
- George, A. L., & Bennett, A. (2005). *Case studies and theory development in the social sciences*. Cambridge, MA: Mit Press.

- Gilligan, C. (1977). In a different voice. *Harvard Educational Review*, 47, 365–378.
- Glaser, M. (2006). The social dimension in ecosystem management: strengths and weaknesses of human-nature mind maps. *Human Ecology Review*, 13, 122.
- Glesne, C., Peshkin, A. et al. (1992). *Becoming qualitative researchers: An introduction*. Longman White Plains, NY.
- Godínez-Alvarez, H., Herrick, J., Mattocks, M., Toledo, D., & Van Zee, J. (2009). Comparison of three vegetation monitoring methods: their relative utility for ecological assessment and monitoring. *Ecological indicators*, 9, 1001–1008.
- Goodloe, S. (2013). Short-duration grazing in retrospect-a practitioner’s experience. *Rangelands*, 35, 67–71.
- Gosnell, H., Haggerty, J. H., & Travis, W. R. (2006). Ranchland ownership change in the greater yellowstone ecosystem, 1990–2001: implications for conservation. *Society and Natural Resources*, 19, 743–758.
- Gow, D. D., & Vansant, J. (1983). Beyond the rhetoric of rural development participation: how can it be done? *World development*, 11, 427–446.
- Grissom, G., & Steffens, T. (2013). Case study: adaptive grazing management at Rancho Largo Cattle Company. *Rangelands*, 35, 35–44.
- Gunderson, L. H. (2000). Ecological resilience—in theory and application. *Annual review of ecology and systematics*, (pp. 425–439). URL: <http://www.jstor.org/stable/221739>.
- Gunderson, L. H. (2001). *Panarchy: understanding transformations in human and natural systems*. Island press.
- Hamilton, T. W., Ritten, J. P., Bastian, C. T., Derner, J. D., & Tanaka, J. A. (2016). Economic impacts of increasing seasonal precipitation variation on Southeast Wyoming

- cow-calf enterprises. *Rangeland Ecology & Management*, *In press*.
- Haraway, D. (1988). Situated knowledges: The science question in feminism and the privilege of partial perspective. *Feminist studies*, *14*, 575–599.
- Haraway, D. J. (2008). *When species meet*. volume 224. Minneapolis, MN: University of Minnesota Press.
- Harding, S. (2006). *Science and social inequality: Feminist and postcolonial issues*. Urbana: University of Illinois Press.
- 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. URL: <http://www.sciencedirect.com/science/article/pii/S0301479798902420>.
- Hart, R. H. (1993). Viewpoint: “invisible colleges” and citation clusters in stocking rate research. *Journal of Range Management*, (pp. 378–382).
- Hart, R. H. (2001). Plant biodiversity on shortgrass steppe after 55 years of zero, light, moderate, or heavy cattle grazing. *Plant Ecology*, *155*, 111–118. URL: <http://link.springer.com/article/10.1023/A:1013273400543>.
- Hart, R. H., & Ashby, M. M. (1998). Grazing intensities, vegetation, and heifer gains: 55 years on shorgrass. *Journal of Range Management*, *51*, 392–398.
- Hartter, J., & Goldman, A. (2011). Local responses to a forest park in western Uganda: alternate narratives on fortress conservation. *Oryx*, *45*, 60–68.
- Heady, H. (1961). Continuous vs. specialized grazing systems: a review and application to california annaul type. *Journal of Range Management*, *14*, 182–193.
- Herman, A. (2015). Enchanting resilience: Relations of care and people–place connections in

- agriculture. *Journal of Rural Studies*, 42, 102–111. URL: <http://linkinghub.elsevier.com/retrieve/pii/S0743016715300310>. doi:10.1016/j.jrurstud.2015.10.003.
- Hinchliffe, S. (2007). *Geographies of nature: societies, environments, ecologies*. Sage.
- Hobbs, R. J. (2013). Grieving for the past and hoping for the future: balancing polarizing perspectives in conservation and restoration. *Restoration Ecology*, 21, 145–148.
- Holechek, J. L. (1988). An approach for setting the stocking rate. *Rangelands*, 10, 10–14.
- Holleman, H. (2016). De-naturalizing ecological disaster: colonialism, racism and the global Dust Bowl of the 1930s. *The Journal of Peasant Studies*, (pp. 1–27).
- Holling, C., & Meffe, G. (1996). Command and control and the pathology of natural resource management. *Conservation Biology*, 10, 328–337.
- Holling, C., & Sundstrom, S. M. (2015). Adaptive management, a personal history. In *Adaptive Management of Social-Ecological Systems* (pp. 11–25). Springer.
- Holling, C. S., & Gunderson, L. H. (2002). Resilience and adaptive cycles. *Panarchy: Understanding transformations in human and natural systems*, (pp. 25–62).
- Holmes, J. (2002). Diversity and change in Australia's rangelands: a post-productivist transition with a difference? *Transactions of the Institute of British Geographers*, 27, 362–384.
- 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. *Ecological Applications*, 25, 662–672. URL: <http://onlinelibrary.wiley.com/doi/10.1890/14-1067.1/full>.
- Huang, J., Tichit, M., Poulot, M., Darly, S., Li, S., Petit, C., & Aubry, C. (2015). Comparative review of multifunctionality and ecosystem services in sustainable agriculture. *Journal*

- of Environmental Management*, 149, 138–147. URL: <http://linkinghub.elsevier.com/retrieve/pii/S0301479714005106>. doi:10.1016/j.jenvman.2014.10.020.
- Huang, R. (2014). *RQDA: R-based Qualitative Data Analysis*. (R package version 0.2-7 ed.). <http://rqda.r-forge.r-project.org/>.
- Huntsinger, L. (2016). The tragedy of the common narrative: Re-telling degradation in the american west. In *The End of Desertification?* (pp. 293–323). Springer.
- Huntsinger, L., Johnson, M., Stafford, M., & Fried, J. (2010). Hardwood rangeland landowners in california from 1985 to 2004: production, ecosystem services, and permanence. *Rangeland Ecology & Management*, 63, 324–334.
- Huntsinger, L., & Oviedo, J. L. (2014). Ecosystem services are social-ecological services in a traditional pastoral system: the case of California’s Mediterranean rangelands. *Ecology and Society*, 19, 8.
- Huntsinger, L., Sayre, N. F., & Wulforst, J. (2012). Birds, beasts and bovines: three cases of pastoralism and wildlife in the USA. *Pastoralism: research, policy and practice*, 2, 1.
- Irisarri, J. G. N., Derner, J. D., Porensky, L. M., Augustine, D. J., Reeves, J. L., & Mueller, K. E. (2016). Grazing intensity differentially regulates ANPP response to precipitation in North American semiarid grasslands. *Ecological Applications*, 26, 1370–1380.
- Jacobson, C., Hughey, K. F. D., Allen, W. J., Rixecker, S., & Carter, R. W. (2009). Toward More Reflexive Use of Adaptive Management. *Society & Natural Resources*, 22, 484–495. URL: <http://www.tandfonline.com/doi/abs/10.1080/08941920902762321>. doi:10.1080/08941920902762321.
- Jaggar, A. (2008). Love and knowledge: Emotion in feminist epistemology. In A. Jaggar (Ed.), *Just Methods* (pp. 378–389). New York, NY: Routledge.

- Joyce, L. A., Briske, D. D., Brown, J. R., Polley, H. W., McCarl, B. A., & Bailey, D. W. (2013). Climate change and north american rangelands: assessment of mitigation and adaptation strategies. *Rangeland Ecology & Management*, *66*, 512–528.
- Kachergis, E., Derner, J. D., Cutts, B. B., Roche, L. M., Eviner, V. T., Lubell, M. N., & Tate, K. W. (2014). Increasing flexibility in rangeland management during drought. *Ecosphere*, *5*, 1–14.
- Kachergis, E. J., Knapp, C. N., Fernandez-Gimenez, M. E., Ritten, J. P., Pritchett, J. G., Parsons, J., Hibbs, W., & Roath, R. (2013). Tools for resilience management: multidisciplinary development of state-and-transition models for northwest Colorado. *Ecology and Society*, *18*, 39.
- Kassam, K.-A. (2008). Diversity as if nature and culture matter: Biocultural diversity and indigenous peoples. *International Journal of Diversity in Organizations, Communities and Nations*, *8*, 87–95.
- Khan, S. (2005). Reconfiguring the native informant: Positionality in the global age. *Signs*, *30*, 2017–2037.
- Kittredge, W. (1996). *Who Owns the West?*. Mercury House. URL: <https://books.google.com/books?id=3-QTAAAYAAJ>.
- 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.
- Knapp, C. N., & Fernandez-Gimenez, M. E. (2009). Knowledge in practice: Documenting rancher local knowledge in northwest Colorado. *Rangeland Ecology & Management*, *62*, 500–509. URL: <http://www.bioone.org/doi/abs/10.2111/08-175.1>. doi:10.2111/08-175.

1.

- Kreuter, U. P., Iwaasa, A. D., Theodori, G. L., Ansley, R. J., Jackson, R. B., Fraser, L. H., Naeth, M. A., McGillivray, S., & Moya, E. G. (2016). State of knowledge about energy development impacts on north american rangelands: An integrative approach. *Journal of environmental management*, 180, 1–9.
- Kruskal, J. B. (1964). Nonmetric multidimensional scaling: a numerical method. *Psychometrika*, 29, 115–129.
- Kuhn, T. S. (2012). *The structure of scientific revolutions*. (4th ed.). Chicago: University of Chicago Press.
- Laca, E. A. (2009). Precision livestock production: tools and concepts. *Revista brasileira de zootecnia*, 38, 123–132.
- Larsen, S. C. (2016). Regions of care: a political ecology of reciprocal materialities. *Journal of Political Ecology*, 23, 159–166. URL: <http://www.academia.edu/download/46185181/Larsen.pdf>.
- Latour, B. (1993). *We have never been modern*. Cambridge, MA: Harvard University Press.
- Lauenroth, W., Burke, I. C., & Gutmann, M. P. (1999). The structure and function of ecosystems in the central North American grassland region. *Great Plains Research*, (pp. 223–259).
- Lauenroth, W., & Sala, O. E. (1992). Long-term forage production of north american shortgrass steppe. *Ecological Applications*, 2, 397–403.
- Lauenroth, W. K., & Burke, I. (2008). *Ecology of the shortgrass steppe: a long-term perspective*. Oxford University Press.
- Lefcheck, J. S. (2016). piecewiseSEM: Piecewise structural equation modelling in R for

- ecology, evolution, and systematics. *Methods in Ecology and Evolution*, 7, 573–579.
- Leopold, A. (1966). *A Sand County almanac*. Oxford University Press New York.
- Leys, A. J., & Vanclay, J. K. (2011). Stakeholder engagement in social learning to resolve controversies over land-use change to plantation forestry. *Regional Environmental Change*, 11, 175–190. URL: <http://link.springer.com/10.1007/s10113-010-0132-6>. doi:10.1007/s10113-010-0132-6.
- Liao, C., Sullivan, P. J., Barrett, C. B., & Kassam, K.-A. S. (2014). Socioenvironmental threats to pastoral livelihoods: Risk perceptions in the Altay and Tianshan mountains of Xinjiang, China. *Risk Analysis*, 34, 640–655.
- Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Thousand Oaks, CA: Sage.
- 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.
- de Loë, R. C., Murray, D., & Simpson, H. C. (2015). Farmer perspectives on collaborative approaches to governance for water. *Journal of Rural Studies*, 42, 191–205. URL: <http://linkinghub.elsevier.com/retrieve/pii/S0743016715300334>. doi:10.1016/j.jrurstud.2015.10.005.
- Lubell, M., Cutts, B., Roche, L., Hamilton, M., Derner, J., Kachergis, E., & Tate, K. (2013). Conservation program participation and adaptive rangeland decision-making. *Rangeland Ecology & Management*, 66, 609–620.
- MacDonald, J. M., & McBride, W. D. (2009). The transformation of US livestock agriculture scale, efficiency, and risks. *Economic Information Bulletin*, .
- Manley, W. A., Hart, R. H., Samuel, M. J., Smith, M. A., Waggoner Jr, J. W., & Manley, J. T. (1997). Vegetation, cattle, and economic responses to grazing strategies and pressures.

- Journal of Range Management*, (pp. 638–646). URL: <http://www.jstor.org/stable/4003460>.
- Marshall, N. A., & Smajgl, A. (2013). Understanding variability in adaptive capacity on rangelands. *Rangeland Ecology & Management*, 66, 88–94.
- Marshall, N. A., & Stokes, C. J. (2014). Influencing adaptation processes on the Australian rangelands for social and ecological resilience. *Ecology and Society*, 19, 14.
- McCune, B., Grace, J. B., & Urban, D. L. (2002). *Analysis of ecological communities* volume 28. MjM software design Gleneden Beach, OR.
- McDowell, G. R. (2001). *Land-Grant Universities and Extension into the 21st Century: Renegotiating or abandoning a social contract..* ERIC.
- Meinzen-Dick, R., & Zwarteveen, M. (1998). Gendered participation in water management: Issues and illustrations from water users' associations in South Asia. *Agriculture and Human Values*, 15, 337–345. URL: <http://link.springer.com/article/10.1023/A:1007533018254>.
- Milchunas, D., Sala, O., & Lauenroth, W. (1988). A generalized model of the effects of grazing by large herbivores on grassland community structure. *American Naturalist*, (pp. 87–106).
- Milchunas, D. G., Forwood, J. R., & Lauenroth, W. K. (1994). Productivity of long-term grazing treatments in response to seasonal precipitation. *Journal of Range Management*, (pp. 133–139).
- Milchunas, D. G., & Lauenroth, W. K. (1993). Quantitative effects of grazing on vegetation and soils over a global range of environments. *Ecological monographs*, 63, 327–366.
- Milchunas, D. G., Lauenroth, W. K., & Burke, I. C. (1998). Livestock grazing: Animal and

- plant biodiversity of shortgrass steppe and the relationship to ecosystem function. *Oikos*, 83, 65. URL: <http://www.jstor.org/stable/3546547?origin=crossref>. doi:10.2307/3546547.
- Milchunas, D. G., Lauenroth, W. K., Chapman, P. L., & Kazempour, M. K. (1989). Effects of grazing, topography, and precipitation on the structure of a semiarid grassland. *Vegetatio*, 80, 11–23.
- Morales, A. L. (1998). The historian as curandera. In B. K. Scott, S. E. Cayleff, A. Donadey, & I. Lara (Eds.), *Women in Culture: An Intersectional Anthology for Gender and Women's Studies* (pp. 134–147). West Sussex, UK: Wiley Blackwell.
- 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 qualitative methods*, 1, 13–22.
- Mortimore, M., & Turner, B. (2005). Does the Sahelian smallholder's management of woodland, farm trees, rangeland support the hypothesis of human-induced desertification? *Journal of Arid Environments*, 63, 567–595.
- Mu, J. E., McCarl, B. A., & Wein, A. M. (2013). Adaptation to climate change: changes in farmland use and stocking rate in the US. *Mitigation and Adaptation Strategies for Global Change*, 18, 713–730.
- Munday, J. (2014). The practice of feminist focus groups. In S. Nagy Hesse-Biber (Ed.), *Feminist research practice: A primer* (pp. 233–263). Sage. (2nd ed.).
- 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. URL: <http://link.springer.com/10.1007/s00267-009-9400-y>. doi:10.1007/s00267-009-9400-y.
- Nagy Hesse-Biber, S. (2014). Feminist approaches to in-depth interviewing. In S. Nagy Hesse-Biber (Ed.), *Feminist research practice: a primer* (pp. 182–232). Sage. (2nd ed.).
- Nakagawa, S., & Schielzeth, H. (2013). A general and simple method for obtaining R² from generalized linear mixed-effects models. *Methods in Ecology and Evolution*, 4, 133–142.
- Naples, N. A. (1996). A feminist revisiting of the insider/outsider debate: The “outsider phenomenon” in rural Iowa. *Qualitative Sociology*, 19, 83–106.
- 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 & Natural Resources*, 27, 436–450. URL: <http://www.tandfonline.com/doi/abs/10.1080/08941920.2013.861562>. doi:10.1080/08941920.2013.861562.
- 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 *Mass Collaboration and Education* (pp. 105–124). Springer. URL: http://link.springer.com/chapter/10.1007/978-3-319-13536-6_6.
- Oksanen, J., Blanchet, F. G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P. R., O’Hara, R. B., Simpson, G. L., Solymos, P., Stevens, M. H. H., Szoecs, E., & Wagner, H. (2016). *vegan: Community Ecology Package*. URL: <https://CRAN.R-project.org/package=vegan> r package version 2.4-0.
- Olsson, L., Jerneck, A., Thoren, H., Persson, J., & O’Byrne, D. (2015). Why resilience is unappealing to social science: Theoretical and empirical investigations of the scientific use

- of resilience. *Science advances*, 1, e1400217.
- Opie, A. (1992). Qualitative research, appropriation of the ‘Other’ and empowerment. *Feminist review*, (pp. 52–69).
- Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge: Cambridge University Press.
- Pannell, D. J., & Vanclay, F. (Eds.) (2011). *Changing land management: Adoption of new practices by rural landholders*. Collingwood VIC, Australia: CSIRO Publishing.
- Petersen, B., Montambault, J., & Koopman, M. (2014). The Potential for Double-Loop Learning to Enable Landscape Conservation Efforts. *Environmental Management*, 54, 782–794. URL: <http://link.springer.com/10.1007/s00267-014-0337-4>. doi:10.1007/s00267-014-0337-4.
- Peterson, R., & Coppock, D. L. (2001). Economics and demographics constrain investment in Utah private grazing lands. *Journal of Range Management*, 54, 106. URL: <http://www.jstor.org/stable/4003169?origin=crossref>. doi:10.2307/4003169.
- Pickett, S., Ostfeld, R. S., Shachak, M., & Likens, G. (2012). *The ecological basis of conservation: heterogeneity, ecosystems, and biodiversity*. Springer Science & Business Media.
- Plumwood, V. (2003). Decolonizing relationships with nature. In W. M. Adams, & M. Mulligan (Eds.), *Decolonizing nature: strategies for conservation in a post-colonial era* chapter 3. (pp. 51–78). Earthscan.
- Porensky, L. M., Mueller, K. E., Augustine, D. J., & Derner, J. D. (2016). Thresholds and gradients in a semi-arid grassland: long-term grazing treatments induce slow, continuous and reversible vegetation change. *Journal of Applied Ecology*, .

- Provenza, F., Pringle, H., Revell, D., Bray, N., Hines, C., Teague, R., Steffens, T., & Barnes, M. (2013). Complex creative systems: principles, processes, and practices of transformation. *Rangelands*, *35*, 6–13.
- Provenza, F. D. (1991). Viewpoint: range science and range management are complementary but distinct endeavors. *Journal of Range Management*, *44*, 181–183.
- Qin, H. (2016). Newcomers and oldtimers: Do classification methods matter in the study of amenity migration impacts in rural America? *Population and Environment*, *38*, 101–114.
- R Core Team (2016). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing Vienna, Austria.
- Rathwell, K., Armitage, D., & Berkes, F. (2015). Bridging knowledge systems to enhance governance of environmental commons: A typology of settings. *International Journal of the Commons*, *9*. URL: <https://www.thecommonsjournal.org/article/view/URN%3ANBN%3ANL%3AUI%3A10-1-117257/>.
- Reed, M., Evely, A. C., Cundill, G., Fazey, I. R. A., Glass, J., Laing, A., Newig, J., Parrish, B., Prell, C., Raymond, C. et al. (2010). What is social learning? *Ecology and Society*, *15*.
- Reeves, J. L., Derner, J. D., Sanderson, M. A., Kronberg, S. L., Hendrickson, J. R., Vermeire, L. T., Petersen, M. K., & Irisarri, J. G. (2015). Seasonal weather-related decision making for cattle production in the Northern Great Plains. *Rangelands*, *37*, 119–124.
- Reeves, J. L., Derner, J. D., Sanderson, M. A., Petersen, M. K., Vermeire, L. T., Hendrickson, J. R., & Kronberg, S. L. (2013). Temperature and precipitation affect steer weight gains differentially by stocking rate in northern mixed-grass prairie. *Rangeland Ecology & Management*, *66*, 438–444.
- Reid, R. S., Fernández-Giménez, M. E., & Galvin, K. A. (2014). Dynamics and resilience of

- rangelands and pastoral peoples around the globe. *Annual Review of Environment and Resources*, 39, 217–242.
- Resnik, J., Wallace, G., Brunson, M., & Mitchell, J. (2006). Open spaces, working places: Local government programs can slow loss of rangelands-but only if urban and ranching interests find ways to work together. *Rangelands*, 28, 4–9.
- Rimbey, N. R., Tanaka, J. A., & Torell, L. A. (2015). Economic considerations of livestock grazing on public lands in the united states of america. *Animal Frontiers*, 5, 32–35.
- 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 Economics*, 92, 1242–1255.
- Robbins, P. (2006). The politics of barstool biology: Environmental knowledge and power in greater Northern Yellowstone. *Geoforum*, 37, 185–199. URL: <http://linkinghub.elsevier.com/retrieve/pii/S0016718505000588>. doi:10.1016/j.geoforum.2004.11.011.
- Roche, L., Cutts, B., Derner, J., Lubell, M., & Tate, K. (2015a). On-ranch grazing strategies: Context for the rotational grazing dilemma. *Rangeland Ecology & Management*, 68, 248–256.
- Roche, L. M., Schohr, T. K., Derner, J. D., Lubell, M. N., Cutts, B. B., Kachergis, E., Eviner, V. T., & Tate, K. W. (2015b). Sustaining working rangelands: Insights from rancher decision making. *Rangeland Ecology & Management*, 68, 383–389.
- Rocheleau, D., Thomas-Slayter, B., & Wangari, E. (2013). *Feminist political ecology: Global issues and local experience*. New York, NY: Routledge.

- Rodela, R. (2013). The social learning discourse: Trends, themes and interdisciplinary influences in current research. *Environmental Science & Policy*, 25, 157–166.
URL: <http://linkinghub.elsevier.com/retrieve/pii/S1462901112001487>. doi:10.1016/j.envsci.2012.09.002.
- Rogers, E. M. (2010). *Diffusion of innovations*. (4th ed.). New York, NY: Free Press.
- Roux, D. J., Rogers, K. H., Biggs, H., Ashton, P. J., & Sergeant, A. (2006). Bridging the science-management divide: Moving from unidirectional knowledge transfer to knowledge interfacing and sharing. *Ecology and Society*, 11.
- Roux, D. J., Stirzaker, R. J., Breen, C. M., Lefroy, E., & Cresswell, H. P. (2010). Framework for participative reflection on the accomplishment of transdisciplinary research programs. *Environmental Science & Policy*, 13, 733–741.
- Rowan, R., Ladewig, H. W., & White, L. D. (1994). Perceptions vs. recommendations: a rangeland decision-making dilemma. *Journal of Range Management*, (pp. 344–348).
- Rowe, H. I., Bartlett, E. T., & Swanson Jr, L. E. (2001). Ranching motivations in two colorado counties. *Journal of Range Management*, 54, 314–321.
- Said, E. W. (1979). *Orientalism*. Vintage.
- Sampson, A. (1951). A symposium on rotational grazing in North America. *Journal of Range Management*, 4, 19–24.
- Sayre, N. F. (2004). Viewpoint: The need for qualitative research to understand ranch management. *Journal of Range Management*, 57, 668–674.
- Sayre, N. F. (2006). *Ranching, endangered species, and urbanization in the Southwest: Species of capital*. Tuscon: University of Arizona Press.
- Sayre, N. F. (2008). The genesis, history, and limits of carrying capacity. *Annals of the*

- Association of American Geographers*, 98, 120–134.
- Sayre, N. F. (2012). The politics of the anthropogenic*. *Annual Review of Anthropology*, 41, 57–70.
- Sayre, N. F. (2015). The Coyote-Proof Pasture Experiment: How fences replaced predators and labor on US rangelands. *Progress in Physical Geography*, 39, 576–593.
- Sayre, N. F., Bestelmeyer, B. T., Havstad, K. M. et al. (2012). “The Range Problem” after a century of rangeland science: new research themes for altered landscapes. *Rangeland Ecology & Management*, 65, 545–552.
- Sayre, N. F., McAllister, R. R., Bestelmeyer, B. T., Moritz, M., & Turner, M. D. (2013). Earth stewardship of rangelands: coping with ecological, economic, and political marginality. *Frontiers in Ecology and the Environment*, 11, 348–354.
- Scasta, J., Henderson, L., & Smith, T. (2015). Drought effect on weaning weight and efficiency relative to cow size in semiarid rangeland. *Journal of Animal Science*, 93, 5829–5839.
- Schwandt, T. (2000). Three epistemological stances for qualitative inquiry: Interpretivism, hermeneutics, and social constructionism. In K. Denzin, & Y. Lincoln (Eds.), *Handbook of Qualitative Research* (pp. 189–214). Sage Publications. (2nd ed.).
- Sheridan, T. E. (2007). Embattled ranchers, endangered species, and urban sprawl: The political ecology of the new American West. *Annual Review of Anthropology Anthropol.*, 36, 121–138.
- Sherren, K., Fischer, J., & Fazey, I. (2012). Managing the grazing landscape: Insights for agricultural adaptation from a mid-drought photo-elicitation study in the australian sheep-wheat belt. *Agricultural Systems*, 106, 72–83.
- Simberloff, D. (2004). Community ecology: is it time to move on? *The American Naturalist*,

163, 787–799.

Sluyter, A. (2002). *Colonialism and landscape: Postcolonial theory and applications*. Lanham: Rowman & Littlefield.

Sluyter, A. (2012). *Black Ranching Frontiers: African Cattle Herders of the Atlantic World, 1500-1900*. New Haven: Yale University Press.

Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global environmental change*, 16, 282–292.

Smith, A. H., & Martin, W. E. (1972). Socioeconomic behavior of cattle ranchers, with implications for rural community development in the West. *American Journal of Agricultural Economics*, 54, 217–225.

Smith, L. T. (1999). *Decolonizing methodologies: Research and indigenous peoples*. Zed books.

Snyder, G. (2010). *The practice of the wild*. (Berkeley ed.). Counterpoint Press.

Spivak, G. C. (1988). Can the subaltern speak? In *Marxism and the Interpretation of Culture* (pp. 271–313). Springer.

Stephenson, G. (2003). The somewhat flawed theoretical foundation of the extension service. *Journal of Extension*, 41, 1–7.

Stoddart, L. A., Smith, A. D. et al. (1955). *Range management*. Ed. 2. New York; Toronto; London; McGraw-Hill Book Company Inc.

Stone-Jovicich, S. (2015). Probing the interfaces between the social sciences and social-ecological resilience: insights from integrative and hybrid perspectives in the social sciences. *Ecology and Society*, 20, 25.

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 and Society*, 11, 39. URL: <http://sustainable-learning.org/wp-content/uploads/2012/01/Unpacking-%E2%80%9Cparticipation%E2%80%9D-in-the-adaptive-management-of-social-ecological-systems-A-critical-review1.pdf>.
- 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. URL: <http://doi.wiley.com/10.1111/j.1365-2664.2011.02070.x>. doi:10.1111/j.1365-2664.2011.02070.x.
- Sylvester, K. M., & Rupley, E. S. A. (2012). Revising the Dust Bowl: High Above the Kansas Grasslands. *Environmental History*, 17, 603–633. URL: <http://envhis.oxfordjournals.org/cgi/doi/10.1093/envhis/ems047>. doi:10.1093/envhis/ems047.
- Talbert, C. B., Knight, R. L., & Mitchell, J. E. (2007). Private ranchlands and public land grazing in the southern Rocky Mountains: Why the private land matters when we think about public lands grazing. *Rangelands*, 29, 5–8.
- Teague, R., Provenza, F., Kreuter, U., Steffens, T., & Barnes, M. (2013). Multi-paddock grazing on rangelands: why the perceptual dichotomy between research results and rancher experience? *Journal of Environmental Management*, 128, 699–717.
- Teague, R., Provenza, F., Norton, B., Steffens, T., Barnes, M., Kothmann, M., Roath, R., & Schroeder, H. (2008). Benefits of multi-paddock grazing management on rangelands: limitations of experimental grazing research and knowledge gaps. *Grasslands: ecology, management and restoration*. Hauppauge, NY, USA: Nova Science Publishers, (pp. 41–80).
- Thornton, P. K. (2010). Livestock production: recent trends, future prospects. *Philosophical*

- Transactions of the Royal Society B: Biological Sciences*, 365, 2853–2867.
- Torell, L. A. (2010). Economics of flexible versus conservative stocking strategies to manage climate variability risk. *Rangeland Ecology & Management*, 63, 415–425.
- Torell, L. A., Lyon, K. S., & Godfrey, E. B. (1991). Long-run versus short-run planning horizons and the rangeland stocking rate decision. *American Journal of Agricultural Economics*, 73, 795–807.
- Torell, L. A., Rimbey, N. R., Tanaka, J. A., Bailey, S. A. et al. (2001). The lack of a profit motive for ranching: implications for policy analysis. In *Proceedings of the Annual Meeting of the Society for Range Management* (p. 23). volume 17.
- Trauger, A., Sachs, C., Barbercheck, M., Kiernan, N. E., Brasier, K., & Schwartzberg, A. (2010). The object of extension: agricultural education and authentic farmers in pennsylvania. *Sociologia Ruralis*, 50, 85–103.
- Tronto, J. C. (1999). Care ethics: Moving forward. *Hypatia*, 14, 112–119. URL: <http://onlinelibrary.wiley.com/doi/10.1111/j.1527-2001.1999.tb01043.x/full>.
- Tronto, J. C. (2001). An ethic of care. In M. B. Holstein, & P. B. Mitzen (Eds.), *Ethics in community-based elder care* (pp. 60–68). New York, NY: Springer.
- Turner, M. (1993). Overstocking the range: a critical analysis of the environmental science of Sahelian pastoralism. *Economic Geography*, 69, 402–421.
- Twidwell, D., Allred, B. W., & Fuhlendorf, S. D. (2013). National-scale assessment of ecological content in the world’s largest land management framework. *Ecosphere*, 4, art94.
- Ullambayar, T., Fernández-Giménez, M. E., Baival, B., & Batjav, B. (2016). Social outcomes of community-based rangeland management in mongolian steppe ecosystems. *Conservation Letters*, 00, 1–11.

- Uphoff, N. T. (1986). *Getting the process right: improving irrigation water management with farmer organization and participation*. Ithaca, NY: Cornell University. URL: http://pdf.usaid.gov/pdf_docs/PNAAV390.pdf.
- U.S. Department of Agriculture (2014). *National Resources Inventory Rangeland Resource Assessment, Natural Resources Conservation Service*. Technical Report Natural Resources Conservation Service Washington, D.C. URL: <http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/nri/?cid=stelprdb1253602>.
- Valdez, C. C. (2015). Rangeland biodiversity: Interrelationships of stocking density and grazing intensity. *International Journal of Agriculture and Forestry*, 5, 182–189.
- Van Dyke, C. (2015). Boxing daze - using state-and-transition models to explore the evolution of socio-biophysical landscapes. *Progress in Physical Geography*, 39, 594–621. URL: <http://ppg.sagepub.com/cgi/doi/10.1177/0309133315581700>. doi:10.1177/0309133315581700.
- Vitousek, P. M., D'antonio, C. M., Loope, L. L., Rejmanek, M., & Westbrooks, R. (1997). Introduced species: a significant component of human-caused global change. *New Zealand Journal of Ecology*, (pp. 1–16).
- Walker, B., & Salt, D. (2012). *Resilience thinking: sustaining ecosystems and people in a changing world*. Island Press.
- Walker, P. A. (2005). Political ecology: where is the ecology. *Progress in Human Geography*, 29, 73–82.
- Weber, E. P., Belsky, J. M., Lach, D., & Cheng, A. S. (2014). The Value of Practice-Based Knowledge. *Society & Natural Resources*, 27, 1074–1088. URL: <http://www.tandfonline.com/doi/abs/10.1080/08941920.2014.919168>. doi:10.1080/08941920.2014.919168.

- Wildi, O. (2010). *Data analysis in vegetation ecology*. West Sussex, UK: John Wiley & Sons.
- Wilkinson, C. (2015). ‘Babe, I like your lipstick’: rethinking researcher personality and appearance. *Children’s Geographies*, (pp. 1–9).
- Willems-Braun, B. (1997). Buried epistemologies: The politics of nature in (post) colonial British Columbia. *Annals of the Association of American Geographers*, 87, 3–31.
- Wilmer, H., & Fernández-Giménez, M. E. (2015). Rethinking rancher decision-making: a grounded theory of ranching approaches to drought and succession management. *The Rangeland Journal*, 37, 517–528.
- Wilmer, H., & Fernández-Giménez, M. E. (2016). Voices of change: Narratives from ranching women of the Southwestern United States. *Rangeland Ecology & Management*, 69, 150–158.
- Wilson, G. A. (2001). From productivism to post-productivism... and back again? exploring the (un) changed natural and mental landscapes of European agriculture. *Transactions of the institute of British Geographers*, 26, 77–102.
- Yahdjian, L., Sala, O. E., & Havstad, K. M. (2015). Rangeland ecosystem services: shifting focus from supply to reconciling supply and demand. *Frontiers in Ecology and the Environment*, 13, 44–51.
- Yeh, E. T. (2015). ‘How can experience of local residents be “knowledge”?’ challenges in interdisciplinary climate change research. *Area*, 48, 34–40.
- Yin, R. K. (2013). *Case study research: Design and methods*. Sage publications.