ENGAGING LOCAL PERSPECTIVES FOR IMPROVED CONSERVATION

AND CLIMATE CHANGE ADAPTATION

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ENGAGING LOCAL PERSPECTIVES FOR IMPROVED CONSERVATION AND CLIMATE CHANGE ADAPTATION

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Abstract

Climate change is a global process that will impact local places in heterogeneous and unpredictable manners. This dissertation considers whose knowledge and observations could contribute to conservation and climate adaptation planning, how perceptions influence social-ecological feedbacks, and how science could be more relevant to decision-makers and local residents. In Chapter 2, I report on interviews (n=36) conducted with ranchers and recreation-based business owners in Colorado to understand their self-perceptions of resilience and vulnerability. I find that ranchers perceive more exposure and sensitivity to climate change and they also demonstrate more adaptive capacity than recreation businesses. In Chapter 3, I convey results from interviews (n=83) completed with various long-term residents of the region surrounding Denali National Park and Preserve. I find that people who have more direct and ongoing experience with natural resources (subsistence users, bus drivers, business owners) have a greater number and more diverse observations of change than Park employees or scientists. In Chapter 4, I describe results from interviews (n=26) with community-defined Gunnison Sage-grouse experts. I find that formal and observational experts had very different explanations of the decline of Gunnison Sage-grouse and disagreed about potential conservation strategies. In Chapter 5, I describe multi-method surveys (41) conducted with ranchers in the Gunnison Basin to understand their perceptions of the potential listing of the Gunnison Sage-grouse under the Endangered Species Act, and their planned responses. I find that ranchers tend to have negative perceptions of the listing and that they plan to take actions, including sales of land and water and decreased participation in conservation efforts, which may result in harm to the Gunnison Sage-grouse. In Chapter 6, I review stakeholder-generated climate change needs assessments (63) to assess the suggestions made to make science more relevant to decision-making. Their suggestions include: interdisciplinary approaches, place-based focus, increased data-sharing and collaboration, and user-driven research. This dissertation demonstrates the importance of understanding perceptions for effective conservation and adaptation, identifies the existence of proactive adaptation strategies, highlights the value of local knowledge in specific situations, and reveals how failure to engage local people may lead to inequitable outcomes.

Dedication.

I would like to dedicate this dissertation to the past, to my Grandmother Nell Olmer, who modeled tenacity, courage, and a sense of unfailing humor, and to the bright lights of the future who never cease to amaze and inspire me (Kya Butterfield, Hans & Nik Bossard, Natasha Bentley, Simon & Emma Allen and Avery & Jenna Knapp).

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Most importantly, thank you Tom. I am blessed every day.

Preface

The chapters included in this dissertation have either been submitted for publication or are in preparation for publication. While the dissertation author is the primary author on each of these publications, other people contributed to the final products. In this section, I will list the contributions of the various authors to each of the final projects. The introduction (Chapter 1) and conclusion (Chapter 7) were written solely by Corrie Knapp and are not intended to be publications, so they are not included in this list. For each chapter, I will also refer to the IRB approval under which the research was conducted.

Chapter 2

This paper was submitted to *Ecology & Society* with co-authors F.S. Chapin and B. Neely. The paper is currently in its second round of reviews. I designed the project, conducted all interviews, completed the analysis and wrote the bulk of the paper. F.S. Chapin helped to review all materials, edit the manuscript and provide feedback throughout the process. B. Neely provided feedback on the design of the interview script and provided edits of manuscript drafts as well as providing guidance during the fieldwork. This research was conducted under UAF IRB approval #251837-1.

Chapter 3

This paper will be submitted to a special issue of *Ecology & Society* related to Arctic sustainability in March 2014 with co-authors F.S. Chapin, G. Kofinas, N. Fresco, C. Carothers, and A. Craver. I designed the project, conducted all interviews, completed the analysis and wrote the bulk of the paper. F.S. Chapin helped to review all materials, edit the manuscript and provide feedback throughout the process. G. Kofinas provided feedback on the interview script and edits on drafts. N. Fresco and C. Carothers provided edits on drafts. A. Craver helped with project planning and design, as well as facilitating connections with project communities. This research was conducted under UAF IRB approval # 220265-3.

Chapter 4

This paper has been published in the Fall 2013 issue of *Human-Wildlife Interactions* with co-authors J.O. Cochran, F.S. Chapin, G. Kofinas and N. Sayre. I designed the project, conducted all interviews, completed the analysis and wrote the bulk of the paper. J.O. Cochran helped to review materials and provide a valuable local perspective. F.S. Chapin helped to review all materials, edit the manuscript and provide feedback throughout the process. G. Kofinas provided feedback on the interview script and edits on drafts. N. Sayre helped with project planning and design as well as providing edits on drafts. This research was conducted under UAF IRB approval # 369551-1.

Chapter 5

This paper will be submitted to *Society & Natural Resources* with co-authors F.S. Chapin and J.O. Cochran. I designed the project, conducted all interviews, completed the analysis and wrote the bulk of the paper. F.S. Chapin helped to review all materials, edit the manuscript and provide feedback throughout the process. J.O. Cochran helped to review materials and provide a valuable local perspective. This research was conducted under UAF IRB approval # 369551-1.

Chapter 6

This paper has been published in *Global Environmental Change* with co-author S. Trainor. I designed the project, identified and reviewed the documents, coded the documents, completed the analysis and wrote the bulk of the paper. S. Trainor provided feedback on methods and edited the manuscript. This research was based on a review of prior publications and did not require IRB approval.

1. Introduction

Climate change is a global phenomenon that impacts local places and their residents in multifaceted and heterogeneous ways (ex. Finan et al. 2002, Vasquez-Leon et al. 2003). As decision-makers wrestle with validating, defining, and understanding the magnitude and broad-scale impacts of a changing climate, they have relied primarily on technical experts (IPCC 2007a). As we move into understanding local impacts and designing adaptation strategies, there is an increasing need to listen to local perspectives (Magistro and Roncoli 2001, Fussel and Klein 2006, Adger et al. 2011). Local residents may offer valuable experiential knowledge of the impacts of climate change, potential and current adaptation strategies, and feedbacks between ecological and social systems (Ford et al. 2006, Keskitalo 2008). At the same time, local people also often need better information to make wise decisions in the context of a changing climate (Moser and Ekstrom 2010, Dilling and Lemos 2011). The uncertainty produced by climate change requires better communication between individuals at multiple scales and with different types of knowledge (Adger et al. 2009, Hulme 2010). This dissertation contributes to our understanding of local impacts and adaptation, contributions of local knowledge, feedbacks between social and ecological systems, and stakeholder suggestions about how the practice and processes of science must adapt in order to provide more useful information to adapt to a changing climate.

1.1. Research Questions

The following are the broad research questions addressed by this dissertation:

- How do people experience and adapt to climate change at a local level?
- What types of local stakeholders are important to engage in adaptation planning?
- In situations where landscapes hold important values for conservation and livelihoods, what are some of the feedbacks between social and ecological systems?
- How can the practices and processes of science adapt in order to facilitate more relevant and useful information in the context of climate change?

1.2. Theories of Knowledge

The questions that this dissertation addresses relate to how we gain knowledge about a changing world and what types of knowledge are most important to consider in climate adaptation planning and conservation. I will provide a brief overview of the theories and debates surrounding approaches to knowledge and describe the challenges of integrating local knowledge into decision-making.

1.2.1. Positivist and phenomenological approaches.

Knowledge refers to the way people understand the world, and the ways in which they interpret and apply meaning to their experiences (Arce and Long 1992). Positivistic approaches to knowledge assume that there is an objective reality that exists and can be known (Comte 1972). Scientific knowledge has been affiliated with the positivistic approach and scientists often believe that it is possible to disconnect observer and observed (Worster 1977), as well as create immutable mobiles (Latour 1986), i.e., concepts or theories that can be applied beyond their original context. Resilience theory, stemming from ecology, follows in this positivistic tradition, assuming the ability to understand and manage social-ecological systems, but with an awareness of the weaknesses of reductionist and disciplinary ways of knowing (Gunderson and Holling 2002). A second approach to knowledge is phenomenological. This approach views all knowledge, including science, as contextual and subjective (Knorr-Cetina 1981, Latour 1987). Political ecology and the sociology of science present complementary perspectives, looking at how knowledge is produced and circulates (sociology of science) as well as how it is applied (political ecology) (Goldman et al. 2011). Political ecology approaches knowledge and expertise from a critical and contextual perspective, believing that knowledge cannot be divorced from power domains (Robbins 2004). Sociology of science approaches knowledge and expertise within science as contextual and a product of the culture, paradigms, tools and scale at which knowledge is collected (Goldman et al. 2011). These approaches argue that knowledge cannot be understood outside its context, whether the knowledge stems from local networks or the scientific process. In this dissertation, I approach knowledge with the assumption that there is an objective reality, but that it is challenging to fully understand this reality because of bounded perspectives, inadequate tools, and constant change.

1.2.2. Local knowledge.

Anthropologists have described how local people gain complex knowledge of their environment, which can contribute valuable insights for a host of applications, including agriculture (Conklin 1954, Thrupp 1989) and fisheries (Mackinson 2001). This type of knowledge has been referred to as indigenous knowledge, traditional ecological knowledge, or local knowledge, depending on its temporal scale, cultural continuity, and content (Berkes 2008). Local knowledge can be defined as a dynamic system of place-based observations, interpretations, and local preferences that inform people's use of and relationship with their environment and other people (Chapin et al. 2009). Local knowledge is more than just information and provides valuable insight into local interpretations, values, interactions and indicators (Berkes et al. 2000, Peloquin and Berkes 2009). Local knowledge has proved valuable by providing hypotheses about change (Knapp and Fernandez-Gimenez 2009), memory of the system (Calvo-Iglesias et al. 2006), local observations (Berkes and Jolly 2001), local adaptation strategies (Adger et al. 2011), and local perceptions of risk (Fischer 2000). While local knowledge is always a valuable resource, it is especially useful to consider in situations where there is high uncertainty and low levels of trust (Fischer 2000). Local knowledge may lower model uncertainty by suggesting appropriate processes and relationships that should be considered, but which otherwise may be overlooked or avoided in scientific studies (Young 2009).

1.2.3. Are there different types of knowledge?

It is important to consider what makes ways of knowing or forms of knowledge "different". Are there substantive, methodological, epistemological or contextual reasons to believe that there are different types of knowledge? While some argue that there are fundamental differences in the substance, methods and applications of local and scientific knowledge (Barnes 1974, Brokensha et al. 1980), others argue that such categorization is inappropriate and there is no difference between these two forms of knowledge (Murdoch and Clark 1994, Agrawal 1995). Philosophers of science have struggled with demarcating how these types of knowledge differ (ex. Popper 1983). While often perceived as more objective, scientific knowledge has a socially constructed aspect, which is apparent in the paradigms that inhibit scientific progress until alternative evidence builds, necessitating the development of a new explanatory paradigm (Kuhn 1962). Both political ecology and science studies demonstrate the political and contextual elements in both the development and application of local knowledge (Goldman et al. 2011). In this dissertation, I take the approach that while all knowledge is contextual, there are different domains of knowledge with different logics and epistemologies (Agrawal 1995). These can be understood on a continuum based on the formality of the knowledge production process, the desire to extrapolate to larger scales, the accessibility of knowledge, and the level of embeddedness in culture and tradition (Raymond et al. 2010). While not fundamentally distinct, there are differences between both types of knowledge that can become apparent based on context (Blaikie et al. 1997). Categorization is a simplification of the true hybridity and heterogeneity of knowledge, but it also allows comparisons to be made and novel contributions to be identified.

1.2.4. Integration challenges.

Integrating local knowledge and science in decision-making can be a problematic endeavor for a host of reasons. The ability to create, circulate (or fail to share) and apply knowledge can consolidate power in some hands and not others. Foucault has described how knowledge is a diffuse form of power: by knowing we control and by controlling we know (Foucault 1977). Knowledge is also heterogeneous within a community, nor is there always agreement within a community about knowledge claims (Davis and Wagner 2003, Berkes 2008, Goldman et al. 2011). Local knowledge is not always transferable outside of a community, nor is it always appropriate to represent the knowledge of others (Davis and Wagner 2003). There is diversity within every type of knowledge, and so there is a constant negotiation about whose knowledge to integrate and how. The knowledge domains that are considered in decision-making vary by culture, and integration always depends on context (Jasanoff 2005). The creation of new knowledge is organized around dominant paradigms (Kuhn 1962) and it may be difficult to acknowledge knowledge that doesn't fit within one's accepted paradigm. For instance, local knowledge is rarely integrated into decision-making if it contradicts science (Fischer 2000). Researchers are often interested in environmental rather than political knowledge, but removing facts from understanding of those facts separates knowledge from its context (Nadasdy 1999). Different types of knowledge are developed in different ways, so it may be difficult to compare information gathered at different scales or with different tools (Raymond et al. 2010). This dissertation doesn't attempt to integrate diverse bodies of knowledge in decision-making, but instead focuses on what types of knowledge diverse stakeholders can contribute to conservation and climate-change adaptation planning.

1.2.5. Credible, legitimate and salient.

For knowledge to be used in practice, it must be credible, legitimate and salient to different actors and decision-makers within the system (Cash et al. 2002). For instance, failure to acknowledge local knowledge after Chernobyl led to a loss of credibility for scientific knowledge as it undercut local social networks and challenged social identities (Wynne 1992). Different people judge these dimensions in different ways based on their context, perceptions, values and worldviews (Cash et al. 2002). Those who take a positivistic approach to knowledge may believe that the scientific method is the most appropriate and reliable way to gain knowledge (Lee 1993). However, political ecology and the sociology of science suggest that all knowledge is contextual, and we need to recognize the limits and context of all knowledge (Goldman et al. 2011). Every culture and knowledge system has ways to validate their knowledge claims (Sillitoe 2007). While science may use falsification, statistical measures of uncertainty, and peer review, local knowledge may be judged by its correspondence with reality, its ability to work in practical situations, and its agreement with elders or passed-down wisdom (Berkes 2009). Epistemological pluralism has been suggested as a technique for producing more integrated and respectful interdisciplinary research (Miller et al. 2008). This approach could better allow us to situate knowledge claims in context and understand the contributions of each.

1.2.6. My approach to knowledge.

In this dissertation, I am interested in informing specific decisions that could be informed by local knowledge including conservation of the Gunnison Sage-grouse as well as climate adaptation planning. While the literature may suggest the need for a focus on knowledge integration processes rather than information products (Clark and Murdoch 1997, Davidson-Hunt 2006, Raymond et al. 2010), this is only possible when those who hold the power over decision-making are willing to participate, share power over decision-making, and invest the time and resources needed. For this project, the decisions under consideration (whether or not to list Gunnison Sage-grouse as endangered under the Endangered Species Act and how Denali might best adapt to climate change) were arenas where this commitment was not fully realized. While in some situations local knowledge documentation may disempower local residents (Escobar 1995), in these cases it helps to make their knowledge more credible and salient. Residents in these communities requested systematic documentation of their knowledge and observations so that these insights were more salient and credible to decision-makers. In the Gunnison Basin, local stakeholders recognized the salience of their knowledge, but lacked credibility and legitimacy. This study helped to increase salience, by making the knowledge visible, and increase credibility, by documenting it in a systematic manner. In the Denali region local knowledge had legitimacy (decision-makers were required to consider it), but it wasn't salient, or visible in a form that could be used for decision-making.

In this dissertation, I take the approach that there is an objective reality, but that it is challenging to ever fully understand this reality because of limited perspective, inadequate tools, and constant change. I also acknowledge the hybridity and heterogeneity of both local and scientific knowledge, but use categorizations as a way to understand what insights different stakeholders can contribute to decision-making. While power differences were apparent, they were not the focus of my research. Neither were the processes whereby local insights might be integrated into decision-making. Based on community interest and upcoming decisions, I focused my dissertation on documenting and collecting local knowledge so that it could be more visible for decision-making.

1.3. The role of the researcher

The literature in sociology of science suggests that it is important to consider the methods and context of knowledge production in order to understand and interpret the resulting findings (Goldman et al. 2011). The researcher influences research outcomes in both qualitative and quantitative research by defining the research question, choosing locations, identifying appropriate methods, and interpreting the results. In all research it is important for the researcher to be self-reflective about how their research decisions may influence research results. In qualitative research, the researcher is intimately involved in gathering data through interviews or focus groups, so it is critical for the researcher to be self-reflective of their role and influence in the research process

(Denzin and Lincoln 2005). I have different relationships with the places in which I conducted the research, which may influence how I was received and the types of information that I was able to access. I am from Colorado and have conducted research in rural ranching communities in the past (Knapp and Fernandez-Gimenez 2009). I have also worked in agriculture, both on farms and ranches, and have some practical knowledge of these settings. I was also able to conduct several projects in the Gunnison area over a three-year period (Ch. 2, 4 and 5), and was able to develop relationships with participants through multiple interactions. I only briefly lived in Alaska prior to conducting interviews in Denali, and my familiarity with local culture, ecology and politics was primarily through reviewing published literature. Due to the distance and cost of travel, as well as the overlap with coursework, I was only able to travel to Alaskan communities 1-3 times and the duration of each trip was short. Qualitative research is often more successful when researchers are able to develop trusting relationships with communities (Denzin and Lincoln 2005).

Sillitoe has described how interpretations of local knowledge are often filtered through the anthropologist, potentially leading to misrepresentation (Sillitoe 2007). I utilized several techniques to ground-truth my representations of local knowledge. In all of the study sites, I requested feedback about my interpretations of knowledge claims from key community members. I also asked participants to interpret the meaning of their own observations as well as those of other participants. In Gunnison, I worked in partnership with several local people who reviewed my interpretations and offered their insights. Feedback at various stages helped me to question my own interpretations and reflect on how my personal context might influence those interpretations (Denzin and Lincoln 2005).

1.4. Research Context and Theoretical Background

My research questions are situated in a complex web of prior research that helped to inform and structure this dissertation. Each chapter of this dissertation is written as a stand-alone paper, which contains a literature review section. While individual chapters contextualize each of my studies, this introduction provides a concise overview of prior research related to each of my broad research questions.

1.4.1. How do people experience and adapt to climate change at a local level?

The way individuals, communities and cultures adapt to their environments has a long history in anthropology (Steward 1972, Bennett 1976, Mazness 1978, Crumley 1994). These studies focus on human adaptation to specific environments (Moran 1981) and adaptation to changing environments (Hamilton et al. 2000). Adaptation to climate change impacts is a newer problem area (for one of the earliest assessments: Easterling 1996). Two complementary approaches to climate change adaptation are vulnerability and resilience. Vulnerability is the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt (Adger 2006, Smit and Wandel 2006). Resilience is the capacity of a system to absorb disturbance and still retain its basic function and structure (Walker and Salt 2006). These approaches provide complementary information, with vulnerability assessing in-depth and short-term responses to change, and resilience assessing broader-scale and longer-term responses at a systems level (Miller et al. 2010, Turner 2010). One element both share is an interest in adaptive capacity, which is the capacity of a system to respond successfully to climate variability and change, including adjustments in both behavior and in resources and technologies (IPCC 2007b). While these concepts are challenging to measure, specific traits have been affiliated with each. These traits have been identified in prior reviews, and include: vulnerability (exposure, sensitivity, adaptive capacity), resilience (adaptive capacity, feedbacks, legacy, modularity, redundancy, and adaptive governance), adaptive capacity (diversity, social learning, ability to innovate, capacity to implement changes) and transformability (identify options and pathways, learn from crisis, navigate thresholds) (Chapin et al. 2009). While resilience and vulnerability have been assessed with quantitative metrics (e.g., Brooks et al. 2005, Alessa et al. 2008), they have also been approached qualitatively, through conversations with local residents about their knowledge and perceptions (e.g., Berkes and Jolly 2001, West and Vasquez-Leon 2008). While exposure and sensitivity may be gauged with quantitative metrics (Brooks et al. 2005), adaptive capacity requires nuanced insights, which may only be available by engaging local knowledge (Adger et al. 2009, Adger et al. 2011). My dissertation builds upon these theoretical perspectives by gauging self-assessments of resilience and vulnerability (Ch. 2), assessing how local knowledge can contribute to resilience (Ch. 3 and 4), understanding feedbacks in social-ecological systems (Ch. 5) and compiling stakeholder suggestions about how the processes and practices of science should adapt to climate change (Ch. 6).

Prior case studies have documented how people perceive climate change (e.g., Berkes and Jolly 2001, Finan et al. 2002, Vasquez-Leon et al. 2003, Ford and Smit 2004, Mertz et al. 2009, Kofinas et al. 2010, Moerlein and Carothers 2012, Wilk et al. 2013), but only rarely have they compared the observations of multiple types of stakeholders (e.g., Finan et al. 2002) or identified local adaptive strategies (e.g., Ziervogel et al. 2006, Tremblay et al. 2008, Mertz et al. 2009). A review of the evolution of vulnerability assessments demonstrates that identification and implementation of adaptation strategies is a relatively new endeavor for applied science (Fussel and Klein 2006). Adaptation actions at one scale may influence opportunities at other scales so it is important to understand how adaptation occurs at multiple scales (Adger et al. 2005, Adger et al. 2009). Local people respond to climate change in combination with other local issues and stressors, so understanding of local context is important to design effective and ethical adaptation strategies (Wilbanks and Kates 2010). This study documents the perceptions, impacts, and current and potential future adaptation strategies of individuals in two landscapes: the region surrounding Denali National Park in interior Alaska and the Upper Gunnison Watershed in south-central Colorado. In both landscapes, I compare and contrast the observations of different stakeholders: long-term residents, subsistence community members, park employees and bus drivers in Denali, and ranching and recreation business owners in Gunnison (Chapters 2 and 3)

1.4.2. How can knowledge and information from different spatial scales and types of experience influence and inform adaptation planning?

Effective adaptation planning requires coordination and knowledge sharing between individuals making decisions at different spatial scales (Adger 2005, Adger et al. 2009). While global forms of knowledge, such as large-scale climate models, are important to understand climate change impacts, they don’t contain the nuance that local knowledge can provide (Hulme 2010). Working alongside local residents to understand climate change impacts and effective responses can also help to better link knowledge with practice and lead to successful implementation (Cash et al. 2003, Danielsen et al. 2010).

As discussed earlier, there is a political and cultural dimension to knowledge creation, diffusion, and application (Foucault 1977, Jasanoff 2005). The incorporation of knowledge from different scales also has an ethical component, as it will influence the types of adaptation strategies that are supported, funded, and implemented (Thomas and Twyman 2005, Paavola and Adger 2006, Paavola 2008). In order to understand adaptation processes at different scales, scholars have recommended planning that involves both top-down and bottom-up processes (Urwin and Jordan 2008, Mastrandrea et al. 2010), as well as ongoing interaction between end-users and scientists to create more relevant science outcomes (Vogel et al. 2007, Dilling and Lemos 2011). While past assessments have documented local perceptions and current adaptations (see above), few have identified local suggestions about potential future adaptation strategies or compared the insights of different types of stakeholders. In this project, I document local suggestions about potential future climate change adaptation strategies as well as highlight what local knowledge can contribute to adaptation planning (Chapters 2 and 3).

1.4.3. What are some of the feedbacks between social and ecological systems?

Social-ecological systems are the primary unit of study for most resilience scholars. The social and ecological components of systems interact both within specific scales and across scales (Gunderson and Holling 2002, Adger et al. 2009). In the context of climate change and other outside stressors, the system can either adapt or transform into a new system (Chapin et al. 2009). Conceptual models of system dynamics can help to identify these specific feedbacks (Cundill et al. 2005, Beers and Bots 2009). Sociologists have stated that, “if men define situations as real, they are real in their consequences” (Thomas and Thomas 1928). While perceptions are understood as an important driver of human action, they have been only minimally incorporated into resilience thinking about social-ecological systems. Prior research has shown that private landowners often have negative perceptions of environmental legislation such as the Endangered Species Act (Brook et al. 2003, Conley et al. 2007); however, there has been little attention given to ways that these perceptions may lead to unintended impacts for the species of concern. In this dissertation, I explore how policy choices (ESA listing) may influence perceptions of ranching viability, which may lead to changes in management that influence habitat and species numbers (Chapter 4 and 5).

1.4.4. In what ways can science be more effective in the context of climate change?

Scientific and research institutions have traditionally operated under the assumption that increased information leads to better decisions (Cash et al. 2006, Feldman and Ingram 2009), but this focus on information is often less effective than focusing on the actors and institutions that may require and utilize this knowledge (Mitchell et al. 2006). Political ecology perspectives suggest that technical information will not solve environmental problems, but rather political and economic change is needed (Blaikie 1985, Robbins 2004). For knowledge to be used in practice, it must be salient, credible and legitimate (Cash et al. 2002). Researchers have debated how to increase the salience, credibility, and legitimacy of science to make it more useful in practice. Post-normal science has emerged as a way to actively engage citizens in finding solutions to their problems (Funtowicz and Ravetz 1993). Scholars have bemoaned the inadequacy of current structures of knowledge production and dissemination, calling for a more collaborative and iterative dialog to improve societies' awareness of and ability to adapt effectively to climate change (Vogel et al. 2007, Dilling and Lemos 2011). A diversity of suggestions to improve knowledge production include co-production of knowledge, increased use of inter- and transdisciplinary methods, integration of different forms of knowledge, user-driven science, and boundary organizations, or entities designed to increase collaboration across traditional boundaries (Berkes 2009, Guston 1999, Pohl 2008, Hulme 2010, Moser and Ekstrom 2010). A portion of this project reviews stakeholder-generated climate-change-research needs assessments to see what stakeholders have to say about how the practices and processes of science might change to lead to more useful and useable science (Chapter 6).

1.5. Dissertation process

Every dissertation has a narrative, a series of planned and unplanned events, moments, mishaps, and coincidences that shape the final outcome. Many dissertations focus on a single question and chapters flow naturally out of the attempt to address that question. My dissertation is an organic collection of papers that emerged as a result of attempting to answer theoretically relevant questions that would also be useful to decision-making processes and communities. In this section, I describe the process that led to this collection of papers. In the next section I provide the organization of the dissertation and the primary questions and outcomes from each.

I began my dissertation with the climate change study in Denali National Park and Preserve (Chapter 3). This study was motivated by a request from Denali's Subsistence Resource Council who wanted to know what local subsistence users were observing about climate change and how it was impacting their lives. For this study I documented and compared the observations of long-term residents related to climate change in the communities surrounding Denali National Park and Preserve. I originally wanted this study to help identify several community-identified research needs that could then be met through a citizen-science project, which would form another chapter of my dissertation. As the interviews progressed, it became clear that the stakeholders interviewed and the communities represented were so diverse and their interests so varied that it would be challenging to find a single question that would be of interest across stakeholder groups and communities. For instance, individuals mentioned interest in furbearer populations, local income generation, travel safety, riverbank erosion and duck populations, but none of these research interests were shared by more than a few people and none were common across stakeholder groups or between communities.

At the same time, I was completing an internship with The Nature Conservancy (TNC) in Colorado, which consisted of a resilience and vulnerability assessment of land-based livelihoods in the Gunnison Basin (Chapter 2). In the course of this project it became clear that the Gunnison community was both concerned and interested in the issue of the potential listing of the Gunnison Sage-grouse (GUSG) as an endangered species under the Endangered Species Act. The community was interested in documenting local knowledge of GUSG (Chapter 4), as well as potential unintended consequences of the listing (Chapter 5). This provided me with a community-driven research question that was relevant and timely, and where the results might inform decision-making processes. I was able to secure funding for this project from the Gunnison County Commissioners, Upper Gunnison Water Conservancy District and the City of Gunnison, confirming widespread community interest and commitment to this project.

Finally, I was interested in a broader-scale assessment of how the practices and process of science itself should adapt to provide more useful information in the context of climate change. I was working on an assessment of climate change research needs statements from a variety of stakeholder groups across Alaska. Although the original purpose was to compile research needs and assess where there were gaps in needs assessment, I was also interested in what these documents conveyed about how research should be conducted, coordinated, and communicated to the public. This led to an assessment of what stakeholder-generated needs assessments were saying about how the process and practices of science should adapt to a warming climate (Chapter 6).

1.6. Dissertation organization

Chapter 2 presents research on the resilience and vulnerability of two land-based livelihoods (ranching and recreation) in the Upper Gunnison Basin (Gunnison CC). The research for this chapter was conducted in order to help inform the Gunnison Climate Working Group, whose goal was to identify and implement a number of climate adaptation strategies. I utilized semi-structured interviews with 36 community members in order to understand how they assessed their own resilience and vulnerability to climate change projections and what they suggested as strategies to maintain the resilience of their livelihoods and the ecosystems they rely upon. I found that participants were already pursuing a number of local adaptations to current stressors, and these might inform the development of adaptation strategies. I also found that there were tradeoffs in the way climate-change scenarios would impact different livelihoods, but there were also synergies in what participants of both livelihoods thought should be done in order to adapt. This project helped to describe the differential impacts of climate change for ranching and recreation livelihoods, as well as the differential impacts perceived within each of these groups. This chapter is currently in review and has been revised for publication in *Ecology and Society*.

Chapter 3 looks at the climate-change observations and impacts to rural communities surrounding Denali National Park and Preserve, compares the knowledge of different groups of long-term residents, and offers suggestions for how the park might adapt to a changing climate (Denali CC). Research for this chapter included semi-structured interviews with 84 long-term local residents including park employees, subsistence community members, bus drivers, business owners and scientists. The study demonstrates that different groups of long-term residents contribute complementary information about climate change, but that residents who use Park resources on a regular basis have both a greater number of observations, and different observations, than do park employees and scientists. This project also suggests that climate change offers an important opportunity to reconsider conservation paradigms that place humans outside of the natural world. This chapter is part of a special issue proposal on Arctic sustainability for *Ecology and Society* and will be submitted in 2014.

Chapter 4 looks at the local knowledge and observations of Gunnison Sage-grouse by long-term local observers (Gunnison LK). For this chapter, I interviewed 26 long-term local Gunnison Sage-grouse experts, as defined by other community members. I found that observational and formal experts have different observations of Gunnison Sage-grouse and different narratives about what has led to their long-term decline. This research also shows that local experts have novel observations and hypotheses that are worthy of future research. This chapter has been published in a special issue of *Human-Wildlife Interactions* on Sage-grouse (Knapp et al. 2013).

Chapter 5 looks at potential social and ecological feedbacks from the proposed decision to list Gunnison Sage-grouse under the Endangered Species Act (ESA) (Gunnison perceptions). For this chapter, I conducted a survey of quantitative and qualitative open-ended questions with 41 ranching families in the Gunnison Basin to gauge their perceptions of a listing decision and their planned responses. While others have looked at feedbacks post-listing, this is the first, to my knowledge, that assesses planned actions prior to a listing decision and considers conservation actions as well as potential sales of land and water. I found that a decision to list the Gunnison Sage-grouse could ironically result in lowered participation in conservation programs as well as increased sales of land and water. It is important to understand the potential unintended consequences from listing decisions so that we can better develop and plan conservation actions. This paper will be submitted for publication in *Society and Natural Resources*.

Chapter 6 reviews 63 climate-change research-needs assessment documents in Alaska to track what stakeholders revealed about how the practices and processes of science need to adapt to a warming climate (Needs assessment). We coded each needs assessment for suggestions about the types of processes, products, and communication stakeholders need from scientists. While the other chapters in the dissertation focus on what local knowledge can contribute to our understanding of environmental change, this chapter identifies how local stakeholders suggest that scientific knowledge can be more relevant and useful. This paper has been published in *Global Environmental Change* (Knapp and Trainor 2013).

The dissertation concludes with a summary chapter (Chapter 7), where I lay out the research questions, primary implications of the research, broader contributions, as well as future research directions. While each chapter contains its own discussion and conclusions, the summary chapter is where I provide overarching conclusions. The primary implications of the dissertation fall into three categories: climate adaptation, knowledge sharing, and place-based research. I then discuss the broader contributions of the dissertation and how they relate to the current body of scholarship. The broader contributions include the importance of understanding perceptions, the existence of proactive adaptation strategies at local levels, the value of local knowledge for effective conservation and adaptation, and the potential for inequitable outcomes if local perspectives are not included in planning efforts. I conclude with suggestions about further research directions.

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2. Proactive climate-change adaptation and tradeoffs between two land-based livelihoods in Gunnison, Colorado

2.1. Abstract

Many economies in rural communities throughout the Western United States depend upon land-based livelihoods and will be impacted by climate change. There are few assessments of how projections of climate change are perceived and interpreted in this region. This project uses semi-structured interviews with ranchers and recreation-business owners in Gunnison, Colorado to understand self-perceptions of resilience and vulnerability and current and future adaptation strategies. We found that both groups have adopted proactive strategies to cope with current stressors that could be used or modified to adapt to climate change. Ranchers may be more vulnerable to climate change impacts because they are more dependent on specific ecosystem services at specific times, while recreation based business owners see opportunity in climate change projections. Ranchers may be more resilient than recreation-based business owners based on their consideration or implementation of a large variety of adaptation options, networks that promote collaboration and social learning, and a history of dealing with adversity. Despite different impacts and a history of conflict, representatives from both livelihoods agree that the greatest opportunity to enhance resilience is greater annual flexibility in public land management. Qualitative place-based assessments of resilience and vulnerability are critical to understanding how climate change may impact specific places and what might be done now to adapt to future projections.

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2.2. Introduction

Land-based livelihoods are the economic base of many small, rural communities in the Western United States (US) and have shaped the identities and values of residents. The region is experiencing the impacts of climate change in increased fire frequency, drought, and beetle kill (Westerling et al. 2006, Allen et al. 2010, Bentz et al. 2010), with implications for rural livelihoods. While it is certain that climate change will create winners and losers (Paavola and Adger 2006), the exact tradeoffs between ecosystem services and livelihoods are poorly understood (Turner 2010). There are many examples of livelihood vulnerability assessments in developing countries (e.g., Ford et al. 2006, Paavola 2008), but few in the Western US (e.g., Finan et al. 2002, Coles and Scott 2009). Assessments often focus on the vulnerabilities of agriculture and subsistence (e.g., Ford et al. 2006, West and Vasquez-Leon 2008, Vasquez-Leon 2009), with fewer addressing recreation-based businesses (Rauken and Kelman 2012). This project explores interlinked vulnerabilities in place and adds to the existing literature on embedded perspectives of climate change.

Climate change impact assessments tend to fit in one of two broad categories: mid- to large-scale quantitative climate impact assessments and small-scale qualitative perspectives. Early impact assessments were often pursued in a top-down manner, which overlooked individual experiences of and responsiveness to climate change (Adger et al. 2011). These assessments primarily used existing data and publications, modeling of scenarios, along with quantitative indicators (e.g., GDP, life expectancy) to assess climate change impacts (e.g., Brooks et al. 2005, Metzger et al. 2005). This top-down model is frequently used in large national or regional assessments (ACIA 2004, US Global Change Research Program 2013) and allows understanding of potential impacts, broad patterns of vulnerability, and prioritization of areas at risk.

In recent years, there have been more explorations of local change that address multiple stressors, multi-scalar dimensions of impacts, governance issues, and equity concerns (Nelson et al. 2009). Local perspectives allow us to better understand local impacts and adapt to them (Magistro and Roncoli 2001). These embedded perspectives often focus on a single stakeholder group and their vulnerability to climate change. For instance, researchers have explored the vulnerability of Hispanic farmers (Vasquez-Leon 2009), ranchers from Arizona (West and Vasquez-Leon 2008), and indigenous residents of the Arctic (Berkes and Jolly 2001) to climate change. These assessments provide rich description and analysis of climate change impacts on specific populations, but there have been fewer assessments on potential tradeoffs between livelihoods (e.g., Finan et al. 2002).

As mitigation efforts have faltered, there has been increased attention on adaptation in order to help communities adjust to foreseeable and unavoidable change. Fussel and Klein (2006) traced the history of climate response, from assessments of impacts to vulnerabilities, and finally to adaptation policy. Developing adaptation policy is fairly recent, and most efforts have come from national and state governments (California State 2009, Executive Office of the President 2013), or agencies (US Fish and Wildlife Service 2012, US Environmental Protection Agency 2013). Top-down adaptation strategies may be gauged successful at some scales, but not others (Adger et al. 2005), and there is the potential for unexpected surprises because of cross-scale interactions (Adger et al. 2009). For instance, government relief programs for drought in Brazil have led to persistent vulnerability at a local level (Nelson and Finan 2009) and policies in southern Africa have failed to build upon and support local-level adaptations (Stringer et al. 2009). Scholars have suggested the need for increased engagement with local communities to develop adaptation strategies (Blanco 2006, Patwardhan et al. 2009), and documentation of these local-level strategies has increased (e.g., Ziervogel et al. 2006, Tremblay et al. 2008, Mertz et al. 2009). In this paper, we explore how two land-based livelihoods are responding to current stressors and climate change projections, in order to understand potential tradeoffs and potential adaptation strategies.

2.2.1. Conceptual framing

We utilize an integrated framework that demonstrates how vulnerability, adaptive capacity, resilience and transformability are interlinked processes that cumulatively influence how systems experience stress, adapt, and transform (Chapin et al. 2009). The relationship between these concepts is complex, and interpretations vary (Gallopin 2006). Vulnerability is the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt (Adger 2006). Resilience is the capacity of linked social-ecological systems to handle stress and maintain their structure and function through adaptation or transformation (Gunderson and Holling 2002, Folke 2006). Prior papers have outlined the differences between these perspectives in terms of epistemology (positivist vs. constructionist), focus (systems vs. actors), boundaries (defined by ecosystems vs. defined by people) and associations (empowering vs. potentially stigmatizing) (e.g., Gallopin 2006, Nelson et al. 2007, Miller et al. 2010). Differences suggest complementary information and scales of assessment, with vulnerability assessing in-depth and short term responses to change, and resilience assessing broader-scale and longer-term responses at a systems level (Miller et al. 2010, Turner 2010).

Our goal was to understand how ranchers and recreation-based businesses perceive their own resilience and vulnerability to climate change projections and compare livelihood responses and tradeoffs. We compared current exposure, sensitivity and adaptive capacity to stressors to a future scenario including climate change (Smit and Wandel 2006). We coded interviews for traits that other authors have associated with the vulnerability, resilience, adaptive capacity and transformability of systems (Levin 1999, Folke et al. 2003, Turner et al. 2003, Chapin et al. 2006, Walker et al. 2006, Chapin et al. 2009). These traits have been identified in prior reviews, and include: vulnerability (exposure, sensitivity, adaptive capacity), resilience (adaptive capacity, feedbacks, legacy and adaptive governance), adaptive capacity (diversity, social learning, ability to innovate, capacity to implement changes) and transformability (identify options and pathways, learn from crisis, navigate thresholds) (Chapin et al. 2009). Since slow variables often define the underlying structure of the system, we paid special attention to these characteristics (Carpenter et al. 2001). Responses to stressors have been categorized as coping, buffering, adapting and transforming. Coping includes short-term strategies to survive stressors, buffering responses help to lessen exposure to the stressor, adaptation improves the resilience of the system to the stressor, and transformation changes the fundamental relationship with the stressor (Davies 1996, Vasquez-Leon et al. 2003, Smit and Wandel 2006). Measurement of these characteristics is imprecise, as traits are dynamic (Nelson et al. 2007). This project provides a snapshot of resilience and vulnerability as self-assessed at a single point in time.

2.3. Background

This project was part of a larger effort of the Gunnison Climate Working Group (GCWG), whose goal is to understand the potential climate-change threats, identify adaptation strategies, and to promote coordinated implementation of strategies in the Upper Gunnison Basin (Appendix 2.1). The Upper Gunnison Basin is a mountainous region in south-central Colorado, in the Western US. The population of the basin is 23,009 (Department of Local Affairs 2010 a and b). Nearly 80% of the basin is public land, which supports about 12% of all jobs (Cheng 2006).

2.3.1. History of land use in Gunnison County

Ranching in this region began in the early 1870's and has always been challenging given low precipitation, cold winters, and short growing season. To adapt to these challenges, ranchers converted riparian areas into hay meadows to produce feed for the long winters and utilized high-elevation public lands for forage during summer. While ranching currently accounts for only 10% of the jobs, it impacts 96% of private land and 89% of US Forest Service lands (Cheng 2006). Each dollar spent in ranching stays in the economy longer than money spent in any other industry (Tadjion and Seidl 2006).

The Gunnison Basin is a region rich in spectacular scenery and recreational opportunities. As early as 1920s, people came to the Gunnison Basin to fish, hunt, hike, raft, and bike, supporting lodging, food, and recreation-based businesses. In 1963 the Crested Butte Ski Area opened, followed by the Blue Mesa Reservoir in 1965. The primary recreation seasons are summer (biking, hiking, fishing, rafting) and winter (skiing, cross-country skiing, snowmobiling). The economy of the Basin has transitioned from ranching to retirees and tourism (Department of Local Affairs 2010 a and b). Tourism is responsible for 23% of local economic activity, and tourism is one of the county's top growth areas (Office of Economic Development 2011).

These businesses co-exist and impact one another. Tourists chose to recreate in Gunnison because of the view sheds that ranching provides (Orens and Seidl 2009).

Scenic beauty and increased recreational opportunities have led to an increase in both tourists and second-home owners. Increased demand for property has increased property values. There has been a decline in overall numbers of ranches and cattle, with an increase in absentee landowners (J. Cochran, personal communication). Conservation easements have been a way to both protect open space and lower land values by limiting development potential. New residents have different values and often prefer conservation and recreation to ranching, which can increase land-use conflicts. Ranchers complain that recreationists sometimes disturb cattle, leave gates open, and tamper with watering infrastructure (Knapp 2011).

2.3.2. Current climate and climate change projections

The Gunnison Basin is a high mountain valley with moderate summer temperatures (16 to 27°C) and cold winter temperatures (-12 to -29°C). The town of Gunnison receives about 28 cm of precipitation a year, while surrounding mountains may receive 40-100 cm depending on topography and elevation. Small amounts of precipitation fall year round, with the majority falling as monsoon rains in July and August. Average annual temperature has increased during the past thirty years, but changes in stream flow are not perceptible from existing data (Barsugli and Mearns 2010). Two climate scenarios (Barsugli and Mearns 2010, Neely et al. 2010) project that, in the next 50 years, the Gunnison Basin will experience warmer temperatures (Table 2.1), a shift in precipitation to the fall and winter, a decrease in stream flow of 5-25%, earlier peak flow, and drier soils during the growing season. Extreme events are also projected to increase in frequency and magnitude (Neely et al. 2011). Potential implications of these projections are increased frequency and duration of droughts, earlier runoff, and more dust-on-snow events due to drought in other regions.

2.4. Methods

2.4.1. Study participants

We wanted to speak with a range of ranching and recreation businesses based on type (e.g., cow-calf or steer, gear store, fly fishing outfitter), size of business, as well as geographic location. GCWG participants and key informants helped us define the characteristics of each business to sample and suggested potential participants. We used this introductory list and snowball sampling to identify participants. We prioritized participants based on total number of referrals and representativeness of important characteristics of the wider population. We recruited participants with an introductory letter and a follow-up phone call. This purposive sampling design allowed us to talk to a subgroup of the population that could provide insight into the larger community of ranching and recreation business owners (Berg 2007).

2.4.2. Data collection

We conducted thirty-six semi-structured interviews with individuals engaged in ranching (19) and recreation (16) and one representative of the local water conservancy district. This sample represents ninety percent of the residents prioritized for interviews, including about a third of all area ranchers and a fourth of all local recreation businesses (personal communication J. Cochran and B. Jackson). Ranching representatives included ranchers (15) and agency employees (4). Ranching operations represented in this sample functioned either as cow-calf operations (47%) or cow-calf-yearling operations (53%), with several ranches also selling hay. Most of the ranchers interviewed (73%) made their incomes entirely from ranching. Recreation interviews were conducted primarily with business owners (14) and a few agency employees (2), and represented a range of businesses from hunting guides to ski-area representatives.

Our interview script contained questions chosen to elicit broad information about the resilience, vulnerability, and adaptive capacity of livelihoods to climate change (Appendix 2.2). We asked each participant about current stressors, the impact of past weather events, potential impacts of projected changes, and strategies for responding to those changes. Questions were open-ended to avoid prescribing the content and themes that emerged. We stopped conducting interviews when all the target business types were represented and we reached a saturation point, where each additional interview no longer added new information (Bernard and Ryan 2009).

2.4.3. Data analysis

We transcribed, coded, and analyzed each interview using the qualitative data-analysis software NVIVO (QSR International 2010) to track themes of interest across the interviews. We started our analysis with a list of codes based on resilience and vulnerability theory. We supplemented this list with emergent codes as we analyzed the interviews. The coding process thus included both deductive and inductive approaches (Bernard and Ryan 2009). We organized the resulting coding reports into data matrices to assess themes of interest. Once preliminary results were drafted, we searched the transcripts for data that contradicted our major findings in order to assure that preliminary results correctly reflected the interviews.

2.5. Results

2.5.1. Ranching

2.5.1.1.1. Community characteristics. Most ranchers described multi-generational connections to the landscape and human community (84%: 16) and said they would stop ranching only if forced out by economics or logistics. Ranchers described a cohesive and supportive community that work together when needed, but are independent in their daily operations. Some ranchers (32%: 6) described tension between old ranching families and new absentee owners, while others (10%: 2) saw absentee owners as a potential benefit to the community, by bringing in new ideas and protecting intact landscapes. Ranchers described a decline in the support they felt from other community members, as demonstrated by impatience with cattle drives and lack of support for cattle use on public lands (47%: 9).

2.5.1.1.2. Current stressors. Ranchers described more numerous and shared stressors (22) than recreation business owners (18) [Figure 2.1]. Many of these stressors were related to the security of public land permits. The majority of Gunnison County (82%) is public land (Gunnison County 2012), which ranchers depend on for summer forage. If access were limited, ranchers would be forced to reduce cattle numbers or move elsewhere. Existing fears about the security of public lands (95%: 18) are compounded by concerns about additional restrictions if the Gunnison Sage-grouse is listed under the Endangered Species

Act (79%: 15), increased recreational pressure and land use conflicts (74%: 14), and lowered community support (47%: 9). Compounding these concerns, ranchers described how leaders were overtaxed (16%: 3), and while there was an increased need for participation, there was not enough time (10%: 2). Ranchers also described economic concerns (74%: 14), with higher costs of inputs, increased land values, and competition for workforce. Ranchers were also concerned about increased elk herds that compete for forage (42%: 8). Finally, ranchers described a series of long-term background stressors, which made Gunnison a challenging place to ranch, including weather (100%: 19), water availability (10%: 2), and distance from markets (10%: 2).

Ranchers were unanimous that drought was the most challenging weather impact (100%: 19), followed by inadequate snowpack (32%: 6). A drought year with adequate snowpack could be tolerated, whereas a drought year with little snowpack means inadequate water for irrigation, less hay for winter feeding, and potential public land restrictions. Multi-year droughts were a concern because they require cattle sales, which lower revenue, making it difficult to rebuild herds. Heavy snow at low elevations could harm cattle and make feeding a challenge (32%: 6). It is important that runoff coincide with hay growth and permit timing so they can irrigate after cattle move to public land allotments and before senior water rights users require the water (53%: 10). For ranchers, two other significant weather windows occur during spring calving (26%: 5) and in the early fall (10%: 2). Moderate weather during these times allows calf survival and decreases the need for fall feeding.

2.5.1.1.3. Current adaptations. Ranchers demonstrated many strategies to deal with current stressors, shared common strategies, and described multiple types of strategies. Frequent

> coping strategies included buying hay (21%: 4), moving cattle (47%: 9), and selling cattle (63%: 12). These activities focus on the fast variables in the system (forage and livestock numbers), in order to keep them in balance. Other coping strategies included storing hay (16%: 3), sharing resources with neighbors (11%: 2), and utilizing grass banks (11%: 2). Buffering strategies included developing additional water sources in their pastures to deal with water scarcity (42%: 8) and participating in insurance programs (21%: 4).

Long-term adaptations to stressors included collaboration with the recreation community to develop educational materials about best practices for recreating on grazing lands (e.g., fence and cattle etiquette) (47%: 9). They purchased additional private land to lessen their dependence on public lands during the spring and summer, when they need to take cattle off hay meadows for irrigating (42%: 8). Ranchers responded to concerns about security of public lands permits by trying to improve relationships (collaboration) or find alternatives (private land purchases). They changed grazing practices and fenced riparian areas to restore ecosystems, making them more resilient to a suite of stressors (32%: 6). They talked about the importance of remaining flexible in order to change management based on changes in multiple interacting stressors (21%: 4). They coordinated with their neighbors to adjust the timing and amount of irrigation water so that each ranch was able to irrigate (26%: 5). One rancher described how he had purchased a feedlot so he controlled more steps in the production process (5%: 1). Ranchers described several transformative responses, including conservation easements to conserve open space and provide cash infusion (53%: 10), and shifts towards holistic land management, which is focused on land health (11%: 2).

2.5.1.1.4. Projection interpretations. Ranchers explained how a slightly warmer climate could mean less demand for winter feed, better forage production, and more comfortable weather to work outside (53%: 10). Additional snow in the winter (68%: 13) would benefit forage production and spring irrigation. Ranchers also saw the potential for new crops or a second cutting of hay (32%: 6). Increased frequency and duration of drought events was the primary concern for ranchers (89%: 17). Ranchers were also concerned about change in the timing of runoff (42%: 8), because they need runoff to coincide with public land permit dates so they can produce hay for overwintering cattle. They were concerned about the timing of precipitation (26%: 5) because rainfall must correspond with plant growth. They were also concerned about extreme heavy snow in the spring, which may make calving and feeding challenging (21%: 4). Finally, ranchers were concerned about hotter temperatures without a longer growing season (11%: 2), and more demand for water resources (11%: 2).

2.5.1.1.5. Potential adaptations. Increased flexibility from land management agencies was the most commonly suggested adaptation strategy (84%: 16). Current permits have rigid dates for entry and exit from allotments, as well as numbers of permitted cattle. Shifts in precipitation, runoff, and forage production might necessitate shifts in the timing of access to allotments. A second suggestion was collaboration in order to generate creative and viable solutions that would benefit both ecosystems and communities (47%: 9). Past collaborations had worked to create shared norms of behavior (multiple-use etiquette). Increased recreation on public lands and climate change impacts provided incentive for future collaborations. They also talked about education and outreach to inform the public about the importance of ranching and bolster community support

(32%: 6). Ranchers considered increasing hay production with warmer weather (32%: 6). Finally, ranchers described buying additional private land (11%: 2), improving land health (5%: 1) and changing the publics' perceptions about the value of food (5%: 1).

Several ranchers stated it was important to improve water storage capacity (32%: 6) in the upper watershed to buffer dry years by regulating the flow for irrigation and providing water sources for cattle. Ranchers also described several intentional transformations, including new models of ranching (21%: 4), a transition from cow-calf to yearlings, ranching for elk, or holistic management. One rancher also described a conscious choice by the community to limit growth and support local agriculture (5%: 1), while another talked about the potential for new crops (5%: 1). Ranchers described several undesired transformations, including loss of family ranches (32%: 6), and increased amenity owners (32%: 6) due to operational challenges and increased land values. Ranchers also described how potential loss of public lands might increase the pressure on private lands (5%: 1).

2.5.1.1.6. Self-perceptions of resilience & vulnerability

The ranching community is highly dependent on temperature and precipitation for producing adequate high quality forage and healthy cattle. They are sensitive to drought conditions, inadequate snowpack and changes in the timing of runoff. Thresholds of concern included multiple years of consecutive drought, or a mismatch of runoff with growing season and public land permits. Ranchers are used to dealing with variability on a variety of spatial and temporal scales. They demonstrate innovation with a variety of current adaptation strategies, and they have social networks to share advice and information. Ranchers described a suite of stressors that may lead to restrictions on public lands including climate change, increased recreation pressure, decreased support from the community, and the proposed listing of the Gunnison Sage-grouse. Ranchers depend on public lands, so they feel vulnerable to potential restrictions and perceived inflexibility of land management agencies. Ranchers were vulnerable to projected climate change, but generally believed they were very resilient to this stressor. They were more concerned about public land regulation and change in community attitudes towards ranching.

2.5.2. Recreation

2.5.2.1.1. Community characteristics. Recreation-based business owners were drawn to the region for its beauty and recreational opportunities. Recreation-business owners described a community of people who are increasingly working together, but whose passion for their favorite recreation activity can create conflict with non-compatible recreational uses (e.g., off-road vehicle users and hikers). Residents of Crested Butte, a ski resort community, also spoke of disagreements between wealthy residents and business owners, who differ in their visions of how Crested Butte should develop. Business owners described each other as competitors who rarely worked together except through the local Chamber of Commerce.

2.5.2.1.2. Current stressors. The most consistent stressor mentioned by recreation-based businesses was economics (63%: 10), especially businesses that depend on a single season for income. Like ranchers, these businesses rely on public lands, and businesses worry about continued access and restrictions (56%: 9). Gunnison is a destination location, and tourists have to travel some distance to participate in recreational activities. In a slowing economy, recreation businesses are concerned that fewer tourists will travel (50%: 8). Finally, the region is receiving more diverse and increased recreational pressure, which may make it challenging to provide a quality recreational experience (31%: 5).

Inadequate snowpack was the primary weather-related concern, as many recreation businesses rely on winter tourism, anchored by the Crested Butte ski area (75%: 12). In a good ski year, a range of recreation businesses across the Basin benefit, from lodging to gear stores. However, too much snow can also be negative, as it makes it difficult for tourists to travel to the area (37%: 6). Drought is also a challenge for many recreation business-owners, who are concerned about fire danger, quality of trails during drought, wildflower abundance, and monsoon rains that are important for fishing and rafting (69%: 11). The timing and rate of runoff also impact river-based recreation such as rafting and fly-fishing (50%: 8). Extreme weather patterns were also a concern, because they can make travel dangerous (44%: 7). Dust-on-snow events (10%: 1) can lead to earlier melt-off times and decreased quality of snow-based recreation experiences. They were also concerned about the short summer season (10%: 1) and how increased rain could be bad for business (10%: 1).

2.5.2.1.3. Current adaptations. Recreation businesses shared fewer strategies than ranchers. Recreation businesses described collaborating among different land users to coordinate and build understanding (19%: 3), diversifying income sources across seasons (13%: 2), and restoring streams and controlling invasive species in order to build the resilience of ecosystems (6%: 1). They also described increased customer service to direct users to the best current recreational opportunities (19%: 3) and increased marketing to bring in additional business (13%: 2). One respondent spoke highly of recent recreation planning and felt it was important to continue planning for change (6%: 1). Gear stores coped with change by adjusting inventory based on local weather conditions and preferences of consumers (13%: 2). They also looked for ways to cut their expenses (6%: 1). The only transformative strategy mentioned was the ski area infrastructure investments to extend recreational opportunities to other seasons (13%: 2).

2.5.2.1.4. Projection interpretations. Recreation-based businesses were enthusiastic about the potential for increased snow during the winter (69%: 11). They equated more snow with increased business and potentially a longer skiing season. Even businesses dependent on other seasons were excited for the impact on stream and reservoir levels. Businesses thought warmer weather could make recreation more pleasant (25%: 4). These businesses also saw a potential increase in tourist traffic because of hot weather in other places (25%: 4). Participants also saw opportunities in earlier snowmelt leading to an earlier hiking/biking season (13%: 2), a warmer spring extending the summer season (6%: 1) and an increase in unpredictable weather leading to increased sales of rain-jackets, gloves and winter coats (6%: 1). Recreation businesses were concerned that increased duration and frequency of drought events may decrease wildflowers, the quality of the fishing and biking experience, lead to hotter conditions, and increase fire risk (56%: 9). Too much snow (38%: 6) was a concern for limiting tourists' ability to travel in and out of the area. Fishing businesses described how they rely on stable and predictable runoff and were concerned about potential changes to the timing of runoff (25%: 4), as well as warming water for fish (25%: 4).

2.5.2.1.5. Potential adaptations. Recreation businesses also spoke about the need for land management agencies to be more flexible with locations and timing of recreational activities (25%: 4). Increased heat, changes in runoff, fire, and timing of precipitation were all factors that may change where and when recreational activities are best and most sustainably pursued. A second strategy was the need to educate the public about how climate change is impacting the region and where to go for the best recreational opportunities in different seasons (19%: 3). Business owners described the need to restore riparian habitats and forests so that these systems would be more resilient to climate change impacts (19%: 3). Several participants described the potential for increased trail maintenance to deal with flooding, microbursts and windstorms (13%: 2). Rarely suggested adaptation strategies included adjusting inventory, investing in water-saving technologies, diversifying income sources, fostering collaboration, promoting business-friendly policies, and continued recreation planning (6%: 1 each).

2.5.2.1.6. Self-perceptions of resilience & vulnerability

Recreation participants were much more diverse than ranching participants in season of use, dependence on the timing of natural resources, as well dependence on ski area and public land access. Businesses with greater dependence on natural resources during specific seasons (i.e. fishing guides, ski guides) described greater sensitivity to climate change than generalists (gear and rental stores). Sensitivity varied with business type, but businesses were most concerned with drought and its outcomes (fire, dusty trails, less wildflowers) and the potential for blizzards, which may impede flights and dissuade drivers from traveling. Given its diversity, the recreation community didn’t consistently refer to a unifying threshold of concern. Many recreation businesses were positive about potential changes and saw the benefits of a longer and better ski season, warmer weather, and increased tourism. They demonstrated fewer current and future responses than ranchers, and rarely mentioned transformative responses. As newer businesses, they have fewer established

> responses, and focus more on short-term adjustments than long-term planning. They also are less connected with one another and have minimal networks through which to share new ideas. Recreation business owners differed in their self-assessments of resilience, but the majority felt that climate change projections could potentially make them less vulnerable. It's possible that this perception may create an illusory confidence that inhibits them from planning for change, but it also may help them focus on future opportunities and pursue them.

2.6. Discussion

This project contributes to a growing body of literature documenting local perspectives and knowledge of climate change. It expands the geographic reach of local assessments into the US Intermountain West, and adds to comparative studies of livelihoods. Case studies such as this one are important for understanding climate change in context, characteristics of resilient and vulnerable livelihoods, and best practices for adaptation.

2.6.1. Identifying current adaptation to inform future planning

Interviews demonstrate that individuals with land-based livelihoods in the Gunnison Basin constantly adjust and adapt to changing environmental conditions and other stressors. This finding contradicts the suggestion that most adaptation is reactive rather than proactive (Adger et al. 2005) by identifying a diverse list of adaptation strategies that community members are currently using that could be mobilized or adjusted to respond to climate change impacts. Local strategies to adapt to change have been identified previously (Berkes and Jolly 2001, Vasquez-Leon et al. 2003), but strategies of multiple stakeholder groups of the same region have rarely been compared. Existing responses can serve as groundwork for adaptation planning in order to understand local efforts to adapt and make sure that adaptation policy doesn't sabotage existing local efforts (Adger et al. 2009). Participants also identified adaptation strategies at a local level that might otherwise be overlooked or not connected with climate change. Prior research has shown that locally derived solutions often have a better chance of being implemented than those that are imposed from outside (Danielsen et al. 2010). Interview data suggest that ranchers demonstrate more total strategies and more forward-looking strategies than recreational business owners and employees. This may be due to ranchers' long history in the area and their commitment to the next generation of ranchers. Proactive adaptation to climate variability and change is already occurring, especially among ranchers. Resilience to climate change would be greatly enhanced by fostering grassroots engagement in climate-adaptation planning both in the Gunnison Basin and elsewhere.

2.6.2. Differential impacts of climate change

Climate change will shift the quality and quantity of ecosystem services, benefiting some while hurting others (Thomas and Twyman 2005, Paavola and Adger 2006). In this case study, ranching was more vulnerable to projected climate change. Projected increases in temperatures may be detrimental for ranchers by decreasing forage production, drying water sources, and increasing potential conflicts with Gunnison Sage-grouse and recreational land users. The same warming temperatures could be a benefit to recreation-based businesses by making winters warmer and increasing the number of tourists escaping hot climates elsewhere. Recreation participants had concerns about drought, but they were primarily aesthetic. Severe drought conditions, however, may harm both types of businesses by drying streams and rivers (impact to fishermen and boaters) and increasing fire risk.

Ranchers, although vulnerable to climate change, were also potentially more resilient. Interviews demonstrated a greater range of current and future adaptation strategies. Ranchers have a long history of dealing with climate change and other stressors, and are innovative in addressing them. Recreation business owners expressed fewer strategies and had fewer long-term strategies. They also have an intact social network for sharing strategies and learning from one another. Populations who live in challenging environments have learned to deal with climate variability and therefore may be resilient to projected climate change (Chapin et al. 2006). Individuals directly dependent on natural resources may acknowledge their vulnerability to climate change projections, while individuals whose dependence on natural resources is more removed may fail to perceive their vulnerability (Finan et al. 2002). It is important to use caution when projecting current resilience and vulnerability to future conditions that may be radically different.

This project corroborates prior research showing that impacts differ among livelihood groups (Vasquez-Leon et al. 2003). Recreation-based businesses that rely on a single season, or a specific natural resource for income generation may be more vulnerable than those with more diverse incomes. For instance, fly fishing guides depended on the summer season and the timing and amount of flow, while gear and rental stores were less concerned about specific conditions. Ranchers with more private land may be less vulnerable than those that rely primarily on public land. These within-group differences are important to identify in order to better understand how climate change will impact local economies and how adaptation strategies may mitigate negative outcomes.

2.6.3. Synergies around adaptation strategies

Both livelihood groups suggested a number of similar strategies that would build general resilience, including increased flexibility by land management agencies, more collaborative efforts, water development, and restoration. Despite different stressors and perceived impacts of current weather and future climate change, livelihood groups agreed on the benefit of these potential actions. Revealing underlying commonalities may help local governments and agencies prioritize and plan for change. For instance, 84% of ranchers and 25% of recreation businesses mentioned the need for greater flexibility in the management of public lands. Others have expressed the need for more responsive and flexible land management (Benson and Garmestani 2011). However this suggestion can be threatening to existing institutions, and top-down development of adaptation strategies would likely fail to suggest this potential strategy. These shared strategies also warrant attention because they come from local people and are more likely to have local support (Danielsen et al. 2010).

2.6.4. Understanding and communicating change

In situations of limited scientific knowledge and high risk, local participation is critical (Daniels and Walker 2001). Engaging residents in a dialogue about current and future impacts of climate change can both improve our understanding of climate change and tailor communication for different stakeholders. In interviews, participants brainstormed potential impacts and described how weather would interact with a host of other stressors. Prior research has demonstrated that observant community members can translate climate-change scenarios into terms that the wider community can relate to

(Magistro and Roncoli 2001). Interviews identified specific concerns of local residents that may mobilize action. Engaging local people also helped to highlight contextual concerns that may have little to do with weather or climate, but interact with them. For instance, climate change may further restrict public lands grazing due to concerns about Gunnison Sage-grouse. This mirrors prior research showing that people experience climate change as part of a total environment of change (Moerlein and Carothers 2012). Focusing planning efforts on the overlap between climate change and other concerns may help to better engage the community by designing adaptation strategies that address multiple concerns (Wilbanks and Kates 2010).

Prior researchers have argued that climate change projections need to be better translated for end-users (Dilling and Lemos 2011, Griggs and Keston 2011). Results suggest how climate information could be tailored to meet the needs of different groups within the community. Ranchers were most concerned about drought and runoff, while recreation businesses expressed concern about extreme weather events such as blizzards. The ranching community may be more interested in learning about long-term trends while the recreation community may be more concerned with variability.

2.7. Speculations

Climate change is an issue that crosses jurisdictional boundaries and is beyond individual control, which can lead to feelings of disempowerment (APA 2010). By engaging local residents in a dialogue where they are viewed as experts and their opinions are valued, community members can recognize the broader value of their knowledge for science and adaptation (Fischer 2000). By personally interacting with climate-change scenarios, residents are able to internalize this global problem and focus on the adaptation options that are open to them. This shift from being recipients to creators of knowledge can be both anticipatory and potentially transformative (Tschakert and Dietrich 2010). Although this project did not measure adaptive capacity gained through the interview process, it illustrates the potential to build adaptive capacity by valuing local knowledge, documenting local adaptation strategies and encouraging community members to reflect on how they have adapted in the past and how they might in the future.

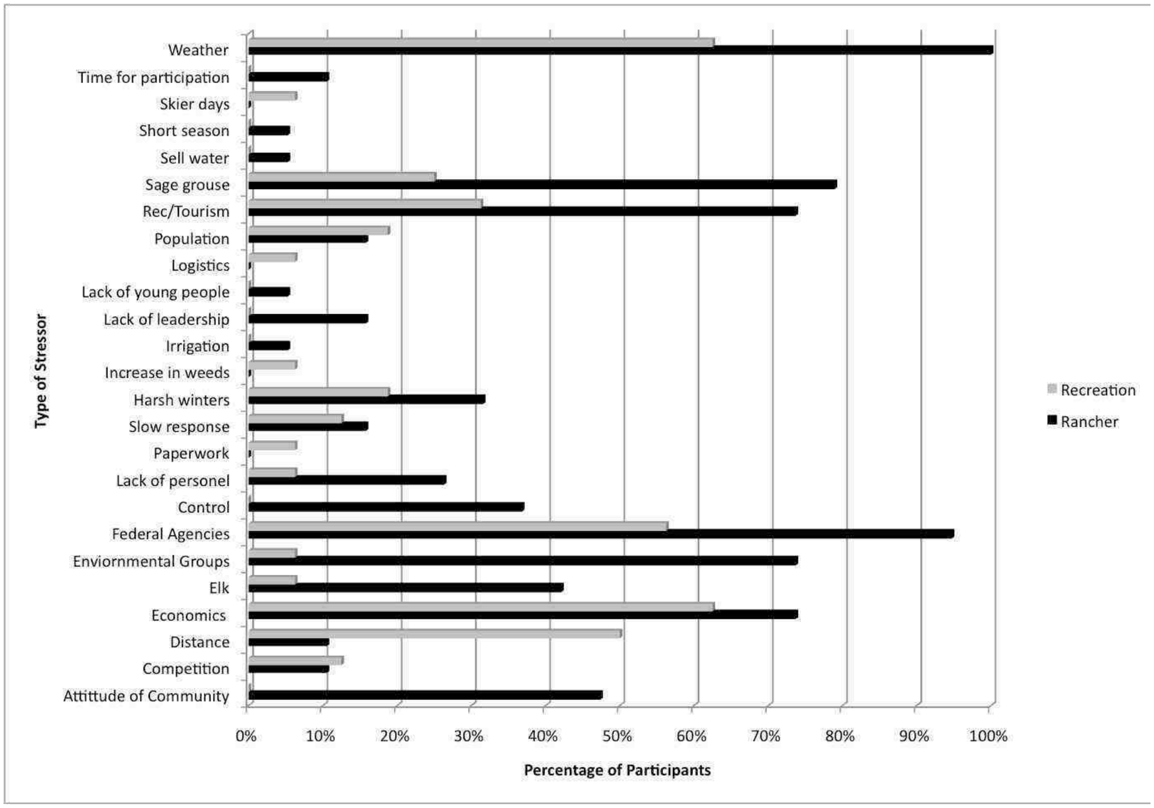

Figure 2.1. Percentage of participants who mentioned the above current threats and stressors to their livelihoods.

Table 2.1. Two scenarios of seasonal precipitation and temperature changes for the Gunnison Basin.

Two scenarios of seasonal precipitation and temperature changes from periods 1950-1999 to 2040-2060 based on the A2 scenario developed by the Intergovernmental Panel for Climate Change. These scenarios were developed from the range of available global and regional climate model projections for the central Colorado Rocky Mountains. The Moderate Scenario is near the median of the model projections. The More Extreme Scenario lies in the top 25% of model projections, but is not the most extreme of the climate model projections.

	Moderate Scenario			More Extreme Scenario		
Season	Precipitation	Temp	Temp	Precipitation	Temp	Temp
	(%)	F	C	(%)	F	C
Annual	0.0	+3.6 to 5.4	+2.0-3.0	-10	5.4	3
Winter	15	3.6	2	0.0	5.4	3
Spring	-12	4.5	2.5	-15	5.4	3
Summer	-15	5.4	3	-20	7	4
Fall	4	4.5	2.5	-10	5.4	3

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Appendix 2.1. Project Context

Our project, reported in the paper *Proactive climate-change adaptation and tradeoffs between two land-based livelihoods in Gunnison, Colorado* (Chapter 2), was part of a larger effort of the Gunnison Climate Working Group (GCWG), a partnership of 16 federal, state and private groups, working to build the resilience of species, ecosystems, and people of the Upper Gunnison Basin. The goals of GCWG are to understand the potential climate change threats, identify adaptation strategies, and to promote coordinated implementation of strategies. The Gunnison Basin is one of four pilot landscapes of The Nature Conservancy's (TNC's) Southwest Climate Change Initiative, which provides scientific information and practical methods to enable local and regional conservation planners, managers and policy makers to develop and implement climate adaptation strategies and policy across Arizona, Colorado, New Mexico and Utah (McCarthy, 2012).

This social assessment complemented an ecological vulnerability assessment (Neely et al., 2011) by addressing the social vulnerability to climate change of two livelihoods in the region. Until recently, TNC and the GCWG partners have focused on identifying adaptation strategies that were ecologically beneficial, which, to date, has resulted in more attention given to strategies that focused on ecological systems and species. This social assessment has helped the Working Group understand the importance of integrating social and ecological concerns to develop adaptation strategies. It has also generated interest within TNC regarding how to better integrate social and ecological vulnerability into conservation planning, resulting in a TNC working group dedicated to this issue. In the Gunnison Basin, one of the ongoing adaptation strategies adopted by the GCWG is a project to improve habitat for Gunnison Sage-grouse on private lands. Residents suggested this adaptation strategy because it is beneficial for both livelihoods and vulnerable species.

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Appendix 2.2. Interview Script

1. **Could you describe for me your [business/operation]?**
    - **a.** How long has this ____ been in operation?
    - **b.** What are primary income-generating activities of this ____?
    - **c.** What are the primary reasons you are in this business?
    - **d.** What are the primary stressors or challenges that your ____ has faced in the past 20 years? How did you respond to them?
    - **e.** What percentage of your total income comes from this ____?
    - **f.** Does your ____interact or coordinate with similar _____in your region? Please explain.

2. **Community context**
    - **a.** How do you define your community? Are there several communities that you are a part of? Please describe them.
        - **i.** How well does your community work together to solve collective problems?
        - **ii.** How often do you share information/insights with others in your community?
    - **b.** Think of some of the primary leaders in your community/communities.
        - **i.** Do you think they are effective?
        - **ii.** Do they help to organize your community around issues important to you?
        - **iii.** Do they listen responsively to the needs of community members?
    - **c.** Think of the primary agencies or government institutions that regulate the use of natural resources that you rely on.
        - **i.** Do you think they are effective?
        - **ii.** Do they listen responsively to the needs of community members?
        - **iii.** Do they integrate your knowledge and insights into management of resources?

3. **Dependence on the environment**
    - **a.** What are the most critical natural resources that you rely on?

b. Are there certain services whose timing is critical to your ____ (runoff times, warm/cool season grasses, etc…)?
c. What natural forces can make your ____ successful/not successful?
    i. Describe for me the context that would make a successful year? A poor year?
d. How are decisions about access to natural resources made?
    i. Do you face any constraints in your use of these resources? Please explain.
    ii. Do you feel like decisions regarding access to natural resources in this area are fair and equitable? Please explain.
e. Are there any factors that currently concern you about the future availability of these resources?

4. Has your [business/operation] been impacted negatively by weather events or inter-annual variations?

a. What type of event/s?
b. How frequently do these events happen?
c. Could you describe the impact they had on your ____?
d. How did you respond to these events?
e. Did you participate in any collective responses to these events?
f. Have you seen any trends (increase/decrease) or do you have any concerns about events like these in the future? Please explain.

5. Climate projections for the Gunnison Basin suggest temperature increases of 3-5 degrees and a shift in precipitation (more in winter, less in summer & spring). This could mean drier soils, earlier runoff, higher peaks in runoff, more drought, and greater variability.

a. If these projections are correct, how would your ____ respond to these changes?
    i. How would it change your business/management practices?
    ii. How would it change your interactions with similar organizations?
    iii. How would it change your income flow?

1. Are there current income generating activities that would no longer be viable?
2. Are there potential income streams you might consider?

iv. What potential opportunities can you see?

v. What potential challenges would it pose?

b. Can you imagine any “tipping points” (either good or bad) for your organization, where you would no longer be able to function as you do currently?

c. Can you see a potential transformation that your ____ could make to adapt to these projections?

6. **Do you have any suggestions about things that you, your neighbors, your community or land management agencies could do now to help the natural resources and economy of the Gunnison Basin to be more resilient in the future?**

7. **Do you have anything else to add?**

3. Parks, people and change: Long-term residents' perceptions of climate change and adaptation in the Denali National Park and Preserve region, USA

3.1. Abstract

Denali National Park and Preserve (Denali) is a vast landscape that is responding to climate change in ways that will impact both ecological resources and local communities. Local observations help to inform understanding of climate change and adaptation planning, but whose knowledge is most important to consider? This project interviews long-term Denali staff, scientists, subsistence community members, bus drivers, and business owners to assess what types of observations each can contribute, how climate change is impacting each, and what they think the National Park Service should do to adapt. The project shows that each type of long-term observer has different types of observations to contribute, but that those who depend more directly on natural resources for their livelihoods have more and different observations than those who do not. These findings suggest that engaging multiple groups of stakeholders who interact with the park in distinct ways adds substantially to the information provided by Denali staff and scientists and offers a broader foundation for adaptation planning. It also suggests that traditional protected area paradigms that fail to learn from and foster appropriate engagement of people may be maladaptive in the context of climate change.

In preparation for *Ecology & Society.* 2014. Knapp, C.N., F.S. Chapin, G. Kofinas, N. Fresco, C. Carothers, and A. Craver. Parks, people, and change: The importance of multi-stakeholder engagement in adaptation planning for conserved areas

3.2. Introduction

Climate change threatens both natural and cultural resources that the U.S. National Park Service (NPS) is tasked to protect (Baron et al. 2009). The National Park Service has received direction to integrate climate change into park planning, and has responded both nationally (NPS 2010a) and within Alaska (NPS 2010b). The NPS Climate Action Plan states, "Partners are essential to acquire new knowledge about climate change and its impacts, raise awareness regarding those impacts to places people care about, and evaluate and implement strategies and actions that require cooperation outside park boundaries (NPS 2012: 18p)." Planning efforts recognize that much of the implementation and actions will come from a local level, but the question remains of who is important to engage in adaptation planning. The impetus for this project emerged simultaneously as a concern raised in a Denali Subsistence Resource Commission (SRC) meeting and as an interest of the first author in how local knowledge might inform adaptation. This project interviews different groups of long-term residents to understand their observations of climate change, how they differentially experience and are impacted by climate change, as well as their suggestions about how Denali National Park and Preserve (henceforth Denali or the Park) could adapt. Our objective is to clarify who is important to engage in NPS adaptation planning.

National Parks have historically relied on the knowledge and opinions of experts, including conservation biologists, plant ecologists and landscape planners, to draw their boundaries, understand conservation resources, and manage conserved areas. Local residents were historically not included in these processes, and often removed from these landscapes in order to establish natural areas devoid of human influence (Catton 1997, Jacoby 2001, Berkes et al. 2009, Dowie 2009). Knowledge of Park resources and change is primarily accomplished through monitoring. In Denali, managers have implemented an ambitious monitoring protocol to systematically track change. This monitoring program is providing valuable information about how climate change is impacting park resources (Roland et al. 2013), but it is expensive and limited to pre-identified variables.

Adaptation has traditionally been a local process that requires local understanding. Global climate change suggests the need for adaptation at larger scales than previously required. This need for widespread adaptation corresponds with the development of institutions that manage large spatial units and knowledge structures that are more specialized and centralized. Institutional structures and regulations can create barriers to adaptive responses to environmental change (Benson and Garmestani 2011). NPS staff have recognized these barriers and expressed concern that adaption is discussed more often than implemented (Jantarasami et al. 2010). Broad suggestions about integrating climate adaptation into planning have been developed by natural resource management agencies (e.g., CEQ 2011, Peterson et al. 2011). However, adaptation processes often focus on those with formal training or official positions, which may exclude some groups of individuals with long-term observations (Ogden and Innes 2009, Cross et al. 2012, Groves et al. 2012). People in official roles or with formal training commonly make fundamental decisions about adaptation, with local stakeholders merely responding to predefined options (Treby and Clark 2004). Failure to more fully engage local stakeholders may relate to issues of power sharing, feasibility or time. As adaptation planning and application increase, it is a critical time to consider why and if it is important to engage the knowledge and observations of different types of long-term residents.

The value of local knowledge and beliefs for informing climate change adaptation is increasingly recognized (Vogel et al. 2007). Local knowledge can contribute observations of change (Krupnik and Jolly 2002), local individual and community-level adaptation (Berkes and Jolly 2001, West 2009), increased commitment to implementing adaptation strategies (Tompkins et al. 2008), and interactions between adaptation strategies developed at different levels (Adger et al. 2005, Nelson and Finan 2009). Local observations may be influenced by interacting factors such as access to information, education, knowledge sharing, and personal life experience (Weber 2010). Knowledge generation is a dynamic and integrative process, and purist definitions of local or scientific knowledge are simplistic (Agrawal 1995). Many of the participants in this study have access to park science through publications, trainings, and seminars. This dialectic relationship between what we learn and what we see is an unavoidable component of human perception. This project compares the insights from long-term Park employees, bus drivers, subsistence community members and business owners to understand what each group has to offer and clarify whose knowledge is important to engage in adaptation planning.

3.3. Description of the study area

Denali was established in south central Alaska in 1917 with 2 million acres and was expanded to 6 million acres in 1980 with the passing of the Alaska National Interest Land Conservation Act (ANILCA). ANILCA was a compromise between conservationists and Indigenous Alaskans to protect vast landscapes and opportunities for subsistence activities. Under ANILCA, many of the lands added to Alaskan National Parks were designated as Preserves, which allow access for subsistence activities, including 1.3 million acres in Denali (USA 1980). Preserves are a type of NPS protected land that allows for certain extractive natural resource activities depending on the specific enabling legislation. In Denali, Preserve areas are open for local subsistence hunting and fishing as well as access to traditional use areas with traditional means of transportation including snowmobile, all-terrain vehicles and boats. Denali is rich in both ecological and cultural diversity. It is surrounded by several Alaska Native and non-Native communities, which rely on resources adjacent to and shared with Denali for their livelihoods. The year-round population of the communities surrounding the Park is less than 2,000, but the annual visitation is over 400,000 visitors.

Our interviews took place in the Denali region (Figure 3.1), which includes the Park, Preserve, and surrounding communities. Interviews took place in Cantwell (residents (r): 207 people), McKinley Village (r: 188), Healy (r: 1,084), Lake Minchumina (r: 12) and Nikolai (r: 94), as well as with park employees. Cantwell, McKinley Village and Healy are all located along the Fairbanks-Anchorage road system. Residents in these communities participate in some subsistence activities, but primarily make their living through employment with the Park, schools, tourism or mining. Lake Minchumina and Nikolai are off the road system, and most of the residents participate in subsistence activities, work for local or tribal governments, or fight fires. The Park is closed to subsistence activities, but some residents utilize areas in the 1980 Preserve additions for subsistence activities. The primary subsistence foods for these communities are salmon, moose, berries and waterfowl (ADFG 2013).

3.4. Methods

Our criteria for selecting community and Denali-employee participants were that they: 1) were either full time or seasonal residents for at least ten years, 2) spend or spent more than thirty days a year on the land, and 3) were recommended by other community members. We asked Denali employees, Denali SRC members, and tribal council members to recommend knowledgeable residents who met these criteria. We used snowball sampling to ask preliminary participants for additional recommendations (Denzin and Lincoln 2005). We prioritized individuals based on the number of recommendations, while making sure we had adequate representation of each community and stakeholder group. In Nikolai, a community liaison was hired to help coordinate interviews with community members. We hosted pre-project community meetings in the two off-road communities to introduce our research, obtain permission, and collect feedback about the methods and utility of the research. Prior to each interview, researchers provided information about the project, its goals, how the information would be used, and then acquired oral consent from each participant (UAF IRB# 220265-3).

Semi-structured interviews allowed collection of information on shared topics without forcing the interview flow. Topics of interest included personal history, perceptions of change, climate change impacts, and potential adaptations. Participants were asked to highlight changes that were most obvious first and then were prompted with a list of potential change areas (e.g., vegetation, wildlife, weather, hydrology, community, infrastructure). The semi-structured interview is a standard technique for gathering local knowledge (Huntington 1998), capable of eliciting the unique knowledge of each interviewee and placing information within a wider social and cultural context (Denzin and Lincoln 2005). The interview process and topic guide were pre-tested prior to collecting project data. We conducted 65 interviews with 83 individuals (Table 3.1). The majority of interviews were with individuals, but we also conducted interviews with couples or small groups. Our primary focus was on subsistence community members (39), but we also interviewed bus drivers (8), NPS employees (18) and business owners (18; e.g., pilots, hotel owners, artists and others). We completed interviews between

2011 and 2012. Interviews lasted between one and three hours, and were audio-recorded and later transcribed.

We used NVIVO, a qualitative data analysis program, to code each interview transcript to track themes of interest across the interviews. We created an introductory coding list based on our research questions and added codes as emergent themes arose (Bernard and Ryan 2010). The first author coded all of the transcripts, so coding consistency is not a concern. A first round of coding captured pre-existing themes of interest, while a second round made sure that all transcripts were coded for emergent themes. NVIVO generates quantitative reports as well as collecting the qualitative text referring to each theme. It also allows categorization of interviews into different groups (NPS staff, bus driver, subsistence and business owners) in order to compare and contrast observations, impacts, and adaptations. Finally, we wanted to understand how long-term observations compared with scientific findings from this region. We searched for peer-reviewed articles in Web of Science, reviewed and summarized the findings. Research results that corroborate local observations are highlighted (Table 3.2). We did not locate contradictory evidence, so it is not included in this table.

3.5. Results

3.5.1. Types of experience and land use

All of the participants had lived in the Denali region for at least a decade (Table 3.1), but they varied in the types of interactions they had with the natural environment. Subsistence users had the most consistent interaction with the natural environment primarily through hunting, trapping, fishing and gathering wood. They often had to travel long distances by boat, snow-machine and dogsled to access resources during all times of the year. Other long-term residents were primarily outdoors during the summer and fall driving buses (bus drivers), monitoring ecosystems and species (scientists and NPS staff), hunting moose (NPS staff and business owners) and recreating (all of the above). All long-term residents had some dependence on lands adjacent to Denali, while subsistence users commonly relied on Preserve areas and other long-term residents relied more commonly on the Park (either through employment or ownership of Park-related businesses).

3.5.2. Observations of change

3.5.2.1.1. Climate Change. Nearly all (98%) participants shared observations related to climate change (Table 3.2). We didn't directly ask whether participants believed in climate change, but only a few (5) expressed skepticism. Our recruitment methods focused on the most knowledgeable local residents, and may have inadvertently excluded some climate skeptics. There was large variation in the number and types of observations: some individuals mentioned only one or two climate-change-related observations, while others mentioned dozens. Many participants specified the timeframe over which they had made the observation (e.g., within the last 20 years, since I started working at the Park). Participants have an average of 42 years of observations in the Park region. They also separated short-term variations (such as drier or wetter years) from long-term trends (lower overall snowfalls). Most participants used their earliest experience in the Denali region as their baseline for change. Individuals therefore had different baselines depending on when they arrived at the Park. Participant observations directly related to climate change fell into three primary categories: hydrology, vegetation and weather. Some observations were mentioned frequently (e.g., warming (71%), vegetation growth (59%), less snow (49%), drying ponds (49%)), while others were less frequently mentioned (e.g., rising firn-line (9%), increased erosion (9%), or had more varied responses (e.g., amount of wind, river level). Subsistence users described phenomena that impacted travel including later freeze up (28%), earlier break up (21%), lowered river levels (31%), and steeper river channels (10%). Although less frequently mentioned, participants who mentioned them agreed that there were increased thunderstorms (14%), winter rain (19%), and later arrival of snow (14%). Many of these observations are consistent with current scientific literature about climate change in the region (Table 3.2), while some observations had not been documented previously.

The nature of participant interactions and experiences with the natural world influenced what they observed and how they interpreted these observations. For instance, subsistence participants need to travel to hunt, gather and trap, so they made more observations about changes that impacted ease of travel across the landscape. Bus drivers, in comparison, described phenomena observable from the Park road. Business owners often observed changes at lower elevations, such as less overall snow, more thunderstorms, drying ponds, and increased vegetation growth. These observations varied based on the type of business owners, with pilots describing landscape changes observed from planes (glacial retreat, vegetation), guides expressing changes on Mt McKinley, and front-country business owners primarily expressing changes along the Park road or on adjacent lands. Both Denali employees (scientists and non-scientists), and scientists affiliated with other institutions described fewer observations of change. Their most common observations were the rise in tree line and increased vegetation growth.

3.5.2.1.2. Other changes. Participants described many changes that are either unrelated or only potentially related to climate change (Table 3.3). These changes were both experienced and described alongside observations of climate change. Conversations with most types of long-term residents weaved environmental and social drivers of change together in a seamless manner, with rapid transitions between the two. This pattern of shifting from environmental to social drivers was more common in subsistence users, bus drivers and business owners, although several long-term Park employees also demonstrated it. The most commonly described changes were changes in wildlife populations (92%) and to the Park experience (47%). While both may be related to climate change, other possible drivers include wildlife population dynamics, visitation, road traffic, and changed Park policies. Others included changes to surrounding communities (41%) and introduction of new technology (40%). Subsistence community members were concerned about the interest and motivation in the next generation (36%). Bus drivers (88%) and long-time local residents (56%) were concerned about increased pressure for access to the Park. These changes were described in tandem with potential climate changes, as part of the lived experience of long-term community members.

3.5.3. Impacts on people's lives

Participants identified ways that climate change was affecting them (87%), and there was greater variation in the types of impacts mentioned (Table 3.4) than in observations of change (Tables 3.2 and 3.3). We asked participants to share how changing climate had impacted them, either positively or negatively. The impacts that were most consistently mentioned included: distribution of animals (36%), wildlife viewing (28%), and changes in river access (22%). Impacts were primarily negative, although some positive impacts were mentioned (e.g., increased gardening season, easier to warm houses). This result matches previous research that documents more negative than positive implications of climate change (Berkes and Jolly 2001). Impacts varied by stakeholder group, with subsistence participants talking more frequently about impacts to distribution of animals (49%), access on rivers (36%) and snow (26%) and ability to locate animals when hunting (26%). Park employees described changes they had made to Park monitoring processes (22%), increased brush along roads (17%), impacts to infrastructure (17%) and distribution of animals (17%). Bus drivers focused on wildlife viewing (75%) as well as changes in how they communicated about climate change (38%). Business owners most consistently described changes in the distribution of animals (44%) and impacts to infrastructure (17%). Subsistence residents made uncommon observations including impacts on gathering berries and wood, trapping and water quality (3% each). Climate change impacts are also amplified or mitigated by their interactions with non-climate-change-related drivers. For instance, warmer weather has lengthened the tourist season, which could further increase the number of people visiting Denali as well as the pressure for increased access. On the other hand, the impact of a warmer fall on storing meat is mitigated by increased use of freezers (technology).

3.5.4. Potential Adaptations

We asked participants to provide advice about how Denali should best adapt to observed changes. Their suggestions stem from observations related to climate change and also to other political, social and economic drivers of change. Participants could list as many adaptation options as they wanted to, or none. A large percentage (45%) of the participants did not mention adaptation actions. This group explained that they either did not know what the Park should do (10%) or did not think their thoughts would be valuable to the Park (35%).

Participants provided five primary suggestions (Table 3.5), including education (25%), maintaining a quality experience (22%), maintaining subsistence (22%), changing Park identity (17%) and continuing current monitoring (12%). Increased education about climate change was seen as an important strategy because of the positive reputation of National Parks and their ability to communicate concrete examples from park experiences that could motivate the public to act. This suggestion arose from all stakeholder groups. Individuals who suggested maintaining the quality of the Park experience tied this suggestion to increased pressure for Park access, changes to Park philosophy that valued infrastructure and revenue over natural resources, and changes in wildlife due to changes in vegetation and hydrology. These participants expressed how caution should be used to protect resources in the midst of multiple drivers of change. Bus drivers were most likely to mention the quality of the Park experience (63%), but business owners (33%) and Denali employees (28%) also mentioned it.

Many of the subsistence users (33%) and some of the NPS employees (22%) stated that it was important to protect the opportunity and practice of subsistence in the regions surrounding and adjoining Denali, including the Preserve. This strategy was connected both to climate change impacts and other drivers of change (outmigration, technology, economics). Participants who mentioned this strategy suggested several ways that subsistence could be supported within a context of climate change including: listening to subsistence users and taking their insights into account, allowing more regulatory flexibility for hunting and trapping, helping to support income generation for surrounding communities, and thinking creatively about how subsistence will be passed on to the next generation. Specific suggestions for changes in Park management included: shifts in hunting regulations based on yearly weather, reestablishment of traditional practices such as sheep hunts, and changes to regulations to allow younger family members to hunt for elders.

Subsistence users (26%) and Park employees (22%) described the need to adjust the Park's identity to reflect a changing environment. Subsistence users suggested the Park should adapt in the same way that subsistence users adjust to changing resources. They suggested adaptation options that maintained basic services of the Park (education, tourism, subsistence) without trying to preserve the current status of natural resources within the park. Park employees also described a need to shift their focus as resources within Park boundaries shift. These suggestions match with resilience theory, which suggests that resisting change may make the overall system less resilient (Chapin et al. 2009). Finally, Park employees often (50%) talked about the need to continue monitoring in order to understand what is changing. Many of these individuals talked about how change can be challenging to see and how accurate and systematic monitoring can help to perceive changes that are gradual or contain a lot of variation.

3.5.5. Suggestions for more effective integration

We asked participants to describe how local observations and knowledge could be more effectively integrated into decision-making around adaptation. Participants all agreed that local observations were an important resource. Many of the participants stated how current information-sharing structures (public comment periods, public meetings) were merely a formality, and that Park decision-makers didn't act on public comment. They often described a need for Park employees to listen, but had few suggestions about what this new structure of knowledge sharing might look like.

3.6. Discussion

3.6.1. Knowledge for adaptation

3.6.1.1.1. Novel observations. Prior studies of local observations of climate change focus primarily on a single type of local resident (e.g., Krupnik and Jolly 2002). While these studies often demonstrate that local observations are an important resource for natural resource management (Berkes and Jolly 2001), they don't compare the observations of different types of long-term residents to see what each contributes. Since decision-making around protected areas is usually informed by science and managed by bureaucrats (Caughley and Gunn 1996), it is important to understand how observations of Park staff and scientists differ from those of other long-term residents. This project finds that long-term residents who interact with the landscape on a regular basis may have more and different types of observations of change than long-term residents who are in official roles (Park employees) or have formal training (scientists). Our study found that subsistence users and business owners perceived changes on the landscape that were rarely mentioned by Park staff or scientists, including changes to the timing of freeze-up, lowered river levels, increased thunder storms, and increased wind. Their practical and daily interaction with the environment provides insights that would otherwise be unrecorded. Observations that were less common were typically associated with phenomena that would only be observed by specific people (pilots: firnline, trappers: steep banks). In contrast, Park staff and scientists were more likely to share observations that corresponded to scientific research. This may be reflect hesitance by staff and scientists to share personal observations that are unsupported by data, but it may also reflect greater familiarity of long-term local residents who rely and interact with the natural environment year round. This suggests the importance of a diverse group of observers who can provide a broader range of climate-change observations. It also suggests the need to create decision-making processes that engage and incorporate the observations of long-term local residents who utilize resources in the Park, Preserve, and surrounding lands.

3.6.1.1.2. Awareness of interactions. It has been suggested that local residents can provide insight about how climate change interacts with other stressors (Nelson and Finan 2009, West 2009, Moerlein and Carothers 2012). This project expands this insight by suggesting that different types of long-term residents are aware of different interactions. Most project participants described how climate change interacts with simultaneous social, political and economic changes. Changes in wildlife were a concern to all long-term residents, while concern about other changes varied by group (Table 3.3). For instance, bus drivers focused on changes in the Park experience and philosophy, while subsistence residents talked about changes to their community and technology. The drivers of change that communities discussed ranged from the local (changes in wildlife) to regional (air quality) to global (technology). Many of these drivers have cross-scale impacts (e.g., economics leading to outmigration and change in community structure, technology changing local practices). This project demonstrates that different types of long-term residents identify different cross-scale interactions, which are important for understanding how to adapt effectively to climate change (Adger et al. 2005). Adaptation decisions based solely on climate-change projections would miss other important drivers of change that also affect Park resources and local communities. If planners and managers proceed with adaptation strategies that ignore this larger context, they are bound to be ineffective or have unintended consequences (Turner et al. 2003, Tyler et al. 2007).

3.6.1.1.3. More equitable outcomes. Subsistence users rely on Preserve areas, while other long-term residents rely more on Park areas for their livelihoods. Changes to policy within Denali in response to climate change could have differential impacts on the ability of different stakeholder groups to maintain their livelihoods. This project demonstrated how stakeholders have different observations of climate change, experienced distinct impacts, and suggested varied ways to adapt. If Park employees make adaptation decisions without engaging long-term residents, they may fail to understand how change is occurring or how it is impacting local residents. Adaptation will happen at all levels of organization and as both conscious strategies and unconscious adjustments to changes in resources. These adaptations can build off each other or they can work at cross-purposes (Adger et al. 2005). Transparent sharing of observations across organizational levels and between stakeholder groups may allow more synchronous adaptation. If individual trappers, subsistence participants, Park employees and Park management better understand the observations and adaptations of one other, broadly compatible adaptation is more likely to occur.

3.6.1.1.4. Increase system resilience. As species and other specific components of ecosystems become more challenging to sustain in their current state, academics as well as managers are suggesting increased focus on the goal of maintaining system resilience, or the capacity of a system to maintain its structure or function despite outside stressors (Folke 2006). This project demonstrates how people who interact with the system on a regular basis can increase its resilience by providing qualities such as memory, diversity, redundancy, and feedbacks, all of which have been associated with higher levels of resilience

(Walker and Salt 2006, Chapin et al. 2009). Participants provided memory of how Denali has changed over time. While visitors perceive Denali as a wildlife-rich landscape, local residents described changes in wildlife populations and distribution. Participants provide diversity through observations made in different locations and in different manners. Observations from a single type of stakeholder would not have provided the range of insights that all the stakeholders were able to provide. Residents provide redundancy by making observations in different places, with different tools, and for different reasons. A joint interest in wildlife suggests an opportunity to learn from one another, although different values may lead to different conclusions about similar observations. Local knowledge provides relatively fast and immediate information about the state and changes in a system that can inform the design of scientific studies that generally detect changes over longer time horizons. Perceptions of climate change are critical to understand, because people make decisions based on what they perceive, and these decisions can influence the ecosystems they rely upon (Gbetibouo 2009, Gearhead et al. 2010). Understanding how people are adjusting to the changes they perceive may provide insights about the indirect impacts and feedbacks of human responses to climate change.

3.6.2. The value of people in nature

Denali National Park and Preserve allows some level of human use in the Park (recreation, science, management activities) and in the Preserve (subsistence). While some level of use continues, removal of residents has been a part of the history of National Parks, with large impacts to traditional residents (Catton 1997). The use of Preserve areas is a historic legacy of negotiations over expansion of the Park, but this study suggests that there is a value in having people on the land and interacting with it in diverse ways. Active use and interaction with landscapes may be an asset by enhancing resilience and providing observations that may otherwise be unavailable. People whose livelihoods rely on particular climate, weather patterns and resources are more likely to be aware to subtle shifts to these patterns and successfully adapt to them. Prior research has shown that protected areas are impacted by surrounding landscapes (Shafer 2012), and that parks can no longer function as islands separated from the larger context, either in terms of biological or social interconnections (McClanahan et al. 2008, Hagerman et al. 2010). This project expands these findings by suggesting that maintaining diverse uses of Park and Preserve resources may help decision-makers better understand how climate change is impacting both resources and people, and how NPS might best adapt to these changes.

3.6.3. Speculations about improved communication structures

Participants felt strongly that Park staff should listen and incorporate their observations into planning efforts, but they did not offer suggestions about how this could best be accomplished. Their silence on this issue may stem from distrust that their observations will be valued and used to inform decision-making. One option for improved communication would be creation of a community observation network where local communities are given incentives to share observations via a collective website. This could serve as a resource for community members, Park staff and Park visitors to both upload and track changes observed in the Denali region.

3.7. Conclusions

Climate change is perhaps the largest system challenge that humanity has ever faced: cumulative human actions are changing every place in ways that are difficult to predict. Large-scale problems in the past have often been addressed with technological or scientific expertise, often with unintended or inequitable consequences. Our institutions and existing funding streams are set up to favor bureaucratic decision-making informed by expert opinion (Robbins 2004). The scientific process can demonstrate that climate change is happening and project how it will occur, but fine-scale information about impacts and adaptations will require local knowledge (Hulme 2010). This project demonstrates that different types of long-term local residents have different observations than Park staff and scientists based on their experience with and use of natural resources. This project suggests that these residents can increase resilience by contributing memory, diversity, redundancy and information about feedbacks.

Figure 3.1. Communities surrounding Denali who participated in project interviews.

Table 3.1. Denali region interview participants and their characteristics.

Category	Specific Role	Community	Residency	Years in Area
Bus Driver		McKinley Village	Seasonal Resident	17
Bus Driver		McKinley Village	Seasonal Resident	24
Bus Driver		McKinley Village	Seasonal Resident	17
Bus Driver		McKinley Village	Seasonal Resident	37
Bus Driver		McKinley Village	Resident	36
Bus Driver		McKinley Village	Resident	33
Bus Driver		McKinley Village	Resident	35
Bus Driver		Other (Fairbanks)	Seasonal Visitor	32
Business Owner	Artist	Cantwell	Resident	28
Business Owner	Multiple Businesses	Cantwell	Resident	52
Business Owner	Guide	Cantwell	Resident	53
Business Owner	Business owner	Cantwell	Resident	43
Business Owner	Business owner	McKinley Village	Resident	46
Business Owner	Business owner	McKinley Village	Resident	54
Business Owner	Artist	McKinley Village	Resident	65
Business Owner	Multiple Businesses	McKinley Village	Resident	49
Business Owner	Multiple Businesses	McKinley Village	Resident	44
Business Owner	Business owner	Healy	Resident	51
Business Owner	Pilot	McKinley Village	Seasonal Resident	27
Business Owner	Pilot	McKinley Village	Resident	31
Business Owner	Pilot	Other (Fairbanks)	Seasonal Visitor	33
Business Owner	Guide	Talkeetna	Resident	43
Business Owner	Multiple Businesses	Talkeetna	Resident	39
Business Owner	Multiple Businesses	Talkeetna	Resident	34
Business Owner	Pilot	Talkeetna	Resident	36
Business Owner	Miner	Talkeetna	Resident	51
NPS or Scientist	Scientist (UAF)	Other (Fairbanks)	Seasonal Visitor	59
NPS or Scientist	Scientist (UAF)	Other (Fairbanks)	Seasonal Visitor	36
NPS or Scientist	Scientist (NPS)	Other (Fairbanks)	Seasonal Visitor	25
NPS or Scientist	NPS Staff	McKinley Village	Resident	34
NPS or Scientist	Scientist (NPS)	McKinley Village	Resident	24
NPS or Scientist	NPS Staff	McKinley Village	Resident	46
NPS or Scientist	NPS Staff	Talkeetna	Resident	33
NPS or Scientist	NPS Staff	McKinley Village	Resident	33
NPS or Scientist	NPS Staff	Other (Anchorage)	Seasonal Visitor	37
NPS or Scientist	NPS Staff	McKinley Village	Resident	34
NPS or Scientist	Scientist (NPS)	McKinley Village	Resident	25
NPS or Scientist	Scientist (NPS)	Other (Fairbanks)	Seasonal Visitor	28
NPS or Scientist	NPS Staff	McKinley Village	Resident	21
NPS or Scientist	NPS Staff	McKinley Village	Resident	37
NPS or Scientist	NPS Staff	McKinley Village	Resident	19
NPS or Scientist	NPS Staff	McKinley Village	Resident	18
NPS or Scientist	Scientist (NPS)	Other (Anchorage)	Seasonal Visitor	28
NPS or Scientist	Scientist (ADFG)	Other (Fairbanks)	Seasonal Visitor	41
Subsistence		Cantwell	Resident	51
Subsistence		Cantwell	Resident	56
Subsistence		Cantwell	Resident	50
Subsistence		Cantwell	Resident	61
Subsistence		Cantwell	Resident	63

Table 3.1. Denali region interview participants and their characteristics (continued).

Subsistence		Cantwell	Resident	51
Subsistence		Cantwell	Resident	73
Subsistence		Cantwell	Resident	32
Subsistence		Cantwell	Resident	37
Subsistence		Cantwell	Resident	50
Subsistence		Upper Kantishna	Seasonal Visitor	24
Subsistence		Upper Kantishna	Resident	24
Subsistence		Upper Kantishna	Resident	24
Subsistence		Healy	Resident	49
Subsistence		Lake Minchumina	Resident	9
Subsistence		Lake Minchumina	Resident	41
Subsistence		Lake Minchumina	Resident	36
Subsistence		Lake Minchumina	Seasonal Visitor	36
Subsistence		Lake Minchumina	Seasonal Visitor	36
Subsistence		Lake Minchumina	Resident	37
Subsistence		Lake Minchumina	Resident	10
Subsistence		Lake Minchumina	Resident	54
Subsistence		Lake Minchumina	Resident	54
Subsistence		Other (McGrath)	Seasonal Visitor	43
Subsistence		Nikolai	Resident	65
Subsistence		Nikolai	Resident	86
Subsistence		Nikolai	Resident	33
Subsistence		Nikolai	Resident	65
Subsistence		Nikolai	Resident	67
Subsistence		Nikolai	Resident	65
Subsistence		Nikolai	Resident	89
Subsistence		Nikolai	Resident	85
Subsistence		Nikolai	Resident	90
Subsistence		Nikolai	Resident	18
Subsistence		Nikolai	Resident	50
Subsistence		Nikolai	Resident	55
Subsistence		Nikolai	Resident	63
Subsistence		Nikolai	Resident	16
Subsistence		Talkeetna	Resident	57

Table 3.2 Climate change related observations of change from each participant group (in percentages).

	Bus Driver	Subsistence Participant	Business owners	NPS Staff or Scientist	TOTAL	Example Quote	Scientific Literature
	n=8	n=39	n=18	n=18	n=83		
Hydrology	**88%**	**87%**	**94%**	**83%**	**91%**		
Ponds: drying out	38%	51%	56%	33%	49%	The lakes have all gotten smaller. A lot of the smaller ponds have just grown in or muskeg bogs now.	Yoshikawa and Hinzman 2003; Riordan 2006.
Snow: less	25%	46%	67%	39%	49%	We don't get the amount of snow that we used to get so it's like you are not in the same place as you were when you were a kid.	
Permafrost: thawing	25%	49%	33%	22%	39%	Melting permafrost is slumping under sections of trail, requiring strenuous travel or rerouting of trail.	Osterkamp and Romanovsky 1999; Serreze et al. 2000; Clow and Urban 2002; Romanovsky et al. 2002; Osterkamp 2003.
Glaciers: retreating	63%	0%	39%	28%	22%	Polychrome glaciers are half the size. They are practically gone.	Chambers et al. 1991; Dowdeswell et al. 1997; Dyurgerov and Meier 1997; Serreze et al. 2000; Arendt et al. 2002.
Rivers: later freeze-up	0%	28%	17%	6%	19%	Rivers freeze 1-3 weeks late, delaying departure in the most important time to start trapping.	Magnuson et al. 2000; Ruhland et al. 2003.
Rivers: lowered levels	0%	31%	11%	6%	19%	But we haven't had the rivers at flood stage now, well it's been a long time. I just see less water.	Bolton et al. 2000.
Rivers: gentler break-up	0%	21%	0%	17%	14%	But one effect we've noticed is the river breakups. They aren't as violent as they used to be.	
Snow: beginning later	13%	10%	17%	17%	14%	Well beginning of September we've have some snow come through, you know, out in the valleys, and we don't have that anymore. It's pretty well gone. So we don't start getting snow till towards the end of September	
Erosion: more	13%	5%	11%	11%	9%	In the last few years I think we have seen more mud slides in the canyon between Igloo and Tatler Creek.	

Table 3.2 Climate change related observations of change from each participant group (in percentages) (continued).

	Bus Driver	Subsistence Participant	Business owners	NPS Staff or Scientist	TOTAL	Example Quote	Scientific Literature
	n=8	n=39	n=18	n=18	n=83		
Snow: summer patches melt earlier	38%	0%	22%	0%	9%	Usually in mid-September there were still a few little patches although they may have been dirty, but now every year they are gone, usually by mid-August or so.	Stone et al. 2002.
Snow: highly variable	13%	8%	6%	6%	8%	You know it is different every year. This year we had a lot of snow and it has varied each year.	
Rivers: steeper channels	0%	10%	6%	0%	6%	In our trapping area, river channels are stabilizing, digging their channels down deeper while sand bars are getting overgrown.	
Vegetation	**100%**	**74%**	**94%**	**94%**	**89%**		
Faster growth	63%	38%	83%	67%	59%	The vegetation is growing a lot faster and there are trees where they weren't before. They seem to be growing a lot faster.	Serreze et al. 2000; Sturm et al. 2001a and b; Jia et al. 2003; Stow et al. 2003; Goetz 2005; Hollister 2005; Sturm 2005; Wahren 2005; Verbyla 2008.
Tree line moving upward	100%	10%	50%	61%	40%	It is so much shrubbier and I know trees are growing in passes that never had trees, for instance on Thoroughfare and Sable.	Chapin 1995; Chapin 1996; Hobbie and Chapin 1998; Serreze et al. 2000; Lloyd and Fastie 2002; Lloyd et al. 2002; Bigelow 2003; Potter 2004; Danby 2007; Soja 2007; Stueve 2011.
Drying	13%	18%	17%	17%	17%	Last year I was hiking up here on Reindeer and it's all dried out. I was walking around and this is all pretty thick peat. I said to myself, "This thing could burn. We could have a tundra fire!"	Verbyla 2008.
Gardening easier	0%	21%	11%	11%	15%	It's got good points: it's easier to garden, longer growing season, plants are overwintering that never overwintered before.	
Phenology earlier	13%	5%	11%	17%	10%	We have only been studying the phenology since 2005 and it has been dramatically variable, like 2-3 weeks difference in green up which is large given our growing season.	
Firn line	13%	0%	28%	6%	9%	You could count on the peaks about 8,000 to always be frozen.	

Table 3.2 Climate change related observations of change from each participant group (in percentages) (continued).

	Bus Driver	Subsistence Participant	Business owners	NPS Staff or Scientist	TOTAL	Example Quote	Scientific Literature
	n=8	n=39	n=18	n=18	n=83		
Weather	**100%**	**95%**	**94%**	**56%**	**90%**		
Warmer	75%	79%	78%	33%	71%	Yeah, I think so because there used to be cold winters. It is hardly cold anymore. I guess the climate has changed a lot.	Chapman and Walsh 1993; Overpeck et al.1997; Serreze et al. 2000.
More frequent fire	25%	38%	33%	28%	35%	We are also getting frequent fires and that is not normal.	Murphy et al. 2000; Soja 2000; Kasischke 2006.
Longer summers	0%	23%	56%	11%	26%	In the fall we had our first freezing morning today and usually after August 15th we'll get a killing frost but that doesn't happen. Obviously the frost-free season is elongating.	Keyser et al. 2000.
More wind	0%	26%	33%	0%	19%	We had more wind, we had heavier snows, and the temperatures were colder.	
More winter rain	25%	18%	17%	17%	19%	One of the biggest changes we have seen here, which remains to be seen as how it is effecting the wildlife, is the winters here are a little shorter and we get winter rains now which is a pretty rare occurrence at this latitude.	Griffith et al. 2002.
More extreme temperatures	0%	21%	17%	11%	16%	Now it will go from an extreme cold to an extreme warm. We are getting a lot more spikes.	
More thunderstorms	25%	5%	33%	6%	14%	We never used to have lightening storms before. When we started to get them they were with rain but now it seems like we are getting lightening without rain.	

Table 3.3. Other long-term observations of change from each participant group (in percentages).

	Bus Driver n=8	Subsistence Participant n=39	Business Owners n=18	NPS Staff or Scientist n=18	TOTAL n=83
Access to Denali	0%	15%	6%	0%	8%
Air quality decline	0%	3%	17%	0%	5%
Change in Park management and philosophy	38%	15%	22%	11%	18%
Changes in wildlife	100%	92%	100%	78%	92%
Community changes (outside Denali)	38%	51%	28%	33%	41%
Less community cohesion	0%	13%	11%	6%	10%
More people and traffic in communities outside Denali	0%	23%	44%	11%	23%
Loss of culture in next generation	0%	36%	6%	0%	18%
Impacts of earthquakes and volcanoes	0%	21%	6%	6%	12%
Increase in technology	13%	56%	28%	28%	40%
Park experience	100%	13%	72%	72%	47%
Change in quality of Park experience	38%	0%	17%	11%	10%
More people in Park	25%	5%	33%	61%	25%
Pressure for more access to the Park	88%	5%	56%	44%	33%
Types of visitors in the Park (e.g., less independent)	50%	0%	6%	17%	10%

Table 3.4. Perceived impact of observed changes by participant group (in percentages).

	Bus Driver n=8	Subsistence n=39	Business Owner n=18	NPS or Scientist n=18	Total n=83
Access	**13%**	**54%**	**44%**	**33%**	**43%**
Air travel	0%	3%	11%	6%	5%
Mountaineering	0%	0%	11%	11%	5%
Rivers	0%	36%	11%	11%	22%
Roads	0%	0%	0%	11%	2%
Snow Travel	13%	26%	0%	0%	13%
Trails	0%	15%	11%	0%	10%
Change to subsistence resources	**0%**	**74%**	**61%**	**33%**	**0%**
Ability to locate for hunting	0%	26%	0%	0%	12%
Change quality	0%	10%	0%	0%	5%
Gathering berries	0%	3%	0%	0%	1%
Fewer to harvest	0%	23%	0%	6%	12%
Gardening extended	0%	21%	11%	11%	14%
Gathering wood	0%	3%	11%	0%	4%
Improve trapping	0%	3%	0%	0%	1%
Distribution of animals	0%	49%	44%	17%	36%
Storing Meat	0%	23%	0%	6%	12%
Water Quality	0%	3%	6%	0%	2%
Social Impacts	**63%**	**5%**	**28%**	**72%**	**30%**
Brush on Roads	13%	5%	0%	17%	7%
Change in tourism season	0%	0%	11%	11%	5%
Change to infrastructure	13%	0%	17%	17%	8%
Change to monitoring	13%	0%	0%	22%	6%
Communication	38%	0%	0%	11%	6%
Easier to heat	13%	0%	11%	0%	4%
Fire Season	0%	0%	0%	6%	1%
Psychological	0%	0%	11%	0%	2%

Table 3.5 Adaptation strategies described by each group of participants (in percentages).

	Bus driver	Subsistence user	Business owner	NPS or scientist	TOTAL	Example Quote
	n=8	n=39	n=18	n=18	n=83	
Education	38%	13%	33%	39%	25%	I think NPS has to be proactive with education about climate change. They need to educate people so that they can understand and change their behavior.
Maintain subsistence	13%	33%	0%	22%	22%	We know why the lands were set aside and why there are exceptions and exclusions made and I think those are things to be celebrated not tolerated.
Provide quality experience	63%	5%	33%	28%	22%	I think they need to accept: when the Sistine Chapel is full and there is no more room it is full
Change identity of Park	0%	26%	0%	22%	17%	Well there are changes and you go with the flow. Everybody has changes. Maybe there are new things that you'll do.
Continue monitoring	0%	0%	6%	50%	12%	I think that in most cases being able to document those changes is going to be beneficial to people.

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4. Putting local knowledge and context to work for Gunnison Sage-grouse conservation

4.1. Abstract

Successful conservation requires adequate understanding of focal species and ecology, practices that may assist species survival, and a community of people willing and able to conserve the species. For many species at risk, we operate with imperfect knowledge in complex conservation contexts. In this case study involving the Gunnison Sage-grouse (*Centrocercus minimus*), we interviewed 26 community-defined local experts, including those with and without related academic degrees, to assess the utility of local knowledge for understanding and informing conservation opportunities. This project suggests several benefits of integrating local knowledge that apply specifically to rare and/or endemic populations including the ability to gain access to 1) a deeper temporal perspective, 2) observations made during different seasons and life-history stages, and 3) insights regarding the applicability of management strategies formed and science conducted on similar species. The contributions of local experts can also help identify conflicting narratives of species decline and therefore important future research directions. The patterns of expert referrals in this project provide evidence that long-term collaboration in conservation has created a pool of local Gunnison Sage-grouse experts with technical training, long-term experience, and a combination of both. Systematic assessment of the pool of local experts may improve long-term conservation by providing increased insight into the conservation context.

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4.2. Introduction

Effective conservation requires not only understanding of the species of interest and its political, social and ecological context, but also a community of people willing and able to act upon that knowledge. While knowledge is often limited for rare and spatially restricted species, there are also barriers to applying that knowledge that have to do with perceived credibility, legitimacy and salience (Cash et al. 2002). Many rural residents distrust of federal agencies and actions, although they often also express support for species conservation (Conley et al. 2007). Complex problems, such as species conservation, are impossible to solve purely with science and often require trust-building and stakeholder engagement (Ludwig 2001). Processes of knowledge production that consider local observations and experience are often seen as more fair and credible than those that fail to consider them (Wynne 1992). In this paper, we explore the knowledge that long-term local experts, both formally trained and not, have gained about the Gunnison Sage-grouse. We define local knowledge as the knowledge people gain from long-term experience in a place, supplemented by a variety of other sources such as monitoring, communication with others, and published resources.

Local knowledge has been identified as an important resource to manage natural resources sustainably and to balance resource use with conservation (Eshuis and Stuiver 2005, Berkes 2008). Local experts can help inform application of knowledge and management practices by describing how the local context alters generalized patterns observed elsewhere (Beall and Zeoli 2008, Brinkman et al. 2009, Low et al. 2009). It may also reveal novel observations that can provide hypotheses for future research (Knapp and Fernandez-Gimenez 2009).

Local knowledge can also reveal how different stakeholders perceive and therefore respond to the same phenomenon, such as changes in species abundance. In complex situations, with multiple interacting variables, people create narratives to make sense of the phenomena they experience (Foucault 1972). These narratives link information together in a cohesive story that illustrates perceived cause and effect, even if the proof of causality is limited and informed by different assumptions, values and worldviews (Cronon 1991). In a conservation context, these narratives may influence what conservation actions are taken and the scale at which they are implemented (Campbell 2007). While justified by ecological arguments, these decisions are not apolitical, but are driven by the values of decision-makers (Campbell 2007). If unreconciled, different narratives may lead to divergent conclusions about needed conservation actions and make it difficult to apply conservation practices on the ground; highlighting these narratives may help to explore underlying assumptions and stimulate community learning.

Local knowledge gained through experience and management is often marginalized as “anecdotal”, since it fails to meet normative standards of science such as hypothesis testing, replication, and falsification (Berkes 2008). Individuals with observational expertise are often marginalized in favor of the local knowledge of formal experts, even if individual knowledge claims of formal experts have little proof (Healy 2009, Arnold et al. 2012). However, every type of knowledge has methods to verify its accuracy. For scientific knowledge, verification can include statistical procedures that measure uncertainty, peer review, and the ability to replicate findings. For local knowledge, accuracy is often assessed through comparison of observations, experience, and knowledge in a social process among local experts. In this study, we do not attempt to evaluate the relative accuracy of different knowledge claims, but rather to document these claims and the relative support for each among local experts, in order to suggest hypotheses for further research.

Grouse are an indicator species for a wide variety of grass and shrubland systems across the western United States, and many are currently in decline (Schroeder et al. 2004, USFWS 2013a). Almost twenty years ago, a diverse group of Gunnison Basin residents including long-term residents, biologists, and agency employees voluntarily came together to address the decline in Gunnison Sage-grouse (GUSG) populations. Their efforts have resulted in local and regional conservation plans (Gunnison Sage-grouse Local Working Group 1997, Gunnison Sage-grouse Rangewide Steering Committee 2005), over $30 million invested in direct conservation actions (Colorado Parks and Wildlife 2013) and county-level land use regulations. In addition, many local ranchers have changed grazing management practices, fenced riparian areas, and placed conservation easements totaling over 40,000 acres in the Gunnison Basin (M. Pelletier, GIS Specialist for Gunnison County, personal communication). GUSG numbers within the Gunnison Basin are stable to increasing at approximately 4,000 birds. However, several of the satellite populations continue to decline, and several are thought to be at risk of extinction (USFWS 2013b). In January 2013, the United States Fish and Wildlife Service (USFWS) proposed that the GUSG be listed as endangered under the Endangered Species Act (ESA). The USFWS proposed rule states that current conservation efforts and regulations are not adequate to slow the decline of the species, and that the listing will assist the species by raising public awareness, developing a recovery plan, providing funding for conservation, and by making certain actions illegal (USFWS 2013b: 2536-7).

Knowledge of the GUSG is limited. Current GUSG population estimates are based on lek (breeding ground) counts, which have been criticized for untested assumptions and inaccuracy (Gunnison Sage-grouse Rangewide Steering Committee 2005), instigating research into new counting methods (Oyler-McCance and St. John 2010, Walsh et al. 2010). Lek counts of GUSG populations began in 1953 (J. Cochran, Gunnison County Wildlife Conservation Coordinator, personal communication), but early protocols lacked rigor and were inconsistent (Braun 1998). Lek counts were standardized in 1982 to allow year-to-year comparisons (Gunnison Sage-grouse Rangewide Steering Committee 2005). Early baseline population estimates are not comparable with later estimates, and some of the best information can be found in historic journals, surveys, oral histories, and the knowledge of long-term residents. Since its recognition as a separate species in 2000 (Young et al. 2000), agencies have monitored GUSG populations and produced multiple internal reports about GUSG. These reports provide valuable information that helps to inform management decision-making.

As is the case for many rare and spatially restricted species, less than twenty peer-reviewed articles have been published about GUSG. Gunnison Sage-grouse-specific research has focused on general natural history (Young et al. 1994), habitat needs during different times of the year (Hupp and Braun 1989, Young et al. 2000, Oyler-McCance et al. 2001, Schroeder et al. 2004, Lupis et al. 2006, Aldridge et al. 2012), genetic diversity of the population (Oyler-McCance et al. 2005, Stiver et al. 2008, Oyler-McCance & St. John 2010, Castoe et al. 2012), and the effectiveness of conservation strategies such as perch deterrents (Prather and Messmer 2010) and removal of non-native species (Baker et al. 2009). The majority of science that is invoked to inform decision-making comes from wider-ranging grouse species, especially the Greater Sage-grouse (GRSG) (USFWS 2010). While the biology of the two species is similar, extrapolation of scientific findings from one species to another may not always be unjustified (Davis 2012).

Until 2000, GUSG were not distinguished from GRSG (Young et al. 2000). The primary differences between the two species are size, plumage, courtship display and genetics (Young et al. 2000). GRSG range across much of the Western United States and part of Canada and have been deemed warranted for listing under the ESA but precluded by the need to take action on other species (USFWS 2013c). A comparative Web of Science search finds nine times more results for GRSG (161) than for GUSG (18). Research on GRSG ranges from habitat selection throughout the year to survival of different age classes and from genetics to methods of measuring population size. The primary threat that has been addressed in GRSG research is the impact of oil and gas development, which is not considered a threat for the GUSG population in the Gunnison Basin.

Conservation decision-making always occurs in contexts of incomplete information. In these contexts, the knowledge of local experts may provide information about the species that is otherwise unavailable. Community efforts, such as the original local working group and the current Gunnison Basin Sage-grouse Strategic Committee, have been admirable in their attempts to bring multiple perspectives together, but their goal was to develop and implement conservation strategies rather than to document local expertise. The USFWS has consulted with grouse biologists about the proposed rule, reviewed local and regional management plans, and accepted comments during the listing process (USFWS 2013b). However, there has been no systematic assessment of what local experts know about the species and how that could contribute to conservation efforts.

It is a critical time to pause and reflect about the knowledge that formal and observational experts have gained from a long history of observations and experience with the GUSG. This project assesses the knowledge of local experts to evaluate how their knowledge can contribute to our understanding and conserving rare species

4.3. Study Area

This study took place in the Upper Gunnison River Basin, a high mountain valley dominated by sagebrush steppe lowlands, predominately mountain big sagebrush (*Artemisia tridentata*) and surrounded by higher-elevation forests of Ponderosa Pine (*Pinus ponderosa*), Douglas Fir (*Pseudotsuga menziesii*), spruce (*Picea spp.*), and aspen (*Populus tremuloides*). The elevation ranges from valley bottoms at 2300 m to high alpine tundra at 2900 m. The Gunnison Basin has an average temperature of 3.1° C and an average precipitation of 27 cm. Public lands make up about 80% of the Basin, almost all of it used for grazing. Private lands, generally found in the productive river bottoms, account for 30% of GUSG critical habitat (USFWS 2013b). The Basin contains the largest and most stable of the remaining populations of GUSG, with approximately 4,000 birds (USFWS 2013b). The human population of the Gunnison Basin is approximately 23,000, primarily in the towns of Gunnison and Crested Butte. The main drivers of the local economy have transitioned from agriculture and ranching to retirees and tourism (Colorado Department of Local Affairs 2010).

4.4. Methods

In this study, members of the Gunnison Basin Sage-grouse Steering Committee (GBSC) defined our pool of participants by providing recommendations of local GUSG experts. The GBSC is comprised of 25 people, including 12 formal experts and 13 observational experts (as defined below) whose mission is to implement programs and steps which will aid in the preservation of GUSG (Gunnison County 2013). We began by asking GBSC members to identify who they thought knew the most about GUSG. We sent an email to each committee member and followed with up to 2 reminder calls. We were able to gain references from 80% of the committee members. As the study progressed, we also asked participants to refer others. We did not set a limit to the number of recommendations, and numbers ranged from 1 to 34, with an average of 10 recommendations per referee. 88 individuals were identified as local experts (formal and observational). We prioritized potential participants based on the number of referrals. There were a total of 39 people with 3 or more referrals, and we were able to speak with 26 of them (Table 4.1). This included all the individuals with 4 or more referrals and 70% percent of those with at least 3. Although this method may fail to include all local experts, perhaps because they are no longer active in GUSG issues or were less well known, we feel this process was able to identify the individuals that the people most engaged in GUSG issues, the GBSC, define as local experts.

Individuals included those with long-term local observations, technical training, or both. Their knowledge came from a variety of sources including experience (ex: active management of ranches, employees for land management agencies), scientific research, or communication with one another. Their knowledge is not purely local or scientific, but a hybrid of both (Turnbull 1997, Fazey et al. 2006). All of the participants are considered local experts, as defined by their community. We differentiate two categories within these local experts: 1) observational experts who have gained most of their knowledge through direct observation and lack formal training and 2) formal experts who have an academic degree related to biology or ecology and conduct systematic monitoring or research on GUSG. Observational experts included ranchers, long-time residents, non-biologist agency employees and politicians, while formal experts included agency or academic biologists. These categories were not exclusive and there were observational experts who were well versed in the scientific literature as well as formal experts who had long-term observations. The objective of these categories was to provide a way to compare those with and without formal training.

We developed an open-ended interview script based on our research question that covered knowledge of habitat, behavior, ecology, conservation strategies, and threats to GUSG. We received approval for conducting these interviews through the Institutional Review Board at the University of Alaska Fairbanks (Approval 369551-1). Semi-structured interviews occurred in July and August of 2012, and each interview ranged from 40 minutes to 2.5 hours. Interviews were transcribed in full and coded in NVIVO (QSR International 2010), a qualitative coding software program. We developed a preliminary coding plan based on research questions and added emergent codes as themes of interest were identified. NVIVO facilitates the systematic collection of data, or quotes from the interviews, related to each theme of interest. A single researcher coded all interviews twice to confirm that all themes of interest were captured.

Our analysis includes both qualitative content analysis and quantitative counts of participants who referenced specific themes. We used triangulation across interviews and with published research to find corroborating data (Denzin and Lincoln 2005). We also used negative case analysis to look for evidence that contradicted our preliminary findings (Denzin and Lincoln 2005). We did not use statistical analyses because of the non-random sample, small sample size, and open-ended nature of many of the interview questions. Our primary research question was whether and how local expert knowledge could inform conservation decision-making. Interviews and content analysis allowed us to collect the rich qualitative data needed to address this question.

We were also interested in the network of community referrals and what they said about how knowledge was held and valued within the community. To explore this question, we generated a network diagram to depict the network of referrals and characteristics of individuals. Our primary interest was to identify patterns of referrals and to understand which types of experts (formal or observational) were most commonly referred (Table 4.1 & Figure 4.1).

4.5. Results

4.5.1. Who are the experts?

The Gunnison Basin Sage-grouse Strategic Committee (GBSC) and project participants made a total of 299 individual referrals. Individuals without formal training provided more total referrals (204) than those with formal training (95). Individuals with formal training referred formal and observational experts almost equally, while individuals without formal training were more likely to refer other observational experts (Figure 4.1). However, both groups recommended individuals who did not share their background. The GBSC and project participants identified a total of 88 knowledgeable people. Of the 83 people in the network who could be identified, there were slightly more observational (45) than formal

(38) experts. We interviewed a total of twenty-six people, including 12 formal and 14 observational experts who received the most referrals (Table 4.1). On average, interviewees had 16 years of experience with GUSG, and 29 years of experience in the Gunnison Basin. Respondents were primarily male (80%), with several women (12%) and two couples (8%).

4.5.2. Types of observations.

Different local experts shared different areas of expertise, with some contributing information about GUSG biology and others more knowledgeable about GUSG management or GUSG habitat (Table 4.1, Column 6). Most (81%: 21) local experts made their observations of grouse primarily in the spring, summer or fall (Table 4.1, Column 7). Only five participants (19%) described ongoing observations during the winter. The majority (58%: 7) of the formal experts described observations primarily in the spring during lekking. Formal experts said they made their observations during lek counts or as part of official research activities, while observational experts made observations opportunistically when they were engaged in other activities (e.g., moving cattle, irrigating, etc.).

4.5.3. Historical memory of GUSG.

Long-time residents were unanimous in recollecting much larger populations of GUSG in the past. As one expressed “They had a regular hunting season for them and we would all go grouse hunting and easily fill your limit, there were so many. In fact, when you were riding a spooky horse you had to be awake because they would jump when the grouse flushed, and we flushed a lot of them”. Long-term residents also described changes in the numbers of cattle (decrease) and predators (increase) over time.

4.5.4. Habitat Use and Quality.

Local knowledge of habitat mirrored the scientific literature. Local experts consistently described the importance of intact sagebrush steppe with a diverse understory of grasses and forbs and proximity to wet or riparian areas (Young et al. 2000). When asked where they were sure to see GUSG, participants described mesic areas and drainages with more diverse understory. As one stated, “I think there was a lot in sagebrush and grass, but if you go up the little streams you would always see some.”

Novel insights related to use and importance of hay meadows, use of small serviceberry islands in the sagebrush steppe, use of snow caves, and several odd but recurring observations in edge habitat and at high elevations (Table 4.2). Participants (31%: 8) commonly described use of hay meadows for lekking and brood-rearing. These sites may have been historic leks prior to conversion, but there was evidence that GUSG were still able to use these landscapes productively. In fact, one of the largest currently active leks in the basin is in a hay meadow. Several participants stated the importance of introduced clover as part of the grouse diet and the ability of irrigated hay meadows to substitute for seeps, springs, and riparian areas. Participants described how small islands of serviceberry were important to conserve because they are mesic sites that often contain needed forbs (19%: 5). Several participants also talked about GUSG use of snow caves for thermal insulation and described how cold, low-snow years could be more detrimental than high-snow years because of the importance of snow caves (23%: 6). Participants also suggested use areas above 9200 ft (31%: 8) and use of the sagebrush/forest interface (23%: 6). Individuals have documented both types of observations, and movements have also been tracked through collared birds. While one peer-reviewed paper mentioned the use of pastures and serviceberry, few of these claims were documented in the published and peer-reviewed literature (Table 4.2).

Several of the formal experts (25%: 3) talked about a different landscape-habitat pattern in which the types of GUSG habitat in this area were overlapping and continuous, making it difficult to identify important habitats. As one participating biologist stated, “They [GUSG] are using a much wider landscape, and you know just the fact that you see so much overlap with those seasonal habitats I think is pretty important because we are trying to think about these boxes of brood-rearing, winter and nesting, but really it all overlaps in all the areas.” These formal experts (25%: 3) stated that this makes it questionable to adapt habitat guidelines created for other grouse species to GUSG. One recent publication describes the large area needed for crucial nesting habitat and suggests important overlap between other life-stage habitats (Aldridge et al. 2012).

4.5.5. Behavior of GUSG.

GUSG behavior is fairly similar to other grouse. As one participant noted, “They are pretty hard-wired birds and they are doing what they do.” However, participants also mentioned several behavioral characteristics that are rarely noted in the literature: GUSG are more prone to flushing in response to disturbance than GRSG, they are less territorial on the leks than GRSG, have been seeing moving with cattle, and have been observed in shallow water (Table 4.2). Seven (27%) participants who had observed both GRSG and GUSG stated that GUSG are more prone to disturbance and more difficult to capture. As one stated, “GUSG for lack of a more scientific term, seemed more skittish. They were far more prone to human influence and disturbance.” Several people noted that they are more likely to flush due to predators or human interference and then fail to return to the lek, while other species (e.g. GRSG) will merely crouch down and then quickly return to dancing. This observation has not been documented in the peer-reviewed literature.

Several participants (15%: 4) also mentioned less territorial behavior on leks than GRSG, with males more willing to move to females and less defensive of individual dancing areas. As one participant stated, “having watched both (GUSG and GRSG), these (GUSG) birds move on the leks more. They are chasing the females.” This observation has also not been documented in the peer-reviewed GUSG literature. Four ranchers, one type of observational expert, described seeing grouse following cattle, both as protection from predators and to feed off grubs left in cow manure. As one rancher noted, “they felt they were secure with the cattle because they knew they were no threat and the coyotes wouldn’t mess with them and they were safe with the cattle around.” One study shows males and broodless females avoiding grazing cattle, although the paper noted that one female with a brood continued to use the pasture (Lupis et al. 2006). Four participants also noted observations of GUSG in shallow open water, which we could find no mention of in the literature.

4.5.6. Threats to the survival of GUSG.

We asked each participant to list threats to GUSG and describe the level of each threat they mentioned (Table 4.3). Participants described the threats they felt were most important, and not every person mentioned every threat. Most (70%) participants agreed that modification of habitat was a medium or high threat to GUSG. Other commonly mentioned threats included predation, recreation, and current/historic grazing. However, many of these threats were given different weights by different groups. For instance, experts differed in their evaluation of the threat level of predation (observational: medium/high, formal: low), historic cattle grazing (observational: medium, formal: high), current cattle grazing (observational: low, formal: medium) and drought (observational: medium, formal: high).

4.5.7. Strategies to conserve GUSG.

We asked each participant to list conservation strategies for GUSG and whether they were beneficial, not beneficial or if they were unsure about the benefit (Table 4.4). Participants described conservation strategies they were familiar with, but not every participant mentioned every strategy. The most commonly referenced beneficial strategies include restoration (50%: 13), improvements in grazing practices (46%: 12), conservation easements (38%: 10), and road closures (38%: 10). Other strategies, including predator control, mechanical sagebrush treatments, and fire, were contested. Half of the observational experts felt predator control was beneficial, while most formal experts were unsure (42%: 5) or felt that it wasn't a benefit (33%:4). About a quarter (27%: 7) of participants were unsure about the benefits of mechanical sagebrush treatments, and formal experts often felt it was not an effective strategy (42%: 5). Fire had some support from each participant group (35%: 9), but a proportion of each group was unsure about its effects (23%: 6).

4.5.8. Research needs.

Participants were asked what they felt were the most pressing research questions regarding GUSG (Table 4.5). Common concerns included the relationship between grazing and GUSG (46%: 12) and better science to inform decision-making (42%: 11). Observational and formal experts overlapped on many of the research questions they felt were most relevant.

4.5.9. Opinions and beliefs about GUSG listing.

Participants were almost unanimous that it was important that GUSG survive in the future (Table 4.1; 88%: 23). Most of the participants described personal observations and concern over decline of GUSG within their lifetime, but few felt that GUSG in the

Gunnison Basin were at risk of extinction (Figure 4.2). Those who had knowledge of the GUSG satellite populations (about 50%) all agreed that they were at risk of going extinct in the next 50-100 years. Several (11%: 3) participants stated that the threat of listing has been useful for getting people to work together. As one stated, “I’m not pro-listing, but I have seen the value of the ESA in motivating action locally”. Some observational experts (36%: 5) felt that the listing of the GUSG was being used as a lever to prevent development and curtail grazing on public lands, and not primarily to protect the species. As one stated, “Environmental groups have taken a number of issues like GUSG to say ‘no growth’ and ‘no development’ and use it as a vehicle to promote their agendas”.

We were also interested in what people expected would be the likely outcomes of listing the GUSG as an endangered species under the ESA. About a quarter of the participants were unsure how the listing would directly impact them (27%: 7), while many formal experts were concerned about additional workload (50%: 6), and a sub-group of observational experts (ranchers) were concerned about their continued access to public lands (80%: 4). Almost half of the participants (42%: 11) were concerned that the listing would frustrate stakeholders, potentially decreasing engagement in and support of future conservation efforts. However, many of this same group said that lowered cooperation wasn’t inevitable (64%: 7) and could be countered with transparent communication and building on current endeavors. Other respondents (31%: 8) felt that the listing wouldn’t have a large impact on the community, because the county government and agencies were already managing as if the bird were listed. This group also cited two programs, the Candidate Conservation Agreement (for public land) and Candidate Conservation Agreement with Assurances (for private land), as measures that would minimize the impact by establishing guidelines for management prior to a listing decision. Finally, we asked participants to reflect on what the outcomes of the listing would be for the GUSG. Participants were split between thinking that the listing would be positive or neutral, with about 15% (4) thinking listing would be negative for the grouse (Table 4.1). The overall pattern held for both subgroups, with two of each feeling the listing was negative and the remainder split between neutral and positive.

4.6. Discussion

The conservation landscape for the GUSG has shifted. After twenty years of local conservation actions to protect the GUSG, the USFWS has proposed to list this species as endangered under the ESA (USFWS 2013b). Given both the long-term local conservation efforts and expertise and the minimal scientific research on this species, we felt this was a crucial time to assess local knowledge and how it might inform management decisions as conservation efforts move forward.

4.6.1. Knowledge networks.

Community-based natural resource management has been lauded for its ability to build understanding about resources, make wise decisions, build local capacity, and get projects done on the ground (Wondolleck and Yaffee 2000, Kofinas et al. 2002, Berkes 2004, Peloquin and Berkes 2009). In this project, we found that an additional benefit of engaging communities in conservation is that it can create a network of local experts that includes conventionally recognized formal experts such as biologists, as well as observational experts such as ranchers and long-time residents. Co-production of knowledge, the ability to share knowledge, learn from one another, and generate new discoveries, is increasingly recognized as an important element for effective community engagement in resource management (Edelenbos et al. 2011, Hegger et al. 2012). In past studies, researchers have often found it challenging to bridge observational and formal knowledge because of issues of legitimacy (Edelenbos et al. 2011). However, after 20 years of cooperation on the GUSG, our referral network demonstrates that participants in the GBSC identify and value the insights of people with different types of experience with GUSG. Rural residents often demonstrate skepticism and distrust of federal regulations such as the Endangered Species Act (Stokstad 2005). At this point, prior to the listing decision, it is important that informal networks of local experts, such as the one identified in this paper, be sustained in order to mitigate distrust and access knowledge drawn from the extensive experience of both observational and formal experts. This could be accomplished by building on efforts of the GBSC to help inform and guide conservation actions post-listing.

4.6.2. Value of local knowledge.

There has been increased interest in the value of local knowledge for decision-making in the past two decades, to address data gaps, provide novel information, inform adaptive governance and contribute not just information but wisdom about appropriate use of resources (Berkes 2008, Chapin et al. 2009). This project suggests several benefits of applying local knowledge to rare and/or endemic populations including providing access to 1) a deeper temporal perspective, 2) observations made during different seasons and life-history stages, and 3) insight into the applicability of management strategies formed on the basis of research on similar species. In complex and contested conservation contexts, speaking with local experts also helps to 1) provide an assessment of local values and motivations, 2) better understand current controversies (Tables 4.3 & 4.4), and 3) highlight important research questions.

4.6.3. Deeper temporal perspective.

Observational experts had long-term experience in the region (Table 4.1, Columns 4 & 5) and provided information about grouse abundance and location from personal memories and oral histories that were otherwise patchy or unavailable. Experts provided insights about a range of associated factors (predator populations, domestic grazer populations, native ungulate populations) that may help to inform both our understanding of these ecosystems and the narratives local experts use to explain declines in GUSG populations.

4.6.4. Observations made during different seasons and life-history stages.

Formal and observational experts made their observations at different times of the year, and the timing and intensity of observations can complement one another (Table 4.1, Column 7). Formal experts made most of their observations during spring or other seasonally specific research projects, while observational experts made observations year round while conducting other activities. Formal experts were more systematic in their observations and included processes designed to count, measure and track GUSG in order to answer specific questions, while observational experts provided qualitative observations across a larger landscape that is otherwise rarely monitored.

4.6.5. Appropriate local application or hypotheses for further research. Participants offered several novel insights about GUSG that may have implications for the local application of science developed for other species and management strategies designed in other places. For instance, observations suggest that GUSG flush from leks more readily than other grouse species and are less likely to return to leks after disturbance, which might inform regulations on new development activities, lek-viewing activities, or recreation. The overlap between habitat types suggests a more integrative form of land conservation that includes both conservation of a range of important habitat types as well as corridors to link them. Local observations may also provide new hypotheses for future research. For instance, observations of the importance of hay meadows and serviceberry stands could inspire research to study the role of these landscape components in the life history of GUSG and the potential for current management practices on private lands to contribute to GUSG conservation.

4.6.6. Assessment of local values and motivations. All of the participants expressed concern over the decline in GUSG, and the vast majority expressed their opinion that it was important that GUSG survive in the future. Many of the participants have been working on the conservation of the GUSG for over 20 years. Despite this demonstrated commitment, only about a quarter (23%: 6) felt like the GUSG was at risk of extinction. The primary explanation participants gave was that they did not believe that this status would provide any greater conservation potential than local conservation efforts had already done, and they were concerned that listing might derail current community conservation efforts. Similar concerns have been raised over the listing of Attwater's prairie chicken (*T. cupido attwateri*), but efforts to maintain good working relationships with stakeholders have overcome these concerns (Morrow et al. 2004). If the proposed listing is approved, it is important that the USFWS foster open and ongoing communication as well as building upon existing conservation efforts.

4.6.7. Better understanding of current controversies. This project highlighted the controversies that still exist surrounding conservation practices and threats. We identify these controversies by looking at the level of disagreement surrounding threats (Table 4.3) and conservation strategies (Table 4.4). Predators, grazing, and sagebrush manipulations are three topics where there is considerable disagreement among local experts. These issues are also places where there is very little science or ongoing monitoring to substantiate either side of the arguments.

4.6.8. Important future research questions.

Interviews with local knowledge holders helped to identify a range of critical research questions that were common across participant types and linked to the controversies described above (Table 4.5). Pursuing answers to these questions may assist the community in moving forward with effective management strategies regarding sagebrush manipulation, grazing, and predators. Research driven by end users is more likely to be applied to management than research that doesn't consider end users (Danielsen et al. 2005). In contested contexts such as this one, where values are difficult if not impossible to separate from fact, it is important to bring diverse stakeholders together to design and implement research to inform decision-making (Jasanoff 2004).

4.6.9. Limitations of local knowledge.

Local knowledge, as scientific or any form of knowledge, can be inaccurate, partial or biased. It is important to locate the most knowledgeable local residents (Davis and Wagner 2003), identified in this case through documenting referrals and prioritizing individuals with three or more referrals. In highly controversial contexts, such as that surrounding the listing of an endangered species, individuals (whether formal or observational experts) may have the incentive to provide information that supports their beliefs (Lewicki et al. 2003). In these situations it is important that individual observations should be treated as hypotheses until they are substantiated by additional observations, monitoring data, or research. Since local knowledge is collected in specific places at specific times, it is also important to understand the spatial and temporal bounds of local knowledge. For instance, observations in the Gunnison Basin population may not be applicable to other GUSG populations because of differences in context (land use, predator populations, weather patterns). Science is typically better at elucidating certain aspects of ecosystem dynamics that are difficult to directly observe, such as the nutritional value of different vegetation and the genetic diversity in sub-populations. However, scientific studies are also collected in specific times and places, although its methods attempt to abstract from those contextual factors.

4.6.10. Questioning conservation narratives.

Formal (biologist) and observational (ranchers, long-term residents and non-biologist agency employees) have their own narratives about why the grouse have declined and what could be done about it. As others have found, conservation narratives link together ecological theory, research results, values, beliefs and observations to explain conservation dilemmas and propose potential solutions (Campbell 2007). In the Gunnison context, it is clear that there are two prevailing narratives about the ecosystem. Most formal experts share a narrative that suggests that habitat modification, drought, and historic grazing have caused decreases in grouse populations, and the solution is in restoration, changed grazing practices, conservation easements, and better science. Most observational experts share a different narrative that proposes that predation, recreation and habitat modification have resulted in decreased GUSG populations, and the solutions include predator control, road closures, interseeding, and changed grazing management practices. These narratives structure the way we understand what the problem is and how it should be addressed (Cronon 1991). In controversial situations, the narratives of formal experts, even if unsupported by data, are often accepted as less biased than those of observational experts (Healy 2009, Arnold et al. 2012). This assumption often leads to lack of cooperation between formal and observational experts, as well as adoption of potentially maladaptive solutions because critical information may be ignored and because observational experts, who are often also managers, are less inclined to support decisions in which they have not participated (Wynne 1992).

The first step toward a shared understanding is recognition of different narratives. Many of those active in the GUSG issue will recognize these different narratives, but may not have taken the step of considering the limits of the evidence behind their own narrative. As GUSG conservation efforts move forward, it will be important that all available information is brought to bear in management decision-making. This will mean consideration of existing peer-reviewed literature, internal agency reports and monitoring data, as well as the insights of long-time local observers. The resulting integration of knowledge has the greatest potential to inform and identify solutions to current debates about best practices that can lead to beneficial outcomes for GUSG.

4.7. Conclusions

Many species of grassland bird face threats worldwide. Their long-term survival requires a new level of partnership and respect between observational and formal experts. This study demonstrated that engaging local knowledge provides benefits for understanding rare and endemic species as well as informing conservation in contested contexts. Local experts can provide a deeper temporal perspective, information on a broader spatial scale and in different seasons, and insight about how to apply knowledge gained in other locations and with other species. Local experts can also help to understand values and highlight controversies that, if not informed by research, might stall conservation efforts. There are two interacting components to any conservation challenge: the social and the ecological. The findings from this project suggest that local experts can inform our understanding of species biology as well as the social context in which conservation occurs.

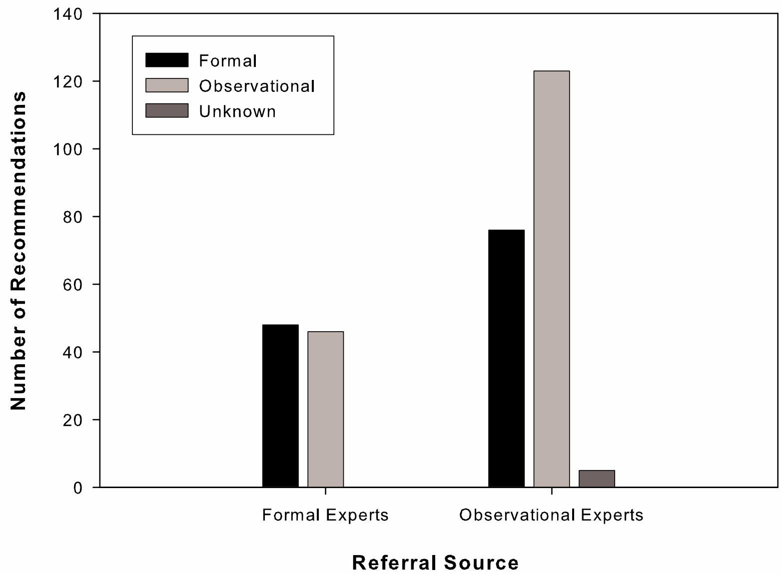

Figure 4.1. Percentage of observational and formal experts referred by individuals with (A) and without (B) formal training

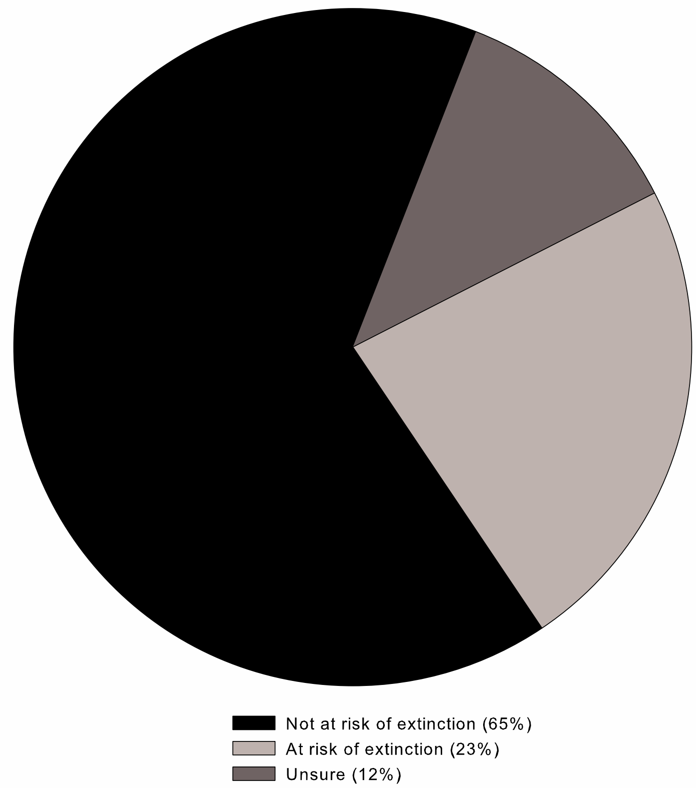

Figure 2.2. Participant opinions about whether the Gunnison Sage-grouse are at risk of extinction.

Table 4.1 Gunnison local knowledge study participants, characteristics, and opinions.

Primary category	Subcategory	Number of referrals	Years in area	Years aware of GUSG	Area of expertise[a]	Season of observation[b]	Endangered?[c]	Should survive?[d]	How would listing impact Gunnison sage grouse?[e]
Formal Expert	Biologist	3	0	2	B, E, M	**SP**, S	D	Y	+
Formal Expert	Biologist	3	13	5	B, C, M	SP, S	N	Y	+
Formal Expert	Biologist	4	16	6	B, E, HA, M	**SP**, **S**, **F**, W	D	Y	Neutral
Formal Expert	Biologist	4	17	17	E, HA	SP, S, F, W	N	Y	Neutral
Formal Expert	Biologist	6	12	11	B, C, E, HA	**SP**, F, W	N	Y	+
Formal Expert	Biologist	6	13	7	B, E, HA, M	**SP**, S, F	N	Y	-
Formal Expert	Biologist	6	24	24	B, C, E, HA, GH	SP, S, F	Y	Y	+
Formal Expert	Biologist	6	16	16	B, C, E, HA	**SP**	Y	Y	Neutral
Formal Expert	Biologist	7	7	7	C, E, HA, M	**SP**, F	N	Y	+
Formal Expert	Biologist	7	8	8	B, C	SP, F	N	Y	Neutral
Formal Expert	Biologist	9	9	16	B, C, M	**SP**, S, F	N	Y	Neutral
Formal Expert	Biologist	12	15	15	C, E, HA, M	SP, **S**, F	N	Y	-
Observational Expert	Non-Biologist Agency	3	30	17	E, H, M	SP, **S**, F	N	Y	+

Table 4.1 Gunnison local knowledge study participants, characteristics, and opinions (continued).

Primary category	Subcategory	Number of referrals	Years in area	Years aware of GUSG	Area of expertise[a]	Season of observation[b]	Endangered?[c]	Should survive?[d]	How would listing impact Gunnison sage grouse?[e]
Observational Expert	Non-Biologist Agency	3	30	22	E, GH, M,S	SP, **S, F**	Y	Y	+
Observational Expert	Non-Biologist Agency	5	31	27	M, S	SP, S, F	N	Y	Neutral
Observational Expert	Non-Biologist Agency	6	15	15	B, E, M	**SP**	N	Y	+
Observational Expert	Rancher	3	94	30	GH, H, S	SP, **S**, F	N	M	Neutral
Observational Expert	Rancher	4	79	30	E, GH, H, M, S	**SP**, S, W	N	Y	-
Observational Expert	Rancher	7	55	30	E, GH, H, M, S	**SP, S**, F, W	Y	Y	Neutral
Observational Expert	Rancher	9	70	20	GH, H, M, S	SP, **S**	N	Y	Neutral
Observational Expert	Rancher	15	43	17	E, GH, H, M, S	**S**, F	N	Y	-
Observational Expert	Resident	3	56	30	B, E, GH, M	SP, **S**, F	D	Y	+
Observational Expert	Resident	4	30	10	S	SP	N	M	Neutral
Observational Expert	Resident	5	25	5	M, S	**SU**, F	N	Y	+

Table 4.1 Gunnison local knowledge study participants, characteristics, and opinions (continued).

Primary category	Subcategory	Number of referrals	Years in area	Years aware of GUSG	Area of expertise[a]	Season of observation[b]	Endangered?[c]	Should survive?[d]	How would listing impact Gunnison sage grouse?[e]
Observational Expert	Resident	7	20	12	S	S	Y	M	Neutral
Observational Expert	Resident	10	40	17	M, S	**SP**, S	Y	Y	+

a. Refers to the primary area(s) of expertise for each participant. [B=Biology, C=Comparison with GRSG, E=Ecology, H=History, HA= Habitat, GH=Grouse History, M=Management, S=Representative of stakeholder group)

b. Refers to the primary season in which participants observe GUSG. [**Bold**=Primary season of observation (if applicable), SP=Spring, S=Summer, F=Fall, W=Winter]

c. Refers to whether the participant feels that GUSG is endangered in the Gunnison Basin Population. [Y=yes, N=no, D=do not know]

d. Refers to whether the participant feels it is important that GUSG survive in the future. [Y=yes, N=no, M=maybe (depends on impacts to economy and livelihood)]

e. Refers to whether the participant thinks the ESA listing of GUSG will have a positive (+), negative (-) or neutral impact on GUSG.

Table 4.2 Novel observations of Gunnison Sage-grouse habitat and behavior.

Observation	Total	Formal	Observational	Corroborating	Conflicting
Habitat					
Use of hay meadows	8	4	4	Young et al. 2000[b]	
Importance of serviceberry	5	5		Young et al. 2000[c]	
Use of snow caves	6	4	2		
Use of edge habitats	6	5	1		
Use of higher elevations	8	5	3		
Overlapping habitats	3	3		Aldridge et al. 2012[d]	
Behavior					
Prone to flushing	7	7			
Less territorial on leks	4	4			
Move with cattle	4		4	Lupis et al. 2006[e]	Lupis et al. 2006[e]
Observed in water	4	2	2		

a. Evidence was only drawn from published peer-reviewed articles related to Gunnison Sage-grouse
b. This study mentions the use of pastures.
c. This study mentions the use of serviceberry.
d. This study describes crucial nesting habitat and suggests overlap with other life-stage habitat.
e. This study showed that males and broodless hens avoided sites during and after grazing, but the hen with a brood used them

Table 4.3 Number of participants who mentioned the following threats to Gunnison Sage-grouse and the magnitude of each.

	Total (n=26)	Observational expert (n=14)				Formal expert (n=12)			
Threat	Overall	Overall	Low threat	Medium threat	High threat	Overall	Low threat	Medium threat	High threat
Predation	84.6%	78.6%	14.3%	35.7%	28.6%	91.7%	83.3%	8.3%	
Recreation	80.8%	71.4%	7.1%	50.0%	14.3%	91.7%	16.7%	66.7%	8.3%
Habitat modification	69.2%	57.1%		28.6%	28.6%	83.3%		8.3%	75.0%
Grazing (cattle-historic)	65.4%	42.9%	7.1%	28.6%	7.1%	91.7%		41.7%	50.0%
Drought	57.7%	42.9%		42.9%		75.0%		8.3%	66.7%
Grazing (cattle-current)	57.7%	42.9%	21.4%	14.3%	7.1%	75.0%	33.3%	41.7%	
Grazing (elk and deer)	46.2%	42.9%	14.3%		28.6%	50.0%	8.3%	33.3%	8.3%
Invasive species	42.3%	35.7%	35.7%			50.0%	16.7%	33.3%	
Research	19.2%	7.1%		7.1%		33.3%	16.7%	8.3%	8.3%
Sagebrush treatments	19.2%	14.3%	14.3%			25.0%	8.3%	16.7%	

Table 4.4 Number of interview participants who described each of the following conservation strategies for the Gunnison Sage-grouse as beneficial, not beneficial, or were unsure about the benefit.

	Beneficial			Unsure about benefit			Not a benefit		
	Total	Observational expert	Formal expert	Total	Observational expert	Formal expert	Total	Observational expert	Formal expert
Strategy	n=26	n=14	n=12	n=26	n=14	n=12	n=26	n=14	n=12
Better science	31%	14%	50%						
Candidate conservation agreements	15%	14%	17%						
Conservation easements	38%	29%	50%						
Control weeds	12%	7%	17%						
Fire	35%	29%	42%	23%	14%	33%	8%	7%	8%
Grazing practices (new)	46%	36%	58%	4%	7%				
Interseeding	27%	36%	17%						
Mark fence lines	4%		8%				8%	14%	

Table 4.4 Number of interview participants who described each of the following conservation strategies for the Gunnison Sage-grouse as beneficial, not beneficial, or were unsure about the benefit (continued).

	Beneficial			Unsure about benefit			Not a benefit		
	Total	Observational expert	Formal expert	Total	Observational expert	Formal expert	Total	Observational expert	Formal expert
Strategy	n=26	n=14	n=12	n=26	n=14	n=12	n=26	n=14	n=12
Mowing leks	15%	7%	25%						
Perching deterrents							4%		8%
Predator control	31%	50%	8%	35%	29%	42%	19%	7%	33%
Regulations (development)	12%	7%	17%				8%	14%	0%
Restoration	50%	29%	75%						
Road closures	38%	36%	42%	4%		8%			
Sagebrush treatments	15%	7%	25%	27%	29%	25%	23%	7%	42%
Transplanting	4%		8%				8%	7%	8%

Table 4.5 Most commonly suggested research needs related to Gunnison Sage-grouse.

Research need	Total	Observational	Formal	Example quote
Interaction between grazing and Gunnison Sage-grouse	12	5	7	“I don’t think we understand that at all: the relationship between cattle and Gunnison Sage-grouse. I think there are things that cattle do and provide that the Gunnison Sage-grouse like, but we could never find out and if it is negative. That is ok, but I want to know and we don’t know.”
Increased science to inform decision-making	11	6	5	“I have always had the sense that there is still a lot about protecting things rather than answering the hard questions and following the answers wherever they go.”
Monitoring sagebrush treatments to assess conservation outcomes	7	2	5	“I would like to see more studies to try to figure out some of those things that we don’t know as well as we should know to manage the species well. Our management has to be based on as good of science as we can get and it is never easy to get good research to support your management decisions in a reasonable timeframe.”
How local activities impact Gunnison Sage-grouse populations (closures, dogs, recreation)	7	3	4	"Does a mountain bike have the same disturbance as a truck checking coal sites or the normal road disturbance to oil and gas pad? We are having a problem because a lot of the science is focusing on that because it is the biggest disturbance, but what is the disturbance of someone walking or a car on a normal road once a week?"
Habitat preference at micro- and meso-scale	7	3	4	"What are the micro-site characteristics that they need? We say they need to get from the nest to a mesic area but what that area is and what it looks like…we need a better understanding of that."
Impact of predation on Gunnison Sage-grouse	6	2	4	"We have very little (science) about predator control, but that is the one thing we really haven’t taken more of a shot at. I would look to put some dollars there."

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5. Landowner perceptions of the Endangered Species Act and the potential for unintended consequences

5.1. Abstract

The Gunnison Sage-grouse (GUSG) is an iconic species recently proposed for protection under the Endangered Species Act (ESA). In Colorado's Upper Gunnison River Basin, ranchers own the majority of water rights and productive river bottoms, and approximately 30% of the most important GUSG habitat. This project used a mix of survey and interview questions with 41 ranch owners to document how ranchers perceive the proposed ESA listing and how they plan to respond to a listing decision. Results show that ranchers support on-the-ground GUSG conservation, but are concerned about listing implications. Ranchers are most concerned about their ability to manage public and private lands productively and continue permitted grazing on public lands. If the species is listed landowners plan to decrease participation in conservation strategies, including plans to adopt conservation easements, participation in conservation programs, and willingness to allow access to private lands for GUSG monitoring. Research results also suggest that the listing may result in increased sales of land and water, which could have negative consequences for GUSG habitat. Qualitative, place-based research is critical for understanding the indirect and unintended effects of species protections in an increasingly interconnected world.

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5.2. Introduction.

Private lands provide crucial habitat for the conservation of endangered species. Unfortunately, the potential for an Endangered Species Act (ESA) listing in the United States (US) often creates concern and resistance among landowners, even though they may be supportive of species conservation (Conley et al. 2007; Sheridan 2007). What are landowner's reasons for negative interpretations and how might these interpretations influence their conservation-relevant behavior? We interviewed members of active ranching families in the Gunnison Bain of southwest Colorado to gauge their perceptions of and planned actions in response to the proposed listing of the Gunnison Sage-grouse (*Centrocercus minimus*). Qualitative research is critical for understanding the feedbacks between livelihoods and conservation in an increasingly interconnected world, and for designing more effective conservation policies (Sayre 2004).

Since the passage of ESA legislation in 1973, ecological understanding has shifted from a paradigm of balance and equilibrium to one of thresholds and non-linear dynamics (e.g., Scheffer 2009). Climate change and other anthropogenic impacts may modify ecological processes such that certain species become extinct despite listing protections (Thomas et al. 2004; Steffen et al. 2007). The ESA, however, requires that listing decisions be based solely on biological information about the species, with no consideration of human dimensions (United States Government 1973). There is increasing recognition of the tight coupling and feedbacks between ecological and social systems (Clark & Dickson 2003; Chapin et al. 2009). In this paper, we explore whether policies formulated to address ecological components (species) may have unintended consequences for human communities, whose actions might then change ecosystem patterns (management practices, land and water use), and in turn impact the target species.

Almost all (90%) endangered species rely on private lands for habitat (GAO 1994), and in the Gunnison Basin, over 30% of the important habitat for Gunnison Sage-grouse (GUSG) is on private lands. Conversion from working ranches to small-acreage amenity properties is a threat across the western US (Gosnell and Travis 2005; Gosnell et al. 2006). In the Gunnison Basin, two-thirds of the properties over 100 acres in size are owned by individuals whose primary residence is outside the Basin, representing 48% of all private land (Gunnison County Assessor 2012; Saguache County Assessor 2012). Shifts from ranching to other types of land use can have negative implications for biodiversity (Maestas et al. 2001) and habitat improvement projects (Plieninger et al. 2012). Fragmentation into smaller land units can impact GUSG directly (Oyler-McCance et al. 2001), or indirectly through an increase in predation by pets or creation of predator movement corridors (Haegen et al. 2002). Landowner decisions will therefore impact GUSG populations.

Despite positive valuation of wildlife, long-time rural landowners often resist government regulation (Layden et al. 2003), particularly ESA listings, because some view it as a tool to remove grazing from public lands (Conley et al. 2007). Conley et al. (2007) found that opposition to ESA listings is correlated with negative perceptions of the federal government, rather than actual number of listed species on the allotments or potential for restrictions on those allotments. Despite incentives, a portion of landowners refuse to participate in conservation efforts due to normative pressure from their peers (Sorice et al. 2011). These norms and perceptions influence how individuals interpret impacts from a listing decision and resulting actions.

Although there is concern that the threat of ESA listings may lead landowners to destroy habitat to prevent increased regulation (Bean and Wilcove 1997), landowner responses to listings have rarely been studied. However, after listing of the Prebles jumping mouse, landowners were split about their willingness to manage for conservation and were less likely to allow monitoring (Brook et al. 2003). Our study expands prior analyses to explore how a listing decision may impact land and water sales as well as conservation actions. It combines qualitative and quantitative methods to explore the context-specific reasons why ranchers oppose a listing decision. We also explore ranchers' baseline perceptions of their livelihood in order to better understand the contribution of potential GUSG listing to general background stress.

5.3. Background

Gunnison Sage-grouse are currently found south of the Colorado River in Colorado and Utah in seven discrete populations (Figure 5.1). GUSG are sagebrush obligates that depend on sagebrush for winter forage and rely on sagebrush cover year-round. They have habitat needs that vary by seasons and life-stage. For instance, they have high fidelity to breeding sites, require mesic areas for brood-rearing, and utilize exposed sagebrush areas during winter. Between 1958 and 1993, an estimated 20% of sagebrush-dominated landscapes on which GUSG depend were lost (Oyler-McCance et al. 2001). The largest remaining GUSG population (estimated 4,082 grouse) resides in the Upper Gunnison River Basin, where this study is focused (Jackson and Seward 2012). While this population has been stable for the past twelve years, the USFWS believes that other smaller satellite populations (estimated 539 grouse in six other populations) are all in decline due to interacting threats including fragmentation, land conversion and increased predators (USFWS 2010). The USFWS recently proposed listing GUSG as endangered under the ESA (USFWS 2013a).

The Gunnison Basin has a long history of GUSG conservation efforts, first organized under the Gunnison Basin Local Working Group (1994), and later incorporated into the Gunnison Basin Sage-grouse Strategic Committee (GBSC) (2005). The community has created local and regional conservation plans (GSLWG 1997; GSRSC 2005), helped to bring in over $30 million dollars for direct conservation actions (J. Cochran, personal communication), and adopted land-use regulations to protect and conserve GUSG and their habitats. In addition, many local ranchers have changed grazing management practices, fenced riparian areas, and placed conservation easements on over 40,000 acres in the Gunnison Basin (M. Pelletier, personal communication). Many of these actions have been taken in hopes of avoiding an ESA listing.

The primary land use in this region is ranching, which occurs on 96% of private lands and 89% of National Forest Lands (Cheng 2006). Private ranchlands are typically lower elevation pastures that are irrigated during the spring and summer to produce hay used to overwinter cattle. Ranchers rely on public lands during the spring and summer, and cattle return to private lands after haying in the fall and winter. The average ranch size is

900 acres (Gunnison County 2013), while the average public land used by each operation is over 17,000 acres (USFS 2012; BLM 2012). Large private parcels, which often abut public land, provide critical habitat. Grouse utilize the margins of hay fields during brood-rearing, and several large breeding areas are on hay meadows. Ranchers also own the majority of water rights (F. Kugel, personal communication). The cumulative decisions of individual ranchers may impact GUSG populations that rely on these landscapes. During prior research, many ranchers spoke of potential land and water sales based on the increased difficulty of ranching in the area if the grouse were listed (Knapp 2011).

5.4. Methods

We were interested in speaking with owners of large ranches in the Gunnison Basin. We obtained a list of landowners who owned more than 100 acres from the county assessors. We culled this list to remove landowners with addresses more than 60 miles outside the Basin's borders. Interestingly, non-local owners own almost half (48%) of all private land in the Basin (Gunnison County Assessor 2012; Saguache County Assessor 2012). We checked this list with several individuals familiar with the ranching community to remove individuals not actively involved in agricultural production. This process resulted in 89 potential participants.

We mailed an introductory letter and followed with two personal phone calls to set up interviews. For those unable to contact over the phone, we also sent a postcard invitation. We conducted 41 in-person interviews in November 2012. Our sample represents 46% of potential participants. Our sample is broadly representative of the ranching community in the Upper Gunnison Basin in terms of size and type of operation (Table 5.1). Our sample was not random, but representative of size and type of operation, while prioritizing those with public lands permits and larger private land ownership. We prioritized these individuals because they may be most affected by a listing decision, and their responses to the listing may also have the largest impact on land and water dynamics. A few individuals declined to speak with us. When asked why they declined they said that they weren't in town (2), didn't enjoy interviews (2), or were busy (1). We conducted a non-response bias survey with a subset of the population (10) that we were unable to speak with and found that non-respondents did not significantly differ from respondents in their responses to research questions.

Interviews were conducted in person and included both quantitative survey questions and qualitative open-ended questions. We used an Apple iPad to collect quantitative answers in a digital survey interface called i-survey, which allows for efficient data entry. Questions about beliefs utilized a Lickert scale to gauge the level of agreement and disagreement with each statement. Interviews were also audio recorded and transcribed in order to fully collect qualitative answers as well as provide a backup for survey data. Quantitative results were compiled and analyzed in SPSS, while qualitative data were transcribed and coded in NVIVO, a qualitative data-analysis program.

5.5. Results

5.5.1. Participant characteristics

Participants were older adults (average: 60 years) who had spent most of their lives ranching in the Gunnison Basin (average: 44 years). The majority of respondents were men (66%), but we also spoke with women (22%) and couples (12%). Participants were well educated (75% had some post-high school education). Over half made the majority of their income from ranching and had been in the area for over three generations. A little less than half (43%) expect their children to continue ranching when they retire. The vast majority (92%: 38) of participants owned at least one parcel that was adjacent to public land. The majority (66%: 27) of participants had leases or permits to graze on land in addition to their private holdings. These participants had both federal permits (93%: 25) and private leases (66%: 18). The average size of private land owned by participants was 1,452 acres, ranging from 100 acres to almost 7,000 acres. All participants were engaged in some type of conservation practice, including adaptive management (64%), allowing monitoring of grouse, participation in Natural Resource Conservation Services (NRCS) programs, conservation easements (61% each), changed management (52%) and participation in the Candidate Conservation Agreement with Assurances (CCAA) Program (29%). Management changes that participants had adopted to benefit the grouse included fencing off riparian areas and springs, adjusting stocking rates, inter-seeding and habitat improvements. The CCAA Program facilitated by the Colorado

Division of Parks and Wildlife and the U.S. Fish and Wildlife Service protects landowners from additional regulatory actions post-listing if they agree to specific management practices prior to listing.

5.5.2. Perceptions of agriculture

Ranchers presented a complex picture of their current assessment of agriculture (prior to a listing). Ranchers listed numerous existing stressors to their livelihoods, including economics, recreation, regulation, limited spring range, and restoration. Drought was a concern, but ranchers did not directly mention climate change. Their views on the future of agriculture and their individual and collective ability to deal with it varied widely. A multiple-question index (Cronbach's alpha= .789) showed a third of the population holding positive (34%), neutral (32%) and negative (34%) views on the future of agriculture. Ranchers were nearly unified in their concern about the survival of ranching in the future (88%: 36) and agreed that it was increasingly challenging to make a living in agriculture (85%: 35). While most ranchers (63%) believed that their ranch would be thriving in ten years, only 37% said that the agricultural community in the Gunnison Basin would be thriving in ten years.

5.5.3. Opinions about listing

The majority of ranchers said it was important for GUSG to survive in the future (90%: 37): however, only 5% [2] said that they should be listed under the ESA. This opinion can be partially explained by perceived impacts, understanding of listing impacts, and potential alternatives (see below).

5.5.4. Impacts to GUSG

Participants believed that the listing of the grouse would have little positive impact on the habitat and numbers of GUSG (Table 5.2). They stated that the listing could be more negative on private land than public land due to potential shifts in grazing pressure from public to private land. A majority (66%: 27) of respondents stated that the listing would have no impact on GUSG numbers with equal percentages (17%: 7) stating it could be positive or negative. In qualitative responses, respondents discussed their reasoning. First, they thought the community had already done a lot, and they were skeptical about what else could be done. Most of the ranchers (63%: 26) expressed that they had already made changes to benefit the grouse, partially to avoid a listing decision. They believed that local regulatory and conservation actions were more effective than top-down actions by the federal government. Second, they described how the listing would not address what they perceived to be the key threat to GUSG: predators (39%: 16). Participants were concerned that post-listing management would focus on grazing rather than controlling predation.

5.5.5. Understanding of Listing

Ranchers were split around whether they understood how the listing would impact the wider Gunnison community, the ranching community, and their own ranch (Table 5.3). Interestingly, the three ranchers who were serving or had served on the strategic committee all strongly disagreed that they understood listing impacts, while those who were less engaged stated they understood the impacts.

5.5.6. Impacts to Community

Participants were nearly unanimous that the listing would have a negative impact on the community (Table 5.2). We asked participants to tell us if they were concerned with 1) their ability to manage grazing in a productive manner, defined as ranchers' ability to both make a living and maintain the productivity of the land, and 2) their ability to continue to lease both federal and private lands. For both types of land there was a statistically significant increase in the number of people who expressed concern both about managing productively and their ability to renew leases between a not listed and listed scenario (Table 5.4). In qualitative answers, ranchers displayed a range of interpretations of the listing's impact from catastrophic to minimal. Despite this concern, the majority cautiously agreed that the agricultural community and their own ranch could survive the listing of the grouse. A multiple question index of the ability of individuals and the community to cope with the listing of GUSG showed that participants scored themselves higher (slightly agree) than the community as a whole (neutral).

5.5.7. Suggested Alternatives to a Listing

Most participants did not want to see GUSG listed as endangered under the ESA, but few described alternatives. Several (12%: 5) described how they would prefer to see a listing of the subpopulations excluding the Gunnison Basin population. They described how the threat of a listing had motivated local efforts, which had helped to increase grouse populations. They felt local level efforts should be encouraged to continue by retaining local control.

5.5.8. Planned and Potential Responses.

5.5.8.1.1. Conservation practices. We asked participants if they planned to adopt or continue ongoing conservation practices if the GUSG was or was not listed. Common conservation practices include conservation easements, where land is protected from future development but often still used for agriculture, National Resources Conservation Service (NRCS) programs, which help to fund conservation actions on private lands such as fencing cattle out of riparian areas, and allowing monitoring of GUSG on private lands. There was a statistically significant decrease in participation for each of the practices if the grouse were listed (Table 5.4). Ranchers explained that they wouldn't adopt additional conservation easements because it would devalue land that they might need to sell if no longer able to ranch. The decrease in NRCS participation was due to concern about participating in federally funded programs that might increase private land monitoring. The lowered willingness to allow monitoring was due to fear of additional regulations based on population numbers (Polasky and Doremus 1998).

5.5.8.1.2. Changes to management practices. Participants had contrasting opinions about how the listing would change their management. Several participants stated that loss or restrictions on public land leases might force them to run more cattle on private lands to compensate for the loss of public lands (12%: 5). Others described how they might lower their cattle numbers (12%: 5), think about diversifying with different species (goats and sheep) (5%: 2), and focus more energy on hay production (7%: 3).

5.5.8.1.3. Land Sales. A third of the participants explicitly stated that they were committed to staying in the Gunnison Basin and learning how to coexist with GUSG. This group expressed connection to place and willingness to work hard in order to remain. However, a smaller proportion (17%: 7) of respondents stated that the listing, in combination with other challenges, might make them more willing to retire or move elsewhere. We asked participants to describe their actions: under a scenario in which the bird is listed and under a scenario in which it is not listed. There was a 133% relative increase in percentage of participants who said they would plan to sell land in the next ten years if GUSG was listed in comparison if it was not (Table 5.4), representing four additional properties, and over 4,000 acres. Potential buyer characteristics are unknown, but given current land sales patterns, it would likely be to non-local owners for smaller ranchettes or subdivisions. There was also a 24% relative decrease in percentage of current rancher participants who said they would buy land.

5.5.8.1.4. Water Sales. Ranchers described that selling water rights was not a preferred action, and most said they would only consider it if they were unable to sell land and needed money. Many ranchers described how they thought it was bad to separate land and water rights. This aversion to water sales corresponds with the way agriculturalists place utilitarian value on natural resources (Ruiz and Domon 2012). Almost all of the participants owned water rights (95%: 39). If listing occurs, 10% (4) of respondents said they planned to sell water rights (0 if not listed), and the number of people who would consider selling water rights would double (3 to 6). Only one of the participants had investigated and found a potential buyer.

5.6. Discussion

5.6.1. Perceptions of ESA

Negative interpretations of ESA have been explained by general beliefs about federal regulation (Conley et al. 2007). This project reveals other context-specific reasons that inform local interpretations of the ESA. The ranching community has adopted tangible conservation strategies in the Gunnison Basin, and most ranchers are skeptical about what more a listing will accomplish. Populations of GUSG are stable in the Gunnison Basin, and local efforts have minimized fragmentation, which has contributed to GUSG decline elsewhere. Local residents have gained local knowledge of GUSG habitats and behavior that have helped to inform local conservation efforts (Knapp et al. 2013). Federal intervention through an ESA listing suggests a preference for scientific over local knowledge, which may lead to local resentment, lack of support, or attempts to undermine expert solutions (Fischer 2000). As shown elsewhere, top-down imposition of expert advice in controversial situations can cause resistance by local residents (Wynne 1992).

Ranchers described how they thought that the listing would address the wrong threats, because grazing is easier to regulate and grazing regulation is more politically viable than predator control. Concerns with predation (primarily ravens, other aerial predators, coyotes, raccoons, ground squirrels and foxes) have been raised since the beginning of conservation efforts, with little support from land managers. Predation issues are complicated, as they are usually interconnected with human activities. Changes in vegetation structure (Watters et al. 2002), fragmentation (Haegen et al. 2002), and increased human development (Bui et al. 2010) can all increase predation of grassland birds. The USFWS has argued that human activities subsidize predators, and management needs to address these subsidies before more predator control is attempted (Hogan 2012). This logic acknowledges social-ecological system feedbacks, and focuses on human activities to resolve the issue. Ranchers, however, are concerned that human activities are diffuse and challenging to control, arguing for a more direct approach to suppress predators, such as shooting, trapping or poisoning. Recent research in the field has suggested that predator control may be an effective way to increase grouse populations (Coates and Delehanty 2010), but local agencies have expressed reservations (GSSC 2013).

Ranchers are concerned about losing public land grazing leases or facing increased regulations. Ranchers rely on public lands for spring and summer forage, when they need to move their cattle off private land in order to irrigate hay meadows. The ESA listing of GUSG, in addition to other stressors, increases existing concerns. The exact form of this impact, and the point at which additional restrictions make use of public land untenable will differ among ranchers based on their dependence on public lands, availability of private leases, and other factors. Landowners were more optimistic about their own operations than about ranchers in general. One explanation is that ranchers are used to adapting in order to thrive in dynamic environments (Knapp and Fernandez-Gimenez 2009). Their experience handling adversity and challenge means that they tend to be optimistic about their personal ability to overcome challenges. Ranchers are rarely motivated by income, and often express motivations linked with lifestyle (Gentner and Tanaka 2002). If they value and wish to continue their lifestyle, it may be more important to retain optimism about ones' own operation than about ranching as a whole. In addition, ranchers simply know their operation better than any other, and thus are better able to assess its potential accurately.

It is likely that landowner concerns about the listing were magnified due to unavailable or unclear information about the potential impacts of the listing. Those most engaged in the process were the least sure about the impacts. This suggests that belief and rumor rather than accurate information, may be influencing assessments. When potential impacts to livelihoods are perceived as high, and information is scarce, people form opinions based on whatever information they can access. These opinions may lead to decision-making about land and water sales that may hurt GUSG in the long run. At the level of individual decision-making, ambiguity is not beneficial for conservation outcomes. Future communication with this population, and others facing similar challenges, should prioritize transparency so that landowners can make good decisions with the best possible information. This is a challenge for the USFWS, who must communicate clearly potential impacts, while acknowledging that the actual impacts will be subject to both public comment and legal challenges. While uncertainty will remain, the factors that contribute to uncertainty should be described and discussed so that landowners better understand the factors that contribute to the application of regulations.

5.6.2. Potential for unintended consequences

The ESA is an important piece of legislation that reflects the values and intentions of most Americans (Czech and Krausman 1999). As a prescriptive law, however, it primarily addresses threats to species and number of individual species, limiting the consideration of feedbacks between social and ecological systems (Benson 2012). Prior studies have shown that listing a species can lead to a decrease in beneficial management practices and in willingness to allow monitoring on private lands (Brook et al. 2003). This study suggests that a listing decision will decrease participation in conservation practices and lead to increased sales of land and water (Table 5.4). This study demonstrates unexpected and ironic outcomes, which oppose ESA intent. The exact impact of landowner decisions will depend on the characteristics of landowners and land, whether planned actions change after listing, or if the actions by a few individuals encourage others to act.

This study highlights the importance of looking at processes that connect livelihoods and landscapes both spatially and temporally. For example, this project documents spatial tradeoffs between public and private landscapes. If ranchers lose public land permits, or are further restricted in their management, they may respond by increasing stocking rates on private lands. The short-term impact of increased regulation may lead to long-term shifts in ownership patterns from local ranching families to non-local ownership. Proactive assessments of perceptions and planned actions can reveal the reasoning behind perceptions, highlight communication needs and possible research questions, and gauge the potential for unintended consequences.

5.6.3. Suggestions for the Endangered Species Act

The intention of the ESA is to prevent extinction of species by protecting habitat. This project demonstrated how the threat of a listing motivated proactive local action, while the listing itself might generate reactive actions that result in negative outcomes for the species that the law was intended to protect. This dynamic is tied to concern about non-local processes and the ways they will prioritize knowledge, change decision-making, increase bureaucracy, and provide leverage to control land use. Small shifts in the application of this law could help to dissuade local fears and avoid reactive decision-making.

Currently, the distinct population segment (DPS) clause is rarely used, and primarily with the intention to list sub-populations facing local extinction (USFWS 2013b). This clause could be amended to allow for the exclusion of sub-populations that are stable or improving. This action would reward local efforts and motivate continued proactive activities. This project identified the importance of clear and transparent communication about impacts in order to avoid reactive and misinformed decision-making. While the USFWS can't know the precise impacts to communities, studies such as this one could help understand potential impacts. The USWFS could clearly articulate the listing process and potential confounding factors. They could also provide case studies of prior listing scenarios in order to clarify potential impacts. These efforts would help to build trust by demonstrating a commitment to transparency. Finally, they could utilize existing local bodies to share decision-making authority post-listing. This would lower concerns over non-local processes and demonstrate a commitment to building off prior efforts.

For the law itself, moving from a single-species to species-in-context approach would be beneficial. Documentation for listing decisions should include conceptual models of species and system interactions to more fully consider these interconnections, including potential human responses. Prior research has shown that focusing on a single species while ignoring its interactions with other species may end up pitting species against one another. For instance, the endangered Southwest Willow Flycatcher (*Empidonax traillii extimus*) is now dependent on the non-native tamarisk, and efforts to protect the rare bird are stopping efforts to remove a species that is changing riparian hydrology (Zavaleta et al. 2001; Sogge et al. 2008). Consideration of species and systems interactions could help clarify the effectiveness, tradeoffs and potential repercussions of various conservation strategies.

5.7. Conclusions

Agricultural landowners in the Upper Gunnison Basin own many of the productive river bottoms as well as the majority of local water rights. This project describes how landowners perceive the listing and documents their planned responses if a listing occurs. It helps to highlight what types of conservation actions may decline (e.g., willingness to allow monitoring) and which may be only minimally impacted (e.g., participation in NRCS conservation programs). It also highlights the potential for land and water sales, which may have long-term impacts on GUSG habitat and populations. Engaging local perspectives may help to avoid conflicts and unintended outcomes that can emerge with inadequate understanding of stakeholders' values and needs. We believe that proactive assessments such as this one provide critical information about tradeoffs of listing decisions, allowing more effective communication and design of conservation strategies that are supported by local communities

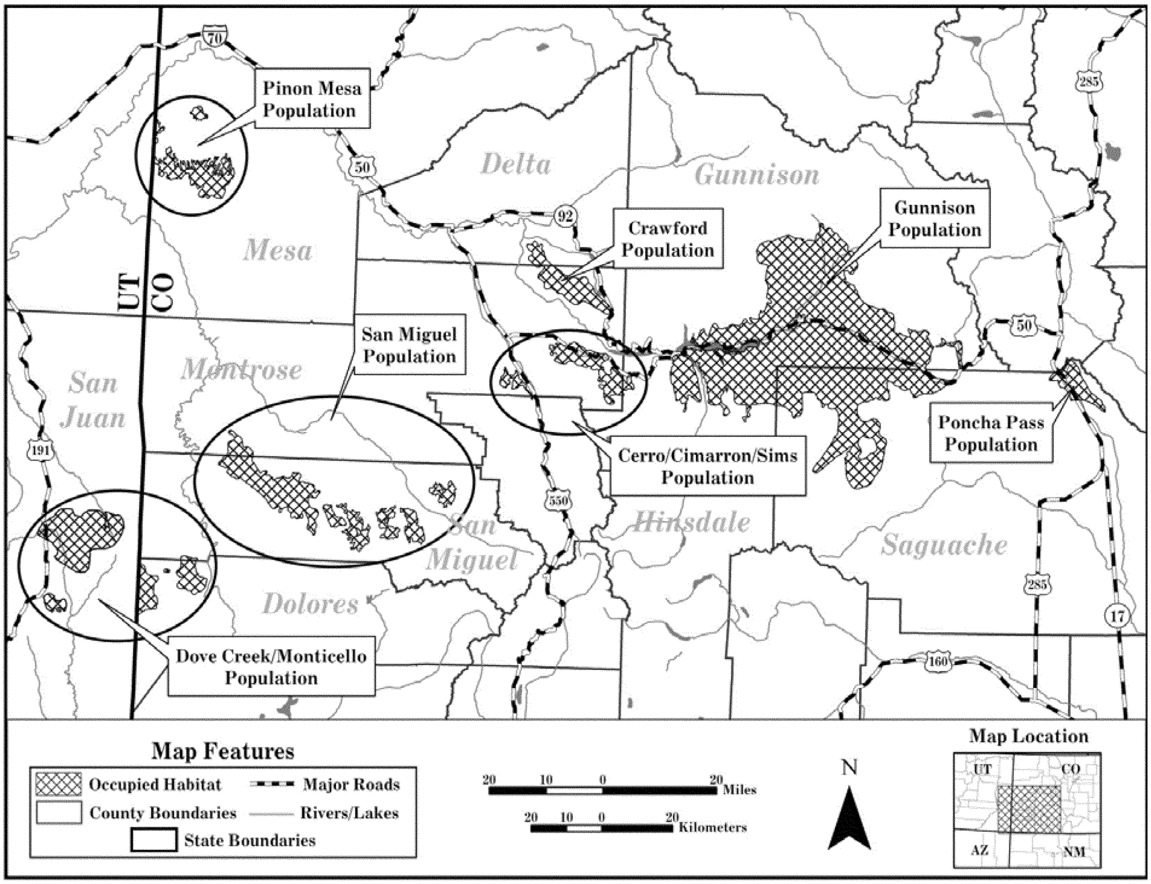

Figure 5.1. Locations of current Gunnison Sage-grouse populations (Federal Register 2010)

Table 5.1 Comparison of total and sampled ranching population by size of private landholdings.

	Total population N=89	Interviews N=41	Composition of sample	Sample as percent of operation size
Private Landholdings				
100-499 acres	41	12	29%	29%
500-999 acres	24	12	29%	50%
1,000-1,999 acres	7	5	12%	71%
2,000-4,999 acres	14	10	24%	71%
5,000 + acres	3	2	5%	66%
TOTAL	89	41	100%	

Table 5.2 Perceptions of how a listing decision will impact social and ecological attributes in the Gunnison Basin.

	Will be beneficial	Neutral	Will be detrimental
Ecological Impacts			
Public land habitat	24.4%	43.9%	21.7%
Private land habitat	12.2%	41.5%	46.3%
Total grouse numbers	17.1%	65.8%	17.1%
Social Impacts			
My ranch	4.8%	22.0%	73.2%
Ranching in general	0.0%	12.0%	88.0%
The economy	0.0%	19.5%	80.5%
Tourism	7.3%	63.4%	29.3%
Housing/Development	2.4%	7.3%	90.3%

Table 5.3 Percentage of participants who expressed the following opinions about their understanding of a listing decision (n=41).

	Strongly Disagree	Moderately Disagree	Slightly Disagree	Neutral	Slightly Agree	Moderately Agree	Strongly Agree
I understand how the listing would impact my ranch.	19.5	14.6	12.2	2.4	14.6	19.5	17.1
I understand how the listing would impact the ranching community.	12.2	17.1	12.2	0	14.6	17.1	26.8
I understand how the listing would impact the Gunnison community.	12.2	19.5	17.1	0	14.6	22	14.6

Table 5.4 Number of participants who expressed the following concerns and planned actions under a listed and not listed scenario.

	Not listed	Listed	Significance*
Concerns			
Federal land (N=25)			
Ability to manage productively	10	20	P < .001
Ability to maintain permit	11	18	P < .001
Leased land (N=22)			
Ability to manage productively	5	12	P < .001
Ability to maintain permit	7	8	P < .001
Planned actions			
Private resources (N=41)			
Sell Land	3	7	P < .001
Buy Land	25	19	P < .001
Sell Water	0	4	P < .001
Conservation actions (N=41)			
Conservation easements	6	3	P < .001
NRCS programs	24	22	P < .001
Allow monitoring	25	19	P < .001

* Chi-squared test

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6. Adapting science to a warming world

6.1. Abstract

Climate change is complicating the variables that Alaskans consider when planning for the future. Communities, agencies and other entities have begun to grapple with both the information that they need to adapt to a changing climate and how the processes and practices of science should change to make science more useful. We reviewed sixty-three documents that expressed practical research needs related to climate change in Alaska. Documents nearly unanimously expressed that science, as it is currently practiced, is inadequate to meet the challenges of climate change. They call for processes that are more transparent, collaborative, and accessible. They recommend changed practices including maintaining accessible data-sharing archives, building networks for knowledge sharing, and creating place-based long-term partnerships with communities. They advocate integrating local knowledge, but infrequently address the complexities of how this is best accomplished. They also suggest the need for improved training in interdisciplinary research and changes in the incentive structure of research institutions. This review complements the climate-change literature by providing concrete suggestions about how to increase the utility of science from a region that is experiencing some of the most dramatic climatic change on the planet.

Knapp, C.N., and S. Trainor. 2013. Adapting science to a warming world. *Global Environmental Change* 23: 1296-1306.

6.2. Introduction

It is difficult to ignore climate change in Alaska. Since 1949, average annual statewide temperature has increased 1.7°C with the highest increases in the winter (Stafford et al., 2000). From melting glaciers to coastline erosion and from permafrost thaw to dangerous ice conditions, Alaskans can see and feel the tangible impacts of a changing climate. Flooding and erosion threaten many indigenous rural communities, as well as changes to traditional subsistence practices due to changes in fire regime, access, and distribution of food resources (United States General Accounting, 2003; Kofinas et al., 2010; Cochran et al., 2013). Changing conditions also threaten diverse sectors, including industry, public works, and public health (Markon et al., 2012). Alaskans face the tangible impacts of climate change, but often lack the long-term data sets and expertise to assess and understand changes in climate, hydrology, and ecology. In the past decade tribal, municipal and state governments, state and federal agencies, and other entities across Alaska have begun to identify not only what they need to know to help them adapt to changing conditions but also how the process of science itself should adapt to meeting increasingly complex information needs. We analyzed sixty-three climate related science needs assessments specific to Alaska. Our objective was to understand what stakeholders suggest about how the process and practices of climate science could change to improve informed response.

The voices of these Alaskans are part of a larger dialogue about how science should be conducted and how it can better inform decision-making. Scientific and research institutions have traditionally operated under the assumption that increased information would lead to better decisions (Feldman and Ingram, 2009; Cash et al., 2006), but this focus on information is often less effective than focusing on the actors and institutions that may require and utilize this knowledge (Mitchell et al., 2006). For knowledge to be used in practice, it must be salient, credible and legitimate (Cash et al., 2002). Salience is the relevance of information for decision-making, credibility addresses whether the knowledge produced is trustworthy and believable, and legitimacy refers to whether the resulting knowledge is judged to be fair and unbiased. Information from science can be rejected or ignored if one of these attributes is not met. Information may fail to be salient because it fails to match the temporal or spatial scale of the decision-space, or it may fail to address the complexity of the issue at hand (Jones et al., 1999). Despite peer review and rigorous methodology, research may fail the test of credibility if research results contradict local experience (Wynne, 1992). Information may be seen as illegitimate if the processes or application of knowledge are seen as unfair.

Researchers have debated how to increase the salience, credibility, and legitimacy of science to make it more useful in practice. Post-normal science has emerged as a way to actively engage citizens in finding solutions to their problems (Funtowicz and Ravetz, 1993). Resilience scholars have encouraged attention to the interactions between social and ecological systems (Folke, 2006). Scholars have bemoaned the inadequacy of current structures of knowledge production and dissemination, calling for a more collaborative and iterative dialogue to improve societies awareness of and ability to adapt effectively to climate change (Dilling and Lemos, 2011). Common suggestions to improve the relevance of science include co-production of knowledge, increased use of inter- and trans-disciplinary methods, integration of different forms of knowledge, user-driven science, and boundary organizations, or entities designed to increase collaboration across traditional boundaries (Berkes, 2009; Guston, 1999; Hulme, 2010; Pohl, 2008). Pettigrew et al. (2003) has suggested that research that helps to deliver both “what is” and “how to” knowledge may be more relevant than research that only focuses on one or the other. These suggestions have come from the research community and while some directly engage the stakeholders and decision-makers, many are generated strictly from expert knowledge. This project builds on existing literature by providing regionally grounded stakeholder suggestions for ways that science can provide more useful and relevant information to facilitate climate adaptation.

These reflections point to a departure from scientific norms and suggest a need for transformation of scientific approach, outcomes, and methods. The suggestions offered in this review may be challenging to implement because of current institutional structures. Institutions embody the “rules of the game” (Young, 2002), and are often fairly conservative or difficult to change. Resistance can be attributed to path dependence, or the way prior decisions constrain and shape current decisions (Pierson, 2000). Systems of knowledge creation and governance tend to become more rigid over time, leading to better system control, but decreasing system resilience (Holling and Meffe, 1996). Science is not just a method of gaining knowledge, but a series of institutions and organizations that structure the way scientific knowledge is produced. While there are signs that a transformation has already begun, implementing the suggestions identified in this review will require significant restructuring of scientific institutions, including new structures for data sharing, more emphasis on science translation, and revised scientific incentive structures.

6.3. Materials and methods

We analyzed sixty-three documents that expressed the climate change science and information needs of a diversity of stakeholders in Alaska. Criteria for document selection were that the document a) is related to climate change, b) addressed concerns of stakeholders in Alaska and, c) focused on answering questions to inform practical and policy decision-making (Clark, 2007). We included documents that were created for agencies, tribes, communities or governmental entities, and removed those that were created for research institutions (Appendix 6.1, Column 5). We identified sixty-three documents through web searches and confirmed the completeness of our sample through conversations with local experts in different sectors. Documents included needs assessments (35%), summaries of climate change impacts (23%), strategies to deal with climate change impacts (12%), presentations about climate change (12%) and letters, notes and other types of documents (17%). All of the documents were created between 1998 and 2012, with over half created since 2010 (Figure 6.1). We completed document identification in March 2012 so more recently created documents are not included in this review.

Documents addressed a range of research needs (Figure 6.2). Research institutions (25%), federal agencies (23%), state government (15%), non-profit groups (14%), state agencies (12%), local governments (5%), and others (5%) initiated needs assessments. Assessments created by research institutions were only included if they conducted the needs assessment to inform practical decision-making and policy. Entities served by needs assessments included local and state government (e.g. State of Alaska), federal agencies (e.g. US Forest Service), state agencies (e.g. Alaska Department of Fish and Game) and non-profit organizations (e.g. Center for Ocean Science Educational

Excellence). Documents in the review were created using expert knowledge (60%) and workshops (22%). More in-depth participatory assessments using interviews (3%), surveys (3%), and focus groups (2%) were rare. A complete list of documents included in the review and web addresses are included in the appendix (Appendix 6.1).

We used qualitative content analysis methods to understand what each document articulated about research needs and scientific process and practices. Content analysis is a technique that gathers sections of text related to similar themes, also called coding, to assess thematic patterns across documents (Bernard and Ryan, 2010). We started with a coding list based on prior research (Markon et al., 2012) and then expanded on this list as new themes of interest emerged (Denzin and Lincoln, 2005). The sixty-three needs assessments represented in this report represent over 4,000 pages of coded material. Each document had an average of 51 codes (separate themes) referenced per document and over 17,000 total coded passages. We coded all documents twice to make sure all stated needs were captured. After preliminary coding in NVivo, a qualitative analysis software, we used the reports and word search features to confirm that we had captured all the research needs identified in the documents. Once the coding was complete, we looked at both quantitative results (how many times each theme was addressed) and qualitative results (what was said about each theme).

6.4. Results

In this paper, we report stakeholder suggestions about how climate change science could be practiced to better inform decision-making. Results about specific information needs will be reported elsewhere (Knapp and Trainor, 2013). Stakeholders in Alaska articulate that the way science is currently practiced needs to change in order to meet growing demands for information and science application. Over 97% of reviewed documents address a need to change the current approach to science, data collection and storage, and the expected products of scientific research.

6.4.1. Scientific approach

Many of the documents in this review address the need for a new approach to climate change research (86%). The primary changes in approach they suggested were better coordination (79%), integration of local knowledge (54%), user-driven research (30%), and interdisciplinary approaches (21%) (Figure 6.3). The majority (79%) of the documents described the need for better coordination to meet climate change needs. The most common type of coordination discussed was coordination of both data management (54%) and data collection (35%), which will be discussed in the next section. Assessments also described the need for interagency (32%) and science-stakeholder coordination (32%). Many documents suggested that, “there needs to be a two-way dialogue to better understand their [local communities’] needs and issues (Appendix 6.1: #7, page 7).” Other types of coordination that were described included coordination between academia and policy-makers, within academia, and also between community members and decision-makers. The documents described how increased communication and coordination between existing entities could allow for more efficient knowledge production, sharing, and application.

Many of the documents describe the importance of integrating local knowledge into research (54%), but few were participatory in nature (8%). Documents discussed the role of local knowledge (48%), when to integrate local knowledge (32%) and best practices of integration (17%). The primary role discussed for local residents was either as data collectors or observers (37%). Although over a tenth of the documents thought local residents should be involved in developing research questions (13%), many fewer mentioned participation in other parts of the research process including reviewing data (2%), interpreting data (2%), or using local knowledge to ground-truth science (5%). Best practices of integration of local knowledge were not widely discussed (17%). The most common were the need to return information to communities (8%), to cultivate relationships with communities (5%), and to train local residents as researchers (5%). The discussion of local knowledge may have been more complete if local people had been more actively involved in the creation of needs assessment documents.

User-driven research was discussed by roughly a third of the stakeholder-generated needs assessments (30%). Assessments addressed the importance of understanding and adjusting research to address local questions and tailoring information to make it more relevant to local contexts. As one document suggested, it is important to “involve academics and decision-makers working together to ensure the value, relevance and impact of the research question (Appendix 6.1: #57, page 3)." The assessments talked about some of the barriers of these partnerships, including power differences, lack of funding for long-term partnerships, lack of incentives for academics to engage with communities, and the time investment needed. Long-term investment in relationships was described as an important component for successful user-driven science to develop. As one document expressed, "Sustained ongoing relationships need to be developed, and the odds of maintaining such relationships are improved if there is an institutional structure … that fosters continuity (Appendix 6.1: #23, page 29)."

A growing need for interdisciplinary approaches was also discussed by a fifth of the assessments (21%). These documents spoke about the importance of an interdisciplinary perspective to better understand the interactions between complex systems (11%) and to be able to contribute to practical solutions (10%). Documents described how interdisciplinary approaches are the best way to understand feedbacks between different system components, leading to more accurate predictions. As one stated, "There is a need for a better understanding of how climate change will interact with other environmental, economic, cultural and political stresses that could greatly amplify negative impacts (Appendix 6.1: #21, page 2)." Many of the documents described challenges associated with interdisciplinary science such as the structure of traditional disciplines, lack of skills in integration, and lack of funding for these efforts.

6.4.2. Data and monitoring needs

Over three-quarters of the needs assessments described data and monitoring needs (83%) including the need for improved monitoring (68%), insufficient baseline data (57%), desire for a central information hub for data sharing (44%), and a need for community involvement in local observation networks (37%). In addition to collecting baseline data, assessments were concerned about long-term monitoring programs in order to understand changes in trends (22%). As one document summarizes, "Nearly everyone, however, unanimously laments the paucity of data, analyses, information infrastructure, and decision support and sharing tools necessary for effective assessment and response to such changes (Appendix 6.1: #53, page 9)." They also described the importance of improved data management so that data are easily accessible and shared between organizations. As one document asserted, "There must be across-the-board improvement in the collection, coordination, and accessibility of information (Appendix 6.1: #10, page 4.8)."

About a third of the assessments suggested the importance of engaging local community members in observation networks (37%). Community monitoring systems were suggested for their ability to engender ownership of monitoring results, to provide local income, to inform indicators, monitoring techniques and interpretation, and to be more cost effective. Engaging community members in local monitoring efforts was also seen as a way for communities to learn about their region. It would also help to build local capacity so that community members can design and monitor indicators of importance to the community. As one document stated, "A key recommendation from our process is to promote and facilitate meaningful participation by communities in monitoring and sharing information about the species and ecosystems they use (Appendix 6.1: #49, page ix)."

6.4.3. Desired research outcomes

The assessments described several desired research outcomes: provide decision-making tools (65%), strengthen climate literacy (44%), create standards for data collection (29%), and better understand uncertainty (19%) (Figure 6.4). Documents discussed the importance of developing tools that decision-makers can use to make more informed decisions in the context of uncertainty (65%). Assessments most commonly addressed modeling, including downscaled climate models (44%) and ecosystem models to understand climate impacts (24%). The reviewed materials also suggested the importance of scenario planning tools to help make decisions in complex and uncertain contexts (14%). Many of the assessments spoke of multiple scales at which tools were needed from local to regional and state levels. Fewer assessments described the need to improve access to (5%) and use of tools (3%).

The importance of increasing climate literacy through education, translation, and capacity building was mentioned by almost half of the assessments (44%). Many of these documents (38%) talked about the need for increased public education and outreach. As one document stated, "Our ability to implement policy changes is largely affected by public perception and understanding. There is a critical need to develop and implement an education and outreach program aimed at improving public understanding of climate change and its affects (Appendix 6.1: #24, page 13)." Assessments also described the importance of translating climate science for specific audiences (19%). As one document stated, "There is a strong interest in improving the dissemination of climate change research, and its translation into information that can be used by decision-makers to support adaptation (Appendix 6.1: #23, page 3)." Assessments also addressed building the capacity of communities to gain understanding of how climate change was impacting local places (14%). Documents suggested it is critical to foster climate change literacy in order to both understand and adapt to changing contexts.

Stakeholders also felt that scientists should develop standards for data collection and analysis so that comparisons can be made across agencies and regions (29%). As one document described, "Currently there is no best practices standard, which results in difficulty communicating between agencies. A comprehensive strategy would complement a collaborative attempt to organize and make existing data accessible (Appendix 6.1: #56, page 3)." Standards were discussed for several fields including engineering design for infrastructure (16%), data collection for biological, physical and health indicators (17%), and vulnerability assessment approaches (2%). Data collection standards, including common practices and documentation metadata, were seen as a way to better coordinate resources and improve understanding of climate change impacts.

Assessments felt that it was important to reduce the uncertainty in climate change projections (16%), find better ways to understand overlapping uncertainties (6%), and then better communicate inherent uncertainty to the public (6%). As one document stated, "The uncertainty and risk of the current predictions should be well understood and incorporated in the decision process (Appendix 6.1: #53, page 31)."

6.5. Discussion

This document review provides practical and grounded reasons why and how the structure and practice of science needs to adapt to meet the challenges of climate change. While the findings mirror discussions in academic circles about the creation of useful science, these suggestions are grounded in stakeholder experience and their desire to understand climate change impacts, use climate-change science to make informed decisions, and adapt to a rapidly changing environment.

6.5.1. Creation of knowledge networks

The increased levels of coordination called for by documents suggest an adaptive and multi-scale form of boundary organization or network of boundary organizations. Boundary organizations connect entities and disciplines that have traditionally operated independently by facilitating dialogue and being accountable to both (Guston, 1999). Boundary organizations typically link science and policy realms, but some papers have mentioned their ability to bridge knowledge coalitions (van Buuren and Edelenbos, 2004) and disciplines (Cash et al., 2002). This review suggests a need for expanding this list of boundary-bridging functions so that boundary organizations serve as critical nodes linking individuals both within entities (scientists across scientific disciplines, agency employees across agencies) and across entities (science to policy, science to community) (Buizer et al., 2010). Documents describe how traditional disconnects between existing entities confound efforts to utilize science effectively in adapting to rapid change. This mirrors lessons from the social capital literature, which suggests that links between relatively isolated groups, or bridging capital, can be a critical resource for confronting challenges (Putnam, 2000). Climate adaptation planning will require new organizations and specialties to network insights from different disciplines and sectors.

6.5.2. Democratic data sharing

Documents suggest that research organizations and agencies have a responsibility to make scientific data publically accessible. Assessments define data as a shared resource rather than a proprietary good subject to the timelines of scientific research and publication. Given the lack of baseline data on many important indicators, the creation of communal repositories for stakeholders to access data would help to make more efficient use of data that exists and make sure that efforts are not being duplicated. Documents did not suggest a specific format for sharing data, but several potential options could be regional databases of ongoing research and relevant data or databases organized around a specific sector or question (e.g. NOAA’s Arctic Environmental Response Management Application (ERMA) tool). Efforts such as this are already occurring, as represented by the earth system grid that improves research efficiency by allowing open access to climate simulation data (Williams et al., 2009).

Social learning is a critical component of adaptive capacity (Chapin et al., 2009). Access to data collected at different spatial scales would facilitate multi-level learning for more sustainable governance of natural resources (Pahl-Wostl, 2009). While the documents in this review identify the need for more data sharing, they do not discuss the outreach and education efforts that may be required for organizations to use this data. A prior study has suggested that providing trainings, forums and opportunities to interface with the data may be as important as data acquisition, site maintenance and interface development for making sure that data informs decision-making (Tribbia and Moser, 2008). As communities wrestle with adaptation decisions, data could be made more accessible and data interpretation services could be provided so that decision-makers can understand potential impacts and viable adaptation strategies.

6.5.3. Partnering with other ways of knowing

More than half of the documents discussed the importance of integrating local knowledge in climate change assessment and adaptation planning. This mirrors research on local and indigenous knowledge suggests that these forms of knowledge can complement scientific knowledge and offer insights that are otherwise unavailable (Berkes, 2008). Results echo ethnographic studies that show how local knowledge can strengthen our overall understanding of climate change impacts and increase the viability of adaptation strategies (Roncoli, 2006). Documents spoke broadly about integrating local knowledge, but rarely mentioned local involvement in interpretation or validation (7%). This lack of attention suggests a need to move beyond data mining toward comprehensive partnerships between scientists and communities (Trainor, in press; Nadasdy, 1999). Partnerships that focus on long-term relationships (Eden, 2011) and co-production of knowledge (Lemos and Morehouse, 2005) are important for effectively integrating local knowledge.

6.5.4. Interdisciplinarity

Stakeholders see the problem with narrow disciplinary understandings and would like to see more integration across disciplines. They describe several barriers to interdisciplinarity including existing "stove-piped" structures of academia and agencies and the inertia that comes with them. This parallels arguments in the literature calling for more integrated, interdisciplinary approaches to climate change and other global environmental problems (Lynch et al., 2008; National Research Council, 2011). Many of the concerns the documents raise are being addressed in the form of increased interdisciplinary training (e.g. Integrative Graduate Education and Research Traineeship-IGERT programs), the rise of interdisciplinary journals (e.g. Climate, Weather and Society), and the establishment and funding of boundary organizations that link science to society (Regional Integrated Sciences and Assessment-RISAs) and that help to coordinate science over large areas (Landscape Conservation Cooperatives-LCCs). While these efforts are signs of change, there is more work to be done. Universities and science funding agencies will need to invest in think tanks, new curriculum, and the development of standards and criteria for interdisciplinary research (Hadorn et al., 2006).

6.5.5. Outcomes of research

There is an increasing gap between scientific and layperson understandings of climate change, and various initiatives have tried to address this gap in perceptions (Griggs and Kestin, 2011). This review described products and outcomes of research that go beyond traditional science outcomes (Cash et al., 2003; Buzier et al., 2010). These suggestions expand upon existing responsibilities of scientists to include the responsibility to: communicate uncertainty effectively, build climate literacy, develop decision-support tools, and set standards for data collection. Each of these recommendations suggests the need for new positions and organizations that can fill these translation or application roles. Boundary organizations at the intersection of science and policy may assist to develop information that is credible, legible and salient (Cutts et al., 2011). Research has suggested that ongoing participation in boundary organizations helps to facilitate the use of climate science in decision-making as it moderates risk aversion and initial skepticism (Kirchhoff et al., 2013).

6.5.6. Interconnections between suggestions

Each suggestion mentioned above provides a snapshot of how science might be practiced in the future. The individual suggestions are interdependent and suggest the need for transparent and open information sharing, focus on practical and applied questions, dialogue between different ways of knowing, and consistency with data collection. For instance, increased coordination between research entities around standard data collection practices could improve the ability to collect ongoing monitoring data. Meaningful integration of local knowledge could inspire user-driven science and stimulate the creation of new positions for local people to collect data. Increased collaboration and communication between local people, decision-makers, and funders may help increase the dialogue about uncertainty and highlight how uncertainty should best be communicated. Iterative testing and discussions of decision-making tools with local decision-makers and across disciplines may make tools more useful and relevant. The findings in this review offer a vision for how science might adapt to climate change, but they are snapshots only and not a roadmap.

6.5.7. Representativeness of Review

Our sample may be biased towards groups that are either proactively planning for climate change or sectors that receive attention because of their importance to society or potential vulnerability. Their suggestions may differ from groups that do not have the resources or will to consider climate change impacts. Almost a third of the assessments were conducted for a group by a secondary entity and over half of these are conducted for tribal entities. Recommendations from these needs assessments may differ from what tribal entities would directly identify for themselves. The suggestions of these experts may be broader and more tailored to decision-making at middle to upper organizational scales. These documents may miss some suggestions from the individual and community level. Despite these potential biases, this review represents a wide variety of groups in Alaska concerned with the practical problems created by climate change. Their suggestions offer insight from the front lines of climate change about how science might be more relevant for decision-making.

6.5.8. Potential for implementation of suggestions in Alaska and beyond

6.5.8.1.1. Potential for implementation in Alaska. Alaska has several unique characteristics that set it apart from other regions and may serve to either impede or expedite implementation of these suggested changes. Alaska is experiencing climate change and its impacts more rapidly than lower latitudes (Intergovernmental Panel on Climate Change, 2007) and is relatively data-poor (Hinzman et al., 2005). Climate data in particular is exceptionally sparse in Alaska (Fleming et al., 2000). For example, Alaska is over 9 times larger than Washington State, and has only twenty (20) National Weather Service first order observation stations, as compared to two hundred (200) stations in Washington (Alaska Climate Research Center, 2013). The scarcity of available data may be the basis for suggestions for greater data sharing, and may promote greater willingness to coordinate and share.

Alaska is home to 40% of all federally recognized tribes in the U.S.A. (Bureau of Indian Affairs, 2010), and poverty rates and food insecurity in rural Alaska are high (United States Department of Agriculture, 2013). Flooding and erosion threaten the majority of rural Alaskan indigenous communities (86%) (United States General Accounting Office, 2003). These immediate threats may motivate more applied research, however practical concerns and historical legacies may pose barriers effective partnerships with communities. There are 229 different village and tribal governments in Alaska, with no overarching entity to connect researchers with the most knowledgeable local residents. Cultural barriers make it difficult to bridge western science and Native ways of knowing (Cajete, 2000, Berkes and Berkes, 2009). In addition, communities are often interested in local, integrative, and community-scale issues, which rarely overlap with the disciplinary approach and spatial scale common to scientific inquiry

(Huntington et al., 2006). These factors have led to historic tensions between researchers and communities. The suggestions for integrating local knowledge and focusing on more interdisciplinary research may stem from these contextual factors. It is possible that there are more climate-change research needs assessments in Alaska due to the immediacy of the threat and the direct impacts on Native communities. While this review acknowledges a need to better connect with community concerns, historic legacies may make it challenging to implement these suggestions.

Alaska has one major research institution, but there are researchers that come from all over the world to study Alaskan systems. This leads to many overlapping research efforts that are poorly coordinated. There are examples of efforts to share topic-specific data (e.g. NOAA's Arctic Environmental Response Management Application (ERMA) tool), but there is no overarching structure to coordinate research and share findings. The spatially and institutionally diffuse structure of research endeavors in Alaska provides the context for desires for a knowledge network and greater data sharing. Existing structures, however, do not facilitate this level of coordination and new organizations or institutions may need to be developed to provide these services.

6.5.8.1.2. How applicable are these results to other places? Despite these unique characteristics, climate change will pose similar challenges for other regions. Climate scientists struggle with how climate change will impact particular places and how best to downscale models to make them practically useful to decision-makers (Leung et al., 2003). Adaptation practitioners wrestle with how to effectively bridge policy and science (Weichselgartner and

Marandino, 2012), and how to communicate climate science more effectively to the general public (Shackley and Wynne, 1996). Barriers to implementation exist in institutions, funding, and education (Averyt, 2010); divergent priorities, cultural values and trust (Weichselgartner and Kasperson, 2010); and methodological consistency and reliability (Murdoch and Clark, 1994). These shared challenges suggest that the procedural revisions suggested in this review are relevant to other regions.

6.5.9. Initial steps forwards

What are some concrete steps that can lead us towards a more adaptive science? On an individual level, researchers can chose to adopt a more place-based approach to research, which may allow researchers to maintain continuity with community members while answering practical and theoretically interesting questions. Researchers can also consider the knowledge-application interface as an exciting opportunity to learn more about the dynamics of social-ecological systems. There is a growing need for transformative learning (O'Brien et al., 2013), the integration of knowledge systems (Cornell et al., 2013), and new organizations that can build bridges between science and application (Buzier et al., 2010). Funders could help to encourage this transformation by encouraging collaboration and data sharing, providing funds for local participation, requiring interdisciplinary teams, and by requesting scientists to use standard data collection techniques. New institutions, or centers within institutions, can provide a tangible example of how the broader incentive structure in academia might shift to value stakeholder engagement, reward the ability to connect science with action, promote community outreach, and set requirements to publish with community members.

6.6. Conclusions

Alaska is currently facing challenges that will be faced more broadly through society as climate change projections are realized. This meta-analysis of stakeholder-generated climate-change needs assessments in Alaska suggests a revised role for science in society that is more relational, contextual, and transparent. While traditional scientific inquiry provides a systematic and valuable form of knowledge acquisition, it often falls short of providing context specific information needed to adapt to rapid climate change in the North. Meeting present day climate challenges requires an evolving relationship between science and practical decision-making. The findings from this study corroborate recent research on the science-policy interface (Weichselgartner and Marandino, 2012), and provide concrete suggestions about how the practices and processes of science might shift. The findings demonstrate that the desire to transform science is not only internal, but has a groundswell of support from a wide range of decision-makers. Practical solutions offered by stakeholders include accessible data-sharing archives, networks for knowledge sharing, long-term science-community partnerships at a regional scale, improved training in interdisciplinary research, changes in the incentive structure of research institutions, and better lines of communication between funders, researchers and stakeholders to prioritize funding. This assessment of stakeholder documents has provided insight into the ways in which science needs to adapt to maintain and increase its credibility, legitimacy, and salience within the context of climate change.

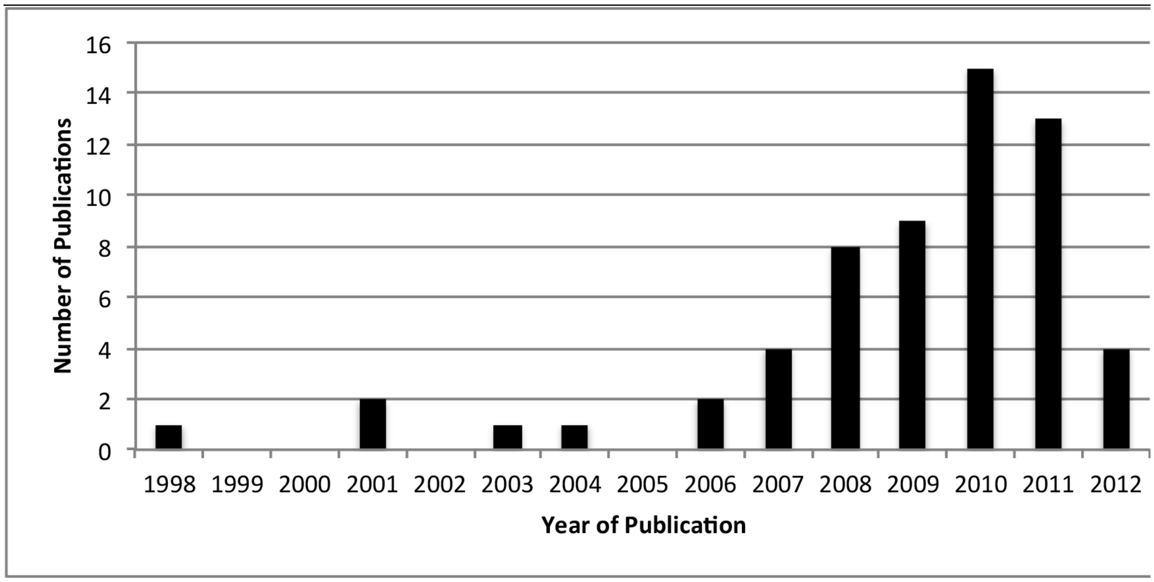

Figure 3.1. Number of needs assessment publications per year included in this review (Publications were collected until March 2012).

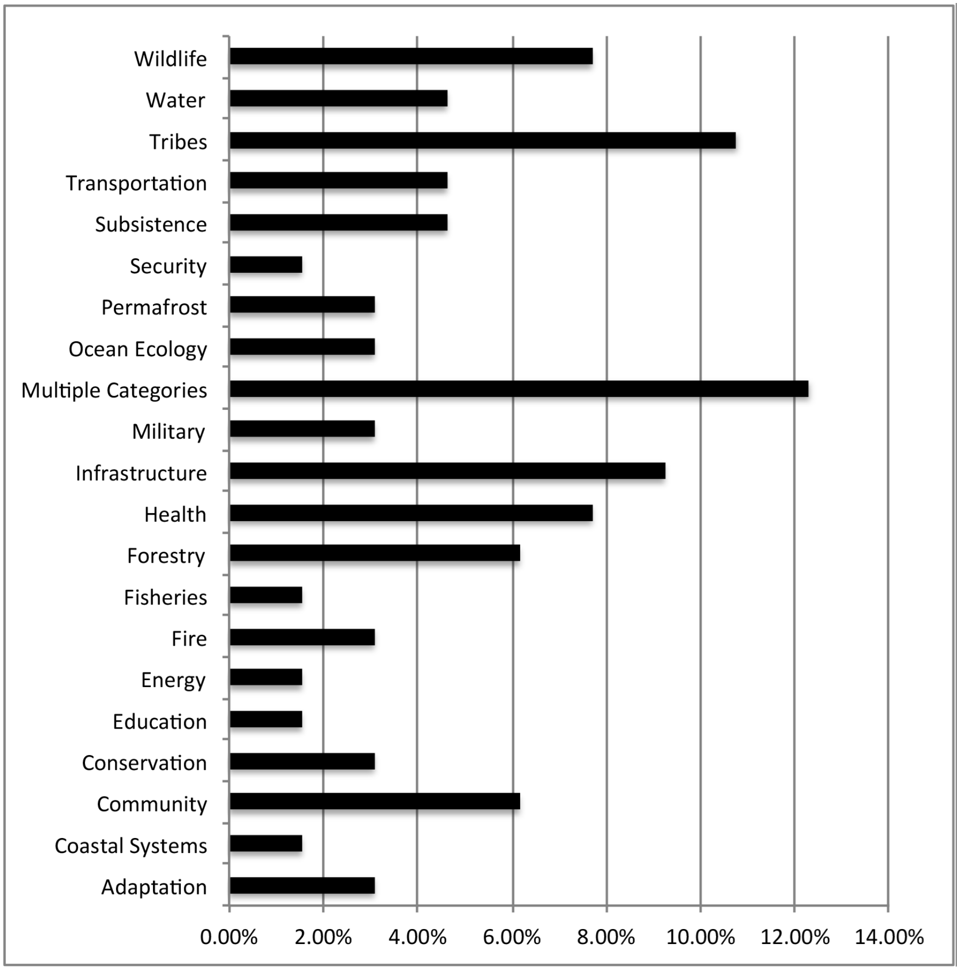

Figure 6.2. Percentage of reviewed documents that addressed the following research themes.

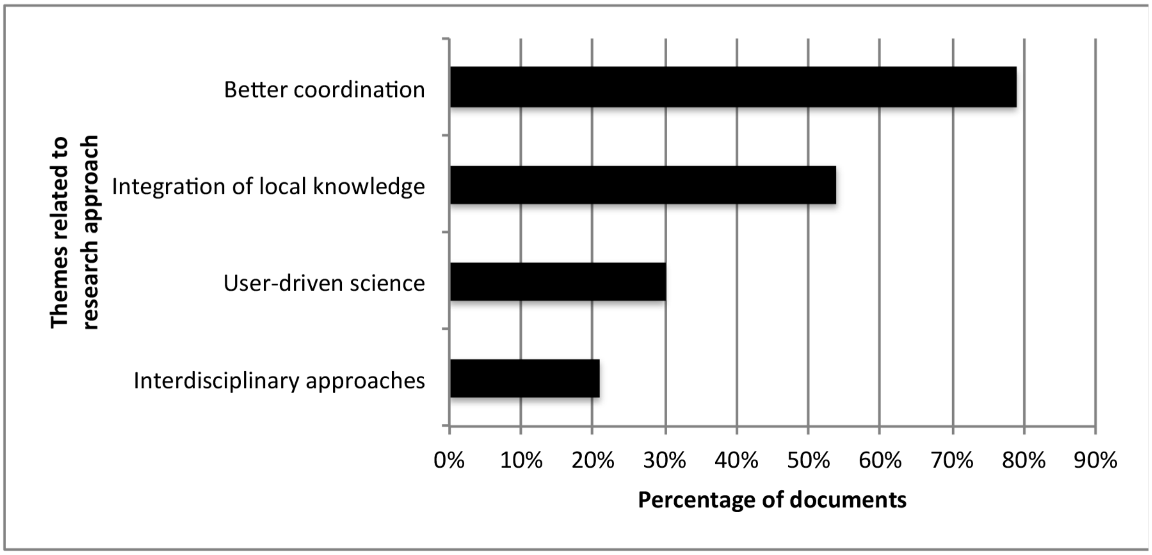

Figure 6.3. Percentage of reviewed documents that mentioned the following themes related to research approach.

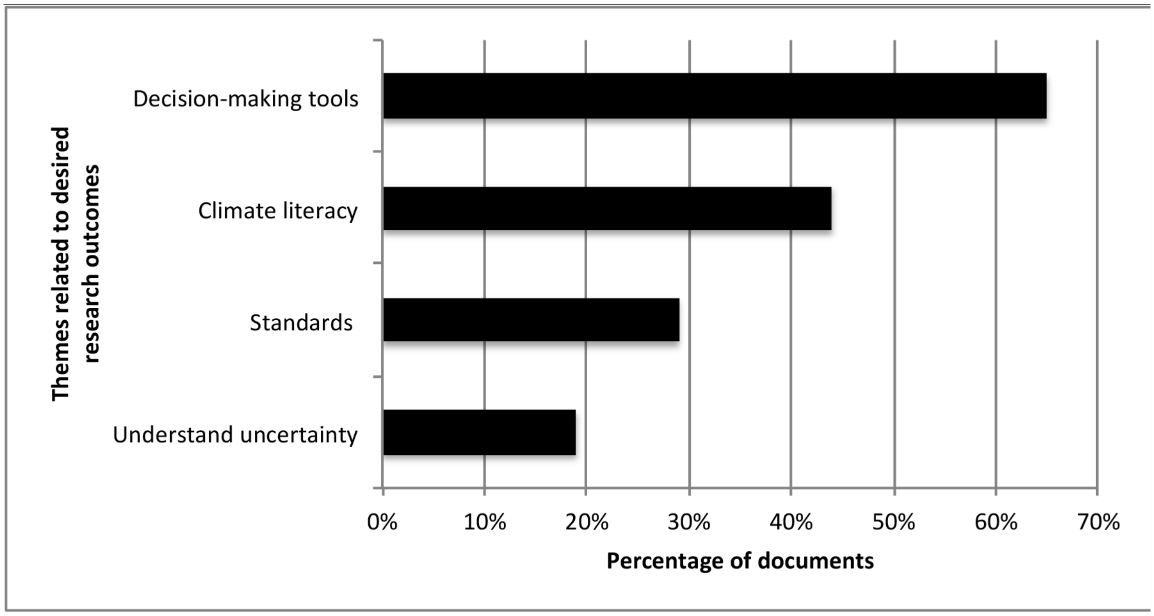

Figure 6.4. Percentage of reviewed documents that mentioned the following themes related to desired research outcomes.

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Appendix 6.1. Documents Included in Needs Assessment Review

#	Title	Date	URL	Conducted for	Type	Primary sector	Method
1	2011 Science Accomplishments	2011	http://www.fs.fed.us/pnw/pubs/2011-science-accomplishments.pdf	United States Forest Service	Summary	Forestry	Expert Knowledge
2	A Summary of the Alaskan Marine Arctic Conservation Action Plan	2010	http://www.nature.org/images/summary-of-arctic-cap-2.pdf	The Nature Conservancy	Strategy	Conservation	Expert Knowledge
3	Adapting to Climate Change: A Call for Federal Leadership	2010	http://www.c2es.org/docUploads/adaptation-federal-leadership.pdf	United States Government	Strategy	Adaptation	Expert Knowledge
4	Alaska Climate Impact Assessment: A Commissioner's Summary of Findings	2008	http://www.uaa.alaska.edu/schoolofengineering/workshops/upload/ACIAC-3-27-08.pdf	Alaska State Legislature	Presentation	General	Expert Knowledge
5	Alaska DOT & PF Adaptation to Climate Change	No Date	http://climatechange.transportation.org/pdf/gregovichadot.pdf	Department of Transportation	Presentation	Infrastructure	Expert Knowledge
6	Alaska Energy Research Needs	2010	ftp://ftp.aidea.org/2010AlaskaEnergyPlan/2010%20Alaska%20Energy%20Plan/Research%20Needs%20Assessment/Research%20Needs%20Assessment.pdf	The Alaska Energy Authority	Needs Assessment	Energy	Expert Knowledge
7	Alaska Region Climate Change Response Strategy 2010-2014	2010	http://www.nps.gov/akso/docs/AKCCRS.pdf	National Park Service	Strategy	Conservation	Expert Knowledge
8	Alaska Subsistence Lifestyles Face Changing Climate	2001	http://www.nwpublichealth.org/docs/nph/f2001/craver_f2001.pdf	Subsistence communities	Article	Subsistence	Expert Knowledge
9	Alaska Wildland Fire Coordinating Group Fire Research Needs 2011	2011	http://fire.ak.blm.gov/content/admin/awfcg_committees/Fire%20Research%20Development%20and%20Application/c.%20AWFCG_Fire%20Research%20Needs_2011_Final.pdf	Alaskan Land management agencies	Needs Assessment	Fire	Expert Knowledge
10	Alaska's Climate Change Strategy	2010	http://www.climatechange.alaska.gov/aag/docs/aag_all_rpt_27jan10.pdf	Alaska State Legislature	Needs Assessment	General	Expert Knowledge
11	Alaska's Climate Change Strategy: Public Infrastructure and Climate Change	2008	http://www.climatechange.alaska.gov/docs/DOT_pfrost_jun08.pdf	Alaska Department of Transportation and Public Facilities	Presentation	Infrastructure	Expert Knowledge

Appendix 6.1. Documents Included in Needs Assessment Review (continued).

12	American Indian and Alaska Native Climate Change Project	2011	http://2011.ruralassembly.org/sites/2011.ruralassembly.org/files/AmericanIndianAlaskaNativeClimateChange.pdf	Tribal governments and native peoples	Notes, letters or other	Tribes	Expert Knowledge
13	Arctic Ocean Synthesis: Analysis of Climate Change Impacts in the Chukchi and Beaufort Seas with Strategies for Future Research	2008	http://www.arcdiv.org/news/NPRB_report2_final.pdf	North Pacific Research Board	Needs Assessment	Ocean Ecology	Workshop
14	Changing Conditions in the Arctic: Strategic Action Plan	2011	http://www.whitehouse.gov/sites/default/files/microsites/ceq/sap_8_arctic_full_content_outline_06-02-11_clean.pdf	Multiple agencies and Arctic governments	Strategy	Ocean Ecology	Expert Knowledge
15	City of Homer: Climate Action Plan	2007	http://www.sustainablehomer.org/climate_change_files/CAP%20Implementation%20Final%20Report%2012-14-09.pdf	City of Homer	Strategy	Community	Literature Review
16	Climate Change and Health Impacts: Point Hope	2009	http://www.anthc.org/chs/ces/climate/upload/Point-Hope-CCHIA-Draft-Final.pdf	Village of Point Hope	Strategy	Health	Interview
17	Climate Change and Private Forest Landowners in Alaska: A Needs Assessment	2011	http://www.tfrec.wsu.edu/pdfs/p2259.pdf	Private forest landowners	Needs Assessment	Forestry	Focus Group
18	Climate Change and Tribes	2012	http://srhrl.aaas.org/coalition/Meetings/2012/January/PowerPoints/Farley.pdf	Tribal governments and native peoples	Presentation	Forestry	Expert Knowledge
19	Climate Change and Water Infrastructure Forum	2008	http://yosemite.epa.gov/R10/ECOCOMM.NSF/95534441d036059c882574740052e10f/47f3373c82647b3a8825746b00600267/$FILE/CCWI%20Forum%20Notes%20092508.pdf	Local governments and tribes	Summary	Water	Workshop
20	Climate Change Impact Assessment for Surface Transportation in the Pacific Northwest and Alaska	2012	http://www.wsdot.wa.gov/research/reports/fullreports/772.1.pdf	Department of Transportation	Needs Assessment	Transportation	Expert Knowledge
21	Climate change impacts, vulnerabilities, and adaptation in Northwest Alaska	2006	http://www.decisionresearch.org/pdf/582.pdf	Northwest Arctic Borough	Summary	Community	Workshop

Appendix 6.1. Documents Included in Needs Assessment Review (continued).

22	Climate Change in Kivalina, Alaska Strategies for Community Health	2011	http://www.anthc.org/chs/ces/climate/upload/Climate-Change-in-Kivalina-Alaska-Strategies-for-Community-Health-2.pdf	Village of Kivalina	Strategy	Health	Interview
23	Climate Change Research Needs Workshop, Meeting of the Western Governors' Association	2007	http://www.westgov.org/wswc/07%20climate%20change%20report.pdf	Western Governor's Workshop	Needs Assessment	Water	Workshop
24	Climate Change Strategy	2010	http://www.adfg.alaska.gov/static/lands/ecosystems/pdfs/climatechangestrategy.pdf	Alaska Department of Fish and Game	Strategy	Wildlife	Expert Knowledge
25	Climate Change, Permafrost, and Impacts on Civil Infrastructure	2003	http://www.arctic.gov/publications/permafrost.pdf	Multiple	Summary	Permafrost	Expert Knowledge
26	Climate change: anticipated effects on ecosystem services and potential actions by the Alaska Region, U.S. Forest Service	2010	http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_038171.pdf	United States Forest Service	Summary	Forestry	Literature Review
27	Climate Change: Predicted Impacts on Juneau	2007	http://www.juneau.org/clerk/boards/Climate_Change/CBJ%20_Climate_Report_Final.pdf	City and Borough of Juneau	Summary	Community	Expert Knowledge
28	Confronting Climate Change: An Early Analysis of Water and Wastewater Adaptation Costs	2009	http://www.amwa.net/galleries/climate-change/ConfrontingClimateChangeOct09.pdf	National water and wastewater sector	Summary	Water	Expert Knowledge
29	Current issues and research agendas from Alaska Native Communities	2004	http://www.nativescience.org/pubs/Current%20Issues%20and%20Research%20Agendas.pdf	Native communities of Alaska	Needs Assessment	Tribes	Workshop
30	Effects of Climate Change on Subsistence Communities in Alaska	1998	http://www.besis.uaf.edu/besis-oct98-report/Subsistence.pdf	Subsistence communities	Summary	Subsistence	Expert Knowledge
31	Elim Hazard Impact Statement	2012	http://www.commerce.state.ak.us/dca/planning/accimp/Elim.html	City of Elim	Summary	Infrastructure	Multiple Methods
32	Emerging Issue Summaries	2009	http://quickplace.mtri.org/LotusQuickr/nssi/PageLibrary8525709E00726B9D.nsf/h_Toc/C0B3943D179ACCFA85257680004EC257/$file/FINAL_Emerging_Issues_01-06-2010.pdf	Multiple	Needs Assessment	General	Expert Knowledge

Appendix 6.1. Documents Included in Needs Assessment Review (continued).

33	Executive Summary on the USFWS and USGS Climate Change Forum for Alaska	2007	http://alaska.fws.gov/climate/pdf/executive_summary.pdf	United States Forest Service and United States Geological Survey	Notes, letters or other	General	Workshop
34	Final Report: Climate Impact Assessment Commission	2008	http://www.housemajority.org/coms/cli/cli_finalreport_20080301.pdf	Alaska State Legislature	Needs Assessment	General	Expert Knowledge
35	Hazard Impact Assessment: Kipnuk, AK	2011	http://www.commerce.state.ak.us/dca/planning/accimp/kipnuk.htm	Kipnuk traditional council	Summary	Infrastructure	Multiple Methods
36	Health and Culture Technical Working Group Meeting Summary	2008	http://www.climatechange.alaska.gov/aag/docs/HC9_Ag_03nov08.pdf	Alaska State Legislature	Notes, letters or other	Health	Expert Knowledge
37	Health Perspective On Climate Change: A Report Outlining the Research Needs on the Human Health Effects of Climate Change	2010	http://www.niehs.nih.gov/health/assets/docs_a_e/climatereport2010.pdf	National public health	Needs Assessment	Health	Expert Knowledge
38	Health Problems Heat Up: Climate Change and the Public's Health	2009	http://healthyamericans.org/reports/environment/TFAHClimateChangeWeb.pdf	National public health	Needs Assessment	Health	Expert Knowledge
39	Immediate Action Work Group Recommendations	2009	http://www.climatechange.alaska.gov/docs/iaw_finalrpt_12mar09.pdf	Alaska State Legislature	Needs Assessment	Community	Expert Knowledge
40	Impacts of Climate Change on Transportation Infrastructure in Alaska	2001	http://climate.dot.gov/documents/workshop1002/smith.pdf	Department of Transportation	Article	Transportation	Literature Review
41	Impacts of Climate Change on Tribes in the United States	2009	Impacts of Climate Change on Tribes in the United States	Tribal governments and native peoples	Summary	Tribes	Expert Knowledge
42	Implications of Climate Change and Research Needs for Built Infrastructure in Cold Regions	2009	http://defenseassetsworkshop2009.uaa.alaska.edu/Zufelt.pdf	Department of Defense: Alaska	Presentation	Infrastructure	Expert Knowledge
43	Implications of Climate Change and Research Needs for Coastal Processes in Cold Regions	2009	http://defenseassetsworkshop2009.uaa.alaska.edu/Kinner1.pdf	Multiple: Department of Defense and land management agencies	Presentation	Coastal Systems	Expert Knowledge

Appendix 6.1. Documents Included in Needs Assessment Review (continued).

44	Implications of Climate Change and Research Needs for Training Lands and Natural Ecosystems in Cold Regions	2009	http://defenseassetsworkshop2009.uaa.alaska.edu/Hayden1.pdf	Department of Defense: Alaska	Presentation	Military	Literature Review
45	Kotzebue Meeting Notes	2010	http://www.arcus.org/files/page/documents/893/lcckotzebuenotes.pdf	Multiple: Regional	Notes, letters or other	General	Workshop
46	Needs Assessment of Alaska Teachers	2010	http://www.coseealaska.net/files/alaska/FinalAKNeedsAssessment.pdf	Alaskan teachers	Needs Assessment	Education	Survey
47	Nelson Lagoon Hazard Impact Statement	2011	http://www.aebfish.org/nl/hiaNL102811.pdf	Aleutians East Borough	Summary	Infrastructure	Multiple Methods
48	Optimizing Military Training Land Use into the Future, NH Joint Engineering Society Conference	2011	http://www.nhjes.org/2011_Joint_Conference/presentations/1B%20Shoop%20%20AK%20training%20lands%20v2[1].pdf	Department of Defense: National	Presentation	Military	Expert Knowledge
49	Our Wealth Maintained	2006	http://www.adfg.alaska.gov/static/species/wildlife_action_plan/cwcs_main_text_combined.pdf	Alaska Department of Fish and Game	Needs Assessment	Wildlife	Expert Knowledge
50	Prioritized fire research topics for Alaska	2011	http://fire.ak.blm.gov/content/admin/awfcg_committees/Fire%20Research%20Development%20and%20Application/f.%20Fire%20Research%20Topic%20Promotion%20Flyer_Final.pdf	Land management agencies	Needs Assessment	Fire	Workshop
51	Priority Information Needs: Federal Subsistence Fisheries	2010	http://alaska.fws.gov/asm/pdf/meetingbooks/ykfall12/frmp.pdf	Multiple: USFWS, Subsistence communities	Request for Proposals	Fisheries	Expert Knowledge
52	Research Needs Statements for Climate Change and Transportation.	2010	http://onlinepubs.trb.org/onlinepubs/circulars/ec144.pdf	National Department of Transportation	Needs Assessment	Transportation	Expert Knowledge
53	Research Needs Work Group: Recommendations on Research Needs Necessary to Implement an Alaska Climate Change Strategy	2009	http://www.climatechange.alaska.gov/docs/rn_12jun09_dftrpt.pdf	Alaska State Legislature	Needs Assessment	Adaptation	Expert Knowledge

Appendix 6.1. Documents Included in Needs Assessment Review (continued).

54	Resource for Consideration by NCA Teams Addressing the Impacts of Climate Change on Native Communities	2011	http://www.tribesandclimatechange.org/project_docs/submission_to_nca_2011_11_30.pdf	Tribal governments and native peoples	Notes, letters or other	Tribes	Workshop
55	Sea Grant's Role in Understanding and Preparing for Climate Change along America's Coast	No Date	http://www.glerl.noaa.gov/seagrant/ClimateChangeWhiteboard/Resources/Other/SeaGrantSelectedClimateChangeImpacts.pdf	Subsistence communities	Notes, letters or other	Subsistence	Expert Knowledge
56	Snow, Ice and Permafrost Hazards in AK	2011	http://ine.uaf.edu/accap/documents/AlaskaCryosphereHazardFinal.pdf	Alaskan agencies and other organizations working on permafrost	Needs Assessment	Permafrost	Workshop
57	The Arctic Climate Change and Security Policy Conference: Final Report and Findings.	2008	http://www.carnegieendowment.org/files/arctic_climate_change.pdf	US Government	Summary	Security	Workshop
58	The effects of a changing climate on key habitats in Alaska	2010	http://www.adfg.alaska.gov/static/lands/ecosystems/pdfs/sp10_14.pdf	Alaska Department of Fish and Game	Summary	Wildlife	Expert Knowledge
59	Tribal Recommendations for the Fiscal Year 2012 Department of the Interior Climate Change Adaptation Initiative	2012	http://www.tribesandclimatechange.org/docs/tribes_345.pdf	Tribal governments and native peoples	Notes, letters or other	Tribes	Expert Knowledge
60	Tribal Science Priorities for the National EPA	2011	http://www.epa.gov/tp/pdf/nts-priorities-guide-2011.pdf	Tribal governments and native peoples	Needs Assessment	Tribes	Expert Knowledge
61	U.S. Climate Change Science Program Stakeholder Listening Session in Anchorage	2008	Not available online	Multiple	Notes, letters or other	General	Workshop
62	Western Association of Fish and Wildlife Agencies Climate Change Committee Annual Update for Committee Members	2011	http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentVersionID=57780	Alaska Department of Fish and Wildlife	Needs Assessment	Wildlife	Survey
63	Wildlife Response to Environmental Arctic Change	2008	http://www.arcus.org/alaskafws/downloads/pdf/WildREACH_Workshop_Report_Final.pdf	USFWS	Needs Assessment	Wildlife	Workshop

7. Conclusion

The previous chapters present the results of a research journey that was equally motivated by research questions and a commitment to generating user-relevant information. In this conclusion, I refer to each chapter by the short title provided in the introduction followed by the chapter number. My primary research question related to what types of information and insights local communities could contribute to adaptation planning. In two case studies (Gunnison CC: 2 and Denali CC: 3), I compared and contrasted the knowledge of different stakeholder groups in order to understand who was important to engage in climate adaptation planning and why. I also explored current adaptation strategies that might be mobilized for adaptation planning (Gunnison CC: 2 and Denali CC: 3). A secondary research question related to how local knowledge and perceptions influence social-ecological systems feedbacks. I documented local knowledge of Gunnison Sage-grouse and uncovered divergent narratives between managers and local residents about species decline (Gunnison LK: 4). I also described local perceptions of an Endangered Species Act listing decision, which may lead to decreased participation in conservation strategies and increased sales of land and water (Gunnison perceptions: 5). Finally, I was interested in what stakeholders had to say about how science could be more relevant and useful to decision-making. For this question, I reviewed stakeholder-driven needs assessments in Alaska to look at stakeholder suggestions about how the practices and processes of science need to change (Needs assessment: 6).

In parallel with my original research questions was a personal commitment to doing research that is useful for community decision-making. Each of the projects described in this dissertation was motivated by interest on the part of communities that I studied, and the final shape of the dissertation was formed by my relationships with community members and awareness of community concerns. The climate change assessment in Gunnison (Gunnison CC: 2) will be used to help inform development of adaptation strategies by the Gunnison County Climate Change Working Group. The climate change observations in Denali National Park and Preserve (henceforth Denali)(Denali CC: 3) will help to inform the Subsistence Resource Commission, the body that makes recommendations to the Governor and Secretary of the Interior about subsistence regulations in Denali, as well as informing adaptation planning efforts within Denali. The chapters on Gunnison Sage-grouse (Gunnison LK: 4, Gunnison perceptions: 5) were submitted to the United States Fish and Wildlife Service during the comment period on the potential listing. The review of needs assessments will clarify for the scientific community what stakeholders suggest about how to make science more salient and legitimate in the context of climate change (Needs assessment: 6).

Most graduate students start with theoretically interesting and unanswered questions rather than with community concerns. This traditional approach allows students to frame their research in existing theory, design their research to inform that theory, and focus on the questions rather than reflecting on what information, methods, and processes might provide the most useful information to community members and decision-makers. In my dissertation research, I started with community concerns and focused on providing information that would be relevant to community members. Although I am aware of the theory that informs these questions, my primary goal was to inform local decision-making. This place-based and user-driven approach is increasingly suggested as a means to make scientific findings more relevant and useful (Moser 2010, Dilling and Lemos 2011, Knapp and Trainor 2013). In this chapter, I will describe the broader implications and theoretical contributions to several bodies of literature, including resilience thinking, political ecology, and the sociology of science.

7.1. Implications

Each chapter of this dissertation discusses findings to a set of specific research questions and implications of those findings. The findings also relate to each other and lead to broader conclusions about climate-change adaptation, knowledge sharing, and place-based research. The findings from climate-change adaptation contribute to the fields of local knowledge, sociology of science, and resilience. The findings related to knowledge sharing contribute to the fields of political ecology, local knowledge, and resilience. The findings about place contribute to the sociology of science and scientific practice. In the following sections, I describe the implications of the body of work represented in this dissertation.

7.1.1. Climate Adaptation

The first broad contribution of this dissertation is to the fields of climate change adaptation, and theories of local knowledge, sociology of science and resilience. Few prior studies have compared the climate-change observations, adaptations and opinions of different stakeholder groups (e.g., Vasquez-Leon et al. 2003). In Chapter 2 (Gunnison CC), I interviewed owners and managers of both ranching and recreation-based businesses to document how vulnerable and resilient they are to current and potential future climates and what they are doing to adapt to current stressors. In Chapter 3 (Denali CC), I interviewed a range of long-term residents of the Denali region (park employees, subsistence residents, business owners) to document their observations of climate change and suggestions about how the National Park Service should adapt. Focusing on a single type of stakeholder would have failed to capture all the observed changes and perceived impacts of change. Critics of the dichotomy between local and scientific knowledge have suggested that all knowledge is hybrid and heterogeneous (Murdoch and Clark 1994, Agrawal 1995). This heterogeneity in knowledge has often been explored within a single stakeholder group or type rather than between them (Davis and Wagner 2003, Knapp and Fernandez-Gimenez 2009). This dissertation demonstrates that no single stakeholder group accounted adequately for all the knowledge available in either Denali or Gunnison. The suggestions for adaptation strategies made by diverse stakeholder groups provided a broader range of potential adaptation strategies than any single group. These studies set a precedent for broader public engagement in decision-making processes related to climate change adaptation and conservation.

Sociology of science has explored the ways that scientific knowledge is produced in specific places (Goldman et al. 2011). This dissertation shows how local knowledge is also produced in specific places through unique experiences and patterns of use. The resulting heterogeneity is important to harness for adaptation planning. For instance, subsistence users (Denali CC: 3) shared novel observations of change based on their use of the natural world, including increased bank erosion and changes to timing of freeze-up. This dissertation found that those who have more direct experiences in the natural world have more and different observations of change than those who spend less time in the natural world. Engaging these stakeholders can help to document multifaceted observations of change as well as an understanding of current and potential future adaptations, potential impacts, and tradeoffs between livelihoods and individuals (Gunnison CC: 2, Denali CC: 3).

This dissertation supports prior research that has suggested the importance of co-production of knowledge (e.g., Hegger et al. 2012) and the synergy of different ways of knowing (Knapp et al. 2011). In a climate-change context, it is especially critical to understand both large-scale patterns and predictions as well as local perceptions and implications. This is due to increasing interconnection between places and potential interactions between adaptation strategies developed at different scales (Adger et al. 2005). This dissertation demonstrates the value of local knowledge in decision-making in the context of climate change and loss of biodiversity. While local knowledge has been valued in the past for many reasons (e.g., Berkes 2008), climate change and loss of biodiversity may provide the context for a paradigm shift in the way different domains of knowledge are valued and integrated into decision-making (Kuhn 1962). This may occur because of increased awareness of the importance of knowledge developed at different scales for designing effective conservation and adaptation strategies.

This dissertation suggests a rethinking of the relationship between resilience and vulnerability. Chapters 2 and 3 (Gunnison CC and Denali CC) demonstrate that individuals more directly dependent on natural resources and weather for their livelihoods often perceive greater exposure and sensitivity to climate change than those who are less directly dependent, but they also demonstrate higher levels of adaptive capacity. In Chapter 2 (Gunnison CC), ranchers described themselves as exposed and sensitive to climate change, especially to the potential for increased drought, but they also demonstrated high levels of resilience (including adaptive capacity) through multiple overlapping adaptation strategies, strong social networks, and demonstrated learning. Prior research has shown that current exposure and sensitivity to stressors can increase adaptive capacity (e.g., Berkes and Jolly 2001). Despite this, vulnerability literature often assumes that those in more exposed locations (coastlines) and with fewer resources to moderate sensitivity will be more vulnerable than others (IPCC 2007). Local case studies have shown that the ability to lower sensitivity through buffering strategies may lead to unintended vulnerability if these buffering strategies are no longer viable (Vasquez-Leon et al. 2003). This project suggests that adaptive capacity may be an underestimated strength for groups that have adapted to prior weather variability. It may be more difficult for those who are less directly dependent on natural resources and weather to correctly assess their vulnerability because it is challenging to interpret how climate change will impact them. For instance, business owners near Denali expressed fewer potential impacts than subsistence users, but did not consider how changes to wildlife, potential for increased tourism and infrastructure might impact them. If current exposure and sensitivity build future adaptive capacity then assessments of future vulnerability may be inaccurate if they don't fully consider adaptive capacity built by prior adaptation. The hypothesis that current exposure and sensitivity to weather variability builds adaptive capacity to climate change should be further explored in other contexts so that we can better inform climate change assessment and adaptation, as well as learning from communities who have learned to cope with weather-related adversity.

This dissertation shows that individuals with land-based livelihoods currently develop and utilize adaptive strategies that could inform or create a foundation for proactive climate-change adaptation strategies (Gunnison CC: 2, Denali CC: 3). Ranchers described a suite of strategies ranging from short-term coping to long-term transformative actions such as adopting conservation easements or shifting production practices. Long-term residents of the Denali Park region described both current strategies (timing of trapping, change in hunting practices, incorporation of climate change into educational materials, etc.) and potential future strategies (education, flexibility, changing identity, etc.). These strategies are often a response to multiple drivers including weather, economics and changes to community structure (Peloquin and Berkes 2009). Prior research has identified current strategies for dealing with variability as a potential resource for dealing with climate change (e.g., Berkes and Jolly 2001). These past strategies could be used as a basis for future strategies, as examples of the suite of possible response options, or to understand so new strategies do not conflict or undermine current strategies. Local knowledge studies often look at the information local knowledge can provide rather than process-based information (Sillitoe 2007). Sociology of science suggests that how we know is as important as what we know (Goldman et. al 2011). This dissertation suggests that engaging local knowledge can help us to understand not only what local people observe about climate change, but also how they have learned to adapt and how those processes could inform future adaptation.

This dissertation demonstrates how long-term residents experience change as the interaction of environmental, social, political, and economic drivers. As sociology of science suggests, all knowledge is contextual. However, local knowledge is often more explicit in its discussion of context (Goldman et al. 2011). In Chapter 2 (Gunnison CC), self-perceptions of exposure and sensitivity are influenced by climate-change projections, potential ESA listing of the Gunnison Sage-grouse, and perceptions of the regulatory environment. In Chapter 3 (Denali CC), participants describe a suite of interacting stressors (technology, changing values, climate change, etc.) that are impacting their livelihoods. These drivers make it challenging to decipher which changes are driven by climate change and which result from a combination of drivers. In Chapter 4 (Gunnison LK), long-term observers describe the interactions between changes in predator control, increased fragmentation, and decreased grouse populations. In Chapter 5 (Gunnison perceptions), participants reveal how their perceptions of potential changes in regulation may change their management decision-making, potentially impacting grouse habitat. This dissertation supports prior research suggesting that local perspectives can highlight important and interacting drivers of change (Ch 2-5) (Wilbanks and Kates 2010).

7.1.2. Knowledge sharing

This dissertation suggests that knowledge sharing needs to be multi-directional to lead to more salient, credible and legitimate information. Prior research has demonstrated the complementary nature of different domains of knowledge (Blaikie et al. 1997, Berkes 2008). In the needs-assessment review, stakeholders described a need to consider local knowledge, practice user-driven science, and foster better communication between stakeholders and scientists in order to make science more relevant to end-users (Needs assessment: 6). Local stakeholders expressed in these documents that they are interested in the process of knowledge creation, not just the information and insights that result. Other chapters demonstrate how both climate adaptation (Gunnison CC: 2 and Denali CC: 3) and the conservation of rare species (Gunnison LK: 4 and Gunnison perceptions: 5) have an important local component, which requires local-scale expertise to understand appropriate application of conservation or adaptation strategies. For example, Chapter 4 (Gunnison LK) documents local observations of Gunnison Sage-grouse that have not been identified in the scientific literature, while Chapter 3 (Denali CC) documents novel observations of climate change by long-term local residents. Since local knowledge is developed in place, it can have more specific insights into that particular place than knowledge developed elsewhere (DeWalt 1994). Political ecology describes how scientific knowledge often works to reorder and recreate the world in order to fit its conception of how the world works (Murdoch and Clark 1994). This dissertation highlights how local stakeholders can interpret the impact of policies (ESA) on communities and livelihoods, as well as how they can translate scientific information (climate change projections) to local places.

Several of the case studies highlight the ways in which local knowledge can increase the resilience of social-ecological systems by contributing diverse sources of knowledge, understanding of system feedbacks, redundancy, and increased learning (Ch 2-5). This potential role of local knowledge has been identified in the resilience literature (Chapin et al. 2009), but this series of studies demonstrates these components explicitly. In Chapter 3 (Denali CC), each type of long-term stakeholder contributed different observations that built a more complete understanding of climate change. This chapter also demonstrated how park employees and subsistence participants were collecting redundant observations of wildlife that complement each other. Chapter 5 (Gunnison perceptions) demonstrates how perceptions of an ESA listing decision influence management decisions, which in turn can impact ecological systems. Chapter 4 (Gunnison LK) highlights how a combination of both scientific and local knowledge about Gunnison Sage-grouse leads to identification of research questions as well as increased opportunities for learning. These findings differ from previous studies by collecting empirical evidence of these traits through direct interaction with individuals within the social-ecological system.

This project described these potential benefits, but the potential to integrate these insights into decision-making has important political dimensions that this project did not address (Goldman et al. 2011). For instance, local knowledge may be ignored because of low legitimacy when it contradicts the values and knowledge of those who control decision-making. For instance, observations of increase in predators and resulting decrease in grouse were ignored for years because predator control was not supported by decision-makers and did not seem politically viable.

Climate change skepticism is often high in conservative communities, but this project suggests that engaging local people in documenting their own observations may be an effective way to start a dialogue about climate change (Gunnison CC: 2 and Denali CC: 3). Ranchers, trappers and subsistence users had personal observations that help to document climate change by identifying local impacts such as less forage or increased danger in winter travel. Even participants who were skeptical of climate change were willing and able to share their personal observations of phenomena that may be the result of climate change. For communities intimately aware of place, the projections of scientists may appear less credible or salient than their own knowledge (Wynne 1992). Creating a dialogue between the two may allow mutual self-reflection that allows for increased learning (Wynne 1992, Davidson-Hunt 2006). These local stories of change may be more effective for climate change outreach and education than large-scale model projections that are not connected directly to community concerns.

This dissertation helped to reveal the exact impacts that local residents are interested in and affected by, which may help to tailor climate-change communication. In Chapter 2 (Gunnison CC), recreation-based businesses were more concerned with gradual change while ranchers were more interested in extreme weather events. This dissertation also highlighted the importance of transparent communication around issues with high uncertainty such as climate change and impacts of the Endangered Species Act. In the meta-analysis, stakeholders described the need for better communication about climate change that helps communities to understand both projected changes and the uncertainty affiliated with them (Needs assessment: 6). Chapter 5 (Gunnison perceptions) demonstrated how lack of clear communication led to confusion within the ranching community about potential impacts of a listing decision, as well as changes to planned actions.

7.1.3. Importance of place-based research

This dissertation explores the importance of place-based long-term research both through analysis and practice. The meta-analysis of research-needs assessments documents a desire from stakeholders for research that expresses community needs and engages community members in processes to resolve local problems (Needs assessment: 6). This dissertation practiced place-based research through a series of interlinked research projects that developed as my familiarity with the communities, community interests, and current decision-making processes increased (Gunnison CC: 2, Gunnison LK: 4, Gunnison perceptions: 5). This process demonstrated that developing ongoing relationships with communities can allow researchers to identify and answer questions that are important to local community members, build a base of knowledge about the research context, and develop social capital that is critical for qualitative research. Sociology of science suggests that all knowledge creation is contextual (Goldman et al. 2011). Place-based research allows for the development of relationships with communities, which helps to identify important questions as well as cultivating the trust necessary to gain access to relevant information. This dissertation also shows that regional-scale assessments of climate-change observations and impacts can inform agency decision-making as well as building community knowledge of a wider range of observations across the landscape (Denali CC: 3).

7.2. Broader contributions

7.2.1. Importance of perceptions for effective conservation and adaptation.

There is an increasing recognition of the tight coupling and feedbacks between ecological and social systems (Clark and Dickson 2003, Chapin et al. 2009). Researchers recognize feedbacks between these subsystems (Gunderson and Holling 2002), but these feedbacks are often ignored in decision-making processes (Benson 2012). Prior scholars have identified the importance of perceptions for motivating human behavior (Thomas and Thomas 1928). Scholars have looked at perceptions and how they influence both conservation (e.g., Conley et al. 2007) and climate change (e.g., Lowe and Lorenzoni 2007, Adger et al. 2009). This dissertation contributes to this literature by demonstrating how perceptions may influence planned actions, which in turn could affect natural systems. While assessments of perceptions have occurred post-listing (Brook et al. 2003), Chapter 5 (Gunnison perceptions) takes a proactive approach in order to gauge unintended feedbacks. Negative perceptions of a listing decision resulted in lowered planned participation in conservation programs and potential increased sales of land and water rights. Perceptions are currently not fully integrated into our understanding of the dynamics of social-ecological systems (Gunderson and Holling 2002, Chapin et al. 2009). This dissertation focuses attention on the role of perceptions in driving social-ecological system change and suggests a more complete consideration in the resilience literature.

Prior studies have looked at how climate-change perceptions influence decision-making and ecosystem management (Gbetibouo, 2009, Gearhead et al. 2010). My study identifies varied levels of exposure and sensitivity in different stakeholder groups and shows how those who perceived higher levels of exposure and sensitivity to climate change impacts were more proactive in their responses than those who perceive lower levels. Broad-scale assessments may overlook these local community or individual-level strengths and propagate certain ways of understanding the world that work to maintain existing power structures. For instance, dependency theory describes how core/developed countries maintain their position by fostering dependency in peripheral/less developed countries (Ferraro 2008). Instead of recognizing the high levels of adaptive capacity in those who are more exposed to climate change, wealthier or less-directly dependent entities may foster dependency by creating top-down solutions that undermine local-level responses. Failure to engage local perceptions of climate change and adaptive capacity may lead to inequitable responses.

7.2.2. Existence of proactive adaptation strategies at the individual level. Adaptation is an ongoing human activity (Steward 1972, Mazness 1978). Some have suggested that climate-change adaptation is typically more reactive than proactive (Adger et al. 2005). Others, however, have documented proactive adaptation strategies to weather variability that could be mobilized to respond to climate change (Berkes and Jolly 2001, Vasquez-Leon et al. 2003). This dissertation suggests that proactive adaptation may occur in situations where individuals currently cope with weather-related stressors, while reactive responses may be more common in groups that experience fewer weather-related stressors. Current exposure and sensitivity to weather-related stressors can stimulate social learning and encourage individuals to develop strategies to adapt. These strategies can be seen as proactive since they presume future weather-related stressors and offer potential planned responses. This dissertation contributes to our understanding of how current responses to stressors (including but not limited to climate change) may provide a foundation for development of effective climate adaptation strategies.

Individuals respond not just to climate change, but also to a total environment of change (Moerlein and Carothers 2012). This dissertation demonstrates how current responses to stressors embody awareness of both climate change and other changes such as community support and public land regulations (Gunnison CC: 2). It is important to understand local stressors and proactive strategies to deal with them so that planners can understand the interactions among multiple threats that people are responding to as well as tailoring adaptation strategies that acknowledge, complement, and build off existing proactive adaptation strategies. Political ecology has demonstrated how application of scientific knowledge detached from its original context has led to poor environmental outcomes (Robbins 2004). In the same way, policies developed solely on climate change science may inadvertently undermine existing local efforts and fail to address the complex interconnections of social-ecological systems.

7.2.3. The value of local knowledge in specific situations.

The value of embedded perspectives and local knowledge has been suggested in many fields ranging from geography to anthropology and spanning food security (Pelletier et al. 1999) to natural resource management (Bollig and Schulte 1999). The value of local knowledge and beliefs for informing climate-change adaptation is increasingly recognized (Vogel et al. 2007), and the community scale is also often where it is possible to identify practical initiatives that increase adaptive capacity and reduce vulnerability (Ford and Smit 2004). This project builds off these prior studies and expands upon them by identifying what information may be overlooked if local perspectives are not integrated. While local knowledge and science may not be fundamentally different (Agrawal 1995), different people have different experiences of a landscape and pay attention to different phenomenon. In Chapter 4 (Gunnison LK), I identify local expert knowledge of grouse behavior (lekking behavior and habitat use) that is not documented in prior scientific literature. In Chapter 3 (Denali CC), I describe the range of climate change observations that long-term residents have, some of which haven't previously been documented in this region, including travel safety and change in distribution of wildlife. These results support the argument that the scientific process can elucidate that climate change is happening and provide estimations of how it will occur, but fine-scale information about impacts and adaptations will require local knowledge (Hulme 2010).

7.2.4. Failure to integrate local knowledge may lead to inequity.

Issues of equity and knowledge have been explored in the past. Foucault described how the ability to create, apply and maintain knowledge is a form of power (Foucault 1972), while science studies and political ecology explore how knowledge is created, circulated and applied (Goldman et al. 2011). Others have discussed how the process of adaptation, as any human activity, is political (Paavola and Adger 2006). Successful climate change adaptation and local-level conservation efforts will require the creation and application of new forms of knowledge. Different stakeholders will have different perceptions of knowledge based on how credible, salient and legitimate they perceive it to be (Cash et al. 2002). Processes of knowledge production that consider local observations and experience are often seen as more fair and credible to local stakeholders than those that fail to consider them (Wynne 1992). This dissertation demonstrates how failure to integrate observations and perceived impacts may result in inequitable outcomes for ecosystems, livelihoods, and cultures. Adaptation policies will differentially impact different groups. Recreation and ranching participants expressed the importance of increased flexibility in the timing of public land use. If this is ignored, those who have more private lands may be able to adapt, while those who rely on public lands may go out of business (Gunnison CC: 2). In Chapter 3 (Denali CC), long-term residents share their observations of more dangerous travel conditions. If policies and regulations do not take these new risks into account, subsistence community members may no longer be able to practice traditional activities.

7.3. Future research

I have described the contributions of this dissertation above, and now I turn to the unanswered questions and future directions that this dissertation suggests. While the dissertation suggests the need for a new mechanism or process for sharing knowledge across scales, it doesn't provide insight about how this has occurred in the past or how it might be best designed for the future. One future project could be a meta-analysis of tools that have been used to share knowledge between scales in order to understand how they functioned, what their outcomes were, and what was most and least effective. This meta-analysis could also explore the political dimensions of knowledge integration (Goldman et al. 2011), which were not explored in this dissertation. This dissertation highlighted the varied observations and perspectives of different stakeholders, but it did not look at how perceptions of climate change varied based on the observers' specific types of interactions with the natural world. It would be interesting to see if perceptions are correlated with type of experience, length of experience, or variables related to core beliefs. This dissertation highlighted how perceptions influence planned decision-making, but it would be valuable to conduct a longitudinal study to see whether these planned actions are taken and why or why not. Finally, this project documented local stakeholders' observations of change and suggested the importance of engaging local people in the process of knowledge creation related to climate change. It would be interesting to expand this research in order to add opportunities for dialogue between local observers, scientists, and existing data and then assess this process to see if participation would change the awareness, beliefs, and planned responses of participants.

7.4. Summary of contributions

This dissertation was focused on applied and user-driven research, but it also supports findings from and contributes to the fields of climate change adaptation, local knowledge, resilience and vulnerability, sociology of science, and political ecology. Climate-change communication has wrestled with the most effective ways to communicate climate change and empower people to action (Weingart et al. 2000). The process and findings of this dissertation suggest that starting with local observations of climate change may engage climate skeptics, be a productive way to start a dialogue about climate change, and increase the credibility, legitimacy, and relevance of climate-change information (Cash et al. 2002). The literature on integrating local knowledge into natural resource management has often focused on the facts local knowledge can bring to management rather than the underlying knowledge system, which includes beliefs, interpretations, and practices (Sillitoe 2007). This approach has been criticized for its lack of understanding of the context in which knowledge is developed (Nadasdy 1999). This dissertation looks at local observations of climate change, but it also explores current adaptation strategies, perceptions of change, and the different discourses of local stakeholders regarding change. It confirms the importance of understanding the context in which knowledge is acquired (Goldman et al. 2011). Humans are increasingly modifying natural systems (Steffen et al. 2007). In this dissertation, I explore two contexts where these modifications are apparent: climate change and conservation. In both contexts, larger-scale processes manifest in specific and particular ways on a local scale. This dissertation suggests that, as humans continue to modify natural systems in ways that have both local and global implications, it may be necessary to shift the paradigm of science to reassess how science values and integrates different domains of knowledge.

Resilience thinking has focused primarily on institutions to understand feedbacks between social-ecological systems (Chapin et al. 2009). This dissertation suggests a need for increased attention to human perceptions as a driver of social-ecological feedbacks. It also suggests that current exposure and sensitivity to weather variability may increase adaptive capacity. Resilience and vulnerability share an interest and awareness of the role of adaptive capacity (Chapin et al. 2009). However, this dissertation suggests that current exposure and sensitivity to weather may increase adaptive capacity. This is a hypothesis that should be explored further through a meta-analysis of case studies. Sociology of science describes the contextual nature of all types of knowledge. This dissertation supports this claim by describing the heterogeneity between and within different stakeholder groups. Political ecology has traced how application of globalized knowledge has led to poor environmental outcomes in specific places (Robbins 2004). Political ecologists have also suggested that the nuanced knowledge of local people may improve these outcomes (Peet et al. 2011). This dissertation shows how local knowledge can provide valuable interpretations of global forms of knowledge, which may lead to more nuanced application of science and policy, and foster more equitable outcomes.

7.5. References

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