THESIS

RANGELAND MANAGERS' ADOPTION OF INNOVATIONS, AWARENESS OF STATE AND TRANSITION MODELS, AND MANAGEMENT OF *BROMUS TECTORUM*: A SURVEY OF RANCHERS AND NATURAL RESOURCE PROFESSIONALS IN WYOMING AND COLORADO

Submitted by

Windy K. Kelley

Department of Forest, Rangeland and Watershed Stewardship

In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Fall 2010

COLORADO STATE UNIVERSITY

July 19, 2010

WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY WINDY K. KELLEY ENTITLED RANGELAND MANAGERS' ADOPTION OF INNOVATIONS, AWARENESS OF STATE AND TRANSITION MODELS, AND MANAGEMENT OF *BROMUS TECTORUM*: A SURVEY OF RANCHERS AND NATURAL RESOURCE PROFESSIONALS IN WYOMING AND COLORADO BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

Committee on Graduate Work

Paul Meiman

Cynthia Brown

Tara Teel

Advisor: Maria Fernandez-Gimenez

Department Head: Skip Smith

ABSTRACT OF THESIS

RANGELAND MANAGERS' ADOPTION OF INNOVATIONS, AWARENESS OF STATE AND TRANSITION MODELS, AND MANAGEMENT OF *BROMUS TECTORUM*: A SURVEY OF RANCHERS AND NATURAL RESOURCE PROFESSIONALS IN WYOMING AND COLORADO

Decision-making tools that help land managers understand the complexity of interactions between the human and biophysical components of rangelands and make decisions in a changing environment are necessary for sustainable rangeland management. To ensure the success of such tools, it is important to understand the end users' knowledge, views, and current management practices related to decision-making tools, as well as the factors associated with their adoption and implementation. We facilitated focus groups and distributed a self-administered mail survey to ranchers and natural resource professionals (NRPs) in Wyoming and Colorado to explore factors associated with ranchers' adoption and implementation of progressive management and business practices and their use of government programs. Additionally, we sought to gain an understanding of ranchers' and NRPs' awareness, attitudes, and current management practices related to two current rangeland topics: state and transition models (STMs), a rangeland assessment, planning, and monitoring tool, and cheatgrass (*Bromus tectorum* L.), a non-native invasive weed. We found that the greatest percentage of ranchers (37%) is in the two most innovative categories, strongly proactive, and innovators. We

recommend a diffusion of innovation strategy that focuses on reaching the most risk-tolerant ranchers first, in order to disseminate innovations into local communities where the proactive ranchers (35% of our respondents) can observe implementation and outcomes associated with adoption of a new practice/program. However, care must be taken to insure innovations are diffused vertically within a population, reaching different socioeconomic levels. In addition, we found that 69% of ranchers were unaware of STMs, and there is much variation among natural resource agencies in their awareness and use of this tool. Both ranchers and NRPs perceive that STMs will help them to achieve their ecological and/or economic objectives. Overall, ranchers and NRPs perceive cheatgrass as a problem, but professionals generally perceive it as a bigger problem than ranchers, and perceptions of both groups vary regionally in Wyoming and Colorado. Ranchers reported they had the most success managing cheatgrass by grazing it in the early spring. NRPs reported they were most successful managing cheatgrass with a combined approach of prescribed fire, herbicide application, and seeding. This study demonstrates the need to develop appropriate outreach and extension material about STMs and the management of cheatgrass for each of the target populations in Wyoming and Colorado.

Windy K. Kelley
Department of Forest, Rangeland and Watershed Stewardship
Colorado State University
Fort Collins, CO 80523
Fall 2010

ACKNOWLEDGEMENTS AND DEDICATION

Thank you to the key informants and community gate keepers who connected us to our study populations, the participants in the focus groups and the survey for their participation in this research, to my committee members which includes Maria Fernandez-Gimenez, Tara Teel, Cynthia Brown, and Paul Meiman, the funders of this research which was the United States Department of Agriculture's (USDA) Cooperative State Research, Education, and Extension Service and the USDA's Natural Resources Conservation Service, and my family and friends for their support. This thesis is dedicated to the memory of my mentor, friend, and older brother James Brandon (J.B.) Kelley (May 1976 – August 2009). His role in my life has in part shaped who I am today.

TABLE OF CONTENTS

LIST OF TABLES, CHARTS, AND FIGURES..……..……...……xi

CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW……...……...1

Thesis Purpose……..……...2

Literature Review……..……...……3

Adoption of Innovation……..… ……...……...……3

State and Transition Models…..……...…….13

Cheatgrass (*Bromus tectorum* L.).…….……17

Conclusion and Thesis Organization….……24

CHAPTER TWO: RANCHERS' RISK ORIENATION AND ADOPTION OF INNOVATION…...…….……..27

Introduction……...27

Adoption of Innovation……..…28

Diffusion of Innovation……..29

Ranchers and Adoption of Innovation……...33

Objectives and Hypotheses……...…….38

Methods…….……40

Phase 1: Focus Groups……...……40

Phase 2: Self-Administered Mail Survey...……43

Results...…….……...…….....51

Respondent Characteristics……..…….53

Ranchers' Risk-Orientation, Adoption of Progressive Practices, and Use of Programs…...…….....53

Factors Associated with Risk-Orientation and Adoption of Innovations.54

Risk-Orientation Mediates Adoption……...……..……57

Factors that Influence the Decision to Implement a New Management Practice……...……59

Discussion……..……60

Factors Associated with Risk-Orientation and Adoption of Innovation…60

Innovations as a Mediating Variable to Adoption..……...……63

Factors that Influence the Decision to Implement a New Management Practice…….……..65

Implications……66

Implications for Outreach and Extension…….....66

Implications for Researchers Developing Innovations……..68

Implications for Researchers Studying the Diffusion of Innovations..…69

Chapter Two Tables, Charts, and Figures……..71

CHAPTER THREE: RANCHERS' AND NATURAL RESOURCE PROFESSIONALS' PERCEPTIONS OF STATE AND TRANSITION MODELS…….....93

Introduction……93

Objectives……...……..…...…..96

Methods……..97

Phase 1: Focus Groups……...……97

Phase 2: Self-Administered Mail Survey……..……..……...101

Results…….…….……....106

Respondent Characteristics……...…..…108

Awareness of State and Transition Models……..…109

Perceived Ecological and Economic Benefits of State and Transition Models……..……109

Use of and Level of Satisfaction with State and Transition Models…....112

Information Needs and Technical Assistance……..…112

Discussion…….…….……..113

Awareness, Perceived Benefits, and Use of State and Transition Models……..……114

Information Needs and Technical Assistance……..……116

Implications……..……118

Chapter Three Tables, Charts, and Figures……..120

CHAPTER FOUR: RANCHERS' AND NATURAL RESOURCE PROFESSIONALS' PERCEPTIONS AND MANAGEMENTOF CHEATGRASS (*BROMUS TECTORUM* L.)……....125

Introduction…….....……....125

Human Dimensions of Cheatgrass Management…….....129

Objectives……...……...……..133

Methods…….……...……...…….133

Phase 1: Focus Groups……...……...……..….134

Phase 2: Self-Administered Mail Survey.……...……..……138

Results……..……..…….....144

Respondent Characteristics……..…146

Perceptions of Cheatgrass as a Problem……..……147

Spread of Cheatgrass……..……..……147

Establishment and Increase of Cheatgrass…….……..……148

Perceptions of Potential Effects of Cheatgrass……...……150

Experienced Effects of Cheatgrass……..…151

Cheatgrass Management Practices and Level of Satisfaction……..…152

Constraints and Barriers to Managing Cheatgrass……...153

Information Needs and Technical Assistance……..153

Discussion……....154

Perceptions of Cheatgrass as a Problem……..…154

Perceptions of and Knowledge about Cheatgrass and Its Impacts……..157

Current Management Practices and Barriers to Management…….160

Implications……..…162

Chapter Four Tables, Charts, and Figures……...…165

CHAPTER FIVE: CONCLUSIONS...……..……..190

Human Dimensions of State and Transition Models……...…192

Human Dimensions of Cheatgrass (*Bromus tectorum* L.)……...……193

LITERATURE CITED……..……..……196

APPENDICES…….102

A: Focus Group Recruitment Script – Ranchers……...……...……102

B: Focus Group Recruitment Script – Natural Resource Professionals…....…105

C: Focus Group Invitation……...……...……108

D: Cover Letter for Focus Groups…….……..……....111

E: Focus Group Script – Ranchers……...……114

F: Focus Group Script – Natural Resource Professionals……117

G: Pre-survey Letter……..…….....120

H: Survey Cover Letter – Ranchers ……...……..……...…122

I: Survey Cover Letter – Natural Resource Professionals…….……..125

J: Mail Survey – Ranchers…….……...……...……128

K: Mail Survey – Natural Resource Professionals……..…….....140

L: Follow-up Thank You and Reminder Post-card……..……152

M: Replacement Survey Cover Letter – Ranchers ……..……...……154

N: Replacement Survey Cover Letter – Natural Resource Professionals…….....156

O: Non-response Bias Phone Script – Ranchers……...…...……158

P: Non-response Bias Phone Script – Natural Resource Professionals……..….166

LIST OF TABLES, CHARTS, AND FIGURES

Table 2.0: Animal Unit Equivalents……..……...……71

Table 2.1: Rancher Respondent Characteristics.…….…….....71

Table 2.2: Rancher' Self-Reported Risk-Orientation……....72

Table 2.3: Ranchers Who Have Tried Management Practices in the Last Five Years…..72

Table 2.4: Ranchers Who Have Tried Business Practices in the Last Five Years…….73

Table 2.5: Ranchers Who Have Tried Government Practices in the Last Five Years…...73

Table 2.6: Ranchers and the Number of Practices and Programs they Participated or Implemented during the Past Five Years……...……74

Table 2.7: Correlation Matrix of Rancher and Operation Demographics ……....75

Table 2.8: Multiple-Regression of the Predictor Variables by the Mediator Variable…..78

Table 2.9: Multiple-Regression of the Predictor and Mediator Variables by the Management Practices Index……...……...…...78

Table 2.10: Multiple-Regression of the Predictor and Mediator Variables by the Business Practices Index…….....78

Table 2.11: Multiple-Regression of the Predictor and Mediator Variables by the Government Programs Index……..……...79

Table 2.12: Path Analysis Regression Results Where Partial or Full Mediation was Detected and Sobel Test Results……80

Table 2.13: Factors that Influence Ranchers Decision to Implement a New Tool or Management Practice…….....81

Chart 2.0: Rancher Respondents Highest Level of Formal Education.……...….82

Chart 2.1: Rancher Respondents Gross Annual Income.……...……82

Chart 2.2: Rancher Respondents Anticipated Future of Their Operation……..……83

Figure 2.0: Focus Group Study Locations in Wyoming and Colorado..……...…...84

Figure 2.1: Self-Administered Mail Survey Study Locations of Ranchers in Wyoming and Colorado……..85

Figure 2.2: Path Analysis – Gross Annual Income and the Adoption of Management Practices…….....86

Figure 2.3: Path Analysis – Gross Annual Income and the Adoption of Government Programs……...…86

Figure 2.4: Path Analysis – Education and the Adoption of Management Practices..…86

Figure 2.5: Path Analysis – Percentage of Income from On-Ranch Sources and the Adoption of Management Practices…….....87

Figure 2.6: Path Analysis – Percentage of Income from On-Ranch Sources and the Adoption of Business Practices……...…..87

Figure 2.7: Path Analysis – Percentage of Income from On-Ranch Sources and the Adoption of Government Programs……...…87

Figure 2.8: Path Analysis – Percentage of Annual Labor Provided by Family and the Adoption of Management Practices……...88

Figure 2.9: Path Analysis – Operation Size and the Adoption of Management Practices…….88

Figure 2.10: Path Analysis – Operation Size and the Adoption of Business Practices.…88

Figure 2.11: Path Analysis – Gross Annual Income and the Adoption Business Practices.....89

Figure 2.12: Path Analysis – Education and the Adoption Government Programs……...89

Figure 2.13: Path Analysis – Education and the Adoption Business Practices…….……89

Figure 2.14: Path Analysis – Percentage of Labor Provided by Family and the Adoption of Business Practices…….…….……90

Figure 2.15: Path Analysis – Percentage of Labor Provided by Family and the Adoption of Government Programs……...90

Figure 2.16: Path Analysis – Age and the Adoption of Government Programs……90

Figure 2.17: Path Analysis – Age and the Adoption of Business Practices……..91

Figure 2.18: Path Analysis – Age and the Adoption of Management Practices……91

Figure 2.19: Path Analysis – Operation Future and the Adoption of Government Programs……...….91

Figure 2.20: Path Analysis – Operation Future and the Adoption of Management Practices…….……92

Figure 2.21: Path Analysis – Operation Future and the Adoption of Business Practices.....92

Table 3.0: Natural Resource Professional Respondent Characteristics……..……120

Table 3.1: Ranchers' Awareness and Use of State and Transition Models…….120

Table 3.2: Natural Resource Professionals' Awareness and Use of State and Transition Models……...…120

Table 3.3: Ranchers' Perceptions of the Ecological Benefits Associated with Using State and Transition Models…….121

Table 3.4: Natural Resource Professionals' Perceptions of the Ecological Benefits Associated with Using State and Transition Models……121

Table 3.5: Natural Resource Professionals' Level of Satisfaction with Using State and Transition Models……122

Table 3.6: Natural Resource Professionals' Perceptions of the Economic Benefits Associated with Using State and Transition Models……...…122

Table 3.7: Natural Resource Professionals' Levels of Satisfaction with Their Use of State and Transition Models…….....123

Table 3.8: Information Needs of Ranchers and Natural Resource Professionals Regarding State and Transition Models……....123

Chart 3.0: Natural Resource Professional Respondent Highest Level of Formal Education…….124

Table 4.0: Ranchers' Perceptions of Cheatgrass as a Problem……165

Table 4.1: Natural Resource Professionals' Perceptions of Cheatgrass as a Problem….166

Table 4.2: Ranchers' Perceptions of the Causes of Cheatgrass Spreading……..166

Table 4.3: Natural Resource Professionals' Perceptions of the Causes of Cheatgrass Spreading…….....167

Table 4.4: Ranchers' Perceptions of the Causes of Cheatgrass Establishment and Increase……...….170

Table 4.5: Natural Resource Professionals' Perceptions of the Causes of Cheatgrass Establishment and Increase……..172

Table 4.6: Ranchers' Expressed Concerns about the Potential Effects of Cheatgrass……174

Table 4.7: Natural Resource Professionals' Expressed Concerns about the Potential Effects of Cheatgrass……...175

Table 4.8: Ranchers' Reported Experiences of the Effects of Cheatgrass……..177

Table 4.9: Natural Resource Professionals' Reported Experiences of the Effects of Cheatgrass……...….179

Table 4.10: Percentage of Ranchers Who Have Tried Specified Practices to Manage Cheatgrass……....182

Table 4.11: Ranchers' Level of Satisfaction with the Use of Specific Management Tools……....182

Table 4.12: Percentage of Natural Resource Professionals Who Have Tried Specified Practices to Manage Cheatgrass……...182

Table 4.13: Natural Resource Professionals' Level of Satisfaction with the Use of Specific Management Tools……....183

Table 4.14: Percentage of Ranchers Who Reported Specific Constraints to Managing Cheatgrass……....184

Table 4.15: Percentage of Natural Resource Professionals Who Reported Specific Constraints to Managing Cheatgrass……...……185

Table 4.16: Information Needs of Ranchers Regarding Cheatgrass……187

Table 4.17: Information Needs of Natural Resource Professionals Regarding Cheatgrass.....188

Figure 4.0: Self-Administered Mail Survey Study Locations of Natural Resource Professionals in Wyoming and Colorado.....189

CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

Rangelands encompass approximately 50 percent of the Earth's land mass (CSREES 2009) and comprise about 34% of the United States (US) land area – more than 770 million acres (USFS 1989). We depend on these grasslands, shrub-lands, and savannahs for a variety of ecosystem services including food, fiber, wildlife habitat, water, recreation, aesthetic values, cultural heritage, community uniqueness such as open spaces near urban areas, and livelihoods related to these services, among other ecological and socioeconomic benefits (Holechek 2007; Wallace et al. 2008).

The western mountain states experienced the most rapid population growth of any US region during the 1990s (Hansen et al. 2002). Prior research suggested that private lands, such as working ranchlands, provide a buffer to public lands, and that in the state of Colorado a greater portion of potential conservation areas for the Colorado Natural Heritage Program occur on private rather than public lands (Talbert et al. 2007). A study conducted in Larimer County, Colorado used spatial analysis to identify benefits associated with private land conservation. The greatest benefits observed were "conservation of riparian areas, contiguity with other protected parcels, protection of big-game concentration areas, and buffering of public protected areas" (Wallace et al. 2008 pg. 292). Many of these benefits are also associated with traditional ranches. However,

the rapid population growth in the Mountain West as well as an increase in outdoor recreation, and rural sprawl have resulted in increased pressure on natural resources (Hansen et al. 2002). As ranch land is converted to exurban development and other uses, the natural buffers for public land are diminished.

Understanding the interactions of the human and biophysical components of rangeland is necessary for sustainable management, as are decision-making tools that help land managers understand and make decisions in a complex environment. To ensure the success of such tools, it is important to understand the end users' or target populations' knowledge, attitudes, and current management practices, as well as the factors associated with their adoption and implementation. Given the importance of working ranchland and public rangelands to natural resource conservation, it makes sense to concentrate on managers of those lands.

THESIS PURPOSE

The overall purpose of this research is to understand ranchers' adoption of innovative practices and programs and the role of risk-orientation as a as a mediating factor in the relationship between rancher characteristics and the adoption of progressive practices and programs. Additionally, it will provide a baseline assessment of the awareness, attitudes, and management practices of ranchers and natural resource professionals (NRPs) (the two populations combined are referred to as land managers here forward) about state and transition models (STMs), and cheatgrass (*Bromus tectorum* L.), which will be reevaluated at the conclusion of the overall project (2012).

This information will serve two purposes. Collection of these baseline data will help to assess the project's effectiveness. Second, it will provide the opportunity to

explore ranchers' and NRPs' knowledge, attitudes and behaviors related to two current rangeland topics, STMs and cheatgrass, about which there has been little scientific study.

This study used a mixed-method approach implemented in two phases; pre-survey focus groups followed by a self-administered mail survey, which were implemented throughout several regions in Wyoming and Colorado. Our objectives for gathering these data were to: 1) inform the development of a diffusion of innovation strategy for our two projects (i.e., STMs and management of cheatgrass); and 2) share with the broader scientific community ranchers' risk-orientation and factors that influence their decision to adopt innovative practices and programs.

In the following sections, I review literature about the diffusion and adoption of innovation generally, as well as research specific to adoption by ranchers, including the characteristics of innovations adopted by ranchers, what motivates ranchers to adopt innovations, and characteristics of ranchers who adopt innovations. I also review literature about two current rangeland topics. The first rangeland topic I will discuss is STMs, which is a conceptual decision-making framework used to guide the inventory, assessment, and monitoring on rangelands. The second rangeland topic I will cover is cheatgrass, an annual, non-native invasive grass.

LITERATURE REVIEW

Adoption of Innovation

Innovations are developed in order to address a problem or meet a need; in general, they are new ideas, practices, or techniques to an individual or group (Brown 1981; Rogers 1995). Ranching innovations may include participating in new programs such as conserving land in perpetuity through conservation easements, implementing progressive

livestock or grazing management practices (e.g., targeted grazing management, low stress livestock handling), other natural resource management practices (e.g., weed control), as well as business innovations (e.g., wind energy development).

The 1928 introduction of a hybrid corn variation by the Iowa State Agricultural Experimentation Station, which resulted in increased crop yields, was the foundation of the diffusion of innovation theory (Stephenson 2003). The theory of diffusion of innovation explains how innovations spread as more and more individuals accept and apply them (Brown 1981; Rogers 1995). The theory has been applied in rural sociology since the early 1940's and it was used to address environmental concerns beginning in the mid-1970's (Rogers 1995). Although the diffusion of innovation theory has been applied and developed for over eight decades, Didier and Brunson (2004) suggest that a deeper understanding of what motivates ranchers to adopt innovations, and when they adopt, is needed to successfully encourage implementation of desired management practices.

Results from prior empirical work have suggested several characteristics of innovations and adopters or non-adopters. Identifying similarities in innovations that have been adopted and gaining a better understanding of the characteristics of adopters will assist researchers and extension agents alike to develop more relevant and effective innovations and strategies to encourage adoption.

Diffusion of Innovation

Diffusion occurs when an "innovation is communicated over time to a social system" (Rogers 1995 pg. 5). Rogers (1995) describes four essential elements to the diffusion process: 1) *innovation*; 2) *communication channels*; 3) *time*; and 4) *social system*. The first element, *innovation*, is an idea or practice that is perceived as new to an individual or

group. Through prior research, five characteristics of innovations that influence the rate of adoption have been identified. They are the perceived:

1) **Relative advantage:** benefits of adopting an innovation compared to the prior practice
2) **Compatibility:** the degree to which an innovation is consistent with existing values, past experience, and needs
3) **Complexity:** the degree of difficulty to understand the innovation and/or the development of new skills
4) **Trialability:** the degree to which an innovation has been tested
5) **Observability:** the degree to which results are visible to potential adopters

(Rogers 1995).

Innovations that are less complex, but have greater degrees of the other four characteristics tend to be adopted first (Rogers 1995).

The second element of diffusion is *communication channels*, the pathways through which information is relayed between entities (Rogers 1995). Rogers (1995) indicates that the most effective form of communication for diffusing innovation is through interpersonal channels, or face to face communication. In a qualitative study of rancher adoption of innovation, several personal characteristics of adopters were identified, including those with larger social networks (Didier and Brunson 2004). These networks enabled producers to observe outcomes of an innovation, satisfying two of Rogers's (1995) characteristics of innovation, trialability and observability.

Rogers (1995) also suggests that the greater the commonality or homogeneity (e.g., socio-economic status, education, etc.) between individuals or groups, the more

likely an innovation will be adopted. In other words, a common problem in the communication process of diffusing innovations is heterogeneity between innovators and potential adopters (Rogers 1995). Rogers (1995) indicates that adoption of innovation is more closely linked to subjective evaluation of an innovation by peers (i.e., homogeneity) than to research findings.

The third element to diffusing innovation is *time*, which is developed around a linear, four step 'innovation decision process' (Rogers 1995). This process can take several years (Rogers 1995). The process begins with a potential adopter first becoming knowledgeable about an innovation either through learning of its existence or gaining understanding of the idea or practice, and is followed by the individual or group either developing a favorable or unfavorable attitude toward an innovation (Rogers 1995). The third step in the process is implementation of an innovation, which can include reinvention of an innovation by an adopter (i.e., altering the innovation to meet an adopters needs) (Rogers 1995). The final phase of the adoption process is confirmation, a time when an adopter or non-adopter either accepts an innovation or reverses their decision and abandons an innovation (Rogers 1995).

Rogers (1995) presents another component of the third element, *time*, which is the rate at which individuals or groups adopt an innovation. Over the past several decades, more than 40 researchers have conducted empirical work to develop categories of adopters based on adopter characteristics, innovations adopted (Stephenson 2003), and the rate of adoption (Brown 1981). Prior empirical work has suggested that some of the systematic differences that influence adoption include, but are not limited to: demographics, locality, and social characteristics (Brown 1981). Rogers (1995) identifies

and describes five categories of adopters that are based on ideal types, which were grounded in empirical studies. The five categories are:

1) **Innovators:** socialize beyond their local peer group, and have access to significant financial resources. They comprehend more complex concepts, and they are comfortable with a higher degree of uncertainty. Innovators are integral to the diffusion process by implementing an innovation from outside of the community. They comprise 2.5% of the general population.
2) **Early adopters:** are well respected in their local community and they hold significant leadership roles. They implement an innovation and communicate a subjective evaluation of it through social networks. Early adopters comprise 13.5% of the general population.
3) **Early majority:** are social, but do not hold leadership roles in their community; however, they are one step ahead of the average person and are deliberate in their adoption of an innovation. They connect the early adopters with the late majority through interpersonal networks. Thirty-four percent of the general population is an early majority.
4) **Late majority:** adopt innovations due to economic necessity or from increase in peer pressure. They are skeptic of innovations and they adopt after the majority of the population. Thirty-four percent of the general population is a late majority.
5) **Laggards:** are the last to adopt innovation. They associate with likeminded individuals or groups and they are skeptical of new ideas. Laggards comprise 16% of the general population.

(Rogers 1995).

An issue with the adopter categories is that they are non-exhaustive, in that they do not account for incomplete adoption or non-adoption (Rogers 1995).

A *social system* is comprised of individuals or groups that cooperate to solve a common problem to reach a mutual goal (Rogers 1995), and is the fourth and final element to the diffusion of innovation. Rogers (1995) suggests that it is important for innovators to understand social structures to be able to predict human behavior to diffuse innovation.

Ranchers and Adoption of Innovation

Ranching is one of the founding professions of the colonized Western United States. Ranchers have continued to persevere despite continuous hardships such as drought and economic downturns. Nevertheless, Western ranchland (privately owned rangeland) is changing ownership. One study of three counties in Colorado, Wyoming, and Montana found that the majority of ranches sold between 1990 – 2001 were bought by amenity and non-local buyers (Gosnell and Travis 2005). Gosnell and Travis (2005) suggested that "another decade of sales will mark the end of all but a very few traditional ranches in the most amenity-rich areas" (pg. 197). Ranchers' ability to adapt and innovate might be what continues to sustain their culture, preserve part of the history of the American West, and maintain the ecosystem services that our society depends on. Additionally, it is imperative for researchers and NRPs to monitor changes in rancher demographics and the evolving management goals of the next generation of ranch managers. Longitudinal studies may help us to understand how different stakeholder groups communicate about issues and management of rangelands, which might enable the development of a common language to ensure the continued conservation of the nation's rangelands.

Characteristics of Innovations Adopted by Ranchers and What Motivates Their Adoption

Several studies that have looked at ranchers' adoption of management practices suggest a number of key attributes of the adopted innovations, which are similar to Rogers' (1995) characteristics of innovations. For example, ranchers generally adopt innovations that have outcomes that are either predictable or controllable (trialability and observability) (Coppock and Birkenfeld 1999; Kennedy and Brunson 2007) and that have immediate, visible results (trialability and observability) (Kennedy and Brunson 2007; Kreuter et al. 2001). This includes observing success or failure of an innovation and comparing it to their personal situation. They are also more interested in innovations that are compatible with their production goals, such as improved animal performance or better forage utilization (Coppock and Birkenfeld 1999; Kennedy and Brunson 2007). Several studies have indicated that ranchers and farmers are more likely to adopt innovations that require few specialized management skills and are simple to implement (complexity) (Coppock and Birkenfeld 1999; Lambert et al. 2007), and that have results that appear to enhance cost effectiveness (relative advantage) (Coppock and Birkenfeld 1999; Kreuter et al. 2001; Lambert et al. 2007; Peterson and Coppock 2001).

Ranchers' motivations to adopt are strongly associated with the characteristics of innovations. As discussed above, adoption is more likely to occur if an innovation aligns with a rancher's priority needs, and personal as well as management goals (compatibility and relative advantage), which might also be a motivation to adopt (Coppock and Birkenfeld 1999; Kennedy and Brunson 2007). For example, implementing a new management practice that inadvertently improves wildlife habitat and attracts wildlife from adjacent lands that are of lesser quality (Didier and Brunson 2004) might result in a

decrease in the amount of available forage for livestock, a potential disincentive to adopt this practice. However, depending on an operation's management objective(s), this may not be an obstacle to adoption. For example, if a rancher depends on a combination of income from livestock production and guided big game hunts, they may want to attract certain species to their land during specific times of the year.

Several external conditions that may influence motivations for adoption of new management practices include drought and rural development (Kennedy and Brunson 2007). For example, a rancher might have to sell some of his or her livestock during a drought, and to off-set potential lost revenue, they might adopt a new business practice such as installing wind energy turbines. Considering another example, property taxes might increase in areas where rural development occurs in order to provide utilities. The increase in property taxes might motivate a rancher to adopt a management or business practice to generate additional revenue or a rancher might participate in a government program, which provides tax incentives.

Ranchers who have implemented new range management practices have indicated that forage production, water quality (Kennedy and Brunson 2007), and profitability are key reasons for adoption (Didier and Brunson 2004; Kennedy and Brunson 2007; Rowan and White 1994). Another reason ranchers and landowners adopt new management practices is to demonstrate their commitment to land stewardship/rangeland health (Didier and Brunson 2004; Kennedy and Brunson 2007; Peterson and Coppock 2001), including protecting biodiversity (Wallace et al. 2008). These and similar motivations might contribute to the preservation of farm and agricultural land, which has been positively associated with progressive and innovative practices such as using sustainable

agricultural practices or participating in land conservation programs such as conservation easements or clustered development (Selfa et al. 2008; Wallace et al. 2008). Lastly, prior empirical work has suggested that ranchers are motivated to innovate to improve public relations (Didier and Brunson 2004).

Characteristics of Ranchers Who Adopt Innovations and Barriers to Innovation

A 1996 – 97 study conducted by Peterson and Coppock (2001) found that 80% of livestock producer respondents self-identified as passive managers or managers who do not implement new management practices. A significant portion of western rangelands are privately owned or leased by ranchers. Therefore, it is imperative for researchers and NRPs to continue to identify and gain an understanding of factors that affect ranchers' ability to adopt new management practices, such as coping strategies, operation scale, and production goals (Coppock and Birkenfeld 1999), particularly if ownership of ranches continues to change.

The socio-economic status of a rancher has been shown to influence their adoption of innovation. For example, higher levels of formal education (Coppock and Birkenfeld 1999; Peterson and Coppock 2001; Selfa et al. 2008) and annual household income (Coppock and Birkenfeld 1999; Kreuter et al. 2008; Peterson and Coppock 2001; Selfa et al. 2008) are positively associated with the adoption of innovations. Full-time producers who live near to or on their ranch and who have few off-ranch obligations (Didier and Brunson 2004; Kennedy and Brunson 2007; Kreuter et al. 2008) are more likely to adopt new practices, as are public land permittees (Peterson and Coppock 2001). Other studies have also found that ranchers who depend more on their ranch (specifically agriculture) for income are more innovative (Kennedy and Brunson 2007; Rowan and

White 1994). A rancher is more apt to be innovative if their operation is multigenerational and the future of the operation is certain (Didier and Brunson 2004). Another factor that has been shown to increase the probability for adoption of an innovation is social networks (Didier and Brunson 2004). Social networks can provide a way for potential adopters to observe outcomes of an innovation implemented by a peer or other member of a social system (e.g., informal groups or organizations), reducing the perceived risk of adopting a new management practice (Didier and Brunson 2004; Kennedy and Brunson 2007; Rogers 1995).

Barriers to adoption of innovation include limited time and resources (Didier and Brunson 2004; Peterson and Coppock 2001), advanced age, and declining health (Peterson and Coppock 2001). Several studies have also indicated that a strong commitment to traditional ranching practices can pose a barrier to adoption of innovation (Didier and Brunson 2004; Rowe et al. 2001; Smith and Martin 1972). Political and legal systems may also hinder adoption of innovation. For example, Didier and Brunson (2004) suggested that when the future of public grazing allotments is uncertain, permittees are less likely to innovate. A survey of Texas landowners suggested that concern over legal liability deterred use of prescribed fire for land management (Kreuter et al. 2008). Finally, Didier and Brunson (2004) indicated that operations that are more spatially fragmented (e.g., checkerboard) are less likely to adopt innovations. This is likely due to a necessary increase in management input(s) to implement a new management practice.

Continued monitoring is needed to understand the changing needs of ranchers and how these might influence their willingness to adopt new management practices. This is particularly important as ranchers continue to encounter stresses and shocks such as

extended drought and economic downturns. Additionally, since transfer of ranch management to new owners is inevitable, whether to heirs of the operation or to absentee, amenity owners, it is important that we understand the evolving needs of ranch managers and their personal and management objectives. It has been suggested that diffusers of innovation pay particular attention to priority needs, especially when differences in socio-economic classes exist (Coppock and Birkenfeld 1999).

Researchers and NRPs will be most successful at sustaining rangelands if they work with and in the same direction as ranchers. Additionally, they must acknowledge that ranchers in each community and region have different needs and characteristics, which may influence their ability and willingness to adopt an innovation.

Our study builds on the limited empirical knowledge about ranchers' risk-orientation, their adoption of innovative management and business practices and use of government programs, and factors associated with ranchers' willingness to innovate. Specifically, our study will take a closer look at the potential mediating role of risk-orientation in the relationship between rancher characteristics and adoption behavior.

State and Transition Models

Traditionally, rangeland managers, including ranchers and NRPs, used an equilibrium based range management framework. Grazing was the primary driver of vegetation dynamics in this framework (Briske et al. 2008; Westoby et al. 1989). This conventional model of rangeland dynamics has been criticized for years for its inability to respond to non-linear dynamics particularly in ecosystems with arid and semi-arid climate (Westoby et al. 1989), and inaccurate predictions of the responses of common plant communities to management actions (Allen-Diaz and Bartolome 1998). Different ecological models have

been developed over several decades, including several non-equilibrium models. Westoby et al.'s (1989) article *Opportunistic Management for Rangelands Not at Equilibrium* proposes one of these models, known as a STM, and describes how it can help land managers to organize their knowledge and implement strategies to achieve management goals.

Over the past decade and a half, STMs have been developed and implemented for many ecological sites throughout the US. The Natural Resources Conservation Service, the United States Forest Service, and the Bureau of Land Management signed a memorandum of understanding in 1997 to commit to developing a uniform foundation for inventory, assessment, and monitoring of rangelands (Bryant et al. 1997), based on the STM framework.

STMs are qualitative 'box and arrow' diagrams that depict how plant communities and their associated soils are affected by different combinations of environmental conditions, natural disturbances, and management practices. STMs can incorporate vegetation drivers and changes that more traditional models are unable to address (e.g., epic natural events, particularly in arid and semi-arid climates, non-native invasive species, irreversible transitions, etcetera) (Briske et al. 2003; Westoby et al. 1989); therefore, STMs complement the traditional succession based approach (Bestelmeyer et al. 2003). The theory of the modern approach indicates that the primary ecological processes, hydrology, nutrient cycling, and energy capture (Stringham et al. 2003) are more vulnerable to external disturbances than traditional management frameworks suggest (Briske et al. 2003). It has been suggested that STMs have the capacity to integrate equilibrium models (Briske et al. 2003; Rodriguez Iglesias and

Kothmann 1997) such as the conventional range condition model, which compares current species composition to composition in the 'climax state' (Clements 1936) and equates climax to the most desirable 'excellent' condition.

Researchers and field practitioners have been exploring the application of STMs to a variety of natural resource contexts including, but not limited to, restoration ecology (Suding et al. 2004) and riparian management (Stringham et al. 2001). It has been suggested that applying alternative state frameworks, such as STMs, to restoration ecology might advance the practice of restoration and the understanding of degraded systems, which includes that some states represent a resilient alternative state (Suding et al. 2004). Additionally, researchers have started to explore the human dimensions of STMs. For example, a study conducted in Northwest Colorado developed a STM derived from local knowledge which was later integrated during stakeholder workshops with a data driven STM for the same area (Knapp and Fernandez-Gimenez 2009; Knapp et al. 2010). Ranchers were concerned about the STM's ability to link connected or adjacent vegetation communities and wanted STMs to address riparian as well as upland vegetation types (Knapp and Fernandez-Gimenez 2009). Overall, ranchers in this research appeared to grasp the complexity of interacting climate and management factors associated with STMs; however, a need was detected for outreach and education efforts to focus on the meaning and application of ecological site-based STMs (Knapp and Fernandez-Gimenez 2009).

STMs are not without problems, including challenges in development and application of the model as an assessment and decision-making tool. For example, Allen-Diaz and Bartolome (1998) found that the framework requires significant detail, time,

and site specific data to develop a representative ecological site description in order to generate an accurate prediction or outcome (e.g., land treatments). Additionally, the long-term, site specific data needed to construct data-driven models are often unavailable (Allen-Diaz and Bartolome 1998). Allen-Diaz and Bartolome (1998) concluded that a majority of issues associated with STMs are the result of human error related to unusual transitions through misclassification and identification of occurrences resulting in misidentified states. From a management perspective, the utility of STMs as a decision-making tool may depend on the availability of sufficient resources (time and money) when ecological opportunities or hazards arise in order to either seize or evade them (Westoby et al. 1989).

A comprehensive approach for the management of vegetation composition and ecological processes, STMs are an evolving tool in the field of rangeland management and other natural resource disciplines. This assessment, planning, and monitoring tool has been adopted by several federal land management agencies and is gaining increased attention from researchers, state and local natural resource agencies, land conservation organizations, consultants, and private landowners throughout the western US. Challenges remain to the application of consistent STM terminology (Briske et al. 2003). Additionally, we need to better understand rangeland managers' awareness of and attitudes toward STMs, as well as how they are using STMs. We also need to learn from practitioners what is and what is not working, and how to improve STMs to make them a more useful decision-making tool for rangeland managers. Similar to STMs, cheatgrass is also a current topic of interest in rangeland management. In the next section, we review a

broad spectrum of literature about cheatgrass, including human dimensions of cheatgrass management.

Cheatgrass (*Bromus tectorum* L.)

Cheatgrass, also known as downy brome, has established throughout most of North America, including the US, Canada, and northern Mexico (Mosley et al. 1999; Smith and Enloe 2006). It has been suggested that this species is the most abundant plant in the western US, "dominating millions of acres of degraded rangelands" (Meyer and Leger 2010 pg. 6), including in Southeast Oregon, where ranchers identified it as the most abundant species (Johnson et al. 2009). Cheatgrass is an aggressive, non-native, invasive winter annual grass (Bradford and Lauenroth 2006; Mosley et al. 1999; Rowe and Brown 2008; Smith and Enloe 2006; Stubbendieck et al. 2003), which evolved in Eurasia and is pre-adapted to climates with cool, wet winters and hot, dry summers (Mack 1981; Mosley et al. 1999; Smith and Enloe 2006). It is believed that cheatgrass was first introduced to the US through soil used in the ballast of ships traveling from Eurasia (Davison et al. 2007; Mosley et al. 1999). Novak and Smith (1993) suggest this ubiquitous species was independently introduced several times throughout North America.

Human movement and activities contributed to the early migration of cheatgrass throughout western North America (Mack 1981). The distribution of cheatgrass exploded from 1915 – 1930 (Mack 1981), following a period of heavy domestic grazing on western rangeland. Cheatgrass increased in prominence as humans depended more on railroads for transportation and the shipment of goods (Mosley et al. 1999). Contaminated bedding and packing straw as well as livestock feces were discarded along the railroad route, and

it is believed this helped to facilitate the dispersion of cheatgrass (Knapp 1996; Mosley et al. 1999). It is estimated that cheatgrass has established on over 40 million hectares of rangeland in the western United States (Rowe and Brown 2008) and that humans, animals (domestic and wildlife), as well as other natural elements continue to be vectors for the spread of the species (Mosley et al. 1999). Land managers have reported the presence of cheatgrass at higher elevations during the past 20 years, where fire cycles have remained intact (Rowe and Brown 2008).

Cheatgrass has demonstrated its adaptability by surviving several years of drought (Smith and Enloe 2006). Young and Clements (2009) report that it is difficult for cheatgrass to compete with established woody and perennial species; however, following a natural or human induced disturbance, cheatgrass is able to outcompete the native seedlings. Cheatgrass has the ability to influence and increase the occurrence of wildfires, creating conditions that further enhance the potential for cheatgrass expansion (Mosley et al. 1999; Rowe and Brown 2008). The increase in fire frequency can be detrimental to some shrub communities such as winter fat (*Ceratoides lanata* (Pursh) J.T. Howell) and shadscale saltbush (*Atriplex confertifolia* (Torr. & Frém.) S. Watson), as well as non-sprouting shrubs such as Wyoming big sagebrush (*Artemisia tridentata* Nutt. Ssp. *wyomingensis* Beetle & Young) (Mosley et al. 1999). Over time, perennial shrubs, grasses, and forbs can be outcompeted by a combination of an increase in fire frequency and competition with cheatgrass (Mosley et al. 1999). Observations and empirical evidence show that cheatgrass can also modify plant communities in semi-arid ecosystems through competitive exclusion of native plants (Mosley et al. 1999; Rowe and Brown 2008) as well as impact wildlife habitat (Young and Clements 2009).

Most scientific studies of cheatgrass focus on infestations in the Intermountain West (Great Basin), where cheatgrass is prolific. Less empirical work has been done on cheatgrass in other states such as Wyoming and Colorado. Smith and Enloe (2006) note that the herbarium records for Wyoming indicate cheatgrass was present throughout much of the state by the early 20th century. Smith and Enloe (2006) report that cheatgrass mostly occurs throughout Wyoming in low density. Since the early 1980s, an increase in cheatgrass establishment has been recorded in eastern Wyoming, and in localized areas the invasive has become the dominant plant in northern mixed prairie communities (Mosley et al. 1999). The Wyoming Pest Detection Program (2009) electronically surveyed Wyoming Weed and Pest District members in 2003, 2005, and 2007 about the distribution and abundance of cheatgrass in their counties. The overall trend map for 2007 indicates that cheatgrass has increased throughout all Wyoming counties except Sublette and Crook (Wyoming Pest Detection Program 2009). Additionally, what is believed to be an extremely invasive isozyme genotype was recently found near Laramie, Wyoming (Schachner et al. 2008), which Meyer and Leger (2010) suggests could lead to an invasion of cheatgrass in an area that previously had minimal invasion.

Wyoming land managers have already expressed concern about the potential of cheatgrass to more readily establish in new areas (Smith and Enloe 2006). Wyoming's diverse elevations and climate are two variables that are believed to influence the distribution and establishment of cheatgrass in the state (Smith and Enloe 2006). The state of Wyoming has not listed cheatgrass as a noxious weed (Jerup 2008). However, the plant is a 'County Declared Weed' in Albany, Converse, Natrona, Platte, and Weston counties (Veckrey and Hardy 2008; Wyoming Pest Detection Program 2009). As a

'county declared weed' the Wyoming Board of Agriculture and the Wyoming Weed and Pest Council have found that cheatgrass is directly or indirectly "detrimental to the general welfare of persons residing within a district (county)" (Wyoming Pest Detection Program 2009). In Wyoming, this statute gives legal authority to stated counties to regulate and manage the declared weed (Wyoming Pest Detection Program 2009).

Colorado State University's herbarium records indicate the first collection of cheatgrass in the state was in Larimer County in 1892 (Graham and Ackerfield 2008). Cheatgrass can be found in eastern Colorado along roadsides and disturbed sites (Davison et al. 2007). The non-native plant follows the foothills of the eastern slope of the Rocky Mountains, while in the western part of the state cheatgrass is found at lower elevations (Davison et al. 2007). In Colorado, cheatgrass has been recorded at elevations ranging from 4000 to 9000 feet, and it has been reported that the plant occurs as widespread, dense populations on 11 to 50 hectares in Rocky Mountain National Park (Center 2003). The state of Colorado has listed cheatgrass as a 'List C Species' on the state's Noxious Weed List, a classification for either widespread non-native species or for species of special interest to the agriculture industry (Agriculture 2009).

Human Dimensions of Cheatgrass Management

In order to manage invasive plants effectively, we must understand not only their ecology, but also how land managers perceive these species, how they manage them, the factors that influence their decisions about whether to invest in weed control, and what methods to employ. Relatively little research has been conducted on the human dimensions of invasive species management generally, or cheatgrass specifically. In this section, we review the literature on the effects of cheatgrass, preferred methods of

treatment for cheatgrass, as well as constraints that have been associated with different treatment methods.

Cheatgrass has documented effects on ecosystems, livestock production, and other economic values. Ranchers in Southeast Oregon identified cheatgrass as the most abundant plant on degraded rangelands; however they did not consider it to be the most problematic species (Johnson et al. 2009). The results of a study conducted in Spain indicated that 'environmental managers' primarily perceive that noxious weeds outcompete native plants (Andreu et al. 2009), a phenomenon associated with cheatgrass in the Intermountain Basin states.

Johnson et al. (2009) suggest that the contradiction in the proportion of infested rangeland by cheatgrass and the perception of ranchers that the species is not the most problematic is likely due to the utility of cheatgrass for livestock forage, compared to other invasive plants. Research has indicated that in some locations cheatgrass can provide forage for animals (domestic and wildlife) during winter and spring months (Stubbendieck et al. 2003). During this time cheatgrass is palatable for six to eight weeks (Mosley et al. 1999). However, when cheatgrass is grazed dry, the long, straight awns can damage the eyes and mouth of grazers (Mosley et al. 1999; Stubbendieck et al. 2003), which if the sores become infected can lead to actinomycosis or lumpy jaw (Mosley et al. 1999).

Other socioeconomic effects that have been observed and associated with cheatgrass include the ability of the seeds to intertwine with the wool of animals (Stubbendieck et al. 2003), contaminating and degrading the use of natural fibers. Additionally, ranchers, local decision makers, and managers of public grazing land

indicated that they believe weed infestations affect the market value of rangeland (Sell et al. 1999). Although it appears there might be some benefits associated with cheatgrass (i.e., winter or early spring livestock forage), the plant's negative ecological and socioeconomic effects can be significant. Therefore, it is important to understand different management approaches, and when and how they have been applied.

Researchers, land managers, and landowners have tried an assortment of approaches to manage invasive weeds including mechanical (e.g., tilling), chemical (i.e., herbicides), biological (which can include livestock grazing), and prescribed fire. The management of invasive weeds can be a significant capital investment, but the benefits can be great and include increased forage quantity and quality and protection of non-infested areas (Griffith 1999).

Several approaches to manage cheatgrass have been explored and include mechanical treatment (including fuel management), chemical applications, biological control (e.g., prescribed grazing), and prescribed fire (Davison et al. 2007). Mosley et al. (1999) supports the former three methods for cheatgrass treatment, but does not agree that prescribed burning is an effective alternative. Ranchers in Southeast Oregon also considered prescribed fire as one of the least effective modes of managing annual grasses (Johnson et al. 2009).

Ranchers ranked herbicide and grazing treatment of annual grasses, such as cheatgrass, as the most effective mode of treatment (Johnson et al. 2009). Several constraints that have been associated with the use of herbicides include: environmental restrictions, damage to non-target species, extensive infestations, and lack of equipment or knowledge to apply herbicides (Johnson et al. 2009; Sell et al. 1999). Public land

managers of non-grazing land, one of the stakeholder groups in the Sell et al. (1999) study, indicated that lack of resources such as time, money, and equipment were not constraints to herbicide treatments. Another study found that stakeholders believe that chemical treatments are not harmful to the environment when used appropriately (Sell et al. 1999).

For the management of cheatgrass, it is generally recommended that a combination of treatments is implemented for the best results (Davison et al. 2007), followed by revegetation (Mosley et al. 1999). Ranchers have indicated that control of invasive annual grasses, such as cheatgrass, are only marginally successful; however a majority of ranchers plan to continue to treat annual species with herbicide, livestock grazing, and revegetation (Johnson et al. 2009). In addition to the reported marginal levels of success with managing cheatgrass, other constraints to managing noxious weeds have been suggested.

Three of the primary constraints that have been identified to managing noxious weeds in general are: 1) insufficient coordination among administrations; 2) lack of public awareness (Andreu et al. 2009); and 3) limited economic resources (Andreu et al. 2009; Sell et al. 1999). Other constraints to managing invasives have included: environmental restrictions and extensive infestations (Sell et al. 1999). However, despite these constraints ranchers perceive that it makes economic sense to manage weeds on rangelands (Johnson et al. 2009).

Overall, prior empirical studies have resulted in a variety of preferred methods for treating or managing noxious and invasive weeds. Several variables may influence a community or individual's preferred method of treatment including, but not limited to:

type of vegetation being treated (i.e., grass, forb, or woody shrub); previous exposure to a management approach (e.g., mis-use of chemicals or a fire that got out of control); education and outreach of the different tools; property or infestation size; available resources to implement and maintain the desired management approach; and the time it takes for visible results.

Cheatgrass has been studied extensively, notably for it impacts on plant community composition, fire regimes, and wildlife habitat. Additionally, it appears there is a never-ending search for a long-term effective and cost efficient management alternative. However, less empirical evidence has been presented about land managers' perceptions of factors that are associated with the spread of cheatgrass and its successful establishment, as well as perceived or experienced ecological and economic impacts of cheatgrass. Few studies have addressed how land managers have tried to manage cheatgrass and their associated level of satisfaction or constraints they have encountered while managing or trying to manage cheatgrass. Gaining an understanding of the current perceptions and management of cheatgrass can provide the foundation for developing an integrated management strategy, one that incorporates a long-term plan "consisting of prevention programs, education activities, and management approaches" (DiTomaso et al. 2010 pg. 43).

CONCLUSION AND THESIS ORGANIZATION

As our society and the western landscape continue to change, it is important that we understand the evolving management needs and goals of ranchers and NRPs. This understanding can help to ensure the sustainability of ecosystem services that current and future generations depend on. Additionally, it can help researchers to develop appropriate

decision-making tools that can aid land managers who are trying to navigate the interactions between the human and biophysical components of rangelands.

Our study will contribute to science in several ways. First, it builds on limited knowledge of ranchers' risk-orientation and adoption of progressive practices, and use of government programs. Second, our work will explore the role of risk-orientation as a potential mediating factor between the relationship of rancher and operation characteristics and the adoption of practices and programs.

Third, a goal of our study was to begin addressing some of the knowledge gaps of STM human dimensions, by exploring stakeholders' awareness of the tool, their perceived potential ecological and economic benefits of using the model, and what changes or additions to STMs would make it more useful for end users. Finally, there is a similar need to fill knowledge gaps about the human-dimensions of cheatgrass, including the degree it is perceived a problem in different regions, and how people have tried to manage it.

The following describes the organization of the remainder of this thesis. Chapters two through four are written in manuscript format and therefore parts of the literature review provided above will reappear throughout these chapters. Additionally, the methods for chapters two through four are similar except for the survey data analysis for each chapter. Furthermore, respondent characteristics are presented in the results sections in each of the chapters two through four. Chapter two has one target population, ranchers, and chapters three and four discuss two populations, ranchers and NRPs.

In chapter two, we will discuss ranchers' risk-orientation and adoption of progressive practices and government programs. The focus of the third chapter is ranchers' and

NRPs' awareness of STMs and perceived potential ecological and economic benefits of using the models. In the fourth chapter, we discuss to what extent land managers' perceive cheatgrass a problem in their area, as well as other human-dimensions associated with the presence and management of the species. Chapter five is a synthesis of the results from chapters two through four, and includes recommendations based on our findings.

CHAPTER TWO: RANCHERS' RISK-ORIENTATION AND ADOPTION OF INNOVATION

INTRODUCTION

Rangelands cover approximately 50 percent of the Earth's land mass (CSREES 2009) and comprise about 34% of the United States (US) land area – more than 770 million acres (USFS 1989). We depend on these grasslands, shrub-lands, and savannahs for a variety of ecosystem services including food, fiber, wildlife habitat, water, recreation, aesthetic values, cultural heritage, community uniqueness such as open spaces near urban areas, and livelihoods related to these services, among other ecological and socioeconomic benefits (Holechek 2007; Wallace et al. 2008).

The western mountain states experienced the most rapid population growth of any US region during the 1990s (Hansen et al. 2002). Prior research suggested that private lands, such as working ranchlands, provide a buffer to public lands, and that in the state of Colorado a greater portion of potential conservation areas for the Colorado Natural Heritage Program occur on private rather than public lands (Talbert et al. 2007). A study conducted in Larimer County, Colorado used spatial analysis to identify benefits associated with private land conservation. The greatest benefits observed were "conservation of riparian areas, contiguity with other protected parcels, protection of big-game concentration areas, and buffering of public protected areas" (Wallace et al. 2008 pg. 292). Many of these benefits are also associated with traditional ranches. However,

the rapid population growth in the Mountain West as well as increase in outdoor recreation, and rural sprawl have resulted in increased pressure on natural resources (Hansen et al. 2002). As ranch land is converted to exurban development and other uses, the natural buffers for public land are diminished.

Understanding the interactions of the human and biophysical components of rangeland is necessary for sustainable management, as are decision-making tools that help land managers understand and make decisions in a complex environment. To ensure the success of such tools, it is important to understand the end users' or target populations' knowledge, attitudes, and current management practices, as well as the factors associated with their adoption and implementation of new practices and innovations. Given the importance of working ranchland and public rangelands to natural resource conservation, it makes sense to concentrate on managers of those lands.

Adoption of Innovation

Innovations are developed in order to address a problem or meet a need; in general, they are new ideas, practices, or techniques to an individual or group (Brown 1981; Rogers 1995). Ranching innovations may include participating in new programs such as conserving land in perpetuity through conservation easements, implementing progressive livestock or grazing management practices (e.g., targeted grazing management, low stress livestock handling), other natural resource management practices (e.g., weed control), as well as business innovations (e.g., wind energy development).

The 1928 introduction of a hybrid corn variation by the Iowa State Agricultural Experimentation Station, which resulted in increased crop yields, was the foundation of the diffusion of innovation theory (Stephenson 2003). The theory of diffusion of

innovation explains how innovations spread as more and more individuals accept and apply them (Brown 1981; Rogers 1995). The theory has been applied in rural sociology since the early 1940's and it was used to address environmental concerns beginning in the mid-1970's (Rogers 1995). Although the diffusion of innovation theory has been applied and developed for over eight decades, Didier and Brunson (2004) suggest that a deeper understanding of what motivates ranchers to adopt innovations, and when they adopt, is needed to successfully encourage implementation of desired management practices.

Results from prior empirical work have suggested several common characteristics of innovations and adopters or non-adopters. Identifying similarities in innovations that have been widely adopted and gaining a better understanding of the characteristics of adopters will assist researchers and extension agents alike to develop more relevant and effective innovations and strategies to encourage adoption, as well as to understand the limitations and constraints of adoption of innovation.

Diffusion of Innovation

Diffusion occurs when an "innovation is communicated over time to a social system" (Rogers 1995 pg. 5). Rogers (1995) describes four essential elements to the diffusion process: 1) *innovation*; 2) *communication channels*; 3) *time*; and 4) *social system*. The first element, *innovation*, is an idea or practice that is perceived as new to an individual or group. Through prior research, five characteristics of innovations that influence the rate of adoption have been identified. They are the perceived:

1) **Relative advantage:** benefits of adopting an innovation compared to the prior practice

2) **Compatibility:** the degree to which an innovation is consistent with existing values, past experience, and needs
3) **Complexity:** the degree of difficulty to understand the innovation and/or the development of new skills
4) **Trialability:** the degree to which an innovation has been tested
5) **Observability:** the degree to which results are visible to potential adopters

(Rogers 1995).

Innovations that are less complex, but have greater degrees of the other four characteristics tend to be adopted first (Rogers 1995).

The second element of diffusion is *communication channels*, the pathways through which information is relayed between entities (Rogers 1995). Rogers (1995) indicates that the most effective form of communication for diffusing innovation is through interpersonal channels, or face to face communication. In a qualitative study of rancher adoption of innovation, several personal characteristics of adopters were identified, including those with larger social networks (Didier and Brunson 2004). These networks enabled producers to observe outcomes of an innovation, satisfying two of Rogers's (1995) characteristics of innovation, trialability and observability.

Rogers (1995) also suggests that the greater the commonality or homogeneity (e.g., socio-economic status, education, etcetera) between individuals or groups, the more likely an innovation will be adopted. In other words, a common problem in the communication process of diffusing innovations is heterogeneity between innovators and potential adopters (Rogers 1995). Rogers (1995) also indicates that adoption of

innovation is more closely linked to subjective evaluation of an innovation by peers (i.e., homogeneity) rather than to research findings.

The third element to diffusing innovation is *time*, which is developed around a linear, four step 'innovation decision process' (Rogers 1995). This process can take several years (Rogers 1995). The process begins with a potential adopter first becoming knowledgeable about an innovation either through learning of its existence or gaining understanding of the idea or practice, and is followed by the individual or group either developing a favorable or unfavorable attitude toward an innovation (Rogers 1995). The third step in the process is implementation of an innovation, which can include reinvention of an innovation by an adopter (i.e., altering the innovation to meet an adopters needs) (Rogers 1995). The final phase of the adoption process is confirmation, a time when an adopter or non-adopter either accepts an innovation or reverses their decision and abandons an innovation (Rogers 1995).

Rogers (1995) suggests that *time* also applies to the rate at which individuals or groups adopt an innovation. Over the past several decades, more than 40 researchers have conducted empirical work to develop categories of adopters based on adopter characteristics, innovations adopted (Stephenson 2003), and the rate of adoption (Brown 1981). Prior empirical work has suggested that some of the systematic differences that influence adoption include, but are not limited to: demographics; locality; and social characteristics (Brown 1981). Rogers (1995) identifies and describes five categories of adopters that are based on ideal typed, which were grounded in empirical studies. The five categories are:

1) **Innovators:** socialize beyond their local peer group, and have access to significant financial resources. They comprehend more complex concepts, and they are comfortable with a higher degree of uncertainty. Innovators are integral to the diffusion process by implementing an innovation from outside of the community. They comprise 2.5% of the general population.
2) **Early adopters:** are well respected in their local community and they hold significant leadership roles. They implement an innovation and communicate a subjective evaluation of it through social networks. Early adopters comprise 13.5% of the general population.
3) **Early majority:** are social, but do not hold leadership roles in their community; however, they are one step ahead of the average person and are deliberate in their adoption of an innovation. They connect the early adopters with the late majority through interpersonal networks. Thirty-four percent of the general population is an early majority.
4) **Late majority:** adopt innovations due to economic necessity or from increase in peer pressure. They are skeptical of innovations and they adopt after the majority of the population. Thirty-four percent of the general population is a late majority.
5) **Laggards:** are the last to the adopt innovation. They associate with likeminded individuals or groups and they are skeptical of new ideas. Laggards comprise 16% of the general population.

(Rogers 1995).

An issue with the adopter categories is that they are non-exhaustive, in that they do not account for incomplete adoption or non-adoption (Rogers 1995).

A *social system* is comprised of individuals or groups that cooperate to solve a common problem to reach a mutual goal (Rogers 1995) and is the fourth and final element to the diffusion of innovation. Rogers (1995) suggests that it is important for innovators to understand social structures to be able to predict human behavior to diffuse innovation, in other words, they should develop a diffusion strategy that accounts for human behavior.

Ranchers and Adoption of Innovation

Ranching is one of the founding professions of the colonized Western United States. Ranchers have continued to persevere despite continuous hardships such as drought and economic downturns. Nevertheless, Western ranchland (privately owned rangeland) is changing ownership. One study of three counties in Colorado, Wyoming, and Montana found that the majority of ranches sold between 1990 – 2001 were bought by amenity and non-local buyers (Gosnell and Travis 2005). Gosnell and Travis (2005) suggested that "another decade of sales will mark the end of all but a very few traditional ranches in the most amenity-rich areas" (pg. 197). Ranchers' ability to adapt and innovate might be what continues to sustain their culture, preserve part of the history of the American West, and maintain the ecosystem services that our society depends on. Additionally, it is imperative for researchers and natural resource professionals (NRPs) to monitor changes in rancher demographics and the evolving management goals of the next generation of ranch managers. Longitudinal studies may help us to better understand how stakeholder groups communicate about issues and management of rangelands. This understanding might enable the development of a common language to ensure the continued conservation of the nation's rangelands.

Characteristics of Innovations Adopted by Ranchers and What Motivates Their Adoption

Several studies have looked at ranchers' adoption of management practices and suggest a number of key attributes of the adopted innovations which are similar to Rogers' (1995) characteristics of innovations. For example, ranchers generally adopt innovations that have outcomes that are either predictable or controllable (trialability and observability) (Coppock and Birkenfeld 1999; Kennedy and Brunson 2007) and that have immediate, visible results (trialability and observability) (Kennedy and Brunson 2007; Kreuter et al. 2001). This includes observing success or failure of an innovation and comparing it to their personal situation. They are also more interested in innovations that are compatible with their production goals, such as improved animal performance or better forage utilization (Coppock and Birkenfeld 1999; Kennedy and Brunson 2007). Several studies have indicated that ranchers and farmers are more likely to adopt innovations that require few specialized management skills and are simple to implement (complexity) (Coppock and Birkenfeld 1999; Lambert et al. 2007), and that have results that appear to enhance cost effectiveness (relative advantage) (Coppock and Birkenfeld 1999; Kreuter et al. 2001; Lambert et al. 2007; Peterson and Coppock 2001).

Ranchers' motivations to adopt are strongly associated with the characteristics of innovations. As discussed above, adoption is more likely to occur if an innovation aligns with a rancher's priority needs, and personal as well as management goals (compatibility and relative advantage), which might also be a motivation to adopt (Coppock and Birkenfeld 1999; Kennedy and Brunson 2007). For example, implementing a new management practice that inadvertently improves wildlife habitat and attracts wildlife

from adjacent lands that are of lesser quality (Didier and Brunson 2004) might result in a decrease in the amount of available forage for livestock a potential disincentive to adopt this practice. However, depending on an operation's management objective(s), this may not be an obstacle to adoption. For example, if a rancher depends on a combination of income from livestock production and guided big game hunts, they may want to attract certain species to their land during specific times of the year.

Several external conditions may influence motivations for adoption of new management practices including drought and rural development (Kennedy and Brunson 2007). For example, a rancher might have to sell some of his or her livestock during a drought, and to off-set potential lost revenue, they might adopt a new business practice such as installing wind energy turbines. Considering another example, property taxes might increase in areas that rural development occurs in order to provide utilities. The increase in property taxes might motivate a rancher to adopt a management or business practice to generate additional revenue or a rancher might participate in a government program that provides tax incentives.

Ranchers who have implemented new range management practices have indicated that forage production, water quality (Kennedy and Brunson 2007), and profitability are key reasons for adoption (Didier and Brunson 2004; Kennedy and Brunson 2007; Rowan and White 1994). Another reason ranchers and landowners adopt new management practices is to demonstrate their commitment to land stewardship/rangeland health (Didier and Brunson 2004; Kennedy and Brunson 2007; Peterson and Coppock 2001), including protecting biodiversity (Wallace et al. 2008). These and similar motivations might contribute to the preservation of farm and agricultural land which has been

positively associated with progressive and innovative practices such as using sustainable agricultural practices or participating in land conservation programs such as conservation easements or clustered development (Selfa et al. 2008; Wallace et al. 2008). Lastly, prior empirical work has suggested that ranchers are motivated to innovate to improve public relations (Didier and Brunson 2004).

Characteristics of Ranchers Who Adopt Innovations

A 1996 – 97 study conducted by Peterson and Coppock (2001) found that 80% of livestock producer respondents self-identified as passive managers or managers who do not implement new management practices. A significant portion of western rangelands are privately owned or leased by ranchers. Therefore, it is imperative for researchers and NRPs to continue to identify and gain an understanding of factors that affect ranchers' ability to adopt new management practices, such as coping strategies, operation scale, and production goals (Coppock and Birkenfeld 1999), particularly if ownership of ranches continues to change.

The socio-economic status of a rancher has been shown to influence his or her adoption of innovation. For example, higher levels of formal education (Coppock and Birkenfeld 1999; Peterson and Coppock 2001; Selfa et al. 2008) and annual household income (Coppock and Birkenfeld 1999; Kreuter et al. 2008; Peterson and Coppock 2001; Selfa et al. 2008) are positively associated with the adoption of innovations. Full-time producers who live near to or on their ranch and who have few off-ranch obligations (Didier and Brunson 2004; Kennedy and Brunson 2007; Kreuter et al. 2008) are more likely to adopt new practices, as are public land permittees (Peterson and Coppock 2001). Similarly, other studies have found that ranchers who depend more on their ranch

(specifically agriculture) for income are more innovative (Kennedy and Brunson 2007; Rowan and White 1994). A rancher is more apt to be innovative if their operation is multigenerational and the future of the operation is certain (Didier and Brunson 2004). Another factor that has been shown to increase the probability for adoption of an innovation is social networks (Didier and Brunson 2004). Social networks can provide a way for potential adopters to observe outcomes of an innovation implemented by a peer or other member of a social system (e.g., informal groups or organizations), reducing the perceived risk of adopting a new management practice (Didier and Brunson 2004; Kennedy and Brunson 2007; Rogers 1995).

Barriers to adoption of innovation include limited time and resources (Didier and Brunson 2004; Peterson and Coppock 2001), advanced age, and declining health (Peterson and Coppock 2001). Several studies have also indicated that a strong commitment to traditional ranching practices can pose a barrier to adoption of innovation (Didier and Brunson 2004; Rowe et al. 2001; Smith and Martin 1972). Political and legal systems may also hinder adoption of innovation. For example, Didier and Brunson (2004) suggested that when the future of public grazing allotments is uncertain, permittees are less likely to innovate. A survey of Texas landowners suggested that concern over legal liability deterred use of prescribed fire for land management (Kreuter et al. 2008). Finally, Didier and Brunson (2004) indicated that operations that are more spatially fragmented (e.g., checkerboard) are less likely to adopt innovations. This is likely due to a necessary increase in management input(s) to implement a new management practice.

Continued monitoring is needed to understand the changing needs of ranchers and how these might influence their willingness to adopt new management practices. This is

particularly important as ranchers continue to encounter stresses and shocks such as extended drought and economic downturns. Additionally, since transfer of ranch management to new owners is inevitable, whether to heirs of the operation or to absentee, amenity owners, it is important that we understand the evolving needs of ranch managers and their personal and management objectives. It has been suggested that diffusers of innovation pay particular attention to potential adopters' priority needs, especially when differences in socio-economic classes exist between the populations (Coppock and Birkenfeld 1999).

Researchers and NRPs will be most successful at sustaining rangelands if they work with and in the same direction as ranchers. Additionally, they must acknowledge that ranchers in each community and region have different needs and characteristics, which may influence their ability and willingness to adopt an innovation.

The purpose of this study is to inform the development of a diffusion of innovation strategy related to two current rangeland topics state and transition models [STMs], a decision-making tool, and management of cheatgrass [*Bromus tectorum* L.], an invasive annual grass). Additionally, we want to build on prior empirical work about ranchers' risk-orientation as well as factors associated with their willingness to adopt innovative practices and program. Specifically, our study will take a closer look at the potential mediating role of risk-orientation in the relationship between rancher characteristics and adoption behavior.

OBJECTIVES AND HYPOTHESES

The objectives of this study were to 1) assess ranchers' self-reported risk-orientation, 2) document ranchers' current use of progressive management and business practices and

use of government programs, and 3) identify factors associated with ranchers' adoption of innovation.

This study is part of a long-term, interdisciplinary integrated research and extension project, which is scheduled to conclude in 2012. In the context of the larger project, this study provides baseline data that will enable researchers and project collaborators (Colorado State University and University of Wyoming extension) to develop appropriate extension material and to diffuse project innovations into study locations.

Based on the literature on ranchers' adoption of innovations, we hypothesized that higher income (Coppock and Birkenfeld 1999; Kreuter et al. 2008; Peterson and Coppock 2001; Selfa et al. 2008), percentage of income generated from on-ranch sources (Didier and Brunson 2004; Kennedy and Brunson 2007; Kreuter et al. 2008), level of formal education (Coppock and Birkenfeld 1999; Peterson and Coppock 2001; Selfa et al. 2008), certainty that the ranch would remain within the family (Didier and Brunson 2004), operation scale (measured in animal units [AUs]), and percentage of annual labor provided by the family would be positively associated with ranchers' risk-orientation (Rogers 1995) (Hypothesis 1). For the first hypothesis, we also hypothesized that age (Peterson and Coppock 2001) would be negatively associated with ranchers' risk-orientation. We also hypothesized that the above variables (except age) as well as risk-orientation would be positively associated with ranchers' adoption of practices and programs (Hypothesis 2). Similar to the first hypothesis, we hypothesized that age would be negatively associated with ranchers' adoption of practices and programs. Finally, we hypothesized that risk-orientation would mediate the relationship between rancher

characteristics (our predictor/independent variables) and adoption of progressive management and business practices, and use of government programs (Rogers 1995) (Hypothesis 3). Full or partial mediation might occur when a third variable is introduced affecting the relationship between the initial variable (predictor/independent) and the outcome (criterion/dependent) (Kenny 2009).

METHODS

This study used a mixed-method approach implemented in two phases with ranchers; pre-survey focus groups followed by a self-administered mail survey. Focus groups were used in this study as an exploratory tool to gain a better understanding of rancher risk-orientation and level of adoption. We asked questions pertaining to two pressing rangeland issues: cheatgrass, an annual invasive grass, and STMs, a conceptual decision making tool. The data gathered about cheatgrass and STMs provided insight about land managers' risk-orientation (e.g., towards methods used to manage cheatgrass) and level of adoption (e.g., knowledge and use of STMs). Additionally, we wanted to find out how ranchers learn about new management tools. Focus group data were also used to inform the development of the self-administered survey.

Phase 1: Focus Groups

Sampling Frame

The study locations and sampling frame varied during each phase of the study. For the first phase of the study, we invited ranchers from one county in Colorado (Larimer) and five counties in Wyoming (Albany, Carbon, Platte, Converse, and Niobrara) to participate in separate focus groups (Figure 2.0). Three focus groups were held.

We defined several criteria for the type of ranchers we wanted to invite to the focus groups. These criteria were: 1) owners of mid to large scale ranch operations (more than 100 acres [40.47 hectares]); and 2) a mix of active and less active individuals in the agriculture community. We contacted individuals who work or live in the communities (see purposive and snowball sampling below) to identify ranchers who met our sampling criteria.

A non-probability sample was conducted for the first phase of the study, which means that the odds that an individual met our sample frame criteria and would be invited to participate in our study was unknown. We identified potential participants through purposive and snowball sampling (Berg 2004; Biernacki and Waldorf 1981; Stewart and Shamdasani 1998). Purposive sampling is when participants are intentionally selected (Stewart and Shamdasani 1998), particularly of populations that can be difficult to access (Neuman 2003), such as rural communities. In this study, the use of purposive sampling helped to ensure that the representative target population was identified. The snowball technique is a method where initial contacts provide researchers with a name or list of names of individuals who meet the sample frame criteria and who might participate in the study (Berg 2004; Biernacki and Waldorf 1981). This technique enabled us to gain access to a broader group of potential respondents. The research team initiated the first step of this method by identifying several key informants, including county extension agents, and representatives from local cattle growers associations, resource conservation district boards, and natural resource agencies who work with area ranchers. We asked key informants to identify potential individual participants that met our sampling criteria (see

above) (Appendix A). A list of 15 – 20 potential participants was compiled for each of the planned focus groups.

Focus Group Design and Implementation

Focus groups are a systematic, qualitative method where homogeneous groups comprised of eight to 12 individuals discuss a particular topic (Fowler 2002; Stewart and Shamdasani 1998). They have been used in a variety of industries since 1941 (Bernard 2002) enabling exploration of respondents' attitudes and perceptions about a topic (Vaske 2008). Focus groups can enhance quantitative social science studies by combining qualitative with quantitative methods (Bernard 2002). By documenting what issues are salient and how participants talk about them, the focus group method can assist researchers in developing relevant survey questions (Bernard 2002). In January and February 2009, we held focus groups with ranchers in each study area. The purpose of the gatherings was to explore ranchers' level of knowledge and use of STMs, and their experience with treatment methods of cheatgrass, in order to assess their risk-orientation and willingness to adopt progressive practices and programs.

Invitations were mailed to selected ranchers on the basis of referrals from key informants (Appendix C). Focus groups were held at community centers, or libraries. Focus group meetings were audio-recorded and a note-taker recorded the discussion on a laptop computer. Additionally, key points were written on a flip-chart and verified by participants. The typed notes were later compared to the audio recordings and completed by a transcriber. We conducted three, two-hour long focus groups with a total of 16 ranchers.

Analysis of Focus Group Data

Focus group data were transcribed and then analyzed using the qualitative data analysis software QSR NVivo version 8 (1996 - 2007). We used a modified version of the Straussian approach to grounded theory and thematic analysis to analyze the data. In the Straussian approach to grounded theory, a question or set of questions is raised based on existing knowledge, information needed to help develop concepts, or to explore relationships (Grbich 2007). We conducted the analysis through open coding and identification of themes across the data, as described by Braun and Clarke (2006) and Grbich (2007). Open coding is the foundation for analyzing data in grounded theory and it occurs each time data are collected (Grbich 2007; Strauss and Corbin 1990). It is an interpretive process of systematically breaking down, examining, conceptualizing, and categorizing qualitative data (Corbin and Strauss 1990; Strauss and Corbin 1990).

Phase 2: Self-Administered Mail Survey

Sampling Frame

The sampling frame for the self-administered mail survey was developed through a two-step process. We first identified counties in Wyoming and Colorado where we wanted to survey ranchers. Our criteria for these counties included: 1) project focal counties where our field-work and outreach activities are conducted; and 2) counties to act as 'controls' or non-project reference sites, which will not be exposed to the same outreach as the focal counties. The study counties in Wyoming were: 1) Converse; 2) Niobrara; 3) Goshen; 4) Platte; 5) Laramie; 6) Albany; 7) Carbon; and 8) Sweetwater. We split the eight counties into two regions: Southeast Wyoming (the initial 6 counties) and South Central Wyoming (the latter two counties) (Figure 2.1). The study counties in Colorado were: 1) Larmier; 2)

Weld; 3) Yuma; 4) Washington; 5) Crowley; 6) Kiowa; 7) Baca; 8) Routt; 9) Moffat; 10) Delta; 11) Montrose; 2) Ouray; and 13) San Miguel. We split the 13 counties into four regions: Northeast Colorado (the first four counties); Southeast Colorado (counties five thru seven); Northwest Colorado (counties eight and nine); and Western Colorado (counties 10 thru 13) (Figure 2.1).

The National Agricultural Statistics Service provided the survey sampling frame, and distributed and collected the surveys. The target population was ranchers with at least 100 acres (40.47 hectares) of private, leased, or permitted land, and a minimum of 20 animal units (AUs) (cattle, horses, goats, and sheep). Dairies and feedlots were excluded, because in general these businesses have different management and business objectives than our population of interest. We mailed the survey to a stratified random sample of 200 ranchers in each of the six geographic regions within our study areas in Colorado and Wyoming (1200 ranches total). We were targeting for 50 percent response rate to minimize the sampling error.

Survey Design and Implementation

A self-administered mail survey was implemented October – December 2009. The objectives of this survey were to obtain quantitative data on ranchers' self-reported risk-orientation, their current level of adoption of new practices and programs, and to identify factors associated with adoption of innovations.

The survey questions were developed on the basis of focus group results and the evaluation needs of the larger project. Survey drafts were reviewed and pretested by two interdisciplinary research teams comprised of eight to 11 researchers and graduate students, as well as one extension agent, one state employee, and two United States

Forest Service employees, and the survey was revised several times before the final version was completed. The survey consisted of five sections: Management Practices and Programs, Perceptions and Management of Cheatgrass (*Bromus tectorum*), Perceptions and Use of State and Transition Models, Information Needs and Preferences and Background (i.e., demographics). The questions about cheatgrass and STMs were included to provide input to two integrated research and extension projects focused on: 1) perceptions of and knowledge about cheatgrass and its impacts, current management practices related to cheatgrass control, and satisfaction with the results of these practices; and 2) awareness and use of STMs and information and technical assistance needs.

A modified version of the Dillman (2000) method guided the implementation of the surveys to maximize our response rate (Bernard 2002; Fowler 2002). This modified process included a four-wave mailing with a pre-survey letter, a survey with a cover letter, and a reminder/thank you postcard (Dillman 2000) (Appendices G, H, J, and L). Additionally, a replacement survey with a cover letter was mailed three weeks after the initial survey mailing, as needed (Appendix M). Because ranchers who returned their survey might differ from those who did not respond, we conducted a random non-response bias check with 36 ranchers (5% of non-respondents) (Appendix O). We included in our statistical analyses data from both respondents to the original mail survey and those non-respondents who participated in the non-response bias check.

Measurements

The survey was comprised of close-ended, ordered response questions (including several based on the Likert Scale) as well as several 'check all that apply' questions, and 'fill-in the blank' responses (Appendix J).

We measured adoption of progressive practices and programs by asking respondents a series of three questions about the type of progressive management and business practices they had participated in during the past five years, as well as their use of government programs, such as land conservation or land retirement programs (Appendix J, Section I, Questions 6 – 8). Respondents were asked to either 'check all that apply' or to answer 'yes' or 'no' for each of the three questions.

We measured ranchers' risk-orientation with a modified version of Roger's (1995) adopter categories. We did this by asking survey respondents to identify one of five statements that best described their approach to engaging in new management practices or programs with their ranching operation (Appendix J, Section I, Question 10). The variable 'risk-orientation' was measured as a continuous variable, in that as the value increased, an individual's risk-orientation increased. For example, a value of one indicates that an individual is an 'observer' (low risk-orientation) and they tend to avoid new management practices/programs, verses a value of five which indicates an individual is 'innovative' (high risk-orientation) and they tend to actively seek new management practices/programs. The following were the five response options:

1) **Observer:** I tend to avoid new management practices/programs if possible, preferring to continue with what's worked in the past
2) **Cautiously active:** Cautious, I adopt new management practices/programs after the majority of people have, generally due to economic necessity or increasing pressure from peers
3) **Proactive:** I like to watch others and see how they do before adopting a new management practice/program, but I adopt before the average person

4) **Strongly proactive:** I seek new management practices/programs from my local resources and in general I am asked by members of the community for my opinion regarding new practices/programs
5) **Innovative:** I actively seek new management practices/programs beyond my local resources and I am willing to take financial risks to try these new practices/programs

(Rogers 1995).

To measure what influences rancher respondents to implement new practices, we asked them to indicate to what degree specified factors influenced (does not influence to strongly influences) their decision to implement new management tools or practices on their ranching operation (Appendix J, Section I, Question 9).

Survey Analysis

Data were analyzed using PASW Statistics version 18.0 for Windows XP ([PASW] 2010). All useable surveys (i.e., returned surveys that respondents answered all or nearly all of the questions) were used for data analysis despite missing values.

We identified respondent characteristics by calculating descriptive statistics (means and percentages of the population, as appropriate to the characteristic) related to personal characteristics and the attributes of the respondent's ranching operation. To calculate AUs we multiplied a respondent's reported number of animals per species by the associated animal unit equivalent (Table 2.0); we then summed the total number of AUs. We also calculated the descriptive statistics (percentage of the population) for questions about ranchers' participation in government programs during the past five

years, and whether or not ranchers had implemented specific management and business practices during the past five years.

We created several new variables in order to calculate correlations and to conduct multiple regressions and path analysis. We created three indices, one each for management and business practices (scores ranged from zero to 22 and zero to six, respectively), and government programs (scores ranged from zero to four), to indicate how many of these programs and practices each rancher adopted. The indices were calculated by summing the total number of programs or practices that respondents indicated they had participated in during the past five years (see ***Measurements*** section above) (Appendix J, Section I, Questions 6 - 8). We excluded continuous year-round grazing and 'other' from the management practice index and 'other' from the business practice index, because several of the practices were not progressive and their inclusion would have skewed our results.

We calculated correlations among all potential independent and dependent variables: approximate gross annual income, percentage of gross annual income from on-ranch sources, age, operation size in AUs, level of formal education, percentage of labor supplied by the family, the anticipated future of the ranching operation, self-reported risk-orientation, management practices index, business practices index, and government programs index.

To test hypotheses one and two, we conducted a series of multiple linear regressions (Vaske 2008). We checked for multicollinearity to determine whether it was appropriate to combine all predictor variables into a single model. The following criteria were used to detect multicollinearity: 1) a tolerance < 0.20; 2) a variance inflation factor

(VIF) $\geq$ 4 (Vaske 2008); and 3) an r-value > 0.5 (effect size) (Cohen 1988). The lowest tolerance among all four of the regressions was 0.826, the highest VIF among the four regressions was 1.211, and the highest r-value was 0.406, indicating it was appropriate to include all variables in the single models. The independent variables for the first multiple regression were: approximate gross annual income; percentage of gross annual income from on-ranch sources; age; operation size in AUs; level of formal education; percentage of labor supplied by the family; and the anticipated future of the ranching operation. The dependent variable was a respondent's self-reported risk-orientation. The independent variables for the latter three multiple regressions were the same as the first multiple regression with the addition of self-reported risk-orientation. The dependent variables for the three latter multiple regressions were: 1) business practice index; 2) management practices index; and 3) government programs index.

To test hypothesis three, we conducted a path analysis using ordinary least squares regression (OLS) to assess the potential mediating role of risk-orientation in the relationship between rancher characteristics (predictor/independent variables) and adoption behavior (criterion/dependent variables), and we followed criteria established by Baron and Kenny (1986) in interpreting our results. Path analysis is used to "estimate the magnitude of the linkages between variables and using these estimates to provide information about the underlying causal process" (Vaske 2008 pg. 575). The predictor variables were: approximate gross annual income; percentage of gross annual income from on-ranch sources; years of age; operation size in AUs; level of formal education; percentage of labor supplied by the family; and the anticipated future of the ranching operation.

A three step process was used to assess the role of risk-orientation as a mediating variable in adoption behavior, derived from standardized coefficients from the following regressions: 1) individually regress criterion variables (adoption indices) on each of the predictor variables (rancher characteristics); 2) individually regress the mediator variable (risk-orientation) on each of the predictor variables, risk-orientation and; 3) individually regress the criterion variables on each of the predictor variables simultaneously with the mediator variable. The standardized coefficient was used for ease of comparison of the effects among the different independent variables (Rowan et al. 1994; Vaske 2008).
We tested for mediation using OLS regression in SPSS. Mediation occurs when a third variable is introduced affecting the relationship between the initial variable (predictor/independent) and the outcome (criterion/dependent) (Kenny 2009). In Baron and Kenny's (1986) approach, medication is established if the following conditions are met: 1) the *predictor variable* (e.g., gross annual income) affects the *criterion variable* (e.g., adoption of progressive management practices); 2) the *predictor variable* affects the *mediator* (e.g., risk-orientation); and 3) the *mediator* affects the *criterion variable* when controlling for the effect of the *predictor variable*. In the third step, it is expected that the effect of the predictor variable on the criterion variable will decrease, compared to step one, with the addition of the mediator to the model. Partial mediation can be demonstrated if all of the above criteria are met. Full medication is established if all criteria are met *and* the predictor variable has no effect on the criterion variable in the final step.

To determine the amount of medication, we calculated the indirect effect and tested whether it was significantly different from zero using the Sobel test (Baron and

Kenny 1986; Preacher and Leonardelli 2003; Sobel 1982). The indirect effect was considered significantly different from zero with a *p*-value < 0.05(Kenny 2009; Sobel 1982; Vaske 2008). We used an interactive calculation tool to calculate the Sobel test (Preacher and Leonardelli 2003). The Sobel equation includes the unstandardized coefficient and standard error between the predictor and mediator variables as well as the mediator and criterion variables (Preacher and Leonardelli 2003; Vaske 2008). The coefficient resulting from this test is equal to the regression coefficient for the predictor/independent variable predicting the mediator multiplied by the regression coefficient for the mediator predicting the dependent variable, after adjusting for the independent variable (Baron and Kenny 1986).

We considered an alpha level of $p < 0.05$ statistically significant. We calculated the strength of the relationships for all of the regressions by taking the square root of the R-squared value, providing an effect size (r-value). We interpreted the effect size using Vaske's (2008) and Cohen's (1988) criteria, where a value of 0.1 indicates a minimal relationship (small), 0.3 a typical relationship (medium), and 0.5 a substantial relationship (large). A minimal or small effect size indicates that although a difference or association exists, it is not observable (Cohen 1988), a typical or medium effect size indicates that "the relationship is common in behavioral science disciplines and methods," and a substantial or large effect size indicates that there "really is a difference or an association" between variables (Cohen 1988; Vaske 2008 pg. 109).

RESULTS

The adjusted response rate, or the proportion of mailed surveys that were completed and returned was 36% ($n = 411$). The response rate of ranchers was similar across all regions

(n = 66 -78), except Southeast Colorado (n = 51). Additionally, we were unable to identify the region for some surveys (n = 41), because the respondents removed the survey identification number and they did not provide their zip code; however, we still included their responses in our data analyses.

Several factors that might have affected the response rate were identified. The sampling frame excluded feedlots and dairies; however, we had 46 survey recipients contact us stating the survey did not apply to them for one of the following reasons: the survey was sent to a feedlot or dairy; the recipient had sold their livestock during the drought and they were no longer in the business; or the recipient was a farmer, raising crops such as sugar beets, onions, etcetera. Surveys that were sent to individuals who did not meet our sample frame criteria were considered non-deliverable and they were excluded from our response rate (i.e., adjusted response rate). We believe our response rate is a conservative estimate of the true proportion of qualified respondents who responded (i.e., the actual response rate is probably slightly higher than we reported), due to the factors that may have affected our response rate.

Non-respondent and respondent ranchers did not differ in the regions that they represented, education level, age, percentage of their operation's annual labor supplied by their family, gender, future of their operation, or gross annual income. Non-respondents did differ in their risk-orientation compared to survey respondents. Respondents were significantly more likely to take risks than non-respondents (Pearson X^2 = 19.33, p-value = 0.001), with a Cramer's V effect size of 0.226, indicating a typical to minimal relationship (Vaske 2008). The relatively small effect size suggested minimal variation, justifying our decision not to make adjustments to our sample. Additionally, this effect

size suggests that we are safe in generalizing to the larger population; however, readers should be aware that the responses represent a slightly more pro-active and concerned sample than the general population of ranchers.

Respondent Characteristics

The average rancher respondent was 58 years old (range 26 – 93 years) (Table 2.1), with some college education (Chart 2.0), and had managed their ranch for 23 years (Table 2.1). Thirty-three percent of rancher respondents reported his or her income in the $80,000 – 199,999 category, the median (Chart 2.1). Income from livestock accounted for 44% of the average rancher respondent's gross annual income, nearly 79% of their operation was on private land, 87% of their operation's annual labor was supplied by family, and they had 214 AUs (Table 2.1). The majority of rancher respondents anticipated their children will take over the operation when they are no longer the operator (Chart 2.2).

Ranchers' Risk-Orientation, Adoption of Progressive Practices, and Use of Programs

Thirty-five percent of ranchers reported they are proactive, followed by observer (21%), strongly proactive (20%), innovative (17%), and cautiously active (7%) (Table 2.2). The most frequently reported progressive management practices ranchers used during the past five years were rotational grazing (75% of respondents), herbicide application (48%), low moisture supplements to distribute livestock (e.g., Crystalyx) (40%), low-stress stock management (39%), and reseeding (37%) (Table 2.3). The most commonly reported innovative business practices used by ranchers in the past five years were direct marketing of livestock products (36%), grass-fed or grass-finished beef, lamb, or goat

(30%), oil or gas leasing or extraction (25%), and charging an access fee for hunting, fishing, or wildlife viewing (25%) (Table 2.4). With respect to participation in government programs, respondents most often participated in working land conservation programs, such as Environmental Quality Incentives Program or Conservation Security Program (24%), followed by land retirement conservation programs, such as the Conservation Reserve Program or the Wetland Reserve Program (16%) (Table 2.5).

Ranchers used an average of five of the specified management practices on their operation during the past five years, with a maximum of 22 (0.5% of respondents), and a minimum of none (11%) (Table 2.6). Ranchers used an average of two of the specified business practices on their operation during the past five years. The maximum number of business practices used was six (1.2% of respondents) and the minimum was none (26% of respondents) (Table 2.6).

The majority of ranchers (60%) reported they had not participated in any of the listed government programs in the past five years (Table 2.6). Most of those who did participate in government programs enrolled in only one program, accounting for 26% of all respondents (Table 2.6). Fourteen percent of respondents enrolled in more than one program, and the maximum number of programs reported by one respondent was four (1% of the respondents) (Table 2.6).

Factors Associated with Risk-Orientation and Adoption of Innovation

We first ran individual correlations between all variables. We found that all of our predictor variables were significantly related to risk-orientation and/or the adoption of practices, or programs (Table 2.7).

Hypothesis 1. The first model, which explored the relationship between rancher characteristics and risk-orientation explained 15% of the variation (Table 2.8) and had a typical to substantial effect-size (r = 0.4). Gross income, income from on-ranch sources, and level of formal education were all positively and significantly related to risk-orientation, and age was negatively and significantly associated with risk-orientation ($p < 0.05$) (Table 2.8). These findings were consistent with our first hypothesis and indicate that younger ranchers, with a higher gross annual income, who generate a greater percentage of their income from on-ranch sources, and that have a higher level of formal education are likely to have a higher risk-orientation. However, contrary to our hypothesis, risk-orientation was not significantly related to the future of an operation, the percentage of annual labor provided by family, and operation scale.

Hypothesis 2. The second model, which explored the relationship between rancher characteristics as well as risk-orientation and the adoption of progressive management practices, explained 11% of the variation (Table 2.9), and had a typical effect size (r = 0.3). When controlling for the effects of all covariates, only risk-orientation was significantly related to adoption of management practices with a positive association (Table 2.9). This finding suggests that ranchers with a higher risk-orientation are more likely to adopt management practices compared to ranchers with a lower risk-orientation. Additionally, this result indicates that rancher characteristics are not reliable predictors of whether or not an individual will adopt progressive management practices.

In the third model, rancher and operation characteristics as well as risk-orientation explained 6% of the variation in adoption of business practices (Table 2.10) and had a typical effect size (r = 0.3). When controlling for the effects of all covariates, operation

size and risk-orientation were significantly and positively related to adoption of business practices (Table 2.10). These findings suggest that large scale ranchers (measured in AUs) that have a higher risk-orientation are more likely to adopt new or progressive business practices compared to other ranchers. Additionally, this result indicates that rancher characteristics, other than operation size, are not reliable predictors of whether or not an individual will adopt new business practices.

The fourth model, rancher and operation characteristics as well as risk-orientation explained 8% of the variation in adoption of government programs (Table 2.11), and had a typical effect size ($r = 0.3$). When controlling for the effects of all covariates, the percentage of annual income from on-ranch sources, anticipated future of an operation, and risk-orientation were significantly and positively related to participation in government programs (Table 2.11). These findings indicate that ranchers with a greater percentage of income from on-ranch sources that anticipate a family member will manage the operation in the future, and that have a higher risk-orientation are more likely to participate in government programs compared to other ranchers.

Our findings with respect to the relationship between risk-orientation and the adoption of progressive management and business practices, as well as use of government programs, were consistent with our second hypothesis. However, findings indicated that when controlling for the influence of risk-orientation, other predictor variables (i.e., rancher and operation characteristics) hypothesized to play a role in affecting adoption practices were less influential, which suggests possible mediation. Adoption of practices and use of government programs were not significantly related, for example, to percentage of annual labor provided by family, age, approximate gross

annual income, and education. An exception to this general trend was the relationship between operation size and adoption of business practices was statistically significant, as was the relationship between the adoption of government programs and the percentage of annual income generated from on-ranch sources, and certainty that the ranch would remain in the family (i.e., operation future).

Risk-Orientation Mediates Adoption

Hypothesis 3. Our third hypothesis was that risk-orientation would mediate the relationship between demographic and operation characteristics, and adoption of practices and programs. We found that risk-orientation fully mediated the relationship between gross annual income and the adoption of innovative management practices and use of government programs (Figure 2.2 and Figure 2.3). In both models, full mediation was demonstrated through the decrease in the absolute value of the coefficient and the increase of the *p*-value, to a non-significant level (path c to path c') (Figure 2.2 and Figure 2.3). Sobel scores indicated that the mediation effect was significant (*p*-value < 0.05) (Table 2.12). Thus, as an individual's gross annual income increases, so does their risk-orientation, which explains their adoption of practices and programs.

Risk-orientation also fully mediated the relationship between education level and adoption of management practices (Figure 2.4). Again, full-mediation was demonstrated through the decrease in the absolute value of the coefficient and the increase of the *p*-value, to a non-significant level (path c to path c') (Figure 2.4). Sobel scores indicated that the mediation effect was significant ($p = 0.0001$) (Table 2.12). Thus, as an individual's level of education increases, so does their risk-orientation, which explains their adoption of management practices.

We found that risk-orientation partially mediated the relationship between the percentage of annual income generated from on-ranch sources and the adoption of progressive management and business practices and use of government programs (Figures 2.5 – 2.7). Partial mediation was demonstrated through the decrease in absolute value of the coefficient, and the increase of the *p*-value, which remained at a significant level (path c to path c') (Figures 2.5 – 2.7). Sobel scores indicated that the mediation effect was significant ($p < 0.05$) (Table 2.12). Thus, the relationship between percentage of annual income generated from on-ranch sources and the adoption of progressive practices and programs is partially explained by an individual's risk-orientation.

Additionally, risk-orientation partially mediated the relationship between the percentage of annual labor provided by family and the adoption of progressive management practices (Figure 2.8). Again, partial mediation was demonstrated through the decrease in absolute value of the coefficient, and the increase of the *p*-value, which remained at a significant level (path c and path c') (Figure 2.8). However, the Sobel scores did not indicate that the mediation effect was significant ($p = 0.06$) (Table 2.12). This finding indicates that although all other criteria for mediation were met, the amount of mediation is not substantive enough to warrant attention. We found that risk-orientation also partially mediated the relationship between operation size and adoption of management and business practices, in the initial three step process assessing for mediation (Figure 2.9 and Figure 2.10). However, because the unstandardized coefficient for the relationship between the predictor and mediator was zero it was not possible to calculate the indirect effect, and therefore to determine the amount of mediation using the Sobel test (Table 2.12).

Several of our findings provide support for our third hypothesis, suggesting that risk-orientation fully or partially mediates the relationship between many rancher characteristics and adoption of progressive management and business practices and use of government programs. However, risk-orientation did not mediate the relationship between all of the predictor and criterion variables as expected (Figures 2.11 – 2.21). We did not detect mediation in the following models: 1) gross annual income and the adoption of business practices; 2) education and the use of government programs, and the adoption of business practices; 3) the percentage of annual labor provided by the family and the adoption of business practices, and use of government programs; 4) age and the use of government programs, and the adoption of management and business practices; and 5) future of an operation and the use of government programs, and the adoption of management and business practices (Figures 2.11 – 2.12).

Factors that Influence the Decision to Implement a New Management Practice

Ranchers indicated that the top three factors that strongly influenced their decisions are: impacts of the management practice on grazing capacity (55%); impacts of a management practice on reducing the spread of invasive weeds (52%); and a potential for direct financial gain from implementing the management practice (51%) (Table 2.13). Rancher respondents reported that the three factors that have the least influence on their decisions are: potential for the management practice to benefit the local economy (26%); the amount of time it takes for the desired results to be achieved (11%); and impacts of the management practice on wildlife habitat (11%) (Table 2.13).

DISCUSSION

Rogers (1995) suggests that the mainstream, general public is either an early or late majority adopter (34% for each category), indicating they deliberately or skeptically (respectively) approach innovation. Similarly, our results indicated that 35% of ranchers consider their risk-orientation as 'proactive' (equivalent to Rogers (1995) 'early majority'). In other words, they prefer to watch others and see how they do before adopting a new management practice/program, but they adopt before the average person. Our non-response bias check indicated that survey respondents were more likely to take risks than non-respondents; therefore our results might represent a slightly more pro-active and concerned population than the general population of ranchers.

Factors Associated with Risk-Orientation and Adoption of Innovation

Hypotheses 1 and 2. Our data suggest that younger, more educated ranchers, with a greater percentage of their income from on-ranch sources (e.g., agriculture, crops, wildlife, etcetera), and with a higher gross annual income have a higher risk tolerance and are more likely to innovate. Our findings about the relationship between income (Coppock and Birkenfeld 1999; Kreuter et al. 2008; Peterson and Coppock 2001; Rogers 1995; Selfa et al. 2008), level of education (Coppock and Birkenfeld 1999; Peterson and Coppock 2001; Rogers 1995; Selfa et al. 2008), age (Peterson and Coppock 2001), and innovativeness are similar to results from prior research (Peterson and Coppock 2001; Rogers 1995). It should be noted that Rogers (1995) suggests there are inconsistent findings about the correlation of age and innovativeness. Our study indicates that younger ranchers in Wyoming and Colorado have a higher tolerance for risk. It was beyond the scope of our study to explore why younger ranchers are more willing to innovate.

However, some possibilities might include physical and mental well-being, the idea of seeing tangible end results from implementing innovations which might take years to surface, and access to assets that they can use to implement innovations. Additionally, we found that younger ranchers have a higher level of education, and as discussed earlier more educated ranchers tend to have a higher risk tolerance and are more likely to innovate.

Our study indicates that ranchers that are more risk tolerant are more likely to implement progressive management and business practices and to use government programs. This finding was not a surprise and is supported by Rogers (1995) who suggests that individuals who are more innovative are willing to endure necessary risks to adopt innovations. Additionally, we found that ranchers who derive a greater percentage of their income from on-ranch sources, and who anticipate a family member will take over the operation when they retire are more likely to participate in government programs. Although prior empirical studies with ranchers have suggested similar findings (Didier and Brunson 2004; Kennedy and Brunson 2007; Rowan and White 1994), this result is interesting because it focused specifically on the adoption of government programs. One factor that might explain these findings is eligibility requirements for government programs. For example, one of the qualifications for the United States Department of Agriculture's Natural Resources Conservation Service's Farm and Ranch Lands Protection Program is that the offered land must "be surrounded by parcels of land that can support long-term agricultural production" (NRCS 2004 pg. 1). This stipulation might exclude some ranchers from participating in the program, particularly in regions

that are experiencing exurban development, resulting in fewer parcels that are able to support long-term agricultural production.

In addition to risk-orientation, ranchers who had larger operations (AUs) were more likely to adopt new business practices. This finding is similar to Rogers' (1995) suggestion that more innovative individuals tend to have 'larger units' such as farms. Other researchers have had a similar finding (Kreuter et al. 2008). Several factors that might increase an operation's tolerance for risk include having more financial and labor resources, and large tracks of land, which might enable them to experiment. These two factors might allow a rancher with a larger operation to tolerate some loss without jeopardizing their operation.

Data from all four of our models testing the relationship between the predictor variables (i.e., rancher and operation characteristics) or factors that influence a rancher's risk-orientation and adoption explain a low percentage of the overall variation in risk-orientation and adoption (range 6 – 15%). Several factors that our survey did not measure may account for the unexplained variation, including environmental conditions (e.g., drought) (Kennedy and Brunson 2007), and economic uncertainty associated with the 2008 economic downturn, particularly for small – mid size operations (Coppock and Birkenfeld 1999). There is always a degree of uncertainty when adopting an innovation, even under optimal conditions. Therefore, when uncontrollable and unpredictable factors exist it might influence individuals to cautiously proceed with their decision-making process, in other words, their risk-orientation.

Additional factors that our study did not take into consideration, but that have been associated with ranchers' willingness or motivation to adopt include personal and/or

management objectives (Coppock and Birkenfeld 1999; Kennedy and Brunson 2007) and social networks, including interactions with other ranchers, association memberships, and relationship with technical assistance agencies (e.g., NRCS, Extension, etc.) (Fernandez-Gimenez et al. 2005; Kennedy and Brunson 2007; Kreuter et al. 2008). For example, if a rancher's personal and management objectives include sustaining the cultural heritage of their family's operation, they might be resistant to adopting a new grazing regime. Or from another perspective, an individual might use a government program such as putting a conservation easement on their ranch not only to conserve the natural resources in perpetuity, but also for associated tax incentives. Further study is needed to determine causal relationships associated with the adoption of progressive management and business practices and the use of government programs. Some of the factors that these studies should consider evaluating are whether or not ranchers have adjusted their risk-orientation due to current events (e.g., drought), personal and management objectives, and the relationship between risk-orientation and social networks.

Innovation as a Mediating Variable to Adoption

Hypothesis 3. This analysis provided insight about the relationship among rancher and operation characteristics, risk-orientation, and adoption of progressive management and business practices as well as the use of government programs. We found that risk-orientation either fully or partially mediates the relationship between three predictor variables (gross annual income, education level, and the percentage of income generated from on-ranch sources) and the adoption of progressive practices and the use of government programs.

These findings help us to understand the importance of the relationship of risk-orientation with both gross annual income and level of education and ranchers' willingness to adopt innovative management practices. Additionally, this finding is important for explaining the relationship between risk-orientation, gross annual income, and a rancher's willingness to participate in government programs. Because risk-orientation fully mediated these relationships, our findings suggest that gross annual income and level of formal education are good predictors of an individual's risk-orientation and their willingness to adopt progressive management practices and to use government programs (only associated with gross annual income).

Risk-orientation partially mediated the relationship between the percentage of income generated from on-ranch sources and a rancher's willingness to adopt progressive practices and programs. In other words, our findings suggest that diffusers of innovations can partially assess an individual's risk-orientation based on the percentage of income generated from on-ranch sources. However, since the relationship is not fully mediated by risk-orientation the percentage of income generated by on-ranch sources should not be completely relied on when assessing an individual's degree of innovativeness and willingness to adopt progressive practices and programs.

We found that all of the predictor variables (i.e., rancher and operation characteristics) were significantly related to risk-orientation except for the future of the operation. All of the variables that were significantly related to risk-orientation had a positive relationship except for age and the percentage of annual labor provided by the family. In other words, younger ranchers and operations that depended on more hired help had a higher risk-orientation.

Factors that Influence the Decision to Implement a New Management Practice

Overall our findings for what factors influence ranchers' decision to implement a new management practice are similar to results from prior studies. For example, over half of our respondents indicated that impacts of the management practice on grazing capacity strongly influence their decision to innovate. Two prior studies found similar results, suggesting ranchers are more likely to adopt practices that are compatible with production goals (Coppock and Birkenfeld 1999; Kennedy and Brunson 2007).

Similarly, more than 50% of our respondents indicated that whether a management practice will help reduce the spread of invasive weeds also strongly influences their decision to innovate. Respondents in a study of multiple stakeholder groups, including ranchers, found that most respondents were concerned about controlling weeds in rangeland (Sell et al. 1999).

Respondents of our study also indicated that the potential for financial gain from implementing a management practice strongly influences their decision to innovate. Several prior studies had a comparable finding (Didier and Brunson 2004; Kennedy and Brunson 2007; Rowan and White 1994). The above three findings are interesting, because they suggest that while financial concerns are important, stewardship goals (e.g., maintaining productivity of forage and controlling weeds) play an even larger role in determining adoption (Didier and Brunson 2004). These three findings from our study also align with several of the innovation characteristics that Rogers (1995) identifies, including relative advantage and compatibility. Similarly, Coppock and Birkenfeld (1999) and Kennedy and Brunson (2007) all suggest that ranchers are more likely to adopt practices that align with their priority needs and personal as well as management

objectives. Although our study did not specifically solicit ranchers' priority needs or objectives, it may be that our findings about what influences ranchers to adopt new management practices indirectly measured their priority needs and objectives.

It should be noted that our respondents indicated that the amount of time it takes for desired results from the management practice to be achieved was among the least influential factors in their decision to try new management practices. This finding is contrary to prior research (Kennedy and Brunson 2007; Kreuter et al. 2001; Rogers 1995), which suggested that the immediacy of results was important.

IMPLICATIONS

As our society and the western landscape continue to evolve it is important for researchers and NRPs to monitor and understand the complexities for adoption or non-adoption of innovations, which in-part includes rancher and operation characteristics. These efforts will help us to stay attuned to ranchers' changing needs and attitudes in order to better serve them. This is particularly important as ranchers encounter new challenges such as introduction of non-native plant species, and other unpredictable, extenuating circumstances such as drought, and economic downturns, which can affect livestock and hay prices. Additionally, we need to ensure we are aware of new ranch managers' or owners' management needs and goals, which might differ from prior owners/generations.

Implications for Outreach and Extension

We found that the largest category (35% of respondents) of ranchers in Wyoming and Colorado are proactive, in other words, they prefer to watch others adopt practices or programs before they will adopt. Thirty-seven percent of ranchers reported they are either

strongly proactive or innovative, which indicates that they search for new practices or programs. Based on the results of our study and the diffusion of innovation theory we recommend that the diffusion of innovative practices and programs for ranchers first target the early adopters (i.e., strongly proactive and innovative). Our study indicates these individuals tend to be younger with a higher level of formal education, a greater percentage of their income is from on-ranch sources, and they have a higher gross annual income. In addition, we also suggest that outreach and extension material about government programs target ranchers who anticipate a family member will take over the operation when they retire. We further recommend that outreach and extension material for progressive business practices are targeted to ranchers with larger operations (AUs).

The strategy of first identifying the early adopters will enable individuals who are less risk tolerant to observe the implementation process, and associated results and it might mitigate the complexity of learning about and implementing an innovation. Additionally, the diffusion of innovation theory suggests that individuals are more likely to adopt innovations that their peers have adopted (e.g., rancher to rancher) (Rogers 1995). However, the theory indicates that diffusers of innovations take caution to insure innovations are disseminated vertically within a population and not just horizontally (Rogers 1995). In other words, an effort must be made to transfer information about the diffusion to different socioeconomic levels and to individuals with various levels of education, etcetera (Rogers 1995). Vertical dissemination can occur by identifying and working with leaders of the different socioeconomic groups within a community, also known as opinions leaders (Rogers 1995). It was beyond the capacity of our study to identify these different community leaders. Therefore, we recommend that diffusers of

innovations explore ways to identify community leaders prior to or during the early stages of diffusing an innovation.

Based on our findings we recommend that outreach material for ranchers about progressive management and business practices as well as the use of government programs integrate how the program(s) or practice(s) will help ranchers with their grazing capacity, reduce the spread of invasive species, and any potential direct financial gains a rancher may experience from adopting a progressive practice or participating in a government program. However, our non-response bias check indicated that survey respondents likely had a higher risk tolerance than non-respondents, therefore we recommend that further research is conducted to identify whether or not the same factors motivate less risk tolerant individuals to adopt progressive practices or programs.

Implications for Researchers Developing Innovations

Our society, the economy, and the landscape are continually changing and adapting to new circumstances. Researchers and other stakeholders are challenged to try to follow and understand the evolving inter and intra dynamics of these non-static, interrelated systems. Therefore, it is important that we continue to research and understand end users' changing needs and attitudes to ensure innovations have practical application.

Our study added to the knowledge of what factors motivate ranchers in Wyoming and Colorado to adopt new practices, and supported findings of several prior studies including the importance of grazing capacity, reduction in the spread of invasive species, and direct financial gains. We also found that ranchers are less concerned about the time it takes to see desired results, which is contrary to prior research. Again, we acknowledge that our sample may have had a higher level of risk tolerance, and as suggested above,

further research is needed to assess what motivates individuals with a lower risk tolerance to adopt. However, our findings do inform what factors motivate individuals with a higher risk tolerance and who are likely to be among the first to adopt an innovation. Therefore, it is important to keep these factors in the forefront when developing an innovation.

Implications for Researchers Studying the Diffusion of Innovations

Similar to researchers understanding end users' changing needs for different innovations and attributes of innovations, is a need for researchers to follow what factors are associated with ranchers' different levels of risk-orientation. Additionally, there is a need to continue to understand the changing demographics of ranch owners and managers.

This study provides greater understanding and predictability with respect to understanding risk-orientation as a full mediator between two predictor variables (gross annual income and education) and the adoption of progressive practices or use of government programs. Additionally, our study indicates that risk-orientation partially mediates the relationship between the percentage of income generated from on-ranch sources and the adoption of progressive management and business practices and the use of government programs. Future studies are needed to better understand the complexities associated with ranchers' risk-orientation and their willingness to adopt progressive practices and to use government programs in order to more effectively disseminate innovative practices and programs to ranchers. Furthermore, continued research is needed to understand how ranchers' risk-orientation might change over time.

In summary, we acknowledge the importance of developing innovations to meet ranchers' personal and management objectives, particularly in a changing world.

Therefore, we recommend that future research specifically elicit ranchers' priority needs and personal as well as management objectives simultaneously with what factors influence their decision to participate in programs and implement new practices to gain a better idea of these relationships. As suggested above, further study is needed about other factors that might influence the adoption of progressive practices and the use of government programs, such as social networks and climate.

Chapter Two Tables, Charts, and Figures

Table 2.0. Kind and class of livestock that rancher respondents reported owning and the suggested animal unit equivalents (AUEs).

Kind and Class of Livestock	AUEs
CATTLE	
Cow and calf pair[1][4]	1.35
Mature cow, nonlactating[1][5]	1
Calves, weaning to 12 months[1]	0.6
Yearlings, 15 - 18 months[1][6]	0.8
Mature bull[1]	1.5
OTHER LIVESTOCK	
Mature, non-lactating sheep[1]	0.2
Mature, non-lactating goat[1]	0.17
Saddle horse, mature[1]	1.25
Bison, mature	1
Llama[2]	0.2
Mules, donkey, and burros[3]	1

[1] Adopted from Vallentine 1990.

[2] Adopted from Willson 2006.

[3] Adopted from Boulder County 2008.

[4] Includes milking cows.

[5] Includes heifers and roping cattle.

[6] Includes yearling bison.

Table 2.1. Rancher respondent characteristics.

	Mean	Standard Error	Median
Age	58.4	0.63	57.0
Years managing currant operation	23.1	0.73	20.0
Percentage of income from various sources			
Livestock	44.3	1.74	40.0
Crops	13.7	1.18	0.00
Wildlife	2.1	0.40	0.00
Other on-ranch sources	2.3	0.58	0.00
Off-ranch sources	34.9	1.86	20.0
Percentage of operation in different land ownerships			
Private	78.9	1.40	95.0
United States Forest Service	4.8	0.70	0.00
State land	4.8	0.59	0.00
Bureau of Land Management	8.8	0.94	0.00
Other land (e.g., railroad)	2.4	0.55	0.00
Percentage of annual labor supplied by family	86.9	1.31	100
Operation Size – Animal units	214.1	26.92	68.0

Table 2.2. Percentage of ranchers and their self-reported risk-orientation[1].

	Percentage of Respondents	n
Observer	21.4	378
Cautiously active	7.1	
Proactive	34.7	
Strongly proactive	20.1	
Innovative	16.7	

[1] Levels of risk-orientation are adopted from Rogers (1995).

Table 2.3. Percentage of ranchers who have tried specified management practices on their operation during the past five years.

	Have Not Participated	Have Participated	n
Rotational grazing	24.6	75.4	411
Continuous, year-round grazing	82.7	17.3	411
Low moisture supplements to distribute livestock	60.3	39.7	411
Managed for sensitive plant or animal species	91.5	8.5	411
Grazed riparian areas for 30 days or less during the year	78.6	21.4	411
Spring development	76.4	23.6	411
Fenced stream banks or riparian areas	87.3	12.7	411
Laid water pipeline	64.2	35.8	411
Prescribed fire	89.3	10.7	411
Mechanical brush removal	71.8	28.2	411
Installed wildlife water development	83.2	16.8	411
Holistic Resource Management	87.6	12.4	411
Put in erosion control structures	81.3	18.7	411
Used a herder to manage livestock distribution	92.5	7.5	411
Low-stress stock management	61.3	38.7	411
Applied herbicides	51.6	48.4	411
Reseeding	62.3	37.3	411
Put in wildlife friendly fencing	80.3	19.7	411
Used companion animal to deter predators	88.8	11.2	411
Put in food plots to distribute foraging	94.6	5.4	411
Multiple species grazing	85.6	14.4	411
Put in living fences	92.9	7.1	411
Non-use of land	82	7.1	411
Other	96.6	3.4	411

Table 2.4. Percentage of ranchers who have tried specified business practices on their operation during the past five years.

	Have Not Participated	Have Participated	n
Direct marketing of livestock products	64.5	35.5	394
Oil or gas leasing or extraction	74.8	25.2	385
Guiding services for hunting and fishing	83.7	16.3	386
Guiding services for wildlife viewing	96.9	3.1	382
Charged access fee for hunting, fishing, or wildlife viewing	75.5	24.5	384
Agri-tourism including rural tourism	96.3	3.7	383
Received carbon off-set or carbon sequestration payments	98.9	1.1	380
Wind energy development	90.3	9.7	383
Geothermal energy development	99.5	0.5	380
Grass-fed or grass-finished livestock	69.8	30.2	388
Certified organic livestock	97.1	3.1	381
Bed and breakfast or other accommodations	96.9	3.1	381
Other	86.8	13.2	151

Table 2.5. Percentage of ranchers who have tried specified government programs on their operation during the past five years.

	Have Not Participated	Have Participated	n
Land retirement conservation programs	84.3	15.7	402
Working land conservation programs	75.8	24.3	400
Wildlife habitat programs	91.6	8.4	395
Agricultural land and grassland preservation programs	97.2	2.8	389
Conservation easements	92.1	7.9	390

Table 2.6. Percentage of ranchers and the number of programs and practices that they participated in or implemented on their operation during the past five years.

Indices	Number of Programs/ Practices	Percentage of Respondents	n
Management practices	0	5.6	23
	1	9.5	39
	2	10.5	43
	3	13.1	54
	4	10.9	45
	5	9.2	38
	6	9.5	39
	7	8	33
	8	6.3	26
	9	6.1	25
	10	4.4	18
	11	1.2	5
	12	3.2	13
	13	0.7	3
	14	0.5	2
	15	0.2	1
	16	0.5	2
	17	0	0
	18	0	0
	19	0	0
	20	0	0
	21	0	0
	22	0.5	22
Business practices	0	25.9	104
	1	31.9	128
	2	21.2	85
	3	11.5	46
	4	7	28
	5	1.2	5
	6	1.2	5
Government programs	0	60	245
	1	25.5	104
	2	12.3	50
	3	1.2	5
	4	1	4

Table 2.7. Correlation matrix of rancher and operation demographics, self-reported risk-orientation, and adoption of management and business practices as well as government programs (indexes). The number of respondents ranged from 330 to 379.

	Gross annual income		**% income on-ranch sources**		**Years of age**		**Operation size (AUs)**	
	Pearson Correlation	**Significance (2 - tailed)**	**Pearson Correlation**	**Significance (2 - tailed)**	**Pearson Correlation**	**Significance (2 - tailed)**	**Pearson Correlation**	**Significance (2 - tailed)**
Gross annual income	1	-	0.093	0.085	-0.105	0.044	0.275	0
% income on-ranch sources	0.093	0.085	1	-	0.091	0.081	0.237	0
Years of age	-0.105	0.044	0.091	0.081	1	-	-0.037	0.47
Operation size (AUs)	0.275	0	0.237	0	-0.037	0.47	1	-
Level of education	0.131	0.01	-0.069	0.176	-0.15	0.002	0.166	0.001
% annual labor by family	-0.137	0.008	-0.085	0.099	-0.038	0.45	-0.222	0
Operation future	0.102	0.047	0.042	0.41	0.079	0.112	0.105	0.038
Risk-orientation	0.247	0	0.165	0.003	-0.166	0.002	0.176	0.001
Government practices	0.146	0.006	0.203	0	-0.085	0.102	0.045	0.367
Management practices	0.128	0.017	0.143	0.005	-0.049	0.348	0.198	0
Business programs	0.022	0.68	0.168	0.001	-0.003	0.957	0.17	0.001

Table 2.7. Continued.

	Level of education		% annual labor by family		Future of the operation		Risk-orientation	
	Pearson Correlation	**Significance (2 - tailed)**	**Pearson Correlation**	**Significance (2 - tailed)**	**Pearson Correlation**	**Significance (2 - tailed)**	**Pearson Correlation**	**Significance (2 - tailed)**
Gross annual income	0.131	0.01	-0.137	0.008	0.102	0.047	0.247	0
% income on-ranch sources	-0.069	0.176	-0.085	0.099	0.042	0.41	0.165	0.003
Years of age	-0.15	0.002	-0.038	0.45	0.079	0.112	-0.166	0.002
Operation size (AUs)	0.166	0.001	-0.222	0	0.105	0.038	0.176	0.001
Level of education	1	-	-0.175	0	-0.053	0.281	0.271	0
% annual labor by family	-0.175	0	1	-	0.02	0.681	-0.122	0.019
Operation future	-0.053	0.281	0.02	0.681	1	-	-0.02	0.709
Risk-orientation	0.271	0	-0.122	0.019	-0.02	0.709	1	-
Government programs	0.052	0.301	0.001	0.989	0.131	0.009	0.202	0
Management practices	0.154	0.002	-0.137	0.006	0.029	0.565	0.311	0
Business practices	0.049	0.339	-0.074	0.143	0.029	0.57	0.229	0

Table 2.7. Continued.

	Government programs		Management practices		Business practices	
	Pearson Correlation	**Significance (2 - tailed)**	**Pearson Correlation**	**Significance (2 - tailed)**	**Pearson Correlation**	**Significance (2 - tailed)**
Gross annual income	0.146	0.006	0.128	0.017	0.022	0.68
% income on-ranch sources	0.203	0	0.143	0.005	0.168	0.001
Years of age	-0.085	0.102	-0.049	0.348	-0.003	0.957
Operation size (AUs)	0.045	0.367	0.198	0	0.17	0.001
Level of education	0.052	0.301	0.154	0.002	0.049	0.339
% annual labor by family	0.001	0.989	-0.137	0.006	-0.074	0.143
Operation future	0.131	0.009	0.029	0.565	0.029	0.57
Risk-orientation	0.202	0	0.311	0	0.229	0
Government programs	1	-	0.201	0	0.142	0.004
Management practices	0.201	0	1	-	0.318	0
Business practices	0.142	0.004	0.318	0	1	-

Table 2.8. Results from a multiple-regression of the anticipated predictor variables (rancher and operation demographics) by the anticipated mediator variable (risk-orientation).

	Adjusted r^2	Standard Error	Standardized ß	t	*p*-value
Gross annual income	0.146	1.24	0.174	3.223	0.001
Annual income from on-ranch sources			0.164	3.083	0.002
Age			-0.127	-2.412	0.016
Operation size			0.04	0.715	0.475
Formal education			0.225	4.194	< 0.001
Annual labor supplied by family			-0.041	-0.759	0.448
Operation future			-0.026	-0.498	0.619

Table 2.9. Results from a multiple-regression of the anticipated predictor variables (rancher and operation demographics) and the anticipated mediator variable (risk-orientation) by management practices index (adoption 1).

	Adjusted r^2	Standard Error	Standardized ß	t	*p*-value
Gross annual income	0.109	3.357	0.01	0.17	0.866
Annual income from on-ranch sources			0.073	1.327	0.185
Age			-0.003	-0.062	0.951
Operation size			0.107	1.857	0.064
Formal education			0.061	1.092	0.276
Annual labor supplied by family			-0.065	-1.188	0.236
Operation future			0.024	0.443	0.658
Risk-orientation			0.253	4.424	< 0.001

Table 2.10. Results from a multiple-regression of the anticipated predictor variables (rancher and operation demographics) and the anticipated mediator variable (risk-orientation) by business practices index (adoption 2).

	Adjusted r^2	Standard Error	Standardized ß	t	*p*-value
Gross annual income	0.064	1.305	-0.076	-1.322	0.187
Annual income from on-ranch sources			0.106	1.868	0.063
Age			0.015	0.264	0.792
Operation size			0.123	2.095	0.037
Formal education			-0.013	-0.218	0.827
Annual labor supplied by family			-0.024	-0.435	0.664
Operation future			0.022	0.409	0.683
Risk-orientation			0.212	3.615	< 0.001

Table 2.11. Results from a multiple-regression of the anticipated predictor variables (rancher and operation demographics) and the anticipated mediator variable (risk-orientation) by government program index (adoption 3).

	Adjusted r^2	**Standard Error**	**Standardized ß**	**t**	***p*-value**
Gross annual income	0.081	0.792	0.089	1.568	0.118
Annual income from on-ranch sources			0.191	3.409	0.001
Age			-0.076	-1.384	0.167
Operation size			-0.064	-1.103	0.271
Formal education			0.026	0.453	0.651
Annual labor supplied by family			0.032	0.574	0.566
Operation future			0.13	2.416	0.016
Risk-orientation			0.146	2.522	0.012

Table 2.12. Results from path analysis regressions where partial or full mediation was detected (SPSS – Regression Results), and results from the Sobel test (Sobel Test Results), testing whether the indirect effect was significantly different from zero.

		SPSS - Regression Results		Sobel Test Results		
	Data Path	**Unstandardized co-efficient**	**S.E. Unstandardized**	**z-value**	**Standard Error**	***p*-value**
Gross Income – Government Programs	Path a	0.242	0.053			
	Path b	0.109	0.034	2.624	0.010	0.009
Gross Income – Management Practices	Path a	0.242	0.053			
	Path b	0.789	0.144	3.508	0.054	< 0.001
Percentage Income From On-Ranch Sources – Government Programs	Path a	0.006	0.002			
	Path b	0.107	0.033	2.202	< 0.001	0.028
Percentage Income From On-Ranch Sources – Management Practices	Path a	0.006	0.002			
	Path b	0.783	0.141	2.639	0.002	0.008
Percentage of Income From On-Ranch Sources – Business Practices	Path a	0.006	0.002			
	Path b	0.208	0.055	2.350	0.001	0.019
Operation Size (AU) – Management Practices	Path a	0	0			
	Path b	0.755	0.138	[1] NaN	0	[1] NaN
Operation Size (AU) – Business Practices	Path a	0	0			
	Path b	0.207	0.054	[1] NaN	0	[1] NaN
Education – Management Practices	Path a	0.349	0.065			
	Path b	0.77	0.142	3.815	0.070	< 0.001
Percentage of Annual Labor Supplied by Family – Management Practices	Path a	-0.006	0.003			
	Path b	0.792	0.137	[1] NaN	[1] NaN	[1] NaN

[1] NaN indicates that because the unstandardized coefficient for the relationship between the predictor and mediator was zero it was not possible to calculate the indirect effect and therefore determine the amount of mediation using the Sobel test.

Table 2.13. Ranchers identified factors that influence their decision to implement a new management tool or practice on their ranching operation. Data are the percentage of rancher respondents and the degree to which a specified factor influences their decisions.

	Does Not Influence	Slightly Influences	Moderately Influences	Strongly Influences	n
Environmental benefits	9.7	19.4	45.2	25.8	372
Benefit local economy	25.6	26.7	37.5	10.2	371
Reduce spread of invasive weeds	3.8	7.8	36.1	52.3	371
Reliable scientific information	9.5	25.9	43	21.6	370
Time it takes for desired results to be achieved	11.1	23.8	49.1	16	369
Time the desired results will last	7.9	12	47.8	32.2	366
Impact on grazing capacity	3.2	5.6	36.5	54.7	375
Impact on wildlife habitat	11.2	31.6	38.8	18.4	376
Potential for direct financial gain	5.6	12	31.7	50.7	375

Chart 2.0. Rancher respondents highest level of formal education.

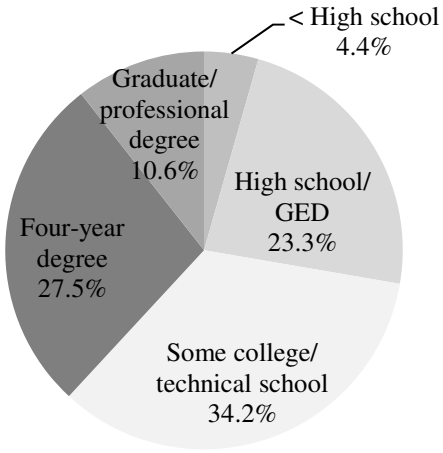


Chart 2.1. Rancher respondents gross annual income.

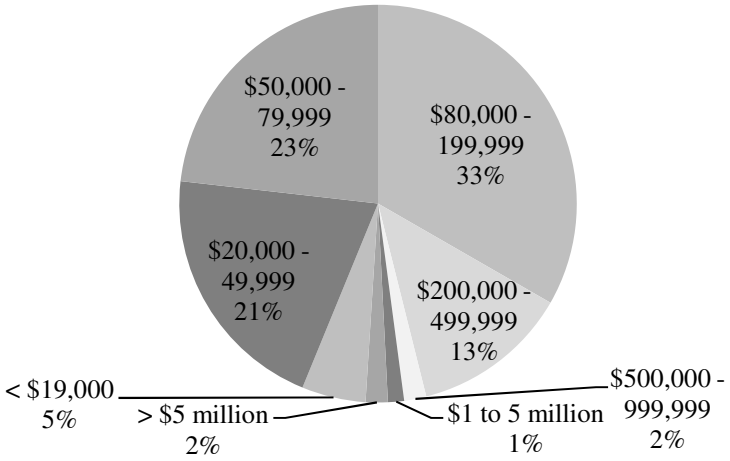


Chart 2.2. Rancher respondents anticipated future of their operation when they are no longer the operator.

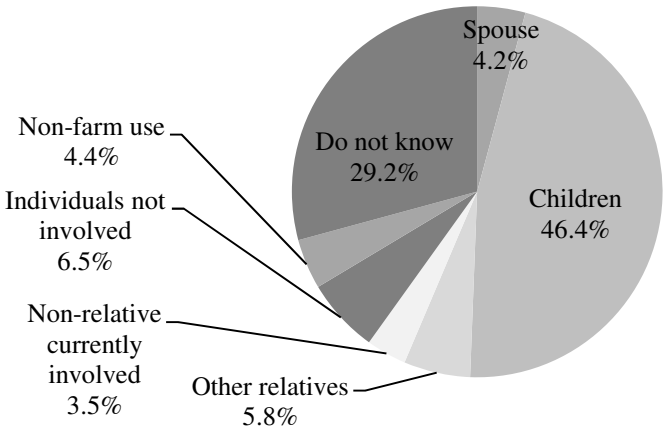


Figure 2.0. Focus group study locations in Wyoming and Colorado, January 2009.

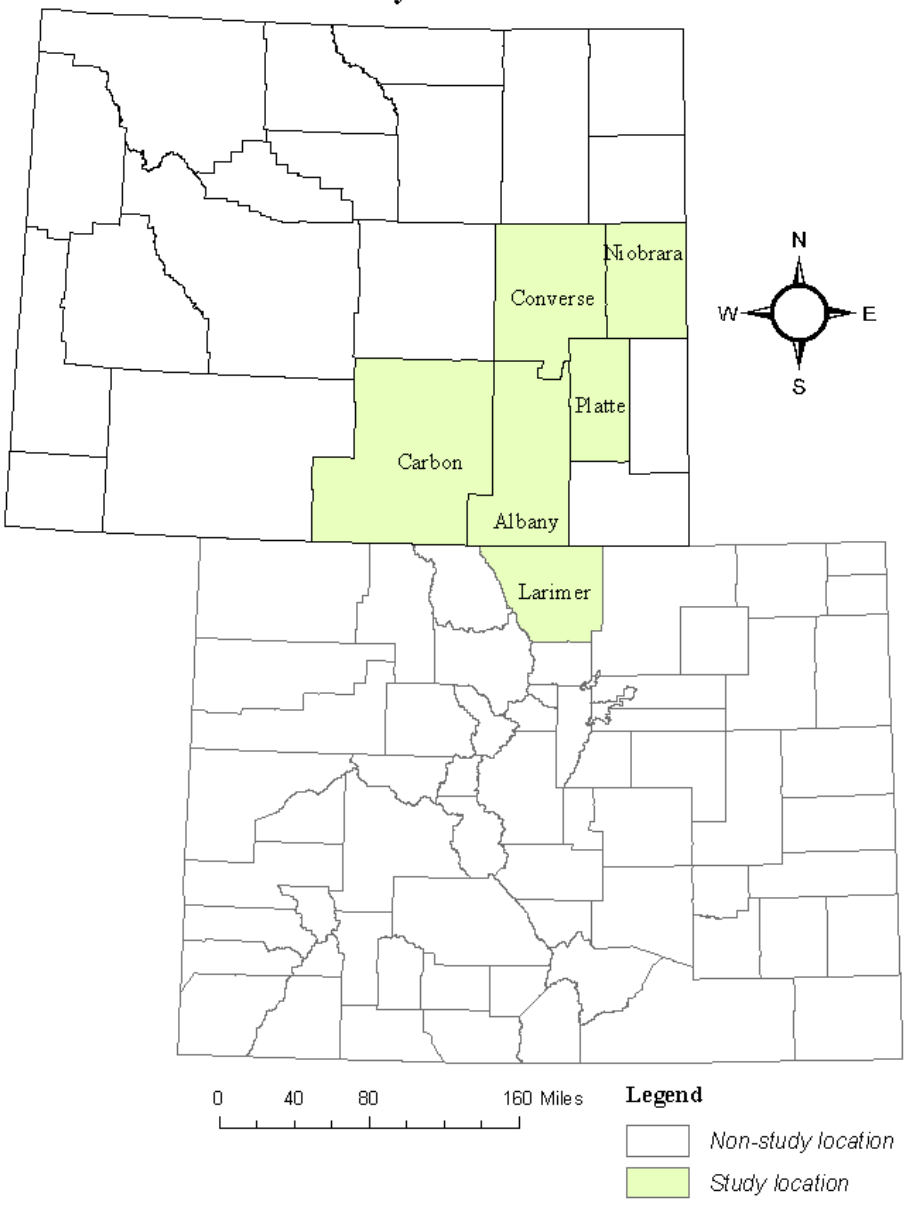


Figure 2.1. Self-administered mail survey study locations
of ranchers in Wyoming and Colorado, October thru December 2009.

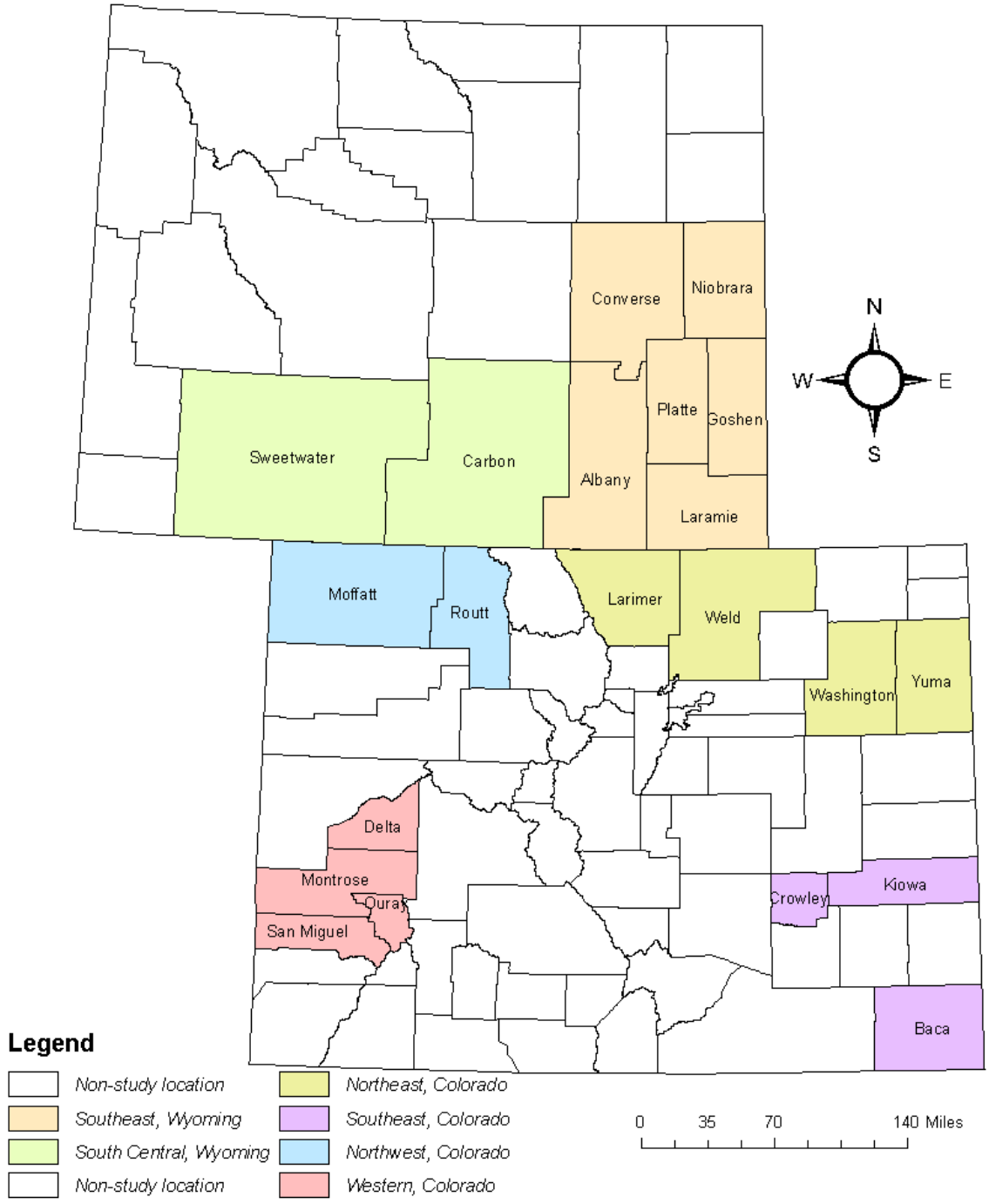
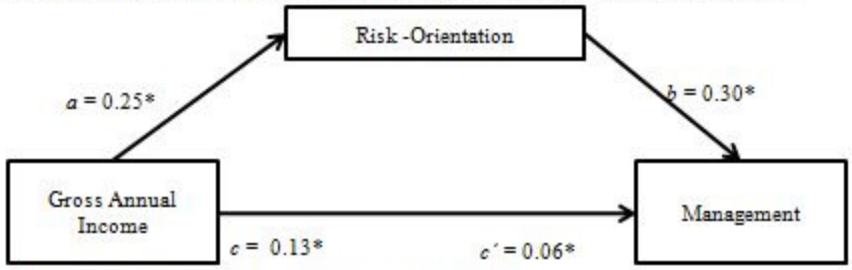
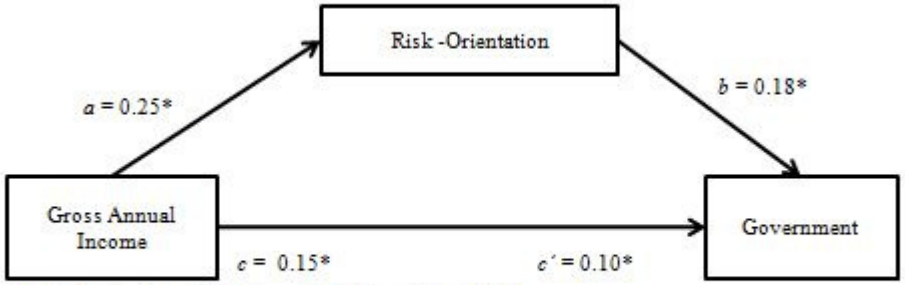


Figure 2.2. Path analysis diagram assessing the role of risk-orientation as a mediating variable between gross annual income and the adoption of management practices. Assumptions for full mediation were met.



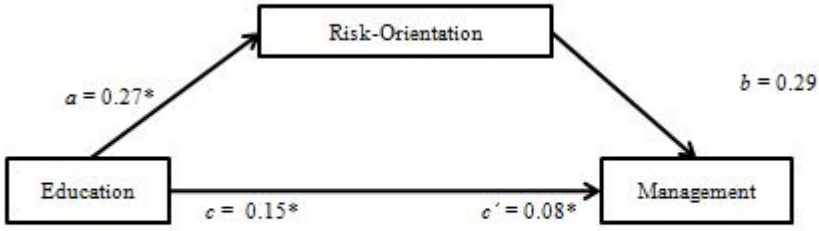
*All standardized path coefficients were significant at $p < 0.05$.
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.058$).
b and c' = Coefficient values regressing the criterion variable on the mediator (b) and predictor variables (c') (adjusted $R^2 = 0.094$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = 0.014$).

Figure 2.3. Path analysis diagram assessing the role of risk-orientation as a mediating variable between gross annual income and the adoption of government programs. Assumptions for full mediation were met.



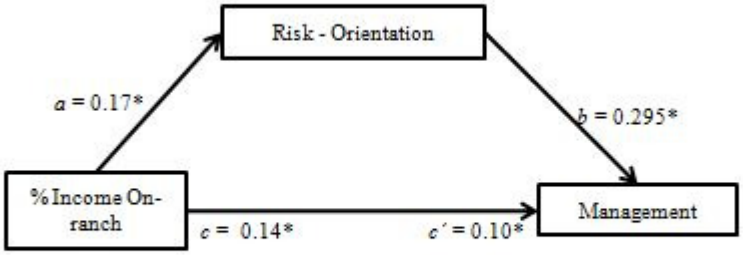
*All standardized path coefficients were significant at $p < 0.05$.
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.058$).
b and c' = Coefficient values regressing the criterion variable on the mediator (b) and predictor variables (c') (adjusted $R^2 = 0.045$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = 0.018$).

Figure 2.4. Path analysis diagram assessing the role of risk-orientation as a mediating variable between education and the adoption of management practices. Assumptions for full mediation were met.



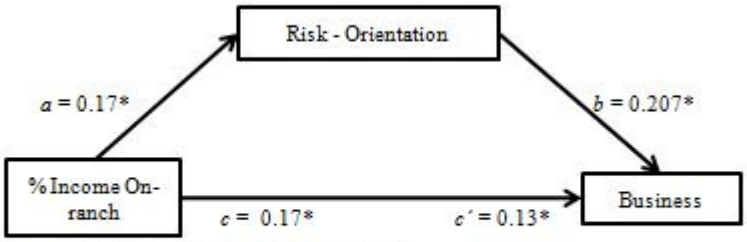
*All standardized path coefficients were significant at $p < 0.05$.
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.071$).
b and c' = Coefficient values regressing the criterion variable on the mediator (b) and predictor variables (c') (adjusted $R^2 = 0.102$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = 0.021$).

Figure 2.5. Path analysis diagram assessing the role of risk-orientation between the percent of income generated by on-ranch sources and the adoption of management practices. Assumptions for partial mediation were met.



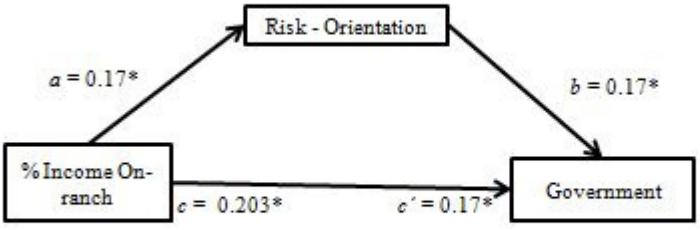
*All standardized path coefficients were significant at $p < 0.05$.
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.024$).
b and c' = Coefficient values regressing the criterion variable on the mediator (b) and predictor variables (c') (adjusted $R^2 = 0.100$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = 0.018$).

Figure 2.6. Path analysis diagram assessing the role of risk-orientation as a mediating variable between the percent of income generated by on-ranch sources and the adoption of business practices. Assumptions for partial mediation were met.



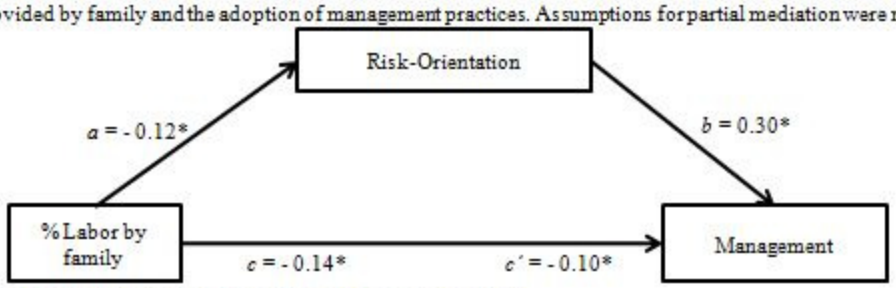
*All standardized path coefficients were significant at $p < 0.05$.
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.024$).
b and c' = Coefficient values regressing the criterion variable on the mediator (b) and predictor variables (c') (adjusted $R^2 = 0.064$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = 0.026$).

Figure 2.7. Path analysis diagram assessing the role of risk-orientation as a mediating variable between the percent of income generated by on-ranch sources and the adoption of government programs. Assumptions for partial mediation were met.



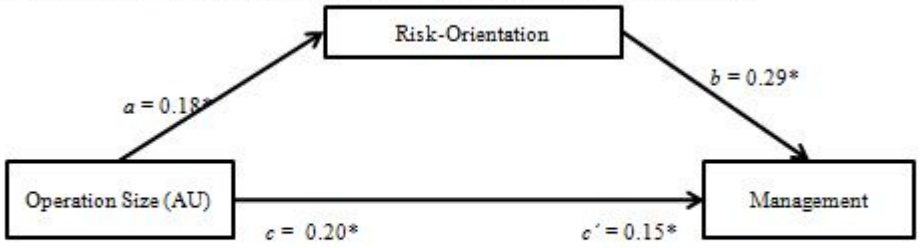
*All standardized path coefficients were significant at $p < 0.05$.
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.024$).
b and c' = Coefficient values regressing the criterion variable on the mediator (b) and predictor variables (c') (adjusted $R^2 = 0.065$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = 0.039$).

Figure 2.8. Path analysis diagram assessing the role of risk-orientation between the percent of annual labor provided by family and the adoption of management practices. Assumptions for partial mediation were met.



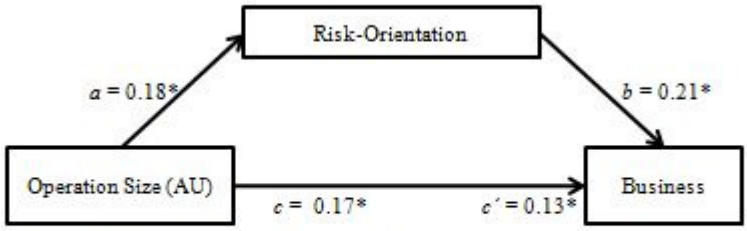
*All standardized path coefficients were significant at $p < 0.05$.
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.015$).
b and c' = Coefficient values regressing the criterion variable on the mediator (b) and predictor variables (c') (adjusted $R^2 = 0.101$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = 0.016$).

Figure 2.9. Path analysis diagram assessing the role of risk-orientation as a mediating variable between operation size and the adoption of management practices. Assumptions for partial mediation were met.



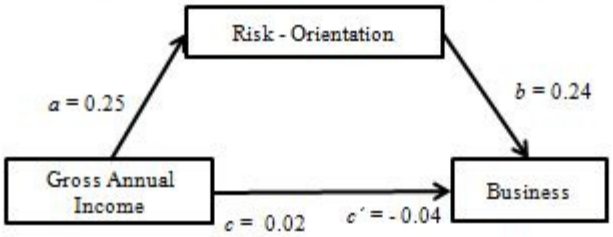
*All standardized path coefficients were significant at $p < 0.05$.
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.028$).
b and c' = Coefficient values regressing the criterion variable on the mediator (b) and predictor variables (c') (adjusted $R^2 = 0.0113$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = 0.037$).

Figure 2.10. Path analysis diagram assessing the role of risk-orientation as a mediating variable between operation size and the adoption of business practices. Assumptions for partial mediation were met.



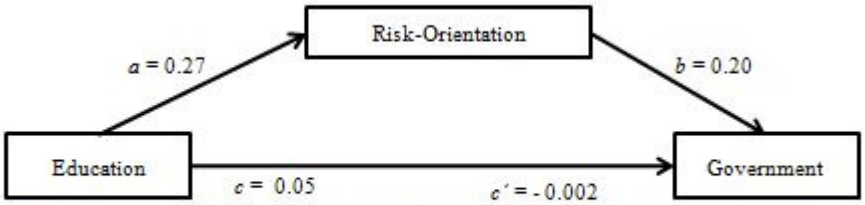
*All standardized path coefficients were significant at $p < 0.05$.
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.028$).
b and c' = Coefficient values regressing the criterion variable on the mediator (b) and predictor variables (c') (adjusted $R^2 = 0.064$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = 0.026$).

Figure 2.11. Path analysis diagram assessing the roll of risk-orientation as a mediating variable between gross annual income and the adoption of business practices. Assumptions for mediation were not met.



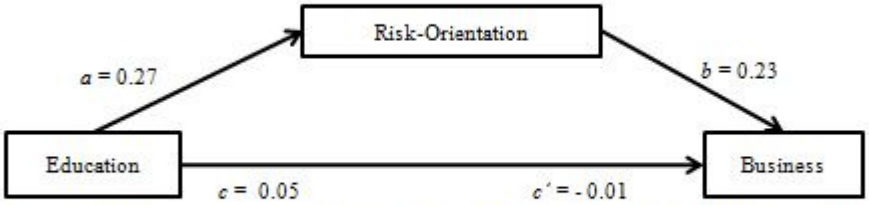
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.058$).
b and *c´* = Coefficient values regressing the criterion variable on the mediator (*b*) and predictor variables (*c´*) (adjusted $R^2 = 0.048$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = 0.002$).

Figure 2.12. Path analysis diagram assessing the roll of risk-orientation as a mediating variable between education and the adoption of government programs. Assumptions for mediation were not met.



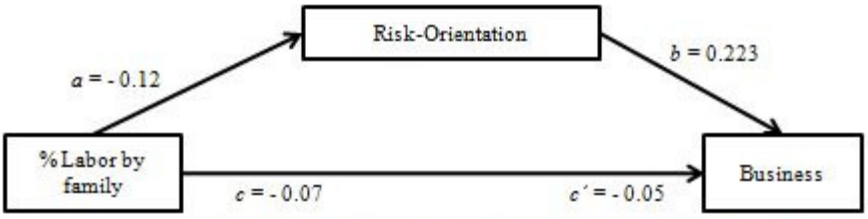
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.071$).
b and *c´* = Coefficient values regressing the criterion variable on the mediator (*b*) and predictor variables (*c´*) (adjusted $R^2 = 0.035$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = 0.003$).

Figure 2.13. Path analysis diagram assessing the roll of risk-orientation as a mediating variable between education and the adoption of business practices. Assumptions for mediation were not met.



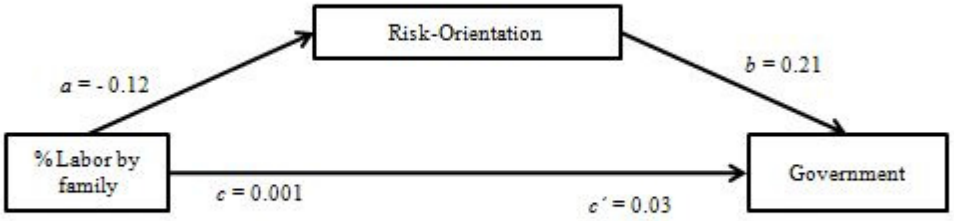
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.071$).
b and *c´* = Coefficient values regressing the criterion variable on the mediator (*b*) and predictor variables (*c´*) (adjusted $R^2 = 0.047$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = 0.000$).

Figure 2.14. Path analysis diagram assessing the roll of risk-orientation as a mediating variable between the percent of annual labor provided by family and the adoption of business practices. Assumptions for mediation were not met.



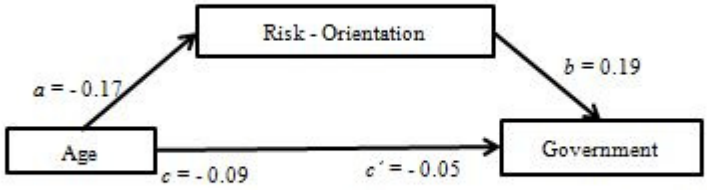
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.015$).
b and *c´* = Coefficient values regressing the criterion variable on the mediator (*b*) and predictor variables (*c´*) (adjusted $R^2 = 0.049$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = 0.003$).

Figure 2.15. Path analysis diagram assessing the roll of risk-orientation as a mediating variable between the percent of annual labor provided by family and the adoption of government programs. Assumptions for mediation were not met.



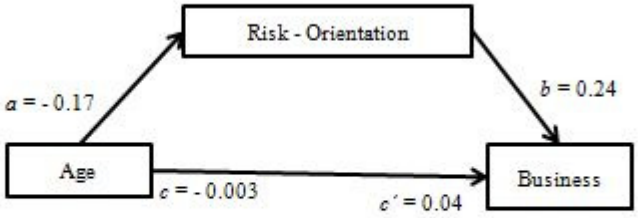
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.015$).
b and *c´* = Coefficient values regressing the criterion variable on the mediator (*b*) and predictor variables (*c´*) (adjusted $R^2 = 0.036$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = - 0.003$).

Figure 2.16. Path analysis diagram assessing the roll of risk-orientation as a mediating variable between respondent age and the adoption of government programs. Assumptions for mediation were not met.



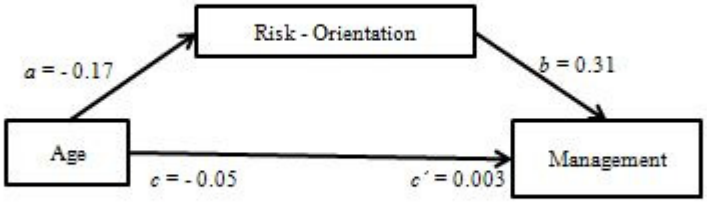
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.025$).
b and *c´* = Coefficient values regressing the criterion variable on the mediator (*b*) and predictor variables (*c´*) (adjusted $R^2 = 0.038$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = 0.038$).

Figure 2.17. Path analysis diagram assessing the roll of risk-orientation as a mediating variable between age and the adoption of business practices. Assumptions for mediation were not met.



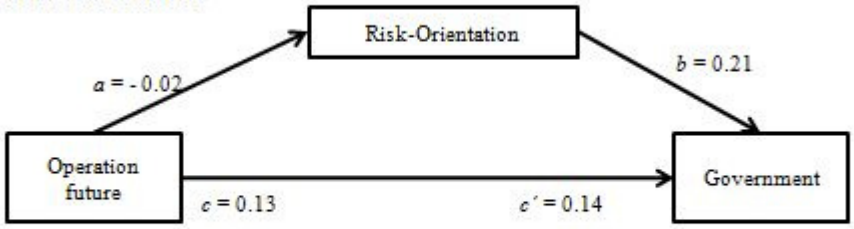
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.025$).
b and *c´* = Coefficient values regressing the criterion variable on the mediator (*b*) and predictor variables (*c´*) (adjusted $R^2 = 0.048$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = - 0.003$).

Figure 2.18 Path analysis diagram assessing the roll of risk-orientation as a mediating variable between respondent age and the adoption of management practices. Assumptions for mediation were not met.



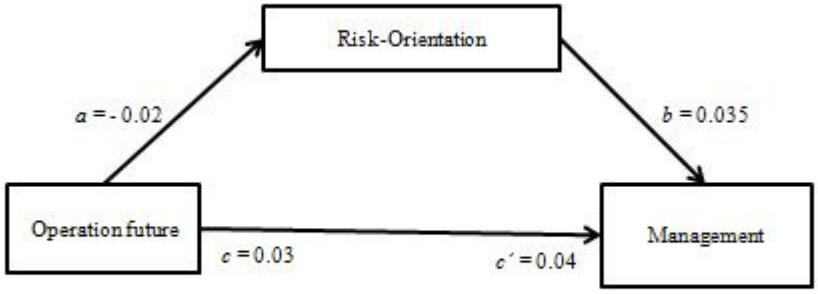
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = 0.025$).
b and *c´* = Coefficient values regressing the criterion variable on the mediator (*b*) and predictor variables (*c´*) (adjusted $R^2 = 0.091$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = - 0.002$).

Figure 2.19. Path analysis diagram assessing the roll of risk-orientation as a mediating variable between the anticipated future of an operation and the adoption of government programs. Assumptions for mediation were not met.



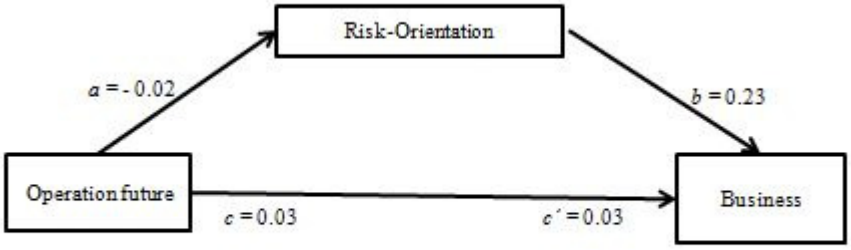
a = Coefficient value regressing the mediator variable on the predictor variable (adjusted $R^2 = - 0.002$).
b and *c´* = Coefficient values regressing the criterion variable on the mediator (*b*) and predictor variables (*c´*) (adjusted $R^2 = 0.054$).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted $R^2 = - 0.0015$).

Figure 2.20. Path analysis diagram assessing the roll of risk-orientation as a mediating variable between the perceived future of an operation and the adoption of management practices. Assumptions for mediation were not met.



a = Coefficient value regressing the mediator variable on the predictor variable (adjusted R^2 = - 0.002).
b and *c* ´ = Coefficient values regressing the criterion variable on the mediator (*b*) and predictor variables (*c* ') (adjusted R^2 = 0.093).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted R^2 = - 0.002).

Figure 2.21. Path analysis diagram assessing the roll of risk-orientation as a mediating variable between the perceived future of an operation and the adoption of business practices. Assumptions for mediation were not met.



a = Coefficient value regressing the mediator variable on the predictor variable (adjusted R^2 = - 0.002).
b and *c* ´ = Coefficient values regressing the criterion variable on the mediator (*b*) and predictor variables (*c* ') (adjusted R^2 = 0.048).
c = Coefficient value regressing the criterion variable on the predictor variable (adjusted R^2 = - 0.002).

CHAPTER THREE: RANCHERS' AND NATURAL RESOURCE PROFESSIONALS' PERCEPTIONS OF STATE AND TRANSITION MODELS

INTRODUCTION

Traditionally, rangeland managers, including ranchers and natural resource professionals (NRPs), used an equilibrium based range management framework. Grazing was the primary driver of vegetation dynamics in this framework (Briske et al. 2008; Westoby et al. 1989). This conventional model of rangeland dynamics has been criticized for years for its inability to respond to non-linear dynamics particularly in ecosystems with arid and semi-arid climate (Westoby et al. 1989), and inaccurate predictions of the responses of common plant communities to management actions (Allen-Diaz and Bartolome 1998). Different ecological models have been developed over several decades, including several non-equilibrium models. Westoby et al.'s (1989) article *Opportunistic Management for Rangelands Not at Equilibrium* proposes one of these models, known as a state and transition model (STM), and describes how it can help land managers to organize their knowledge and implement strategies to achieve management goals.

Over the past decade and a half, STMs have been developed and implemented for many ecological sites throughout the US. The Natural Resources Conservation Service (NRCS), the United States Forest Service (USFS), and the Bureau of Land Management (BLM) signed a memorandum of understanding in 1997 to commit to developing a

uniform foundation for inventory, assessment, and monitoring of rangelands (Bryant et al. 1997), based on the STM framework.

STMs are qualitative 'box and arrow' diagrams that depict how plant communities and their associated soils are affected by different combinations of environmental conditions, natural disturbances, and management practices. STMs can incorporate vegetation drivers and changes that more traditional models are unable to address (e.g., epic natural events, particularly in arid and semi-arid climates, non-native invasive species, irreversible transitions, etcetera) (Briske et al. 2003; Westoby et al. 1989), therefore STMs complement the traditional succession based approach (Bestelmeyer et al. 2003). The theory of the modern approach indicates that the primary ecological processes, hydrology, nutrient cycling, and energy capture (Stringham et al. 2003), are more vulnerable to external disturbances than traditional management frameworks suggest (Briske et al. 2003). It has been suggested that STMs have the capacity to integrate equilibrium models (Briske et al. 2003; Rodriguez Iglesias and Kothmann 1997) such as the conventional range condition model, which compares current species composition to composition in the 'climax state' (Clements 1936) and equates climax to the most desirable 'excellent' condition.

Researchers and field practitioners have been exploring the application of STMs to a variety of natural resource contexts including, but not limited to restoration ecology (Suding et al. 2004) and riparian management (Stringham et al. 2001). It has been suggested that applying alternative state frameworks, such as STMs, to restoration ecology might advance the practice of restoration and the understanding of degraded systems, which includes that some states represent a resilient alternative state (Suding et

al. 2004). Additionally, researchers have started to explore the human dimensions of STMs. For example, a study conducted in Northwest Colorado developed a STM derived from local knowledge, which was later integrated during stakeholder workshops with a data driven STM for the same area (Knapp and Fernandez-Gimenez 2009; Knapp et al. 2010). Ranchers were concerned about the STM's ability to link connected or adjacent vegetation communities, and wanted STMs to address riparian as well as upland vegetation types (Knapp and Fernandez-Gimenez 2009). Overall, ranchers appear to grasp the complexity of interacting climate and management factors associated with STMs; however, a need was detected for outreach and education efforts to focus on the meaning and application of ecological-site based STMs (Knapp and Fernandez-Gimenez 2009).

STMs are not without problems, including challenges in development and application of the model as an assessment and decision-making tool. For example, Allen-Diaz and Bartolome (1998) found that the framework requires significant detail, time, and site specific data to develop a representative ecological site description in order to generate an accurate prediction or outcome (e.g., land treatments). Additionally, the long-term, site specific data needed to construct data-driven models are often unavailable (Allen-Diaz and Bartolome 1998). Allen-Diaz and Bartolome (1998) concluded that a majority of issues associated with STMs are the result of human error related to unusual transitions through misclassification and identification of occurrences resulting in misidentified states. From a management perspective, the utility of STMs as a decision-making tool may depend on the availability of sufficient resources (time and money)

when ecological opportunities or hazards arise, in order to either seize or evade them (Westoby et al. 1989).

A comprehensive approach for the management of vegetation composition and ecological processes, STMs are an evolving tool in the field of rangeland management and other natural resource disciplines. This assessment, planning, and monitoring tool has been adopted by several federal land management agencies and is gaining increased attention from researchers, state and local natural resource agencies, land conservation organizations, consultants, and private landowners throughout the western United States. Challenges remain to the application of consistent STM terminology (Briske et al. 2003). Additionally, we need to better understand rangeland managers' awareness of and attitudes toward STMs, as well as how they are using the tool. We also need to learn from practitioners what is and what is not working, and how to improve STMs to make them a more useful decision-making tool for rangeland managers.

OBJECTIVES

The objectives of this study were to document and compare ranchers' and NRPs' awareness and use of STMs, and to determine to what extent managers perceive their operation, agency, or management unit would benefit ecologically or economically from use of STMs as a decision support tool. We also sought to identify potential improvements to the models that would make them more useful. Finally, we wanted to learn what information and technical assistance about STMs land managers' want or need.

This study is part of a long-term, interdisciplinary integrated research and extension project, which is scheduled to conclude in 2012. In the context of the larger

project, this study provides baseline data that will enable us to evaluate, after the project's conclusion, the extent to which extension efforts are successful in increasing land managers' awareness, knowledge, and use of STMs.

METHODS

This study used a mixed-method approach implemented in two phases, pre-survey focus groups followed by a self-administered mail survey. We sampled two populations, ranchers and NRPs. Focus groups were used in this study as an exploratory tool to gain a better understanding of rancher and NRPs' awareness and knowledge of STMs, their ideas about what would make the model a more useful management tool, and how each population learns about new management tools. Focus group data were also used to inform the development of the self-administered mail survey.

Phase 1: Focus Groups

Sampling Frame

The study locations and sampling frames varied during each phase of the study. For the first phase of the study, we invited ranchers and NRPs from one county in Colorado (Larimer) and five counties in Wyoming (Albany, Carbon, Platte, Converse, and Niobrara) to participate in separate focus groups (Figure 2.0). Three focus groups were held with ranchers and three with NRPs.

We defined several criteria for the type of ranchers we wanted to invite to the focus groups. These criteria were: 1) mid to large scale ranch operations (more than 100 acres [40.47 hectares]); 2) individuals active in the agriculture community; and 3) individuals that are less active in the agriculture community. We contacted individuals

who work or live in the communities (see purposive and snowball sampling below) to identify ranchers who met our sampling criteria.

NRPs included employees of the NRCS, USFS, BLM, Colorado Division of Wildlife (CDOW), Wyoming Game and Fish Department (WGFD), not-for-profits, and local agencies (i.e., Extension, weed districts, and city/county natural areas). The following criteria were outlined to identify which NRPs to invite to the focus groups: 1) individuals who manage weeds, rangeland, habitat/wildlife, or who provide extension services; 2) individuals responsible for making and implementing management decisions; and 3) a variety of local, state, and federal agencies as well as non-profit organizations. By using these guidelines, we sought to ensure that the sample for each focus group offered a mixture of individuals within the homogeneous groups (i.e., ranchers and NRPs).

A non-probability sample was conducted for the first phase of the study, which means that the odds that an individual met our sample frame criteria and would be invited to participate in our study was unknown. We identified potential participants through purposive and snowball sampling (Berg 2004; Biernacki and Waldorf 1981; Stewart and Shamdasani 1998). Purposive sampling is when participants are intentionally selected (Stewart and Shamdasani 1998), particularly of populations that can be harder to access (Neuman 2003), such as rural communities. In this study, the use of purposive sampling helped to ensure that the representative target populations of ranchers and NRPs were identified. The snowball technique is a method where initial contacts provide researchers with a name of individuals who meet the sample frame criteria and who might participate in the study (Berg 2004; Biernacki and Waldorf 1981). This technique enabled us to gain

access to a broader group of potential respondents. The research team initiated the first step of this method by identifying several key informants, including county extension agents, local cattle growers associations, resource conservation district boards, and natural resource agencies. We asked key informants to identify potential individual participants and organizations that met our sampling frame criteria (see above) (Appendices A and B). A list of 15 – 20 potential participants was compiled for each of the planned focus groups.

Focus Group Design and Implementation

Focus groups are a systematic qualitative method where homogeneous groups comprised of eight to 12 individuals discuss a particular topic (Fowler 2002; Stewart and Shamdasani 1998). They have been used in a variety of industries since 1941 (Bernard 2002) enabling exploration of respondents' attitudes and perceptions about a topic (Vaske 2008). Focus groups can enhance quantitative social science studies by combining qualitative with quantitative methods (Bernard 2002). By documenting what issues are salient and how participants talk about them, the focus group method can assist researchers in developing relevant survey questions (Bernard 2002). In January and February 2009, we held focus groups with ranchers and NRPs in each study area. The purpose of the gatherings was to explore what land managers knew about STMs, how STMs were being used, what type of ecological and economic benefits were perceived from using STMs, participants' perceptions of how STMs could be made more useful, and how individuals prefer to get technical information.

Invitations were mailed to selected ranchers and NRPs on the basis of referrals from key informants (Appendix G). Focus groups were held at non-participating agency

offices, community centers, or libraries. Focus group meetings were audio-recorded and a note-taker also recorded the discussion on a laptop computer. Additionally, key points were written on a flip-chart and verified by participants. The typed notes were later compared to the audio recording and completed by a transcriber. Six focus groups were carried out, three each with ranchers and NRPs. A total of 16 ranchers and 17 NRPs participated in the focus groups, each lasted nearly two hours.

Analysis of Focus Group Data

Focus group data were transcribed and then analyzed using the qualitative data analysis software QSR NVivo version 8 (1996 - 2007).We used a modified version of the Straussian approach to grounded theory and thematic analysis to analyze the data. In the Straussian approach to grounded theory, a question or set of questions are raised based on existing knowledge, information needed to help develop concepts, or to explore relationships (Grbich 2007). We conducted the analysis through open coding and identification of themes across the data, as described by Braun & Clarke (2006) and Grbich (2007). Open coding is the foundation for analyzing data in grounded theory and it occurs each time data are collected (Grbich 2007; Strauss and Corbin 1990). It is an interpretive process of systematically breaking down, examining, conceptualizing, and categorizing qualitative data (Corbin and Strauss 1990; Strauss and Corbin 1990). We coded directly in the data, identifying key words, phrases, and occasionally sentences. The key themes of interest were: land managers' awareness of STMs (e.g., recognize 'box and arrow' description or the ability to describe how the tool works); potential ecological and economic benefits of using STMs (e.g., having a balance of cool and

warm season grasses); and perceived effective communication of STMs to ranchers (a key theme in NRP focus groups).

Phase 2: Self-Administered Mail Survey

Sampling Frame

The sampling frame for the second phase of the study, a self-administered mail survey, was different for the two populations. The rancher sampling frame was developed through two phases. We first identified counties in Wyoming and Colorado where we wanted to survey ranchers. Our criteria for these counties included: 1) project focal counties where our fieldwork and outreach activities are conducted; and 2) counties to act as 'controls' or non-project reference sites, which will not be exposed to the same outreach as the focal counties. The study counties in Wyoming were: 1) Converse; 2) Niobrara; 3) Goshen; 4) Platte; 5) Laramie; 6) Albany; 7) Carbon; and 8) Sweetwater. We split the eight counties into two regions Southeast Wyoming (the initial six counties) and South Central Wyoming (the latter two counties) (Figure 2.1). The study counties in Colorado were: 1) Larimer; 2) Weld; 3) Yuma; 4) Washington; 5) Crowley; 6) Kiowa; 7) Baca; 8) Routt; 9) Moffat; 10) Delta; 11) Montrose; 12) Ouray; and 13) San Miguel. We split the 13 counties into four regions: Northeast Colorado (the first four counties); Southeast Colorado (counties five thru seven); Northwest Colorado (counties eight thru nine); and Western Colorado (counties 10 thru 13) (Figure 2.1). It should be noted that the greater research and extension project is conducting field and outreach work in Routt and Moffat counties, therefore the remaining counties are control counties.

The National Agricultural Statistics Service provided the survey sampling frame for ranchers, and mailed out, and received the returned surveys. The target population

was ranchers with at least 100 acres (40.47 hectares) of private, leased, or permitted land, and a minimum of 20 animal units (AUs) (cattle, horses, goats, and sheep). Dairies and feedlots were excluded, because in general, these businesses have different management and business objectives than our population of interest. We mailed the survey to a stratified random sample of 200 ranches in each of the six geographic regions within our study areas in Wyoming and Colorado (1200 ranches total). We were targeting for a 50 percent response rate to minimize the sampling error.

We developed the NRP sampling frame using current employee directories for the target federal, state, and local agencies. If we did not find a current directory with the necessary information, we directly contacted agencies and requested the information (e.g., USFS). Agencies in the sampling frame included the USFS, BLM, NRCS, WGFD, CDOW, University of Wyoming and Colorado State University extension, local weed management programs and districts in Wyoming and Colorado, and local parks and open space departments. The sampling frame included NRPs in the following positions: weeds, range, wildlife, habitat, and National Environmental Policy Act specialists; ecologist; soil scientist; and agriculture and natural resource extension agents. We compiled a list of over 1000 NRPs throughout the two states. The Wyoming and Colorado lists were combined and stratified into five categories by agency or agency type: 1) local agencies (extension agents, weed authorities, and city and county open spaces); 2) state (WGFD and CDOW); 3) BLM; 4) USFS; and 5) NRCS. The survey was mailed to a stratified random sample of 100 professionals in each of the five agencies or agency types (500 individuals). We were targeting for a 50 percent response rate to minimize sampling error.

Survey Design and Implementation

A self-administered mail survey was implemented October – December 2009. The survey questions were developed on the basis of focus group results and the evaluation needs of the larger project. Survey drafts were reviewed and pretested by two interdisciplinary research teams comprised of eight to 11 researchers and graduate students, as well as one extension agent, one state employee, and two USFS employees. The survey was revised several times before the final version was completed. The survey consisted of five sections: Management Practices and Programs; Perceptions and Management of Cheatgrass (*Bromus tectorum*); Perceptions and Use of State and Transition Models; Information Needs and Preferences; and Background (i.e., demographics) (Appendix J and Appendix K). The third section, Perceptions and Use of State and Transition Models, included a schematic of a STM with a brief description of the model and how the NRCS, USFS, and BLM are using the model. The questions about cheatgrass (*Bromus tectorum* L.) were included to provide input to a separate, but related, integrated research and extension project focused on cheatgrass management.

A modified version of the Dillman (2000) method guided the implementation of the surveys. This method has resulted in high survey response rates (Bernard 2002; Fowler 2002). The modified process included a four-wave mailing with a pre-survey letter, a survey with a cover letter, and a reminder/thank postcard (Dillman 2000) (Appendices G – L). Additionally, a replacement survey with a cover letter was mailed three weeks after the initial survey mailing, as needed (Dillman 2000) (Appendices M and N). Because ranchers and agency professionals who returned their surveys might differ from those who did not respond, we conducted a random non-response bias check

with 36 ranchers (5% of non-respondents), and 11 NRPs (6% of non-respondents) (Appendices O and P).

For both ranchers and NRPs, we included in our statistical analyses data from both respondents to the original mail survey and those non-respondents who participated in the non-response bias check.

Measurements

Two surveys were developed, one for ranchers and one for NRPs. The surveys were almost identical and were comprised of close-ended, ordered response questions (including several based on the Likert Scale) as well as several 'check all that apply' questions, and 'fill-in the blank' responses (Appendix J and Appendix K). The differences between the rancher and NRP surveys included questions in the first section (e.g., number of private acres in a ranching operation versus the number of years employed as a NRP), and in the fifth section where ranchers were asked more questions (e.g., What is the anticipated future of your ranching operation?) than agency professionals. The following explains how we presented and measured specific variables.

Awareness of STMs. Respondents were asked to identify their familiarity with the term or application of STMs prior to the survey. We provided four response options, which were: 1) I have never heard of STMs before today; 2) I have heard about STMs, but I have not read or used one; 3) I have read about STMs; and 4) I have used STMs (Appendices J and K, Section III, Question 1).

Ecological and Economic Benefits. Respondents were asked to indicate to what degree ('No Benefits' to 'Major Benefits') they thought STMs might help them to reach

their ecological/land condition, and economic objectives for their ranch operation or management area (Appendices J and K, Section III, Questions 2 and 4).

Use of and Level of Satisfaction with State and Transition Models. Several potential applications of STMs were presented in the questionnaire and respondents were asked to identify to what degree they were satisfied ('Completely Dissatisfied' to 'Completely Satisfied') with each specific application of STMs or to indicate that they had never used STMs for that purpose (Appendices J and K, Section III, Question 3).

Information Needs and Technical Assistance. Rancher and NRPs were asked what information about STMs they currently need or would like to have (Appendices J and K, Section IV, Question 4). Respondents were also asked to qualitatively describe what would make STMs a more useful management tool for them (Appendices J and K, Section III, Question 5).

Survey Analysis

Data were analyzed using PASW Statistics version 18.0 for Windows XP ([PASW] 2010). The response rate for individual questions varied because some individuals did not answer all questions. We included all useable surveys (returned surveys that respondents answered all or nearly all of the questions) were used for data analysis despite missing values.

We identified respondent characteristics by calculating descriptive statistics (means and percentages of the population, as appropriate to the characteristic) related to personal characteristics and the attributes of the respondent's ranching operation, for ranchers, and personal characteristics for NRPs. We calculated a new variable for the attribute 'operation size,' which was measured in animal units (AUs). The first step to

create this new variable was to multiple a respondents reported number of animals per species by the associated animal unit equivalent (Table 2.0) (2008; Vallentine 1990; Wilson 2006), we then summed the total number of AUs.

Similarly, we calculated the overall awareness of STMS by tabulating descriptive statistics. Additionally, we tabulated the levels of awareness within and between regions (for ranchers) and agencies (for NRPs) using Crosstabulations. We calculated frequency to assess the perceived ecological and economic benefits of using STMs, as well as the use of STMs and the associated level of satisfaction. Finally, we calculated descriptive statistics to assess information needs and technical assistances. We also qualitatively compared rancher and NRP results (see the Discussion).

RESULTS

The adjusted response rate, or the proportion of mailed surveys that were completed and returned by ranchers was 35% (n = 411) and 65% of NRPs (n = 312) responded to the survey. The response rate for ranchers was similar across all regions (n = 66 - 78) except Southeast Colorado (n = 51). Additionally, we were unable to identify the region for some surveys (n = 41), because the respondents removed the survey identification number and they did not provide their zip code. The response rate for NRPs varied across all regions (n = 10 – 39), the Intermountain Basins of Colorado had the lowest response rate and South Central Wyoming had the highest. However, the response rate was comparable for all surveyed agencies.

Several factors that might have affected the response rate for ranchers were identified. The sampling frame excluded feedlots and dairies; however, we had 46 survey recipients contact us stating the survey did not apply to them for one of the following

reasons: the survey was sent to a feedlot or dairy; the recipient had sold their livestock during the drought and they were no longer in the business; or the recipient was a farmer, raising crops such as sugar beets, onions, etcetera. Factors that may have influenced the response rate of agency professionals included the perception that the survey did not apply to the recipient's position, lack of time to complete the survey, or the perception that responses from multiple individuals from the same agency and office were redundant and unnecessary. We were notified by 20 people that the selected person was no longer with that agency/field office. Surveys that were sent to individuals who did not meet our sample frame criteria were considered non-deliverable and they were excluded from our response rate (i.e., adjusted response rate). We believe our response rate is a conservative estimate of the true proportion of qualified respondents who responded (i.e., the actual response rate is probably slightly higher than we report), due to the factors that may have affected our response rate.

Non-respondent and respondent ranchers did not differ in the regions that they represented, education level, age, percentage of their operation's annual labor that is supplied by their family, familiarity with STMs, gender, future of their operation, or gross annual income. Non-respondents did differ in their risk-orientation compared to survey respondents. Respondents were significantly more likely to take risks than non-respondents (Pearson $X^2 = 19.33$, p-value = 0.001), with a Cramer's V effect size of 0.226, indicating a typical to minimal relationship. The relatively small effect size suggested minimal variation, justifying our decision not to make adjustments to our sample. Additionally, this effect size suggests that we are safe in generalizing to the

larger population, however readers should be aware that the responses represent a slightly more pro-active and concerned sample than the general population of ranchers.

Non-respondent agency professionals did not differ from respondents in the number of years they have worked as a NRP or for their current employer, risk-orientation, awareness of STMs, education level, age, gender, or the type of agency that employs them (e.g., local, state, BLM, etcetera). Therefore, we feel confident that data from respondents can be generalized to the sampled population.

Respondent Characteristics

Ranchers

The average rancher respondent was 58 years old (range 26 – 93 years) (Table 2.1), with some college education or they had attended a technical school (Chart 2.0), and had managed his or her ranch for 23 years (Table 2.1). Thirty-three percent of rancher respondents reported their income in the $80,000 – 199,999 category, the median (Chart 2.1). Income from livestock accounted for 44% of the average rancher respondent's gross annual income, and nearly 79% of their operation was on private land, 87% of their operation's annual labor was supplied by family, and they had 214 AUs (Table 2.1). The majority of rancher respondents anticipated their children will take over the operation when they are no longer the operator (Chart 2.2).

Natural Resource Professionals

The average NRP respondent was 46 years old (range 23 – 66 years) (Table 3.0), with a four-year degree (Chart 3.0), and had worked as a NRP for 16 years (Table 3.0). The average respondent had worked for their current agency for 14 years (Table 3.0). Nearly 72% of the NRP respondents were male.

Awareness of State and Transition Models

Across all regions, nearly 70% of ranchers had never heard of STMs before completing the survey, 20% had heard about them, but not read or used them, and only 2% had actually used STMs. Northwest Colorado had the greatest percentage of rancher respondents (4%) who had used STMs, followed by Western Colorado (3%) (Table 3.1). For all of the regions, over 55% of ranchers had never heard of the models, with the greatest percentage in Northeast Colorado (86%) (Table 3.1).

Among NRPs, 24% had never heard of STMs before completing the survey, 19% had heard about them, but not read or used them, 30% had read about STMs, and 30% had actually used them (Table 3.2). At the agency level, half of local NRPs had never heard of STMs before the survey and the NRCS had the fewest (10%) employees who had never heard of STMs (Table 3.2). The NRCS had the greatest percentage (52%) of respondents who had used STMs, followed by the BLM (37%), and the USFS (26%) (Table 3.2).

Perceived Ecological and Economic Benefits of State and Transition Models

Ecological Benefits

More than 50% of all rancher respondents perceived moderate to major benefits for all specified variables except ‘to better manage habitat for livestock and wildlife’ (47%) (Table 3.3). Similarly, more than 50% of all NRPs perceived moderate to major benefits for all specified variables (Table 3.4).

Ranchers and NRPs perceived the greatest potential ecological benefits of STMs as shifting plant community composition (25% of ranchers and 50% of NRPs) and helping them understand the ecological conditions of their land (24% of ranchers and

53% of NRPs) (Table 3.3 and Table 3.4). Few rancher respondents perceived benefits from STMs for managing *habitat* for livestock and wildlife (8%) (Table 3.3), while few NRP respondents perceived benefits for managing *nutrient* needs for livestock and wildlife (5%) and for retaining soil and limiting erosion potential (4%) (Table 3.4).

Nearly 16% of rancher respondents perceived 'other' ecological benefits from using STMs (Table 3.3). Some of the comments that rancher respondents wrote in the survey included that using STMs could increase productivity of the land, could [help to] control prairie dogs, and [help to] maintain ecological function. Another rancher expressed the importance of assessment regardless of the framework, "No matter what model or method you use, detection, knowledge, [and] inventory must be done and paid for." While another felt that STMs have been misused, "I am not a big fan of STMs and [I] feel that most of the models that have been used in our area have caused several problems."

Approximately 35% of NRPs perceived 'other' ecological benefits from using STMs (Table 3.4). Some of the comments that respondents wrote in the survey included that using STMs could increase water storage, and can be used to communicate potential conditions as well as management opportunities (e.g., "Help others [to] understand ecological principles governing a system, so a clearer conversation about management can occur"). One NRP expressed concern about use of STMs as a regulatory tool, "Landowners will be subject to lawsuits from environmental groups in effort to close grazing on federal lands."

Economic Benefits

More than 55% of rancher respondents perceived moderate to major economic benefits for all specified economic variables (Table 3.5). The greatest number of NRPs perceived benefits from using STMs to better manage habitat for livestock and wildlife (29%), followed by increase livestock productivity (12%) (Table 3.6). None of the NRPs perceived even moderate benefits from using STMs to manage nutrient needs for livestock and wildlife, increasing pounds per acre of palatable forage, and increasing pounds per acre of nutritious forage from using STMs (Table 3.6).

Nearly 67% of rancher respondents perceived slight to major benefits for 'other' economic objectives from using STMs, in other words, benefits other than those listed (Table 3.5). Some of the benefits included, reducing fire danger and managing poisonous plants such as larkspur.

Almost 40% of the ranchers believe there are no additional economic benefits, other than those listed in the survey, from using STMs. Individuals did not elaborate as to why they do not perceive any additional economic benefits from STMs, however several people wrote they are not knowledgeable enough [about STMs].

Approximately 22% of NRPs perceived slight benefits for 'other' economic objectives from using STMs (Table 3.6). One of these benefits was managing habitat for threatened and endangered species. Six NRPs indicated that their agency does not have economic objectives or they are not concerned about economic objectives. Over 75% of NRP respondents indicated that there are no economic benefits associated with utilizing STMs (Table 3.6).

Use of and Level of Satisfaction with State and Transition Models

As indicated earlier, most ranchers had not heard of STMs prior to the survey, and only 2% had used them (Table 3.1). Ranchers did respond to the question about their use of and level of satisfaction with STMs. However, due to a greater percentage of ranchers indicating they had used STMs and their level of satisfaction with using them compared to the question that asked their awareness of STMs, we believe our data for this question are unreliable. Therefore, we opted not to present them.

Of the NRP respondents who had used STMs, they were most satisfied using the tool to gain a better understanding of rangeland systems (34% of respondents were completely satisfied), followed by 25% of respondents who had used the model to identify appropriate indicators to use in monitoring rangelands, and 24% of NRPs had used it to understand how a specific rangeland area came to be in its current state (Table 3.7). Of the NRPs who indicated they had used STMs, on the four point scale from completely dissatisfied to completely satisfied, over 70% of them were satisfied in their application of the tool in the following four capacities: 1) identify and assess the current state of rangelands in their management area; 2) assess or monitor the ecological condition of rangelands in their management area; 3) used STMs to develop a management plan; and 4) used STMs to identify management objectives were satisfied (Table 3.7). Less than 8% of respondents were completely dissatisfied with applying the STMs to the specific descriptions (Table 3.7).

Information Needs and Technical Assistance

Ranchers and NRPs were most interested on 'how to use STMs to help make land management decisions' (34% of ranchers and 52% of NRPs), 'how to use STMs to meet

management objectives' (37% of ranchers and 47% of NRPs), and 'where to access STMs' (34% of ranchers) and 'benefits of using STMs over the more traditional range condition approach' (39% of NRPs) (Table 3.8).

Several ranchers wrote that they want STMs to be peer reviewed by consultants, and repeatedly ranchers wrote that a class or workshop about STMs would be beneficial. It appeared that there are some misconceptions about STMs. For example, one rancher wrote they are not interested in STMs and they do not want more government paper work to fill out.

A few suggestions that NRPs wrote that they believe would make STMs more useful include providing a summary of how STMs deal with non-native, invasive species, and how to apply STMs to riparian communities. Additionally, several respondents indicated there is a need to develop STMs for forested areas, including aspen communities. Several NRPs indicated that they understand the theory of STMs, however there is a need for workshops or additional training for how to apply the theory to a practical situation.

DISCUSSION

Based on our findings, STMs can be considered an innovation to a lot of people. Innovations are developed to address a problem or meet a need, and in general they are a new concept to an individual or group (Brown 1981; Rogers 1995). An innovation is diffused by communicating about it over time to a social system, which can be comprised of individuals, or formal or informal groups, etcetera (Rogers 1995). Through prior research, five characteristics of innovations that influence the rate of adoption have been identified. The characteristics are the perceived: 1) relative advantage; 2) compatibility;

3) complexity; 4) trialability; and 5) observability (Rogers 1995). It has been suggested that innovations that are less complex, but have greater degrees of the other four characteristics will be adopted first (Rogers 1995). As with any new innovation, the process of developing and implementing STMs is still evolving.

Awareness, Perceived Benefits, and Use of State and Transition Models

We found that the majority (nearly 70%) of ranchers had never heard about STMs prior to our survey, while 76% of NRPs had at least heard of, if not read about or used them. It was not surprising that ranchers in Northwest Colorado were more aware of STMs compared to other regions, because this region is the host to the field and outreach components of the broader, long-term research and extension project. Similarly, it was not surprising that a greater portion of NRCS employees had used STMs compared to employees at other agencies, because of the agency's active role in the development and use of the tool. This said, it was surprising that 10% of NRCS respondents had never heard of STMs, and we can only speculate why.

It is concerning that so few ranchers are aware of STMs, particularly because there is a potential that in the future the tool could impact public-land ranching operations in a regulatory framework. Similarly, one NRP wrote in their survey that "landowners will be subject to lawsuits from environmental groups in an effort to close grazing on federal lands, some landowners will reject STMs on that basis." And although a significantly greater percentage of NRPs had used STMs compared to ranchers, there appears to be a gap in the type of agencies that are aware of and using the tool. Staff of agencies other than NRCS that could benefit from using STMs do not know about them. This knowledge gap is both a missed opportunity and could create miscommunication

within, or among agencies using different assessment and monitoring frameworks. Several NRPs wrote supporting comments in their survey. For example, a respondent with a state agency wrote, "STMs would be more useful to me if the people I work with knew what they were and how to use them." Another professional respondent wrote that there is a need for "more multiagency buy-in from the USFS, BLM, National Park Service, counties, and …" Yet another NRP wrote that there is a need for "agency acceptance of [STM] use, industry acceptance of their use, other disciplines acceptance of their use, … , application to other uses such as recreation …" Thus, while many NRPs are aware of the potential benefits of STMs, they are frustrated by the lack of awareness of their peers, and also advocate for a broader range of management applications (beyond grazing management).

It was interesting that although relatively few ranchers had prior awareness of STMs, more than half of them perceived that using the tool would result in moderate to major ecological and economic benefits for all of the stated potential benefits. Prior research on adoption suggests that innovations that result in greater benefits compared to existing practices (i.e., relative advantage), and that are compatible with existing values, needs, and past experience (i.e., compatibility) are two characteristics that increase the rate of adoption (Rogers 1995). The high degree of perceived benefits of a relatively unknown innovation suggests that ranchers might be willing to adopt STMs as a decision making tool.

More than half of NRPs also perceived that using STMs would result in moderate to major benefits for all specified ecological variables. However, they were more conservative in their perceptions that using the tool would result in economic benefits. In

other words, they indicated that using STMs might result in moderate to major benefits for management of habitat for livestock and wildlife, and to increase livestock productivity, two of the six potential economic benefits specified in the survey. Several NRPs wrote comments in their surveys indicating that their agency does not have economic objectives. For example, one professional wrote the "NRCS has no economic objectives," and another professional wrote that either they or their agency are "not really concerned about economic objectives." This finding indicates that NRPs may not perceive a strong linkage between natural resource health and economics, or that their interpretation of their agency's mission is that it does not prioritize economic outcomes.

The high level of satisfaction with the application of STMs indicates that the tool might provide relative advantage and compatibility to existing management approaches and needs (i.e., characteristics of innovations) (Rogers 1995). However, it was beyond the scope of our study to identify whether or not respondents' perceived that using STMs had similar, if not greater benefits compared to their prior practice(s) (relative advantage) or that using STMs was compatible with their existing values, prior experience, and needs (compatibility) (Rogers 1995).

Information Needs and Technical Assistance

Based on the survey results, outreach and extension efforts about STMs should focus on where to access the tool, how to use STMs to make land management decisions and meet management objectives (i.e., application of the tool), and the benefits of using STMs, specifically benefits over the more traditional range condition approach. Numerous individuals indicated they are not familiar enough with STMs to comment about what would make the tool more useful. For example, one rancher wrote "the fact that I have

never heard about this [STMs] before today pretty much explains it all," another rancher wrote "no prior knowledge about STMs to comment."

NRPs expressed a greater need for accessing STMs and information about them. For example, one NRP wrote "better access (promotion) of these tools, so that all people (not just range folks) know about them," and another professional wrote "I understand STMs as a concept, not as a management practice or management tool …" These data indicate a need for more outreach and education about STMs, where they are available, and, especially, how to apply them.

Additionally, qualitative comments written in the ranchers' and NRPs' surveys indicated a need for the development of STMs that are more applicable to specific sites. For example, one rancher wrote "They [STMs] are too general. I think that the only time STMs are very useful is where they are developed at a specific site, even a few miles or less away from the development site. Enough conditions are different to cause the results to vary to the point that conclusions are wrong for more than one area." A NRP respondent wrote there is a "need to develop STMs for alpine tundra and aspen communities," and another NRP wrote there is a need for "more specific, better coverage of mountain areas."

Numerous NRPs provided qualitative comments stating a need for more validation of STMs. For example, one professional wrote there is a "need [for] greater peer – reviewed scientific basis for all aspects of STMs," and another professional wrote "Many of the STMs need additional validation and quantification in west central Wyoming. We are still describing them in qualitative terms, more field data collection and analysis is needed for verification."

IMPLICATIONS

Few ranchers are aware of STMs and the level of awareness varies greatly among different natural resource agencies. Based on these findings, we recommend that a greater effort be made to develop appropriate outreach and extension materials targeted for each specific population, for example different materials could be developed for ranchers, wildlife agencies, local open space and park managers, and land conservation organizations. These specific outreach and extension materials will help target populations to understand how they can use STMs and potential ecological or environmental benefits associated with their application of the decision-making tool. Our results also suggest that both populations perceive that STMs will help them to achieve their ecological and/or economic objectives, and that most ranchers and professionals who have used STMs are satisfied with the results. As studies validate perceived benefits of adopting this land management tool, we recommend that the benefits are incorporated into outreach and education material.

Our results indicate that ranchers might perceive that using STMs has relative advantage and compatibility with existing values, past experience, and needs, as we suggested in the discussion (Rogers 1995). According to the diffusion of innovation theory, relative advantage and compatibility are two of the five characteristics that influence the rate that an innovation is adopted (Rogers 1995). It appears that there is a need for more application of STMs (trialability) in order for the implementation process of STMs and the results to be observable, two more of the five characteristics of innovations (Rogers 1995). Diffusers of STMs might consider demonstrating the trialability and observability of STMs by presenting case studies during workshops.

Based on our results, overall both populations indicated there is a need for STM workshops. Workshops about how to use STMs might mitigate the perceived complexity of STMs, the fifth characteristic that influences the rate of adoption of innovations (Rogers 1995). Future research about STMs should explore how end users of the decision making tool perceive the relative advantage, compatibility, trialability, observability, and complexity of STMs.

Based on qualitative feedback in our surveys and prior empirical work, we further suggest that it would be advantageous for researchers and NRPs to validate STMs through a peer review process and with individuals living on the associated landscape. This validation process might increase support of STMs by stakeholders. This study provided a baseline assessment of the awareness of STMs and it will be repeated in 2012 to evaluate the effectiveness of the extension component to the broader project.

Chapter Three Tables, Charts, and Figures

Table 3.0. Natural resource professional (NRP) respondent characteristics.

	Mean	Standard Error	Median
Age	45.5	0.60	47.0
Years worked as a NRP	16.0	0.57	15.0
Years worked at current agency	13.7	0.57	11.0

Table 3.1. Ranchers' awareness and use of state and transition models (STMs). Data are percentage of respondents.

	Never heard of STMs before today	Have heard about STMs, but have not read/used one	Read about STMs	Have used STMs
Southeast Wyoming	62.1	24.2	12.1	1.5
South Central Wyoming	61.1	25.0	11.1	2.8
Northeast Colorado	86.0	8.8	3.5	1.8
Southeast Colorado	56.4	33.3	10.3	0.0
Northwest Colorado	64.9	21.1	10.5	3.5
Western Colorado	80.0	11.7	5.0	3.3
TOTAL	68.7	20.2	8.8	2.3

Table 3.2. Natural resource professionals' awareness and use of state and transition models (STMs). Data are percentage of respondents in each agency category.

	Never heard of STMs before today	Have heard about STMs, but have not read/used one	Read about STMs	Have used STMs
Local	50.0	15.2	23.9	10.9
State	31.8	19.7	25.8	22.7
Natural Resources Conservation Service	10.3	17.2	20.7	51.7
United State Forest Service	15.1	22.6	35.8	26.4
Bureau of Land Management	16.9	20.3	25.4	37.3
TOTAL	24.1	19.1	26.2	30.5

Table 3.3. Ranchers' perceptions of the ecological benefits associated with using State and Transition Models. Data are the percentage of respondents that perceive each level of benefits.

	No Benefits	Slight Benefits	Moderate Benefits	Major Benefits	No Opinion	n
To better manage habitat for livestock and wildlife	8.0	17.3	28.1	19.0	27.6	352
To better manage nutrient needs for livestock and wildlife	7.2	12.9	33.0	19.5	27.5	349
To better understand the ecological conditions of the land	5.5	12.9	30.2	23.9	27.6	348
Increase plant species diversity	7.5	10.9	31.6	22.7	27.3	348
Shift plant community to a more desirable composition	7.2	11.0	28.9	25.4	27.5	346
Retain soil and limit erosion potential	7.2	15.6	28.5	21.6	27.1	347
Other ecological objectives	3.1	4.2	5.2	6.3	81.3	96

Table 3.4. Natural resource professionals' perceptions of the ecological benefits associated with using STMs. Data are the percentage of respondents that perceive each level of benefits.

	No Benefits	Slight Benefits	Moderate Benefits	Major Benefits	No Opinion	n
To better manage habitat for livestock and wildlife	1.3	8.9	41.3	36.1	12.5	305
To better manage nutrient needs for livestock and wildlife	4.9	22.3	37.0	18.0	17.7	305
To better understand the ecological conditions of the land	0.3	5.9	28.6	53.3	11.8	304
Increase plant species diversity	2.3	13.8	36.1	35.4	12.5	305
Shift plant community to a more desirable composition	2.0	6.20	29.8	49.5	12.5	305
Retain soil and limit erosion potential	3.6	17.0	38.4	26.6	14.4	305
Other ecological objectives	1.9	1.9	7.4	25.9	63.0	270

Table 3.5. Ranchers' perceptions of the economic benefits associated with using state and transition models. Data are the percentage of respondents that perceive each level of benefits.

	No Benefits	Slight Benefits	Moderate Benefits	Major Benefits	n
To better manage habitat for livestock & wildlife	15.0	29.0	36.0	19.9	286
To better manage nutrient needs for livestock & wildlife	14.0	25.6	40.4	20.0	285
Increase livestock productivity	15.9	24.4	37.5	22.3	283
Increase pounds per acre of palatable forage	15.1	18.9	40.4	25.6	285
Increase pounds per acre of nutritious forage	14.8	20.1	38.7	26.4	284
Other economic objectives	39.4	31.0	19.7	9.9	71

Table 3.6. Natural resource professionals' perceptions of the economic benefits associated with using state and transition models. Data are the percentage of respondents that perceive each level of benefits.

	No Benefits	Slight Benefits	Moderate Benefits	Major Benefits	n
To better manage habitat for livestock & wildlife	4.50	21.3	45.1	29.1	268
To better manage nutrient needs for livestock & wildlife	23.7	76.3	0.00	0.00	267
Increase livestock productivity	17.3	32.3	38.5	11.9	260
Increase pounds per acre of palatable forage	34.7	65.3	0.00	0.00	266
Increase pounds per acre of nutritious forage	31.1	68.9	0.00	0.00	265
Other economic objectives	77.8	22.2	0.00	0.00	21

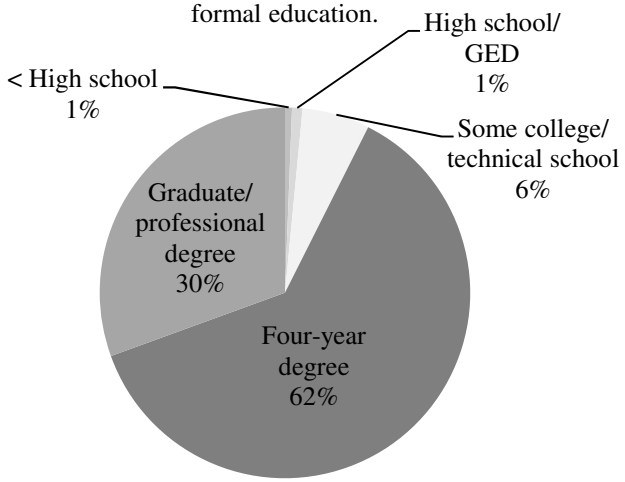
Table 3.7. Of those that have used them, natural resource professionals' levels of satisfaction with their use of state and transition models (STMs). Data are the percentage of respondents.

	Completely Dissatisfied	Dissatisfied	Satisfied	Completely Satisfied	n
Identify & assess the current state of rangelands	0.0	9.1	72.7	18.2	203
Identify thresholds & how to avoid threats or seize opportunities to achieve or maintain a desired state	2.8	13.9	69.4	13.9	108
Assess or monitor the ecological condition of rangelands	0.0	8.3	70.8	20.8	120
Develop a management plan	0.9	10.8	71.2	17.1	111
Identify management objectives	0.0	11.3	70.4	18.3	115
Identify potential actions to achieve management objectives	2.5	5.0	74.2	18.3	120
Identify appropriate indicators to use in monitoring rangelands	0.0	12.7	61.9	25.4	118
Evaluate the potential risks & benefits of specific management actions	0.9	16.4	69	13.8	116
Evaluate the feasibility or likely success of a potential management action	0.0	14.4	67.6	18	111
Understand how a specific rangeland area came to be in its current state	0.8	9.7	65.3	24.2	124
Gain a better understanding of rangeland systems	0.0	4.5	61.2	34.3	134
Other uses of STMs	0.0	0.0	0.0	0.3	1

Table 3.8. Information needs of ranchers and natural resource professionals (NRPs) regarding state and transition models. (STMs) Data presented are the percentage of respondents who wanted information on the listed topics.

	Ranchers %	NRPs %
Where to access STMs	34.1	35.9
How to use STMs to meet management objectives	36.8	46.8
How to determine a threshold	14.0	34.3
How to use STMs to help make land management decisions	33.8	51.6
Benefits of using STMs over the more traditional range condition approach to rangeland assessment and monitoring	28.4	39.4
How to develop an ecological site description	12.3	22.1
Where to find an existing ecological site description	9.5	19.6
How are STMs developed	18.8	23.1
What to do if there is no ecological site description for my type of land	12.1	29.2
Other	3.0	2.9

Chart 3.0. Natural Resource Professional respondent highest level of formal education.



CHAPTER FOUR: RANCHERS' AND NATURAL RESOURCE PROFESSIONALS' PERCEPTIONS AND MANAGEMENTOF CHEATGRASS (*BROMUS TECTORUM* L.)

INTRODUCTION

Cheatgrass (*Bromus tectorum* L.), also known as downy brome, has established throughout most of North America, including the United States (US), Canada, and northern Mexico (Mosley et al. 1999; Smith and Enloe 2006). It has been suggested that this species is the most abundant plant in the western US, "dominating millions of acres of degraded rangelands" (Meyer and Leger 2010 pg. 6), including in Southeast Oregon, where ranchers identified it as the most abundant species (Johnson et al. 2009). Cheatgrass is an aggressive, non-native, invasive winter annual grass (Bradford and Lauenroth 2006; Mosley et al. 1999; Rowe and Brown 2008; Smith and Enloe 2006; Stubbendieck et al. 2003), which evolved in Eurasia and is pre-adapted to climates with cool, wet winters and hot, dry summers (Mack 1981; Mosley et al. 1999; Smith and Enloe 2006). It is believed that cheatgrass was first introduced to the US through soil used in the ballast of ships traveling from Eurasia (Davison et al. 2007; Mosley et al. 1999). Novak and Smith (1993) suggest this ubiquitous species was independently introduced several times throughout North America.

Human movement and activities contributed to the early migration of cheatgrass throughout western North America (Mack 1981). The distribution of cheatgrass exploded from 1915 – 1930 (Mack 1981), following a period of heavy domestic grazing on western

rangeland. Cheatgrass increased in prominence as humans depended more on railroads for transportation and the shipment of goods (Mosley et al. 1999). Contaminated bedding and packing straw as well as livestock feces were discarded along the railroad route, and it is believed this helped to facilitate the dispersion of cheatgrass (Knapp 1996; Mosley et al. 1999). It is estimated that cheatgrass has established on over 40 million hectares of rangeland in the western US (Rowe and Brown 2008) and that humans, animals (domestic and wildlife), as well as other natural elements continue to be vectors for the spread of the species (Mosley et al. 1999). Land managers reported the presence of cheatgrass at higher elevations during the past 20 years, where fire cycles have remained intact (Rowe and Brown 2008).

Cheatgrass has demonstrated its adaptability by surviving several years of drought (Smith and Enloe 2006). Young and Clements (2009) report that it is difficult for cheatgrass to compete with established woody and perennial species, however, following a natural or human induced disturbance, cheatgrass is able to outcompete the native seedlings. Cheatgrass has the ability to influence and increase the occurrence of wildfires, creating conditions that further enhance the potential for cheatgrass expansion (Mosley et al. 1999; Rowe and Brown 2008). The increase in fire frequency can be detrimental to some shrub communities such as those characterized by winterfat (*Ceratoides lanata* (Pursh) J.T. Howell), and shadescale (*Atriplex confertifolia* (Torr. & Frém.) S. Watson), as well as non-sprouting shrubs such as Wyoming big sagebrush (*Artemisia tridentata* Nutt. Ssp. *wyomingensis* Beetle & Young) (Mosley et al. 1999). Over time, perennial shrubs, grasses, and forbs can be outcompeted by a combination of an increase in fire frequency and competition with cheatgrass (Mosley et al. 1999). Observations and

empirical evidence show that cheatgrass can also modify plant communities in semi-arid ecosystems through competitive exclusion of native plants (Mosley et al. 1999; Rowe and Brown 2008), as well as impact wildlife habitat (Young and Clements 2009).

Most scientific studies of cheatgrass focus on infestations in the Intermountain West (Great Basin), where cheatgrass is prolific. Less empirical work has been done on cheatgrass in other states such as Wyoming and Colorado. Smith and Enloe (2006) note that the herbarium records for Wyoming indicate cheatgrass was present throughout much of the state by the early 20th century. Smith and Enloe (2006) report that cheatgrass mostly occurs throughout Wyoming in low density. Since the early 1980s, an increase in cheatgrass establishment has been recorded in eastern Wyoming, and in localized areas the invasive has become the dominant plant in northern mixed prairie communities (Mosley et al. 1999). The Wyoming Pest Detection Program (2009) electronically surveyed Wyoming Weed and Pest District members in 2003, 2005, and 2007 about the distribution and abundance of cheatgrass in their counties. The overall trend map for 2007 indicates that cheatgrass has increased throughout all Wyoming counties except Sublette and Crook (Wyoming Pest Detection Program 2009). Additionally, what is believed to be an extremely invasive isozyme genotype was recently found near Laramie, Wyoming (Schachner et al. 2008), which Meyer and Leger (2010) suggests could lead to an invasion of cheatgrass in an area that previously had minimal invasion.

Wyoming land managers have already expressed concern about the potential of cheatgrass to more readily establish in new areas (Smith and Enloe 2006). Wyoming's diverse elevations and climate are two variables that are believed to influence the distribution and establishment of cheatgrass in the state (Smith and Enloe 2006). The

state of Wyoming has not listed cheatgrass as a noxious weed (Jerup 2008). However, the plant is a 'County Declared Weed' in Albany, Converse, Natrona, Platte, and Weston counties (Veckrey and Hardy 2008; Wyoming Pest Detection Program 2009). As a 'county declared weed' the Wyoming Board of Agriculture and the Wyoming Weed and Pest Council have found that cheatgrass is directly or indirectly "detrimental to the general welfare of persons residing within a district (county)" (Wyoming Pest Detection Program 2009). In Wyoming, this statute gives legal authority to stated counties to regulate and manage the declared weed (Wyoming Pest Detection Program 2009).

Colorado State University's herbarium records indicate the first collection of cheatgrass in the state was in Larimer County in 1892 (Graham and Ackerfield 2008). Cheatgrass can be found in eastern Colorado along roadsides and disturbed sites (Davison et al. 2007). The non-native plant follows the foothills of the eastern slope, while in the western part of the state cheatgrass is found at lower elevations (Davison et al. 2007). In Colorado, cheatgrass has been recorded at elevations ranging from 4000 to 9000 feet and it has been reported that the plant occurs as widespread, dense populations on 11 to 50 hectares in Rocky Mountain National Park (Center 2003). The state of Colorado has listed cheatgrass as a 'List C Species' on the state's Noxious Weed List, a classification for either widespread non-native species or for species of special interest to the agriculture industry (Agriculture 2009). This study addresses ranchers' and land managers' perceptions of the causes and consequences of cheatgrass spread in Colorado and Wyoming, states where the species is less well known than in the Great Basin.

Human Dimensions of Cheatgrass Management

In order to manage invasive plants effectively, we must understand not only their ecology, but also how land managers perceive these species, how they manage them, and the factors that influence their decisions about whether to invest in weed control. Relatively little research has been conducted on the human dimensions of invasive species management generally, or cheatgrass specifically. In this section, we review the literature on the effects of cheatgrass, preferred methods of treatment for cheatgrass, as well as constraints that have been associated with different treatment methods.

Cheatgrass has documented effects on ecosystems, livestock production, and other economic values. Ranchers in Southeast Oregon identified cheatgrass as the most abundant plant on degraded rangelands, however they did not consider it the most problematic species (Johnson et al. 2009). Results from a study in Spain indicated that 'environmental managers' primarily perceive that noxious weeds outcompete native plants (Andreu et al. 2009), a phenomena associated with cheatgrass in the Intermountain Basin states.

Johnson et al. (2009) suggest that the contradiction in the proportion of infested rangeland by cheatgrass and the perception of ranchers that the species is not the most problematic is likely due to the utility of cheatgrass for livestock forage, compared to other invasive plants. Research has indicated that in some locations cheatgrass can provide forage for animals (domestic and wildlife) during winter and spring months (Stubbendieck et al. 2003). During this time cheatgrass is palatable for six to eight weeks (Mosley et al. 1999). When cheatgrass is grazed dry, the long, straight awns can damage

the eyes and mouth of grazers (Mosley et al. 1999; Stubbendieck et al. 2003), which if the sores become infected can lead to actinomycosis or lumpy jaw (Mosley et al. 1999).

Other socioeconomic effect that has been observed and associated with cheatgrass include the ability of the seeds to intertwine with the wool of animals (Stubbendieck et al. 2003), contaminating and degrading the use of natural fibers. Additionally, ranchers, local decision makers, and managers of public grazing land indicated that they believe weed infestations affect the market value of rangeland (Sell et al. 1999). Although it appears there might be some benefits associated with cheatgrass (i.e., winter or early spring livestock forage), the plant's negative ecological and socioeconomic effects can be significant. Therefore, it is important to understand different management approaches, and when and how they have been applied.

Researchers, land managers, and landowners have tried an assortment of management approaches to manage invasive weeds including mechanical treatment (e.g., tilling), chemical application (i.e., herbicides), biological control (which can include livestock grazing), and prescribed fire. The management of invasive weeds can be a significant capital investment, but the benefits can be great and include increased forage quantity and quality and protection of non-infested areas (Griffith 1999). The next couple of paragraphs discuss preferred methods for treating cheatgrass, and potential constraints associated with some of the treatment methods.

Several approaches to manage cheatgrass have been explored and include mechanical treatment (including fuel management), chemical, biological (e.g., prescribed grazing), and prescribed fire (Davison et al. 2007). Mosley et al. (1999) supports the former three methods for cheatgrass treatment, but does not agree that prescribed burning

is an effective alternative. Ranchers in Southeast Oregon also considered prescribed fire as one of the least effective modes of managing annual grasses (Johnson et al. 2009), such as cheatgrass.

Ranchers ranked herbicide and grazing treatment of annual grasses, such as cheatgrass, as the most effective mode of treatment (Johnson et al. 2009). Several constraints that have been associated with the use of herbicides include: environmental restrictions; damage to non-target species; extensive infestations; and lack of equipment or knowledge to apply herbicides (Johnson et al. 2009; Sell et al. 1999). Public land managers of non-grazing land, one of the stakeholder groups in the Sell et al. (1999) study, indicated that lack of resources such as time, money, and equipment were not constraints to herbicide treatments. Another study found that stakeholders believe that chemical treatments are not harmful to the environment when used appropriately (Sell et al. 1999).

For the management of cheatgrass, it is generally recommended that a combination of treatments is implemented for the best results (Davison et al. 2007), followed with revegetation (Mosley et al. 1999). Ranchers have indicated that control of invasive annual grasses, such as cheatgrass, are only marginally successful, however a majority of ranchers plan to continue to treat annual species with herbicide, livestock grazing, and revegetation (Johnson et al. 2009). In addition to the reported marginal levels of success with managing cheatgrass, other constraints to managing noxious weeds have been suggested.

Three of the primary constraints that have been identified to managing noxious weeds in general are: 1) insufficient coordination among administrations; 2) lack of

public awareness (Andreu et al. 2009); and 3) limited economic resources (Andreu et al. 2009; Sell et al. 1999). Other constraints to managing invasives include: environmental restrictions, and extensive infestations (Sell et al. 1999). However, despite these constraints ranchers perceive that it makes economic sense to manage weeds on rangelands (Johnson et al. 2009).

Overall, prior empirical studies have resulted in a variety of preferred methods for treating or managing noxious and invasive weeds. Several variables may influence a community or individual's preferred method of treatment including, but not limited to: type of vegetation being treated (i.e., grass, forb, or woody shrub); previous exposure to a management approach (e.g., mis-use of chemicals or a fire that got out of control); education and outreach of the different tools; property or infestation size; available resources to implement and maintain the desired management approach; and the time it takes for visible results.

Cheatgrass has been studied extensively, notably for its impacts on plant community composition, fire regimes, and wildlife habitat. Additionally, it appears there is a never-ending search for a long-term effective and cost efficient management alternative. However, less empirical evidence has been presented about land managers' perceptions of factors that are associated with the spread of cheatgrass and its successful establishment, as well as perceived or experienced ecological and economic impacts of cheatgrass. Few studies have addressed how land managers have tried to manage cheatgrass and their associated level of satisfaction or constraints they have encountered while managing or trying to manage cheatgrass. Gaining an understanding of the current perceptions and management of cheatgrass can provide the foundation for developing an

integrated management strategy, one that incorporates a long-term plan "consisting of prevention programs, education activities, and management approaches" (DiTomaso et al. 2010 pg. 43). There is a need to understand ranchers' and Natural Resource Professionals' (NRPs) perceptions of cheatgrass, what methods they have used to manage the species and their associated level of satisfaction, and factors that might influence the control of cheatgrass, specifically constraints to management. To address these gaps, we facilitated focus groups with ranchers and (NRPs) and distributed a self-administered mail survey to the two populations in several regions throughout Wyoming and Colorado.

OBJECTIVES

The objectives of this study were to document and compare ranchers' and NRPs' 1) perceptions of and knowledge about cheatgrass and its impacts, 2) current management practices related to cheatgrass control and satisfaction with the results of these practices, and 3) information and technical needs.

This study is part of a long-term, interdisciplinary integrated research and extension project, which is scheduled to conclude in 2011. In the context of the larger project, this study provides baseline data that will enable us to evaluate, after the project's conclusion, changes in managers' awareness, knowledge, and management of cheatgrass resulting from our extension efforts.

METHODS

This study used a mixed-method approach implemented in two phases, pre-survey focus groups followed by a self-administered mail survey. We sampled two populations, ranchers and NRPs. Focus groups were used in this study as an exploratory tool to gain a better understanding of rancher and NRP concerns about invasive plants on their

rangelands, including the primary invasive plant species that concern them and the extent to which cheatgrass is a problem or concern in their area. We also explored whether or not participants had experienced economic or ecological effects or other impacts that they associated with cheatgrass, how they manage cheatgrass, and the primary constraints or obstacles they encountered when managing or trying to manage cheatgrass. Additionally, we wanted to find out how each population learns about new management tools. Focus group data were also used to inform the development of the self-administered survey.

Phase 1: Focus Groups

Sampling Frame

The study locations and sampling frame varied during each phase of the study. For the first phase of the study, we invited ranchers and NRPs from one county in Colorado (Larimer) and five counties in Wyoming (Albany, Carbon, Platte, Converse, and Niobrara) to participate in separate focus groups (Figure 2.0). Three focus groups were held with ranchers and three with NRPs.

We defined several criteria for the type of ranchers we wanted to invite to the focus groups. These criteria were: 1) mid to large scale ranch operations (more than 100 acres [40.47 hectares]); 2) individuals active in the agriculture community; and 3) individuals that are less active in the agriculture community. We contacted individuals who work or live in the communities (see purposive and snowball sampling below) to identify ranchers who met our sampling criteria.

NRPs included employees of the Natural Resources Conservation Service (NRCS), United States Forest Service (USFS), Bureau of Land Management (BLM), Colorado Division of Wildlife (CDOW), Wyoming Game and Fish Department (WGFD),

not-for-profits, and local agencies (i.e., Extension, weed districts, and city/county natural areas). The following criteria were outlined to identify which NRPs to invite to the focus groups: 1) individuals who manage weeds, rangeland, habitat/wildlife, or who provide extension services; 2) individuals responsible for making and implementing management decisions; and 3) a variety of local, state, and federal agencies as well as not-for-profits. By using these guidelines, we sought to ensure that the sample for each focus group offered a mixture of individuals within the homogeneous groups (i.e., ranchers and NRPs).

A non-probability sample was conducted for the first phase of the study, which means that the odds that an individual met our sample frame criteria and would be invited to participate in our study was unknown. We identified potential participants through purposive and snowball sampling (Berg 2004; Biernacki and Waldorf 1981; Stewart and Shamdasani 1998). Purposive sampling is when participants are intentionally selected (Stewart and Shamdasani 1998), particularly of populations that can be harder to access (Neuman 2003), such as rural communities. In this study, the use of purposive sampling helped to ensure that the representative target populations of ranchers and NRPs were identified. The snowball technique is a method where initial contacts provide researchers with a name or list of names of individuals who meet the sample frame criteria and who might participate in the study (Berg 2004; Biernacki and Waldorf 1981). This technique enabled us to gain access to a broader group of potential respondents. The research team initiated the first step of this method by identifying several key informants, including county extension agents, local cattle growers associations, resource conservation district boards, and natural resource agencies. We asked key informants to identify potential

individual participants and organizations that met our sampling criteria (see above) (Appendices A and B). A list of 15 – 20 potential participants was compiled for each of the planned focus groups.

Focus Group Design and Implementation

Focus groups are a systematic qualitative method where homogeneous groups comprised of eight to 12 individuals discuss a particular topic (Fowler 2002; Stewart and Shamdasani 1998). They have been used in a variety of industries since 1941 (Bernard 2002) enabling exploration of respondents' attitudes and perceptions about a topic (Vaske 2008). Focus groups can enhance quantitative social science studies by combing qualitative with quantitative methods (Bernard 2002). By documenting what issues are salient and how participants talk about them, the focus group method can assist researchers in developing relevant survey questions (Bernard 2002). In January and February 2009, we held focus groups with ranchers and NRPs in each study area. The purpose of the gatherings was to explore how ranchers and NRPs perceived cheatgrass (to what extent it is perceived a problem in their area), their views about the ecological and economic effects of cheatgrass, their experience with treatment methods, the barriers they encountered trying to manage cheatgrass, and how they prefer to get technical information.

Invitations were mailed to selected ranchers and NRPs on the basis of referrals from key informants (Appendix C). Focus groups were held at non-participating agency offices, community centers, or libraries. Focus group meetings were audio-recorded and a note-taker also recorded the discussion on a laptop computer. Additionally, key points were written on a flip-chart and verified by participants. The typed notes were later

compared to the audio recording and completed by a transcriber. Six focus groups were carried out, three each with ranchers and NRPs. A total of 16 ranchers and 17 NRPs participated in the focus groups, each lasted nearly two hours.

Analysis of Focus Group Data

Focus group data were transcribed and then analyzed using the qualitative data analysis software QSR NVivo version 8 (1996 - 2007). We used a modified version of the Straussian approach to grounded theory and thematic analysis to analyze the data. In the Straussian approach to grounded theory, a question or set of questions are raised based on existing knowledge, information needed to help develop concepts, or to explore relationships (Grbich 2007). We conducted the analysis through open coding and identification of themes across the data, as described by Braun and Clarke (2006) and Grbich (2007). Open coding is the foundation for analyzing data in grounded theory and it occurs each time data are collected (Grbich 2007; Strauss and Corbin 1990). It is an interpretive process of systematically breaking down, examining, conceptualizing, and categorizing qualitative data (Corbin and Strauss 1990; Strauss and Corbin 1990).

We coded directly in the data, identifying key words, phrases, and occasionally sentences. The key themes of interest were: the degree cheatgrass is considered a problem; perceived ecological and economic effects of cheatgrass; approaches to managing cheatgrass (e.g., stabilize or eradicate populations of the plant, monitoring, using available resources, etcetera); methods of treatment (e.g., grazing, herbicide application, burning, etcetera); benefits of cheatgrass; perceived causes of spreading and establishment of cheatgrass; constraints to managing cheatgrass (e.g., cost prohibitive, currently other weeds are a higher priority, etcetera); and management concerns (e.g.,

growing at or above perceived elevation limits, cheatgrass is not a state listed noxious weed [Wyoming], etcetera).

Phase 2: Self-Administered Mail Survey

Sampling Frame

The sampling frame for the second phase of the study, a self-administered mail survey, was different for the two populations. The rancher sampling frame was developed through two phases. We first identified counties in Wyoming and Colorado where we wanted to survey ranchers. Our criteria for these counties included: 1) project focal counties where our field-work and outreach activities are conducted; and 2) counties to act as 'controls' or non-project reference sites, which will not be exposed to the same outreach as the focal counties. The study counties in Wyoming were: 1) Converse; 2) Niobrara; 3) Goshen; 4) Platte; 5) Laramie; 6) Albany; 7) Carbon; and 8) Sweetwater. We split the eight counties into two regions Southeast Wyoming (the initial six counties) and South Central Wyoming (the latter two counties) (Figure 2.1). The study counties in Colorado were: 1) Larimer; 2) Weld; 3) Yuma; 4) Washington; 5) Crowley; 6) Kiowa; 7) Baca; 8) Routt; 9) Moffat; 10) Delta; 11) Montrose; 12) Ouray; and 13) San Miguel. We split the 13 counties into four regions: Northeast Colorado (the first four counties); Southeast Colorado (counties five thru seven); Northwest Colorado (counties eight and nine); and Western Colorado (counties 10 thru 13) (Figure 2.1). It should be noted that the greater research and outreach project is conducting field and/or outreach work in Platte, Laramie, and Albany counties (Wyoming), therefore the remaining counties are control locations.

The National Agricultural Statistics Service provided the survey sampling frame for ranchers, and mailed out, and received the returned surveys. The target population was ranchers with at least 100 acres (40.47 hectares) of private, leased, or permitted land, and a minimum of 20 animal units (AUs) (cattle, horses, goats, and sheep). Dairies and feedlots were excluded, because in general these businesses have different management and business objectives than our population of interest. We mailed the survey to a stratified random sample of 200 ranchers in each of the six geographic regions within our study areas in Wyoming and Colorado (1200 ranches total). We were targeting for a 50 percent response rate to minimize the sampling error.

We developed the NRP sampling frame using current employee directories for the target federal, state, and local agencies. If we did not find a current directory with the necessary information, we directly contacted agencies and requested the information (e.g., USFS). Agencies included in the sampling frame were the USFS, BLM, NRCS, WGFD, CDOW, University of Wyoming and Colorado State University extension, local weed management programs and districts in Wyoming and Colorado, and local parks and open space departments. The sampling frame included NRPs in the following positions: weed, range, wildlife, habitat, and National Environmental Policy Act specialists; ecologist; soil scientist; and agriculture and natural resource extension agents. We compiled a list of over 1000 NRPs throughout the two states. The Wyoming and Colorado lists were combined and stratified into five categories by agency or agency type: 1) local agencies (extension agents, weed authorities, and city and county open spaces); 2) state (WGFD and CDOW); 3) BLM; 4) USFS; and 5) NRCS. The survey was mailed to a stratified random sample of 100 professionals in each of the five agencies or

agency types (500 individuals). We were targeting for a 50 percent response rate to minimize the sampling error.

Survey Design and Implementation

A self-administered mail survey was implemented October – December 2009. The survey questions were developed on the basis of focus group results and the evaluation needs of the larger project. Survey drafts were reviewed and pretested by two interdisciplinary research teams comprised of eight to 11 researchers and graduate students, as well as one extension agent, one state employee, and two USFS employees. The survey was revised several times before the final version was completed. The survey consisted of five sections: Management Practices and Programs; Perceptions and Management of Cheatgrass (*Bromus tectorum*); Perceptions and Use of State and Transition Models; Information Needs and Preferences; and Background (i.e., demographics) (Appendix J and Appendix K). The questions about state and transition models were included to provide input to a separate, but related, integrated research and extension project focused on awareness and use of state and transition models.

A modified version of the Dillman (2000) method guided the implementation of the surveys. This method has resulted in high survey response rates (Bernard 2002; Fowler 2002). The modified process included a four-wave mailing with a pre-survey letter, a survey with a cover letter, and a reminder/thank you postcard (Dillman 2000) (Appendices G – L). Additionally, a replacement survey with a cover letter was mailed three weeks after the initial survey mailing, as needed (Dillman 2000) (Appendices M and N). Because ranchers and agency professionals who returned their surveys might differ from those who did not respond, we conducted a random non-response bias check

with 36 ranchers (5% of non-respondents), and 11 NRPs (6% of non-respondents) (Appendices O and P).

For both ranchers and NRPs, we included in our statistical analyses data from both respondents to the original mail survey and those non-respondents who participated in the non-response bias check.

Measurements

Two surveys were developed, one for ranchers and one for NRPs. The surveys were almost identical and were comprised of close-ended, ordered response questions (including several based on the Likert Scale) as well as several 'check all that apply' questions, and 'fill-in the blank' responses (Appendix J and Appendix K). The differences between the rancher and NRP surveys included questions in the first section (e.g., number of private acres in a ranching operation versus the number of years employed as a NRP) and in the fifth section where ranchers were asked more questions (e.g., What is the anticipated future of your ranching operation?) than agency professionals. The following explains how we presented and measured specific variables.

Perceptions of Cheatgrass as a Problem. Respondents were asked to what degree they considered the presence of cheatgrass in their county (ranchers), or management unit or area (NRPs) a problem ('Not a Problem' to 'Extreme Problem') (Appendices J and K, Section II, Question 1).

Spread of Cheatgrass. Respondents were asked to indicate the degree ('Not a Cause' to 'Major Cause') to which they thought specific factors contribute to the spread of cheatgrass to new areas (Appendices J and K, Section II, Question 2).

Establishment and Increase of Cheatgrass. Respondents were asked to indicate to what degree they thought specific factors influence the establishment and increase of cheatgrass ('Not a Cause' to 'Major Cause') (Appendices J and K, Section II, Question 3).

Respondents' Perceptions of Potential Effects of Cheatgrass. Respondents were asked to indicate to what degree ('Not Concerned' to 'Extremely Concerned') they or their agency is concerned about the effects of cheatgrass (Appendices J and K, Section II, Question 4).

Respondents' Experienced Effects of Cheatgrass. Respondents were asked to indicate to what degree ('Not a Problem' to 'Extreme Problem,' or 'Have Not Experienced') their ranching operation or their management area/units have experienced specific effects that they associate with cheatgrass (Appendices J and K, Section II, Question 5).

Respondents' Cheatgrass Management Practices and Level of Satisfaction. Respondents were asked whether or not they had used specific management practices to eradicate cheatgrass or shift the dominance of cheatgrass infested areas to more native plants, and if so, to what degree they are satisfied ('Completely Dissatisfied' to 'Completely Satisfied,' or 'Have Not Tried') with the results (Appendices J and K, Section II, Question 6).

Constraints and Barriers to Managing Cheatgrass. Respondents were asked to indicate which specified constraints or barriers they have encountered to managing cheatgrass (check 'yes' or 'no') (e.g., long-term treatment is not financially viable) (Appendices J and K, Section II, Question 7).

Information and Technical Assistance Needs. Respondents were asked what information about cheatgrass management they currently need or would like to have (Appendices J and K, Section IV, Question 3).

Survey Analysis

Data were analyzed using PASW Statistics version 18.0 for Windows XP ([PASW] 2010). The response rate for individual questions varied because some individuals did not answer all questions. All useable surveys (returned surveys that respondents answered all or nearly all of the questions) were used for data analysis despite missing values.

We identified respondent characteristics by calculating descriptive statistics (means and percentages of the population, as appropriate to the characteristic) related to personal characteristics and the attributes of the respondent's ranching operation, for ranchers, and personal characteristics for NRPs. We calculated a new variable for the attribute 'operation size,' which was measured in AUs. The first step to create this new variable was to multiple a respondents reported number of animals per species by the associated animal unit equivalent (2008; Vallentine 1990; Wilson 2006), we then summed the total number of AUs (Table 2.0).

We used Chi-square analysis in the Crosstabulations function of PASW to assess whether ranchers' and NRPs' perceptions and beliefs about cheatgrass, management practices, and constraints varied by region. The ranchers' data were analyzed using the six regions that were defined earlier in the 'Mail Survey: Sampling Frame' section (see above). However, we surveyed NRPs from throughout Wyoming and Colorado. Therefore, we used similar, but different regions to analyze the NRPs' data than the ranchers' data (Figure 4.0). We considered results significant at $p < 0.05$. If there were no

significant differences among regions for a variable, we aggregated that data and report the results for the population as a whole. Additionally, we qualitatively compared rancher and NRP results (see the Discussion).

Due to the number of regions and the number of respondents from each region, the expected cell counts in Crosstabulations were lower than expected for several variables, however this was expected, therefore the data were still included.

RESULTS

The adjusted response rate, or the proportion of mailed surveys that were completed and returned by ranchers was 35% (n = 411) and 65% of NRPs (n = 312) responded to the survey. The response rate for ranchers was similar across all regions (n = 66 - 78) except Southeast Colorado (n = 51). Additionally, we were unable to identify the region for some surveys (n = 41), because the respondents removed the survey identification number and they did not provide their zip code. The response rate for NRPs varied across all regions (n = 10 – 39), the Intermountain Basin of Colorado had the lowest response rate and South Central Wyoming had the highest. However, the response rate was comparable for all surveyed agencies.

Several factors that might have affected the response rate for ranchers were identified. The sampling frame excluded feedlots and dairies; however we had 46 survey recipients contact us stating the survey did not apply to them for one of the following reasons: the survey was sent to a feedlot or dairy; the recipient had sold their livestock during the drought and they were no longer in the business; or the recipient was a farmer, raising crops such as sugar beets, onions, etcetera. Factors that may have influenced the response rate of agency professionals included the perception that the survey did not

apply to the recipient's position, lack of time to complete the survey, or the perception that responses from multiple individuals from the same agency and office were redundant and unnecessary. We were notified by 20 people that the selected person was no longer with that agency/field office. Surveys that were sent to individuals who did not meet our sample frame criteria were considered non-deliverable and they were excluded from our response rate (i.e., adjusted response rate). We believe our response rate is a conservative estimate of the true proportion of qualified respondents who responded (i.e., the actual response rate is probably slightly higher than we report), due to the factors that may have affected our response rate.

Non-respondent and respondent ranchers did not differ in the regions that they represented, education level, age, percentage of their operation's annual labor that is supplied by their family, familiarity with STMs, gender, future of their operation, or gross annual income. Non-respondents did differ in their risk-orientation compared to survey respondents. Respondents were significantly more likely to take risks than non-respondents (Pearson $X^2 = 19.33$, p-value = 0.001), with a Cramer's V effect size of 0.226, indicating a typical to minimal relationship.

In general, a greater portion of rancher respondents perceived cheatgrass to be a slight problem, and a greater portion of non-respondents perceived cheatgrass to not be a problem. The portion of respondents and non-respondents who perceived cheatgrass to be an extreme or moderate problem were comparable (Pearson $X^2 = 9.60$, p-value = 0.02), with a Cramer's V value of 0.151, indicating a minimal relationship. The relatively small effect size suggested minimal variation, justifying our decision not to make adjustments to our sample. Additionally, this effect size suggests that we are safe in generalizing to

the larger population, however readers should be aware that the responses represent a slightly more pro-active and concerned sample than the general population of ranchers.

Non-respondent agency professionals did not differ from respondents in the number of years they have worked as a NRP or for their current employer, risk-orientation, awareness of State and Transition Models, education level, age, gender, the type of agency that employees them (e.g., local, state, BLM, etcetera), or the degree to which they consider cheatgrass in their management area or units a problem. Therefore, we feel confident that data from respondents can be generalized to the sampled population.

Respondent Characteristics

Ranchers

The average rancher respondent was 58 years old (range 26 – 93 years) (Table 2.1), with some college education (Chart 2.0), and had managed his or her ranch for 23 years (Table 2.1). Thirty-three percent of rancher respondents reported their income in the $80,000-199,999 category, the median (Chart 2.1). Income from livestock accounted for 44% of the average rancher respondent's gross annual income, nearly 79% of their operation was on private land, 87% of their operation's annual labor was supplied by family, and they had 214 AUs (Table 2.1). The majority of rancher respondents anticipated their children will take over the operation when they are no longer the operator (Chart 2.2).

Natural Resource Professionals

The average NRP respondent was 46 years old (range 23 – 66 years) (Table 3.0), with a four-year degree (Chart 3.0), and had worked as a NRP for 16 years (Table 3.0). The

average respondent had worked for their current agency for 14 years (Table 3.0). Nearly 72% of the NRP respondents were male.

Perceptions of Cheatgrass as a Problem

Ranchers differed significantly by region in the degree to which they considered cheatgrass a problem (Table 4.0). Ranchers in Southeast Wyoming perceived the greatest problem with cheatgrass, with 68% reporting that cheatgrass was a moderate to extreme problem in their area (Table 4.0). Sixty-three to 81% of ranchers, in the other five regsions, perceived cheatgrass as a slight to moderate problem (Table 4.0).

NRPs also differed significantly by region in the degree to which they considered cheatgrass a problem (Table 4.1). NRPs across all Wyoming regions considered cheatgrass a problem to some degree (Table 4.1). Sixty to 95% of NRPs in Wyoming considered cheatgrass a moderate to extreme problem in their area, with the greatest problem reported in the Big Horn Basin (92%) and Eastern Wyoming (95%) (Table 4.1). In Colorado, NRPs in the Western region reported the most extensive problem with cheatgrass, with 84% reporting a moderate to extreme problem (Table 4.1). In six of the Colorado regions, NRPs primarily considered cheatgrass a slight to moderate problem (range 65 – 94%) and 90% of NRPs in the Intermountain Basins considered the plant only a slight problem (Table 4.1). None of the NRPs from the intermountain basins, San Louis Valley, and the Southeast regions of Colorado considered cheatgrass an extreme problem (Table 4.1).

Spread of Cheatgrass

Ranchers in different regions did not differ significantly in their responses for any of the factors that might cause the spread of cheatgrass. Overall, ranchers perceived wind or

rain runoff as the greatest cause for the spread of cheatgrass with 61% considering this a moderate to major cause, followed by contaminated crop, revegetation seed mixes, or hay (contamination) (57% reported moderate to major cause), and development activities (54% reported moderate to extreme cause) (Table 4.2). Forty-four to 47% of ranchers reported that recreational activities, off-road vehicles, and livestock and wildlife movement are minor causes for the spread of cheatgrass (Table 4.2).

For NRPs, there were significant differences among regions in the perceived causes of cheatgrass spread for four of the factors: recreational activities; development activities; wind or rain runoff; and contamination (Table 4.3). NRPs perceived development activities, such as roads, as the greatest cause (51 – 93%, major cause) for the spread of cheatgrass in all regions except Southeast and Western Colorado where 58 – 94% (respectively) considered it a moderate to major cause (Table 4.3). NRPs perceived contamination to be the second greatest factor for the spread of cheatgrass, with 50 – 82% of respondents in four regions reporting it as a moderate to extreme cause (Table 4.3). Seventy-five to 88% of respondents from eight of the regions perceived contamination as a minor to moderate cause for the spread of cheatgrass (Table 4.3). Overall, the majority of NRPs considered recreation activities, wind or rain runoff, off-road vehicles, and livestock and wildlife movements as minor to moderate causes for the spread of cheatgrass (Table 4.3).

Establishment and Increase of Cheatgrass

Ranchers differed significantly among regions in their responses for four of the seven factors that might cause the establishment and increase of cheatgrass: drought; overgrazing by livestock or wildlife; disturbance of soil or vegetation by development;

and natural or prescribed fire (Table 4.4). Ranchers perceived drought as the greatest cause for the establishment and increase of cheatgrass, with 61% of ranchers from Southeast Wyoming perceiving it as a major cause (Table 4.4). Fifty-three to 79% of ranchers in the remaining five regions consider drought as a moderate to major cause for the establishment and increase of cheatgrass (Table 4.4). Sixty-six to 85% of rancher respondents perceived overgrazing as the next greatest cause (moderate to major) in all regions except Western Colorado, where 53% perceive it as a minor to moderate cause (Table 4.4). Ranchers perceived the third greatest cause for the establishment and increase of cheatgrass as disturbance. A greater percentage of respondents in South Central Wyoming (68%), followed by ranchers in Northwest Colorado (77%) perceived disturbance as a moderate to major cause compared to the other regions, where 49 – 72% reported it as a minor to moderate cause (Table 4.4). Sixty-three to 70% of all ranchers perceived the remaining factors (timing of rainfall or snow, too little grazing by livestock or wildlife, and fire suppression) to be a minor to moderate cause for the establishment and increase of cheatgrass, with no differences among regions (Table 4.4).

NRP perceptions of the causes of cheatgrass establishment also varied significantly among regions for three of the seven factors: overgrazing; disturbance; and fire (Table 4.5). Fifty-nine to 79% of NRPs perceived disturbance as a major cause for the establishment and increase of cheatgrass, except in Southeast Colorado where 67% considered this factor a moderate to major cause (Table 4.5). All Wyoming NRPs and those in four Colorado regions considered overgrazing at least a slight cause for the establishment and increase of cheatgrass (Table 4.5). Fifty-six percent of NRPs in Northern Wyoming perceive overgrazing as a major cause for the establishment and

increase of cheatgrass, followed by 73 – 92% that perceive it as a moderate to major cause, and 50 – 68% a moderate cause (Table 4.5). For remaining factors, NRPs perceived the greatest causes for the establishment and increase of cheatgrass as timing of rainfall or snow (76%), and drought (71%) (Table 4.5).

Perceptions of Potential Effects of Cheatgrass

Ranchers differed significantly among regions in their responses for two of the eight potential effects of cheatgrass: causes loss of desirable plants; and increased fire frequency (Table 4.6). Ranchers reported they are most concerned with the loss of desirable plants due to cheatgrass with the greatest concern (moderately to extremely concerned) in Southeast (87%) and South Central Wyoming (59%), and Northeast Colorado (67%) (Table 4.6). Seventy-three percent of ranchers were moderately to extremely concerned that cheatgrass will reduce livestock and wildlife forage, followed by 65% that are moderately to extremely concerned that cheatgrass will reduce crop value (Table 4.6).

NRPs also differed significantly among regions in their responses for two of the eight potential effects of cheatgrass: loss of plants; and fire frequency (Table 4.7). There were no NRPs in all Wyoming regions and in the intermountain basins, San Louis Valley, Southeast, Western, and Foothills of Colorado that reported 'Not Concerned' that cheatgrass will cause the loss of plants, the effect NRPs reported being most concerned about (Table 4.7). Fifty-three to 95% of NRPs reported they are extremely concerned for the loss of plants due to cheatgrass except in Southeast Colorado (75% moderately to extremely concerned) (Table 4.7). Sixty percent of NRPs are extremely concerned that

cheatgrass will cause the loss of wildlife habitat, and 54% of NRPs are slightly to moderately concerned that cheatgrass will reduce forage (Table 4.7).

Experienced Effects of Cheatgrass

Ranchers differed significantly among regions in their responses for four of the eight experienced effects of cheatgrass: loss of desirable plants for livestock forage; alteration of management activities; increased fire frequency; and reduced crop value (Table 4.8). Forty-one to 73% (slight to moderate) of ranchers reported that the loss of livestock forage is the effect from cheatgrass they have experienced the most (Table 4.8). For the remaining three effects, 49 – 57% of respondents perceived them as 'Not a Problem,' but perceptions differed significantly among regions (Table 4.8). Fifty-two to 85% of ranchers reported that loss of desirable plants for wildlife habitat, reduced land value, interference with recreational activities, and increased soil erosion was 'Not a Problem' (Table 4.8).

NRPs also differed significantly among regions in their responses for five of the eight experienced effects: loss of wildlife habitat; loss of livestock forage; alteration of management activities; increased fire frequency; and increased soil erosion (Table 4.9). NRPs reported that the effect that has been the greatest problem has been loss of wildlife habitat, with the greatest impact reported in Eastern Wyoming (81% reported moderate to extreme problem), followed by the Big Horn Basin (56% moderate problem), and Western Colorado (50% moderate problem) (Table 4.9). NRPs reported increased fire frequency as the next greatest effect they have experienced due to cheatgrass, with the greatest impact reported in Western Colorado (50% reported moderate to extreme problem), and followed by 38 – 64% of NRPs in all Wyoming regions and the Foothills

of Colorado that reported increased fire frequency as a slight to moderate problem (Table 4.9). The third greatest effect that NRPs reported was the loss of desirable plants for livestock forage, with NRPs in Eastern Wyoming reporting the greatest problem (76% reported moderate to extreme problem), followed by the Big Horn Basin and Northern Wyoming (52% and 56% reported moderate problem, respectively) (Table 4.9). Sixty to 68% of NRPs reported that reduced land value, interference with recreational activities, and reduced crop value are 'Not a Problem' (Table 4.9).

Cheatgrass Management Practices and Level of Satisfaction

Overall, ranchers indicated the top three management tools they had tried to manage cheatgrass with were 'increasing stocking rate early in the spring to graze out cheatgrass' (early spring grazing), followed by seeding 'a more desirable seed mix,' and 'shifting grazing to later in the fall or early winter to facilitate perennial plant growth' (fall-winter grazing) (Table 4.10). Of the rancher respondents who indicated they had tried the specified management practices to manage cheatgrass, they reported being most satisfied with early spring grazing, with 79% of respondents somewhat to completely satisfied, followed by seeding (74% reported somewhat to completely satisfied) (Table 4.11). A similar percentage of ranchers were somewhat to completely satisfied with applying an 'imazapic-based herbicide' (70%), and 'any combination of prescribed fire, herbicide application, or seeding' (combined approach) (67%) (Table 4.11).

Overall, NRPs indicated the top three management practices they had tried for cheatgrass management were seeding, followed by herbicide application, and a combined approach (Table 4.12). NRPs differed significantly among regions in their level of satisfaction in a combined approach for managing cheatgrass (Table 4.13). NRPs

reported the greatest level of satisfaction with a combined approach, with 46% of NRPs in the Foothills and 33% in Northeast Colorado reporting complete satisfaction (Table 4.13). Fifty-two to 100% of NRPs were somewhat satisfied with a combined approach across all regions, and no one reported being completely dissatisfied in four of the five Wyoming regions and seven of the eight Colorado regions (Table 4.13). Sixty-two to 70% of NRPs were somewhat satisfied with results from herbicide application, seeding, and fall-winter grazing (Table 4.13).

Constraints and Barriers to Managing Cheatgrass

Ranchers indicated that the top three constraints they have encountered to managing cheatgrass are: 'other weeds are currently a higher priority to manage' (77%); 'limited human resources/labor available' (54%); and lack of information about effective management tools to control cheatgrass (52%) (Table 4.14).

NRPs differed significantly among regions in their responses for two of the seven potential constraints to managing cheatgrass: 'long-term treatment is not financially viable;' and 'other weeds are currently a higher priority' (Table 4.15). NRPs indicated that the top three constraints they have encountered to managing cheatgrass are that other weeds are a higher priority (50 – 92%), limited human resources/labor (65%), and long-term treatment is not financially viable (60%) (Table 4.15).

Information Needs and Technical Assistance

Ranchers differed significantly among regions in their responses for three of the 11 specified information needs: 'livestock grazing strategies for cheatgrass control;' 'cheatgrass control options;' and 'proper use of control methods' (Table 4.16). Overall, ranchers expressed little need for information about cheatgrass management; however,

they were most interested in livestock grazing strategies (51%) (Table 4.16). Ranchers' second greatest interest was control options (45%) followed by the time of year to treat cheatgrass (41%) (Table 4.16). NRPs were most interested in learning about different cheatgrass control options (65%), livestock grazing strategies (53%), and herbicide effectiveness (51%) (Table 4.17).

DISCUSSION

This study had several purposes including contributing to the knowledge of the broader field of human dimensions of ranchers and NRPs and the management of non-native invasive species, specifically cheatgrass. Although our results varied by region overall, we found that ranchers and NRPs perceived cheatgrass to be a problem to some degree throughout all of our study sites. We learned about ranchers' and NRPs' perceptions of and knowledge about cheatgrass and its impacts, and current management practices related to cheatgrass control, including the satisfaction with the results of these practices.

These findings can inform the development of appropriate outreach and extension material for ranchers and NRPs about the management of cheatgrass. Our findings can direct researchers, NRPs, and other stakeholders of what barriers need to be overcome to ease the process of managing the species. Additionally, our results can be used to guide future studies by identifying perceptions that might need to be verified by rigorous scientific studies.

Perceptions of Cheatgrass as a Problem

The differences in the perceived severity of the cheatgrass problem within and between states were expected due to a variety of variables including elevation and climate. In Eastern Wyoming a greater percentage of NRPs perceived cheatgrass as a moderate to

extreme problem compared to ranchers, however for both populations this region reported a greater problem with cheatgrass than any other region in Wyoming or Colorado. We found that a similar percentage of ranchers (81%) and NRPs (83%) in South Central Wyoming perceived cheatgrass as a slight to moderate problem. In general, our findings for perceived severity of the cheatgrass problem in different regions of Wyoming correspond with the Wyoming Pest Detection Program's (2009) estimated acres of cheatgrass by county as reported by Weed and Pest District members.

Ranchers and NRPs in Western Colorado reported a greater problem with cheatgrass than any other Colorado region, with a greater percentage of NRPs reporting the plant as a moderate to extreme problem (94%) than ranchers (53%). Respondents from the Northeast region of Colorado reported the next greatest problem with cheatgrass, again with a greater percentage of NRPs (63%) reporting the plant as a moderate to extreme problem than ranchers (53%). Similarly, a greater percentage of NRPs than ranchers in Northwest and Southeast Colorado reported cheatgrass as a slight to moderate problem and within the populations the percentages were similar between regions (70% of ranchers in the Northwest region compared to 63% of ranchers in the Southeast region and 73% of NRPs in the Northwest and Southeast regions). Sell et al. (1999) had similar findings, where NRPs of public, grazed lands reported that invasive weeds are the most important problem on rangelands, in contrast to ranchers, who expressed more concern about livestock prices.

Although cheatgrass is a 'List C noxious weed' in the state of Colorado, the Department of Agriculture has not collected state-wide data of the distribution and abundance of the species (Agriculture n.d.). However, the United States Department of

Agriculture (USDA) NRCS Plants Database (2010) cites an unpublished source (Johnston, B., *List of Colorado Plants*) from 1991 that depicts the distribution of cheatgrass throughout roughly two-thirds of counties in Colorado. Counties without cheatgrass included three of the four counties in the intermountain basins, four of the seven counties in the Central Mountains, four of the 13 counties in the Foothills, three of the 10 counties in the Southeast region, five of the six counties in the San Louis Valley, and two of the nine counties in the Western region (Natural Resources Conservation Service 2010). Cheatgrass is present in one of the Intermountain Basin counties (Jackson) that the USDA's Plants Database does not show (Kelley 2010). In general, these data coincide with our findings that the intermountain basins, San Louis Valley, Central Mountains, and Southeast regions of Colorado have the least problem with cheatgrass. For a greater understanding of the current distribution and abundance of cheatgrass as well as to track any long-term changes, a formal state-wide field inventory is needed.

It should be noted that during our focus groups as well as in the surveys, respondents indicated that other weeds are more problematic than cheagrass, such as Canada thistle (*Cirsium arvense* (L.) Scop.), musk thistle (*Carduus nutans* L.), pricklypear (*Opuntia polyacantha* Haw.), halogeton (*Halogeton glomeratus* (M. Bieb.) C.A. Mey), mustard family (*Brassicaceae*), yellow toadflax (*Linaria vulgaris* Mill.), houndstongue (*Cynoglossum officinale* L.), whitetop (*Lepidium draba* L.), and yellow star-thistle (*Centaurea solstitialis* L.), among other species. This finding is similar to prior empirical studies where ranchers perceived cheatgrass as the most dominant species on infested rangeland, but they did not consider it as the most problematic (Johnson et al. 2009). However, several researchers have stated that of the estimated 300 weeds on

western rangelands, cheatgrass is among the most problematic and damaging (DiTomaso et al. 2010; Frasier and Mack 2009). Perhaps part of the discrepancy between our findings and the suggestions of researchers is that cheatgrass is not as widely distributed and established in Wyoming and Colorado compared to the Intermountain states where the species is much more prolific and impacts are more apparent.

Perceptions of and Knowledge about Cheatgrass and Its Impacts

If the general public understands how cheatgrass affects them and how it spreads, establishes and increases, it is likely that society will be better prepared to limit further spread of this species. We found that ranchers and NRPs had different views about the primary factors causing the spread of cheatgrass. Ranchers were most likely to attribute spread of cheatgrass to wind and water movement, while NRPs believed that disturbance such as development is the main cause. In an interview published in *Rangelands*, Richard Mack suggested that the spread of seeds by animals is too small to establish a population of an invasive species, but that more quantification of this mode of transportation is needed (Frasier and Mack 2009). There is a chance this theory might also apply to wind and water movement. Both ranchers and NRPs perceived contaminated crop or revegetation seed mixes or hay as the second greatest factor that contributes to cheatgrass spread. This mode of transportation was identified as one of the most common inadvertent ways that invasives spread, due to current acceptable levels of seed contamination in hay and reseeding mixes (Frasier and Mack 2009). Ranchers perceived development activities (54% reported moderate to major) as the third greatest cause for the spread of cheatgrass.

Ranchers indicated that the primary factor associated with the establishment and increase of cheatgrass is drought. This finding is somewhat expected due to the drought in the early 2000s, particularly because cheatgrass is an early, cool season grass, which uses available soil moisture before native, later season perennial grasses initiate growth for the year. NRPs differed in their response, perceiving that disturbance is the primary factor. Research has shown that with increased disturbance, disturbed sites favor invasives, particularly annuals (Vasquez et al. 2010). Both populations perceived overgrazing by livestock or wildlife as the second greatest factor that contributes to the establishment and increase of the plant, with more NRPs considering overgrazing a moderate to major cause than ranchers.

Both ranchers and NRPs reported their primary concern about cheatgrass is the potential loss of desirable plants, with a greater proportion of NRPs expressing a higher level of concern than ranchers about plant loss. Reduced livestock and wildlife forage due to cheatgrass was within the top three effects that ranchers and NRPs expressed being most concerned about, with a greater proportion of NRPs expressing a higher level of concern than ranchers. These findings are similar to a study conducted in Spain, where environmental managers primarily perceived that noxious weeds outcompete native plants (Andreu et al. 2009). Further, it is believed that cheatgrass has the ability to decrease production on rangelands through reducing the most limiting rangeland nutrient for plant growth, nitrogen (Eviner et al. 2010). Ranchers and NRPs differed in the third potential effect that they are most concerned about due to cheatgrass, with ranchers being more concerned about reduced crop value, and NRPs more concerned about the loss of wildlife habitat. The differences between ranchers and NRPs and the potential effects

they are concerned about might be related to the economic or ecological management objectives of each population. For example, a rancher's management objectives are more likely to include production of a certain amount of crops to feed their livestock during the winter months or to sell for additional revenue, compared to NRPs who might be more focused on managing for wildlife habitat, which might be linked to an agency's annual revenue from hunting and fishing licenses or admission permits.

Ranchers considered loss of livestock forage the greatest problem they have experienced due to cheatgrass. Although NRPs differed among regions in the effects they experienced, their primary effect was similar to ranchers, loss of desirable plants for wildlife habitat. The reported difference between the two populations may also be due to a difference in management objectives. Overall, NRPs reported that cheatgrass has caused more problems to their area than ranchers; with a majority of ranchers reporting that the specific effects were 'Not a Problem.'

During our focus groups ranchers indicated they do receive some benefit from cheatgrass through early spring grazing, and several NRPs stated they know ranchers who like to have some cheatgrass on their operation for early forage. Additionally, during focus groups, a few NRPs stated that they would "rather have cheatgrass than nothing on a blow-out." Several ranchers included written comments in their surveys stating that cheatgrass is "gold in the spring when you need it" and since it's the first thing up in the spring they "rely heavily on it." Additionally, some ranchers reported they would rather have cheatgrass than bare ground and that cheatgrass can prevent increased soil erosion. These perceptions likely have several implications. For example, they might influence the degree to which an individual perceives cheatgrass as a problem. Furthermore, these

perceptions might influence whether or not an individual or to what degree an individual tries to manage cheatgrass.

Current Management Practices and Barriers to Management

For both ranchers and NRPs, reseeding was among the most commonly used treatments for cheatgrass, although a greater proportion of NRPs than ranchers used this approach. Additionally, reseeding was the most commonly used treatment method among NRPs. This finding was surprising to learn considering that the arid climate of Wyoming and Colorado makes seeding an investment with uncertain payoffs. The populations differed in the other two primary treatment methods that they had used.

Ranchers reported using early spring grazing, followed by fall or winter grazing to manage cheatgrass, whereas NRPs reported using herbicide and any combination of herbicide, reseeding, and fire. These findings were expected. The primary cost of grazing cheatgrass to ranchers appears to be time. Through qualitative data, from focus groups and written comments in the survey, ranchers indicated that if they closely monitor the physiological state of cheatgrass and they have livestock within a reasonable distance, they can graze cheatgrass prior to emergence of the inflorescence. If a rancher's timing is right, it's a twofold win. First, cheatgrass provides early forage for their livestock, enabling them to save other resources such as hay. Second, by grazing the cheatgrass prior to the seed emerging, the ranchers are mitigating the copious amount of seed dispersion associated with cheatgrass, reducing the seed bank. In a focus group, a ranch manager reported that they had reduced the cheatgrass population on their operation during the past few years through short duration, intensive grazing during the early spring.

In general, it makes sense that the most common treatments reported by NRPs were herbicide and a combined approach. We speculate that one reason that NRPs have not relied on livestock grazing to manage cheatgrass is due to logistics (i.e., time and resources of coordinating with permittees to transport their livestock to the infested site).

Of the ranchers and NRPs that indicated they had tried different management practices, a greater percentage of ranchers reported a higher level of satisfaction with the results than NRPs. Overall, most ranchers had tried to manage cheatgrass with early-spring grazing and they were most satisfied with this management approach. In contrast, NRPs most often tried reseeding, but they were most satisfied with a combined approach. Data gathered from ranchers during our focus groups support the finding that early-spring grazing is the most commonly used control method and has resulted in the greatest satisfaction. Johnson et al. (2009) had a similar finding with ranchers, who indicated that livestock grazing is one of the most effective modes of treating annual grasses and although they reported only marginal success with controlling annual invasive grasses, a majority of the ranchers plan to continue to treat the annual species. Davison et al. (2007) suggests the best approach to managing cheatgrass is a combined approach, a similar finding to the NRPs in our study.

Ranchers and NRPs reported that two of the primary constraints they had encountered to managing cheatgrass are: 1) other weeds are a higher priority; and 2) limited human resources. The two surveyed populations reported the former of the two constraints as the greatest barrier to managing cheatgrass. This finding was supported by data that were collected during our focus groups as well as written into the survey that species such as Canada thistle (*Cirsium arvense* (L.) Scop.), musk thistle (*Carduus*

nutans L.), halogeton (*Halogeton glomeratus* (M. Bieb.) C.A. Mey), mustard family (*Brassicaceae*), yellow toadflax (*Linaria vulgaris* Mill.), houndstongue (*Cynoglossum officinale* L.), and yellow star-thistle (*Centaurea solstitialis* L.), among other species are a higher priority. Additionally, NRPs who participated in the focus groups in Wyoming indicated that other species are a higher priority because of funding allocated to treat classified noxious and invasive weeds. The state of Wyoming has not classified cheatgrass (Jerup 2008). Whether managing livestock, applying herbicide, or organizing a prescribed burn, all modes of treatment require significant human resources, including the time it takes to have individuals in the field monitoring plant community conditions.

Ranchers reported the lack of information about effective ways to treat cheatgrass as the third greatest constraint they have encountered to managing the species, while NRPs reported that long-term treatment is not financially viable as their major constraint. Other studies about invasive plant species have also identified cost as a top constraint (Andreu et al. 2009; Sell et al. 1999). It should be noted that numerous ranchers provided qualitative data in their surveys indicating that they are unfamiliar with cheatgrass. It is unknown why they are unfamiliar with the species. Several potential explanations are that cheatgrass is sparse in areas that respondents indicated they are not familiar with the species or that individuals do not know how to identify the plant.

IMPLICATIONS

Billions of dollars are spent and lost annually to control the spread of invasive species and manage side-effects associated with their presence such as increased frequency and intensity of fires, and reduced livestock production (DiTomaso 2000; Eviner et al. 2010; Healy 2001; Pimentel et al. 2005). These costs do not include other financial

ramifications associated with weeds such as water quality, and erosion control, among other ecological services directly and indirectly related to economics. Therefore, it is imperative that society continue to work towards preventing the spread of invasives such as cheatgrass and to efficiently and effectively manage existing populations.

As we stated in the discussion, it appears that cheatgrass is not as widely distributed and established in Wyoming and Colorado compared to the Intermountain states. Overall, ranchers and NRPs, in our study locations, perceive cheatgrass as a problem, and we believe there is a need for more public education to raise awareness to avoid the potential for cheatgrass to become an even bigger problem. Based on our study, outreach and extension material about cheatgrass should focus on the following four points: 1) control options including costs and benefits of each method (e.g., combined approach, early spring grazing, herbicide application, etcetera); 2) livestock grazing strategies and whether or not they are an effective tool, if they are effective how and when to implement, if livestock grazing is not an effective tool for managing cheatgrass, there is a need to educate land managers' why it is not effective method; 3) time of year to treat cheatgrass; and 4) herbicide effectiveness. Additionally, qualitative data written in the survey by ranchers leads us to believe that outreach and extension efforts should include how to identify cheatgrass, which might influence the degree to which individuals consider the species a problem, and how to more effectively control the spread and establishment of cheatgrass.

We recommend that the state of Colorado formally implement a state-wide inventory of the distribution and abundance of cheatgrass and that the state of Wyoming continue their monitoring efforts. Additionally, we suggest that greater efforts be made to

quantify the ecological and economic effects associated with cheatgrass and that the findings be communicated at all levels of government and to other stakeholder.

Based on our findings and building on findings from prior research, we recommend that there be continued research for more effective and economically viable methods to treat cheatgrass (Johnson et al. 2009). Considering the significant dichotomy between the proportion of ranchers and NRPs who are using livestock to manage cheatgrass, we recommend that further research of the effectiveness of different grazing treatments of cheatgrass occur, and the results are diffused appropriately to the associated populations. Additionally, we recommend that outreach and extension material, for both populations, incorporate effective methods of treatment for cheatgrass as well as how to prioritize when it makes economic and ecological sense to treat cheatgrass in a way that is effective and financially viable in the long-run.

Chapter Four Tables, Charts, and Figures

Table 4.0 Ranchers' perceptions of cheatgrass as a problem by region[1]. Data are the percentage of rancher respondents and the degree to which they perceive cheatgrass a problem.

Regions	Not a Problem	Slight Problem	Moderate Problem	Extreme Problem	n
Wyoming					
Southeast	8.5	23.9	42.3	25.4	71
South Central	14.7	40	41.3	4	75
Colorado					
Northeast	12.9	33.9	40.3	12.9	62
Southeast	33.3	35.4	27.1	4.2	48
Northwest	20.6	27	42.9	9.5	63
Western	16.2	30.9	45.6	7.4	68
Other					
Unidentified	28.1	25	40.6	6.3	32
TOTAL	17.7	31.3	40.6	10.5	419

[1] Pearson X^2: 41.938; p-value = 0.001; Cramer's V value: 0.183

Table 4.1. Natural Resource Professionals' (NRP) perceptions of cheatgrass as a problem by region[1]. Data are the percentage of NRP respondents and the degree to which they perceive cheatgrass a problem.

	Not a Problem	Slight Problem	Moderate Problem	Extreme Problem	n
Wyoming					
Eastern	0	4.5	54.5	40.9	22
Western	0	40	40	20	15
South Central	0	29.7	54.1	16.2	37
Northern	0	11.8	47.1	41.2	17
Big Horn Basin	0	7.7	57.5	34.6	26
Colorado					
Intermountain Basins	10	90	0	0	10
San Louis Valley	9.1	36.4	54.5	0	11
Northeast	3.7	33.3	44.4	18.5	27
Southeast	27.3	54.5	18.2	0	11
Northwest	9.1	31.8	40.9	18.2	22
Western	5.4	10.8	54.1	29.7	37
Central Mountains	29.4	35.3	29.4	5.9	17
Foothills	2.9	35.3	58.8	2.9	34
Other					
Unidentified	14.3	35.7	21.4	28.6	14
TOTAL	6	28	46	20	300

[1] Pearson X^2: 107.08; p-value < 0.001; Cramer's V value: 0.345

Table 4.2. Ranchers' perceptions of the causes of cheatgrass spreading. Data are the percentage of rancher respondents and the degree to which they perceive each listed factor as a cause of cheatgrass spread.

Factor	Not a Cause	Minor Cause	Moderate Cause	Major Cause	n
Recreational activities	39.2	47	12.4	1.4	355
Off-road vehicles	27.9	43.6	23.1	5.4	351
Development activities	13.7	32.3	33.3	20.8	351
Livestock and wildlife movement	14.7	45.6	35.4	4.2	353
Wind or rain runoff	11.5	27.5	40.4	20.5	356
Contaminated crop or revegetation seed mixes	12.5	30.4	34.8	22.3	359

Table 4.3. Natural Resource Professionals' (NRP) perceptions of the causes of cheatgrass spreading. Data are the percentage of NRP respondents in each region[5] and the degree to which they perceive each listed factor as a cause of cheatgrass spread.

RECREATIONAL ACTIVITIES[1]					
Regions	**Not a Cause**	**Minor Cause**	**Moderate Cause**	**Major Cause**	**n**
Wyoming					
Eastern	4.8	66.7	23.8	4.8	21
Western	0	20	60	20	15
South Central	13.2	63.2	21.1	2.6	38
Northern	6.3	75	12.5	6.3	16
Big Horn Basin	12	32	44	12	25
Colorado					
Intermountain Basins	20	30	50	0	10
San Louis Valley	0	54.5	36.4	9.1	11
Northeast	6.9	48.3	31	13.8	29
Southeast	25	41.7	33.3	0	12
Northwest	8	52	36	4	25
Western	2.8	63.9	30.6	2.8	36
Central Mountains	5.9	41.2	23.5	29.4	17
Foothills	10.5	44.7	31.6	13.2	38
Other					
Unidentified	18.8	50	31.7	0	16
TOTAL	9.1	50.8	31.7	8.4	309
DEVELOPMENT ACTIVITIES[2]					
Regions	**Not a Cause**	**Minor Cause**	**Moderate Cause**	**Major Cause**	**n**
Wyoming					
Eastern	0	5	30	65	20
Western	0	0	6.7	93.3	15
South Central	2.6	10.5	21.1	65.8	38
Northern	0	12.5	25	62.5	16
Big Horn Basin	4	16	20	60	25
Colorado					
Intermountain Basins	0	10	20	70	10
San Louis Valley	0	0	18.2	81.2	11
Northeast	0	27.6	20.7	51.7	29
Southeast	25	16.7	33.3	25	12
Northwest	0	16	16	68	25
Western	0	5.6	47.2	47.2	36
Central Mountains	0	0	25	75	16
Foothills	0	10.5	15.8	73.7	38

Other					
Unidentified	0	6.7	46.7	46.7	15
TOTAL	1.6	10.8	24.8	62.7	306
WIND OR RAIN RUNOFF[3]					
Regions	**Not a Cause**	**Minor Cause**	**Moderate Cause**	**Major Cause**	**n**
Wyoming					
Eastern	5	30	65	0	20
Western	0	60	26.7	13.3	15
South Central	5.4	62.2	24.3	8.1	37
Northern	18.8	31.3	37.5	12.5	16
Big Horn Basin	0	64	20	16	25
Colorado					
Intermountain Basins	11.1	22.2	55.6	11.1	9
San Louis Valley	18.2	45.5	27.3	9.1	11
Northeast	3.4	31	55.2	10.3	29
Southeast	25	33.3	41.7	0	12
Northwest	16	56	16	12	25
Western	3	51.5	42.4	3	33
Central Mountains	11.8	35.3	35.3	17.6	17
Foothills	8.3	27.8	58.3	5.6	36
Other					
Unidentified	12.5	62.5	12.5	12.5	16
TOTAL	8.3	45.2	37.5	9	301
CONTAMINIATED CROP, REVEGETATION SEED MIXES, OR HAY[4]					
Regions	**Not a Cause**	**Minor Cause**	**Moderate Cause**	**Major Cause**	**n**
Wyoming					
Eastern	5	40	45	10	20
Western	0	26.7	33.3	40	15
South Central	5.3	42.1	39.5	13.2	38
Northern	6.3	25	37.5	31.3	16
Big Horn Basin	4	48	40	8	25
Colorado					
Intermountain Basins	20	30	0	50	10
San Louis Valley	9.1	9.1	36.4	45.5	11
Northeast	0	40.7	44.4	14.8	27
Southeast	25	16.7	41.7	16.7	12
Northwest	12.5	45.8	29.2	12.5	24
Western	11.4	37.1	48.6	2.9	35
Central Mountains	6.7	40	46.7	6.7	15
Foothills	2.6	39.5	36.8	21.1	38

Other					
Unidentified	28.6	35.7	35.7	0	14
TOTAL	8	37	38.7	16.3	300
	Not a Cause	**Minor Cause**	**Moderate Cause**	**Major Cause**	**n**
Off-road vehicles	6.5	25.5	42.7	25.6	309
Livestock and wildlife movements	4.3	36.1	45.6	14.1	305

[1] Pearson X^2: 54.773; p-value = 0.048; Cramer's V value: 0.243.

[2] Pearson X^2: 85.797; p-value < 0.001; Cramer's V value: 0.306.

[3] Pearson X^2: 60.550; p-value = 0.015; Cramer's V value: 0.259.

[4] Pearson X^2: 63.093; p-value = 0.009; Cramer's V value: 0.265.

[5] When NRPs differed significantly by region, otherwise the average percentage is presented.

Table 4.4. Ranchers' perceptions of the causes of cheatgrass establishment and increase. Data are the percentage of rancher respondents in each region[5] and the degree to which they perceive each listed factor as a cause of cheatgrass establishment and increase.

DROUGHT[1]					
Regions	**Not a Cause**	**Minor Cause**	**Moderate Cause**	**Major Cause**	**n**
Wyoming					
Southeast	1.6	4.9	32.8	60.7	61
South Central	3.3	18	47.5	31.1	61
Colorado					
Northeast	3.6	19.6	51.8	25	56
Southeast	11.8	35.3	14.7	38.2	34
Northwest	0	25	40.4	34.6	52
Western	12.7	25.5	32.7	29.1	55
Other					
Undetermined	7.1	21.4	50	21.4	28
TOTAL	5.2	20.2	39.2	35.4	347
OVERGRAZING BY LIVESTOCK OR WILDLIFE[2]					
Regions	**Not a Cause**	**Minor Cause**	**Moderate Cause**	**Major Cause**	**n**
Wyoming					
Southeast	5	10	36.7	48.3	60
South Central	8.6	25.9	36.2	29.3	58
Colorado					
Northeast	5.4	19.6	46.4	28.6	56
Southeast	11.4	17.1	40	31.4	35
Northwest	7.5	17	47.2	28.3	53
Western	32.7	27.3	25.5	14.5	55
Other					
Undetermined	14.3	28.6	25	32.1	28
TOTAL	11.9	20.3	37.4	30.4	345
DISTURBANCE OF SOIL OR VEGETATION BY DEVELOPMENT[3]					
Regions	**Not a Cause**	**Minor Cause**	**Moderate Cause**	**Major Cause**	**n**
Wyoming					
Southeast	8.2	31.1	36.1	24.6	61
South Central	6.8	25.4	28.8	39	59
Colorado					
Northeast	24.6	29.8	19.3	26.3	57
Southeast	13.9	36.1	36.1	13.9	36
Northwest	7.8	15.7	39.2	37.3	51
Western	19.6	25	37.5	17.9	56

Other					
Undetermined	14.3	35.7	28.6	21.4	28
TOTAL	13.5	27.6	32.2	26.7	348
NATURAL OR PRESCRIBED FIRE[4]					
Regions	**Not a Cause**	**Minor Cause**	**Moderate Cause**	**Major Cause**	**n**
Wyoming					
Southeast	40.7	40.7	11.9	6.8	59
South Central	20.3	22	35.6	22	59
Colorado					
Northeast	48.2	33.9	10.7	7.1	56
Southeast	37.1	40	17.1	5.7	35
Northwest	31.4	29.4	29.4	9.8	51
Western	36.4	30.9	25.5	7.3	55
Other					
Undetermined	25	42.9	14.3	17.9	28
TOTAL	34.7	33.2	21.3	10.8	343
	Not a Cause	**Minor Cause**	**Moderate Cause**	**Major Cause**	**n**
Timing of rainfall or snow	6.3	28.1	41.8	23.8	349
Too little grazing by livestock or wildlife	21.8	39.7	27.9	10.6	340
Fire suppression	30.4	44	18.8	6.8	336

[1] Pearson X^2: 52.251; p-value < 0.001; Cramer's V value: 0.224.

[2] Pearson X^2: 49.764; p-value < 0.001; Cramer's V value: 0.219.

[3] Pearson X^2: 30.752; p-value = 0.03; Cramer's V value: 0.172.

[4] Pearson X^2: 38.212; p-value = 0.004; Cramer's V value: 0.193.

[5] When ranchers differed significantly by region, otherwise the total percentage is presented.

Table 4.5. Natural Resource Professionals' (NRPs) perceptions of the causes of cheatgrass establishment and increase. Data are the percentage of NRP respondents in each region[4] and the degree to which they perceive each listed factor as a cause of cheatgrass establishment and increase.

OVERGRAZING BY LIVESTOCK OR WILDLIFE[1]					
Regions	**Not a Cause**	**Minor Cause**	**Moderate Cause**	**Major Cause**	**n**
Wyoming					
Eastern	0	9.5	47.6	42.9	21
Western	0	26.7	26.7	46.7	15
South Central	0	13.5	48.6	37.8	37
Northern	0	18.8	25	56.3	16
Big Horn Basin	0	8	68	24	25
Colorado					
Intermountain Basins	30	20	50	0	10
San Louis Valley	9.1	0	54.5	36.4	11
Northeast	3.6	17.9	46.4	32.1	28
Southeast	8.3	8.3	50	33.3	12
Northwest	0	17.4	39.1	43.5	23
Western	0	8.6	48.6	42.9	35
Central Mountains	0	11.8	58.8	29.4	17
Foothills	0	13.5	37.8	48.6	37
Other					
Unidentified	0	25	37.5	37.5	16
TOTAL	2	13.9	45.9	38.3	303
DISTURBANCE OF SOIL OR VEGETATION BY DEVELOPMENT[2]					
Regions	**Not a Cause**	**Minor Cause**	**Moderate Cause**	**Major Cause**	**n**
Wyoming					
Eastern	0	5	20	75	20
Western	0	6.7	20	73.3	15
South Central	2.7	2.7	24.3	70.3	37
Northern	0	25	12.5	62.5	16
Big Horn Basin	4.2	0	33.3	62.5	24
Colorado					
Intermountain Basins	0	20	10	70	10
San Louis Valley	9.1	0	18.2	72.7	11
Northeast	0	6.9	34.5	58.6	29
Southeast	16.7	16.7	25	41.7	12
Northwest	4.2	0	16.7	79.2	24
Western	0	2.9	40	57.1	35
Central Mountains	0	0	35.3	64.7	17

Foothills	0	13.2	13.2	73.7	38
Other					
Unidentified	0	25	25	50	16
TOTAL	2	7.6	24.7	65.8	304
NATURAL OR PRESCRIBED FIRE[3]					
Regions	**Not a Cause**	**Minor Cause**	**Moderate Cause**	**Major Cause**	**n**
Wyoming					
Eastern	0	9.5	52.4	38.1	21
Western	0	0	53.3	46.7	15
South Central	5.4	16.2	32.4	45.9	37
Northern	0	12.5	31.3	56.3	16
Big Horn Basin	4.2	0	12.5	83.3	24
Colorado					
Intermountain Basins	22.2	11.1	44.4	22.2	9
San Louis Valley	27.3	45.5	18.2	9.1	11
Northeast	20.7	37.9	24.1	17.2	29
Southeast	50	8.3	33.3	8.3	12
Northwest	0	12.5	25	62.5	24
Western	5.7	22.9	37.1	34.3	35
Central Mountains	5.9	29.4	41.2	23.5	17
Foothills	18.9	27	37.8	16.2	37
Other					
Unidentified	12.5	0	18.8	68.8	16
TOTAL	10.6	17.8	32.7	38.9	303
	Not a Cause	**Minor Cause**	**Moderate Cause**	**Major Cause**	**n**
Drought	2.6	21.6	39	36.7	305
Timing of rainfall or snow	2.3	26.7	41.3	29.7	303
Too little grazing by livestock or wildlife	38.3	39.6	18.8	3.3	303
Fire suppression	26.9	41.2	22.9	9	301

[1] Pearson X^2: 74.210; p-value = 0.001; Cramer's V value: 0.286.

[2] Pearson X^2: 61.962; p-value = 0.01; Cramer's V value: 0.261.

[3] Pearson X^2: 113.36; p-value < 0.001; Cramer's V value: 0.353.

[4] When NRPs differed significantly by region, otherwise the total percentage is presented.

Table 4.6. Ranchers' expressed concerns about the potential effects of cheatgrass. Data are the percentage of rancher respondents in each region[3] and their reported level of concern about specific potential impacts.

CAUSES LOSS OF DESIRABLE PLANTS[1]					
Regions	**Not Concerned**	**Slightly Concerned**	**Moderately Concerned**	**Extremely Concerned**	**n**
Wyoming					
Southeast	4.8	8.1	43.5	43.5	62
South Central	16.4	24.6	27.9	31.1	61
Colorado					
Northeast	7	26.3	29.8	36.8	57
Southeast	12.8	23.1	43.6	20.5	39
Northwest	7.4	29.6	38.9	24.1	54
Western	13.6	22	42.4	22	59
Other					
Unidentified	21.4	14.3	28.6	35.7	28
TOTAL	11.1	21.4	36.7	30.8	360
INCREASES FIRE FREQUENCY[2]					
Regions	**Not Concerned**	**Slightly Concerned**	**Moderately Concerned**	**Extremely Concerned**	**n**
Southeast	9.7	19.4	25.8	45.2	62
South Central	24.6	24.6	27.9	23	61
Colorado					
Northeast	22.8	17.5	31.6	28.1	57
Southeast	40.5	29.7	21.6	8.1	37
Northwest	18.5	25.9	31.5	24.1	54
Western	23.7	25.4	22	28.8	59
Other					
Unidentified	28.6	10.7	14.3	46.4	28
TOTAL	22.6	22.3	26	29.1	358
	Not Concerned	**Slightly Concerned**	**Moderately Concerned**	**Extremely Concerned**	**n**
Reduces land value	19.9	32.3	27.6	20.2	362
Causes loss of wildlife habitat	28.6	39.7	22.9	8.8	353
Interferes with recreation	62.4	27.6	6.7	3.3	359
Reduces livestock and wildlife forage	11.3	15.9	32.1	40.7	364
Reduces crop value	16.9	17.2	28.2	37.1	361
Increases soil erosion	31.3	31.8	23.2	13.7	358

[1] Pearson X^2: 29.070; p-value = 0.05; Cramer's V value: 0.164.
[2] Pearson X^2: 33.749; p-value = 0.01; Cramer's V value: 0.117.
[3] When ranchers differed significantly by region, otherwise the total percentage is presented.

Table 4.7. Natural Resource Professionals' (NRP) expressed concerns about the potential effects of cheatgrass. Data are the percentage of NRP respondents in each region[3] and their reported level of concern about specific potential impacts.

CAUSES LOSS OF DESIRABLE PLANTS[1]					
Regions	**Not Concerned**	**Slightly Concerned**	**Moderately Concerned**	**Extremely Concerned**	**n**
Wyoming					
Eastern	0	0	4.8	95.2	21
Western	0	0	20	80	15
South Central	0	2.7	29.7	67.6	37
Northern	0	0	31.3	68.8	16
Big Horn Basin	0	4	12	84	25
Colorado					
Intermountain Basins	0	10	10	80	10
San Louis Valley	0	9.1	9.1	81.8	11
Northeast	6.7	16.7	20	56.7	30
Southeast	0	25	41.7	33.3	12
Northwest	4	16	24	56	25
Western	0	5.6	38.9	55.6	36
Central Mountains	5.9	17.6	23.5	52.9	17
Foothills	0	13.2	34.2	52.6	38
Other					
Unidentified	6.3	6.3	18.8	68.8	16
TOTAL	1.6	8.7	24.6	65	309
INCREASES FIRE FREQUENCIES[2]					
Regions	**Not Concerned**	**Slightly Concerned**	**Moderately Concerned**	**Extremely Concerned**	**n**
Wyoming					
Eastern	0	9.5	23.8	66.7	21
Western	0	6.7	33.3	60	15
South Central	0	7.9	39.5	52.6	38
Northern	6.3	18.8	31.3	43.8	16
Big Horn Basin	8	0	16	76	25
Colorado					
Intermountain Basins	10	20	60	10	10
San Louis Valley	0	36.4	27.3	36.4	11
Northeast	10	20	40	30	30
Southeast	9.1	54.5	9.1	27.3	11
Northwest	4	12	28	56	25
Western	8.3	5.6	33.3	52.8	36
Central Mountains	23.5	17.6	41.2	17.6	17
Foothills	5.3	18.4	44.7	31.6	38
Other					

Unidentified	6.3	6.3	37.5	50	16
TOTAL	6.1	13.9	34	46	309
	Not Concerned	**Slightly Concerned**	**Moderately Concerned**	**Extremely Concerned**	**n**
Reduces land value	19	38.7	31.3	11	310
Causes loss of wildlife habitat	2.6	11	26.2	60.2	309
Interferes with recreation	21.8	45.9	25.7	6.5	307
Reduces livestock and wildlife forage	2.3	10.1	33.8	53.9	308
Reduces crop value	35.7	30.8	21.8	11.7	308
Increase soil erosion	7.1	18.8	39.8	34.3	309

[1] Pearson X^2: 54.277; p-value = 0.05; Cramer's V value: 0.242.

[2] Pearson X^2: 71.128; p-value = 0.001; Cramer's V value: 0.277.

[3] When NRPs differed significantly by region, otherwise the total percentage is presented.

Table 4.8. Ranchers' reported experiences of the effects of cheatgrass. Data reported are the percentage of rancher respondents in each region[6] who reported the specified impacts.

LOSS OF DESIRABLE PLANTS FOR LIVESTOCK FORAGE[1]					
Regions	**Not a Problem[5]**	**Slight Problem**	**Moderate Problem**	**Extreme Problem**	**n**
Wyoming					
Southeast	7.9	23.8	49.2	19	63
South Central	35.9	31.3	23.4	9.4	64
Colorado					
Northeast	25	19.6	41.1	14.3	56
Southeast	53.7	14.6	26.8	4.9	41
Northwest	31.6	29.8	24.6	14	57
Western	40	20	30	10	60
Other					
Unidentified	44.8	6.9	37.9	10.3	29
TOTAL	32.2	22.4	33.2	12.2	370
ALTERATION OF MANAGEMENT ACTIVITIES[2]					
Regions	**Not a Problem[5]**	**Slight Problem**	**Moderate Problem**	**Extreme Problem**	**n**
Wyoming					
Southeast	20	30	41.7	8.3	60
South Central	69.8	12.7	15.9	1.6	63
Colorado					
Northeast	48.3	17.2	22.4	12.1	58
Southeast	65.9	19.5	14.6	0	41
Northwest	50.9	17.5	21.1	10.5	57
Western	46.7	20	28.3	5	60
Other					
Unidentified	44.4	18.5	25.9	11.1	27
TOTAL	49.2	19.4	24.6	6.8	366
INCREASED FIRE FREQUENCY[3]					
Regions	**Not a Problem[5]**	**Slight Problem**	**Moderate Problem**	**Extreme Problem**	**n**
Wyoming					
Southeast	41.3	22.2	14.3	22.2	63
South Central	73.4	15.6	9.4	1.6	64
Colorado					
Northeast	46.6	17.2	24.1	12.1	58
Southeast	82.9	7.3	9.8	0	41
Northwest	60.7	14.3	16.1	8.9	56
Western	49.2	17.5	17.5	15.9	63
Other					

Unidentified	53.6	14.3	14.3	17.9	28
TOTAL	57.4	16.1	15.3	11.3	373
REDUCED CROP VALUE[4]					
Regions	**Not a Problem[5]**	**Slight Problem**	**Moderate Problem**	**Extreme Problem**	**n**
Wyoming					
Southeast	34.9	22.2	25.4	17.5	63
South Central	71.9	17.2	6.3	4.7	64
Colorado					
Northeast	43.9	17.5	24.6	14	57
Southeast	65.9	12.2	22	0	41
Northwest	51.8	17.9	21.4	8.9	56
Western	37.7	18	27.9	16.4	61
Other					
Unidentified	50	7.1	32.1	10.7	28
TOTAL	50.3	17	21.9	10.8	370
	Not a Problem[5]	**Slight Problem**	**Moderate Problem**	**Extreme Problem**	**n**
Loss of desirable plants for wildlife habitat	51.8	27.8	17.8	2.7	371
Reduced land value	62.4	18	14.2	5.4	372
Interfered with recreational activities	85.1	10.3	3	1.6	370
Increased soil erosion	65.6	20.6	11.9	1.9	369

[1] Pearson X^2: 44.64; p-value < 0.001; Cramer's V value: 0.201.

[2] Pearson X^2: 45.12; p-value < 0.001; Cramer's V value: 0.203.

[3] Pearson X^2: 41.02; p-value = 0.002; Cramer's V value: 0.191.

[4] Pearson X^2: 38.28; p-value = 0.004; Cramer's V value: 0.186.

[5]The value 'Have Not Experiences' was aggregated with the value 'Not a Problem.'

[6] When ranchers differed significantly by region, otherwise the total percentage is presented.

Table 4.9. Natural Resource Professionals' (NRP) reported experiences of the effects of cheatgrass. Data reported are the percentage of NRP respondents in each region[7] who reported the specified impacts.

Regions	Not a Problem[6]	Slight Problem	Moderate Problem	Extreme Problem	n
LOSS OF DESIRABLE PLANTS FOR WILDLIFE HABITAT[1]					
Wyoming					
Eastern	0	19	47.6	33.3	21
Western	6.7	40	33.3	20	15
South Central	2.9	45.7	34.3	17.1	35
Northern	6.3	31.3	43.8	18.8	16
Big Horn Basin	0	8	56	36	25
Colorado					
Intermountain Basins	50	50	0	0	10
San Louis Valley	27.3	36.4	27.3	9.1	11
Northeast	13.3	36.7	33.3	16.7	30
Southeast	27.3	36.4	36.4	0	11
Northwest	24	28	28	20	25
Western	5.6	25	50	19.4	36
Central Mountains	35.3	47.1	17.6	0	17
Foothills	13.5	32.4	40.5	13.5	37
Other					
Unidentified	26.7	6.7	53.3	13.3	15
TOTAL	13.5	30.9	38.2	17.4	304
LOSS OF DESIRABLE PLANTS FOR LIVESTOCK FORAGE[2]					
Regions	**Not a Problem[6]**	**Slight Problem**	**Moderate Problem**	**Extreme Problem**	**n**
Wyoming					
Eastern	9.5	14.3	47.6	28.6	21
Western	6.7	40	46.7	6.7	15
South Central	5.6	38.9	41.7	13.9	36
Northern	18.8	12.5	56.3	12.5	16
Big Horn Basin	0	12	52	36	25
Colorado					
Intermountain Basins	70	30	0	0	10
San Louis Valley	18.2	45.5	36.4	0	11
Northeast	23.3	23.3	46.7	6.7	30
Southeast	36.4	36.4	18.2	9.1	11
Northwest	16	32	32	20	25
Western	13.9	22.2	44.4	19.4	36
Central Mountains	58.8	29.4	5.9	5.9	17
Foothills	41.2	29.4	17.6	11.8	34

Other					
Unidentified	20	26.7	33.3	20	15
TOTAL	21.2	27.2	36.4	15.2	302
ALTERATION OF MANAGEMENT ACTIVITIES[3]					
Regions	**Not a Problem[6]**	**Slight Problem**	**Moderate Problem**	**Extreme Problem**	**n**
Wyoming					
Eastern	23.8	28.6	33.3	14.3	21
Western	40	33.3	26.7	0	15
South Central	22.2	41.7	25	11.1	36
Northern	50	12.5	31.3	6.3	16
Big Horn Basin	12	28	44	16	25
Colorado					
Intermountain Basins	90	10	0	0	10
San Louis Valley	81.8	9.1	9.1	0	11
Northeast	41.4	24.1	34.5	0	11
Southeast	54.5	9.1	36.4	0	11
Northwest	40	32	24	4	25
Western	27.8	22.2	41.7	8.3	36
Central Mountains	81.3	12.5	6.3	0	16
Foothills	43.2	27	24.3	5.4	37
Other					
Unidentified	26.7	26.7	13.3	33.3	15
TOTAL	39.3	25.4	27.7	7.6	303
INCREASED FIRE FREQUENCY[4]					
Regions	**Not a Problem[6]**	**Slight Problem**	**Moderate Problem**	**Extreme Problem**	**n**
Wyoming					
Eastern	20	30	25	25	20
Western	33.3	26.7	26.7	13.3	15
South Central	22.2	47.2	16.7	13.9	36
Northern	43.8	25	12.5	18.8	16
Big Horn Basin	8	20	44	28	25
Colorado					
Intermountain Basins	90	0	10	0	10
San Louis Valley	81.8	9.1	0	9.1	11
Northeast	43.3	26.7	10	20	30
Southeast	72.7	9.1	0	18.2	11
Northwest	40	20	16	24	25
Western	33.3	16.7	30.6	19.4	36
Central Mountains	100	0	0	0	16
Foothills	38.9	36.1	19.4	5.6	36

Other					
Unidentified	33.3	13.3	46.7	6.7	15
TOTAL	40.4	23.8	20.2	15.6	302
INCREASED SOIL EROSION[5]					
Regions	**Not a Problem[6]**	**Slight Problem**	**Moderate Problem**	**Extreme Problem**	**n**
Wyoming					
Eastern	14.3	28.6	52.4	4.8	21
Western	20	33.3	33.3	13.3	15
South Central	11.1	52.8	30.6	5.6	36
Northern	31.3	12.5	43.8	12.5	16
Big Horn Basin	20	20	36	24	25
Colorado					
Intermountain Basins	70	30	0	0	10
San Louis Valley	63.6	18.2	18.2	0	11
Northeast	43.3	26.7	26.7	3.3	30
Southeast	54.5	36.4	9.1	0	11
Northwest	28	44	8	20	25
Western	19.4	38.9	33.3	8.3	36
Central Mountains	56.3	31.3	12.5	0	16
Foothills	16.2	51.4	27	5.4	37
Other					
Unidentified	40	40	6.7	13.3	15
TOTAL	28.9	35.9	26.6	8.6	304
	Not a Problem[6]	**Slight Problem**	**Moderate Problem**	**Extreme Problem**	**n**
Reduced land value	59.7	27.7	11.2	1.3	21
Interfered with recreational activities	61	28.9	7.9	2.3	305
Reduced crop value	68	18.8	8.9	4	303

[1] Pearson X^2: 77.403; p-value < 0.001; Cramer's V value: 0.291.

[2] Pearson X^2: 90.150; p-value < 0.001; Cramer's V value: 0.546.

[3] Pearson X^2: 80.112; p-value < 0.001; Cramer's V value: 0.297.

[4] Pearson X^2: 99.625; p-value < 0.001; Cramer's V value: 0.332.

[5] Pearson X^2: 79.923; p-value < 0.001; Cramer's V value: 0.296.

[6] The value 'Have Not Experienced' was aggregated with the value 'Not a Problem.'

[7] When NRPs differed significantly by region, otherwise the total percentage is presented.

Table 4.10. Percentage of ranchers who have tried specific practices to manage cheatgrass.

Management Tool	Have Tried	Have Not Tried	n
Prescribed fire	21.5	78.5	354
Herbicide	16.6	83.4	349
Seeded	39.8	60.2	349
Combined approach	24.6	75.4	345
Early spring grazing	54.6	45.4	355
Fall or winter grazing	35.7	64.3	353
Other	9.9	90.1	121

Table 4.11. Of those that have tried them, ranchers' level of satisfaction with the use of specific management tools.

Management Tool	Completely Dissatisfied	Somewhat Dissatisfied	Somewhat Satisfied	Completely Satisfied	n
Prescribed fire	25	22.4	47.4	5.3	76
Herbicide	12.1	17.2	60.3	10.3	58
Seeded	6.5	19.4	61.9	12.2	139
Combined approach	9.4	23.5	60	7.1	85
Early spring grazing	3.6	17.5	61.9	17	194
Fall or winter grazing	11.9	25.4	54.8	7.9	126
Other	33.3	50	0	16.7	12

Table 4.12. Percentage of Natural Resource Professionals who have tried specific practices to manage cheatgrass.

Management Tool	Have Tried	Have Not Tried	n
Prescribed fire	43.9	56.1	294
Herbicide	62.5	37.5	293
Seeded	64.5	35.5	296
Combined approach	54.1	45.9	294
Early spring grazing	46.3	53.7	296
Fall or winter grazing	36.7	63.3	297
Other	31.1	68.8	260

Table 4.13. Of those that have tried them, Natural Resource Professionals' level of satisfaction with the use of specific management tools.

Regions	Completely Dissatisfied	Somewhat Dissatisfied	Somewhat Satisfied	Completely Satisfied	n
COMBINED APPROACH[1]					
Wyoming					
Eastern	0	0	81.8	18.2	11
Western	0	14.3	57.1	28.6	7
South Central	0	34.8	52.2	13	23
Northern	12.5	12.5	62.5	12.5	8
Big Horn Basin	0	25	65	10	20
Colorado					
Intermountain Basins	0	0	100	0	1
San Louis Valley	0	0	100	0	5
Northeast	0	0	66.7	33.3	15
Southeast	0	0	100	0	3
Northwest	0	8.3	75	16.7	12
Western	3.6	7.1	82.1	7.1	28
Central Mountains	0	0	80	20	5
Foothills	0	0	53.8	46.2	13
Other					
Unidentified	0	50	50	0	8
TOTAL	1.3	13.8	68.6	16.4	159
	Completely Dissatisfied	**Somewhat Dissatisfied**	**Somewhat Satisfied**	**Completely Satisfied**	**n**
Prescribed fire	31	34.1	31.8	3.1	129
Herbicide	2.2	15.3	69.9	12.6	183
Seeded	4.2	22	67	6.8	191
Early spring grazing	13.9	32.1	46	8	137
Fall or winter grazing	4.6	24.8	62.4	8.3	109

[1] Pearson X^2: 55.743; p-value = 0.040; Cramer's V value: 0.342.

Table 4.14. Percentage of ranchers who reported specific constraints to managing cheatgrass.

Constraint	No	Yes	n
Lack of information about management tools	47.9	52.1	334
Not a state listed noxious weed	65.7	34.3	303
Treatment is not financially viable	54.7	45.3	316
Aerial herbicide application is prohibited	92.1	7.9	303
Alternative grazing is not feasible	69.3	30.7	323
Limited human resources/labor available	46.4	53.6	323
Other weeds are a higher priority	22.8	77.2	342
Other	15.2	84.8	46

Table 4.15. Percentage of Natural Resource Professionals who reported specific constraints to managing cheatgrass.

TREATMENT IS NOT FINANCIALLY VIABLE[1]			
Regions	**No**	**Yes**	**n**
Wyoming			
Eastern	40	60	20
Western	38.5	61.5	13
South Central	22.9	77.1	35
Northern	56.3	43.8	16
Big Horn Basin	16	84	25
Colorado			
Intermountain Basins	70	30	10
San Louis Valley	63.6	36.4	11
Northeast	46.4	53.6	28
Southeast	50	50	12
Northwest	29.2	70.8	24
Western	36.4	63.6	33
Central Mountains	66.7	33.3	15
Foot Hills	40	60	35
Other			
Unidentified	58.3	41.7	12
TOTAL	40.5	59.5	289
OTHER WEEDS ARE A HIGHER PRIORITY[2]			
	No	**Yes**	**n**
Wyoming			
Eastern	40	60	20
Western	23.1	76.9	13
South Central	41.7	58.3	36
Northern	50	50	16
Big Horn Basin	28	72	25
Colorado			
Intermountain Basins	50	50	10
San Louis Valley	36.4	63.6	11
Northeast	25.9	74.1	27
Southeast	8.3	91.7	12
Northwest	25	75	24
Western	14.7	85.3	34
Central Mountains	21.4	78.6	14
Foot Hills	11.4	88.6	35
Other			
Unidentified	42.9	57.1	14

TOTAL	28.2	71.8	291
	No	**Yes**	**n**
Lack of information about management tools	53.1	46.9	290
Not a state listed noxious weed	60.6	39.4	284
Aerial application is prohibited	73.3	26.7	281
Alternative grazing is not feasible	74.9	25.1	283
Limited human resources/labor available	35.5	64.5	293

[1] Pearson X^2: 26.699; p-value = 0.01; Cramer's V value: 0.304.
[2] Pearson X^2: 23.496; p-value = 0.04; Cramer's V value: 0.284.

Table 4.16. Information needs of ranchers regarding cheatgrass. Data presented are the percentage of respondents who wanted information on the listed topics.

LIVESTOCK GRAZING STRATEGIES[1]			
	No	**Yes**	**n**
Wyoming			
Southeast	46.3	53.7	67
South Central	42	58	69
Colorado			
Northeast	35	65	60
Southeast	60	40	45
Northwest	54.1	45.9	61
Western	53	47	66
Other			
Unidentified	70	30	30
TOTAL	49.5	50.5	398
CONTROL OPTIONS[2]			
	No	**Yes**	**n**
Wyoming			
Southeast	48.5	51.5	68
South Central	59.4	40.6	69
Colorado			
Northeast	43.3	56.7	60
Southeast	68.9	31.1	45
Northwest	44.3	55.7	61
Western	63.6	36.4	66
Other			
Unidentified	60	40	30
TOTAL	54.6	45.4	399
PROPER USE OF CONTROL METHODS[3]			
	No	**Yes**	**n**
Wyoming			
Southeast	75	25	68
South Central	87	13	69
Colorado			
Northeast	86.7	13.3	60
Southeast	84.4	15.6	45
Northwest	63.9	36.1	61
Western	80.3	19.7	66
Other			
Unidentified	86.7	13.3	30

TOTAL	79.9	20.1	399
	No	**Yes**	**n**
Herbicide safety	88.9	11.1	398
Herbicide effectiveness	68.2	31.8	399
How cheatgrass spreads	71.4	28.6	399
Economic sense to treat cheatgrass	64.7	35.3	399
Time of year	59.4	40.5	398
Starting to control cheatgrass	76.2	23.8	399
Biological controls	80.2	19.8	398
Groups/organizations managing cheatgrass	86.5	13.5	399
Other	98	2	397

[1] Likelihood Ratio X^2: 14.98; *p*-value = 0.02; Phi value: 0.192.

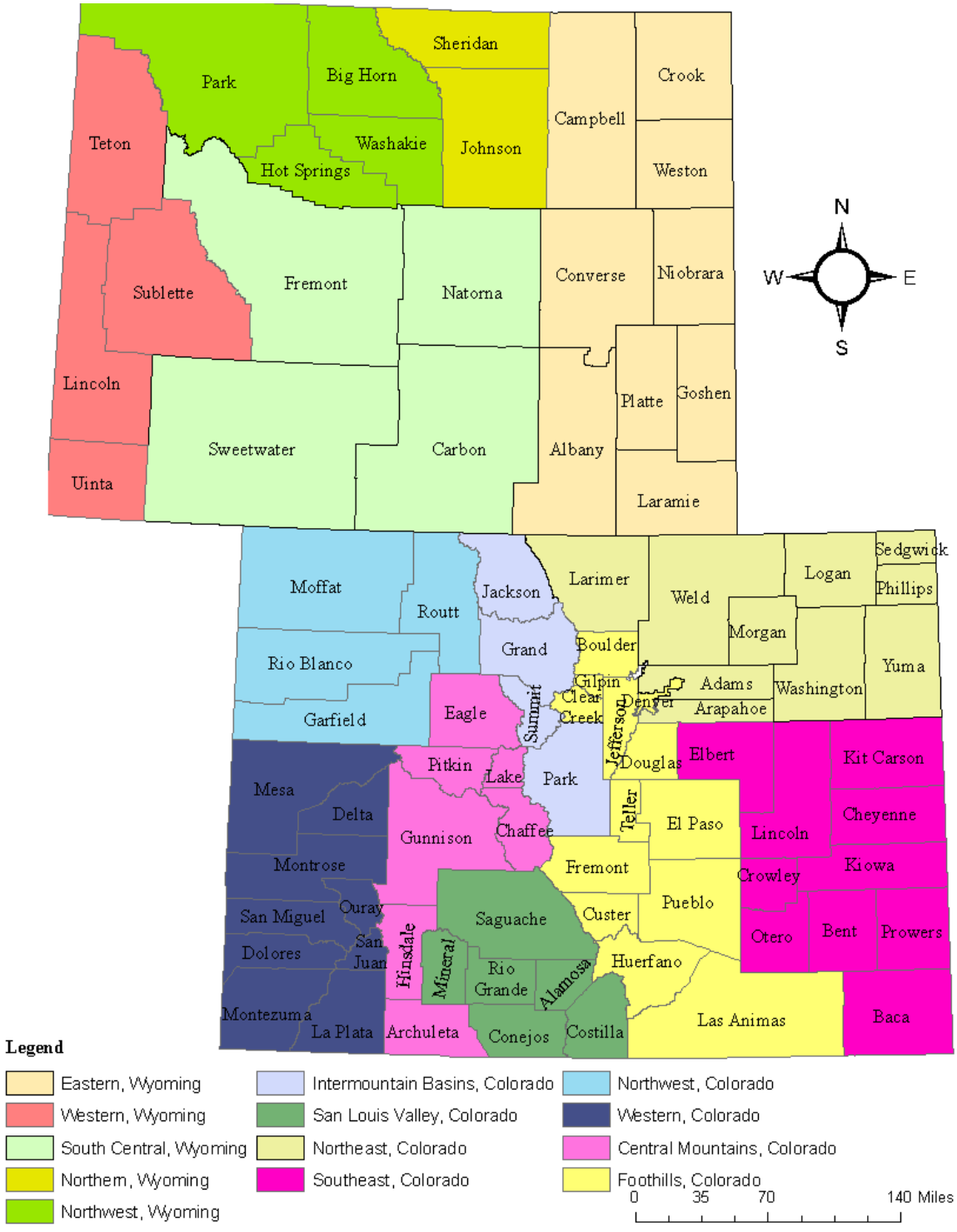
[2] Likelihood Ratio X^2: 13.73; *p*-value = 0.03; Phi value: 0.185.

[3] Likelihood Ratio X^2: 15.12; *p*-value = 0.02; Phi value: 0.200.

Table 4.17. Information needs of Natural Resource Professionals regarding cheatgrass. Data presented are the percentage of respondents who wanted information on the listed topics.

	No	**Yes**	**n**
Herbicide safety	89.4	10.6	312
Herbicide effectiveness	49	51	312
Livestock grazing strategies	46.8	53.2	312
How cheatgrass spreads	76.9	23.1	312
Economic sense to treat cheatgrass	62.8	37.2	312
Time of year	63.8	36.2	312
Control options	34.6	65.4	312
Proper use of control methods	67	33	312
Starting to control cheatgrass	75	25	312
Biological controls	49.7	21.2	312
Groups/organizations managing cheatgrass	78.8	21.2	312
Other	96.5	3.5	312

Table 4.0. Self-administered mail survey study locations of natural resource professionals in Wyoming and Colorado, October thru December 2009.



CHAPTER FIVE: CONCLUSIONS

Our society depends on rangelands directly and indirectly for a variety of services, including food, water, and wildlife habitat. Rangelands are dynamic and complex systems composed of interacting human and biophysical components. Researchers, natural resource professionals (NRPs), ranchers, and other stakeholders are continually challenged to seize new opportunities and to avoid risks in an effort to sustain the ecosystem services we all depend on. As we learn more about rangelands and how they function, we might be able to better manage them into the future and guide their management by developing innovative decision-making tools. However, new knowledge and decision making tools will be ineffective if we do not understand the intended end users' management needs and goals.

Understanding the management needs and goals of ranchers and NRPs is an ongoing challenge. The average rancher is 55 years old (NASS 2009), and as they continue to age it can be expected that many operations will change hands in the coming years, either passed on to heirs of the current owners, sold to amenity buyers, or sold for development. These new ranch owners might have different management perspectives and needs as well as access to different resources. These new perspectives and needs may influence future ranch owners'/managers' willingness and ability to adopt progressive practices and make use of government programs. Similarly, it is expected that a significant portion of federal and state employees will retire during the next decade (USBLS 2009), which indicates that the workforce will be comprised of predominately

younger individuals. As with ranchers, in order to communicate and extend new management tools effectively, we need to understand how the characteristics and management perspectives and goals of NRPs change over time.

Our study explored Wyoming and Colorado ranchers' risk-orientation and adoption behavior. We found that the greatest percentage of ranchers (37%) in Wyoming and Colorado are in the most innovative two categories, strongly proactive and innovators. Individuals in these two groups seek new management practices either from local resources or beyond local resources, respectively.

Younger ranchers who have a higher level of education, that generate a greater percentage of their income from on-ranch sources, and who have a higher gross annual income are likely to be among the first to adopt progressive practices and participate in government programs. Therefore, we recommend that outreach and extension programs and materials about innovations be developed to reach these individuals first. This strategy will help to diffuse information about innovations into communities through ranchers enabling proactive ranchers to observe the implementation and outcomes of adopting progressive practices or government programs. However, care must be taken to ensure innovations are diffused vertically within a population, reaching different socioeconomic levels. Additionally, innovators and individuals who develop outreach and extension programs and materials should consider whether or not their innovation can help ranchers to sustain their resources (e.g., grazing capacity) and if there are any direct financial benefits associated with implementing a new practice or participating in a government program. These are several of the primary factors that ranchers indicated influence their decision to implement a new practice or program.

Human Dimensions of State and Transition Models

There is a need to better understand rangeland managers' awareness of and attitudes toward state and transition models (STMs), as well as how they are using the tool. We also need to learn from practitioners what is and what is not working with the design of STMs, and how to improve the model to make them a more useful decision-making tool for rangeland managers.

We found that only 69% of ranchers had never heard of STMs prior to our survey and only a tiny fraction (2.3%) have used STMs. Further, the level of awareness about STMs varies greatly among different natural resource agencies. Based on these findings, we recommend that a greater effort be made to develop appropriate outreach and extension materials targeted for each specific population, for example different materials could be developed for ranchers, wildlife agencies, local open space and park managers, and land conservation organizations.

Our results also suggest that both populations perceive that STMs may help them to achieve their ecological and/or economic objectives, and that most professionals who have used STMs are satisfied with the results. As studies validate perceived benefits of adopting this land management tool, we recommend that information about these benefits be incorporated into outreach and extension material, with specific examples where possible. We recommend that workshops about STMs be developed for each of the populations and that they include case studies of how the tool has been applied and the associated story of the application of the tool (e.g., success and challenges). Although overall ranchers and NRPs perceived potential benefits from using STMs, several individuals expressed a need for validating the tool. This validation process might include

a peer review process and input from individuals who live on the landscape. This validation process might create a greater understanding of, and buy in for STMs by stakeholders.

Human Dimensions of Cheatgrass (*Bromus tectorum* L.)

We examined ranchers' and NRPs' perceptions of and knowledge about cheatgrass (*Bromus tectorum* L.) and its impacts, current management practices related to cheatgrass control and satisfaction with the results of these practices, and information and technical assistance needs. Although our results varied by region overall, we found that ranchers and NRPs perceived cheatgrass to be a problem to some degree throughout all of our study sites. Ranchers and NRPs in Eastern Wyoming reported a greater problem with cheatgrass than any other region in Wyoming or Colorado, with a greater percentage of NRPs perceiving cheatgrass as a moderate to extreme problem than ranchers. Ranchers and NRPs in Western Colorado reported a greater problem with cheatgrass than any other Colorado region, with a greater percentage of NRPs perceiving cheatgrass as a moderate to extreme problem than ranchers. Overall, our findings about the perceived severity of the cheatgrass problem in different regions of Wyoming and Colorado correspond with data from other sources (USDA 2010; Wyoming Pest Detection Program 2009).

Ranchers reported they were most successful in managing cheatgrass by grazing it in the early spring, while NRPs reported they were most successful using a combined approach of prescribed fire, herbicide application, and seeding. Many more ranchers than NRPs are using livestock to manage cheatgrass. Therefore, we suggest that further research on the effectiveness of different cheatgrass grazing treatments is needed, and

recommend that the results of this research be extended appropriately to the associated resource manager populations.

We also recommend that outreach and extension material incorporate effective methods of treatment for cheatgrass and how to prioritize when it makes economic and ecological sense to treat the species. We believe there is a need for more public education to raise awareness to avoid the potential for cheatgrass to become a bigger problem. Based on our study, outreach and extension material about cheatgrass should focus on control options, livestock grazing strategies, time of year to treat cheatgrass, and herbicide effectiveness. Outreach and extension efforts should also include how to identify cheatgrass, which might influence the degree to which individuals consider the species a problem, and how to more effectively control the spread and establishment of the invasive.

The Wyoming Pest Detection Program (2009) has started to monitor the distribution and abundance of cheatgrass although the state has not listed cheatgrass as a noxious weed. Contrary, the state of Colorado has listed cheatgrass as a List C noxious weed (Agriculture n.d.). To our knowledge the state of Colorado is not tracking the distribution and abundance of cheatgrass, despite its designation as a noxious weed. We recommend that Wyoming continue its monitoring efforts and that the state of Colorado implement a state-wide inventory of the distribution and abundance of cheatgrass. Additionally, we suggest that greater efforts be made to quantify the ecological and economic effects associated with cheatgrass and that the findings be communicated at all levels of government and to other stakeholders.

This study is part of a long-term, interdisciplinary integrated research and extension project, which is scheduled to conclude in 2012. In the context of the larger project, this study provides baseline data that will enable us to evaluate, after the project's conclusion, the extent to which extension efforts are successful in increasing ranchers' and NRPs' awareness, and influencing their attitudes, and management practices related to STMs and cheatgrass.

LITERATURE CITED

1996 - 2007. QSR NVivo 8. Victoria, Australia: QSR International Pty Ltd 2007.

2008. *Keeping Animals in Boulder County*. Available at: http://www.bouldercounty.org/lu/info_center/handouts/planning/pdf/01_keeping_animals.pdf. Accessed February 3, 2010.

[PASW]. 2010. PASW Statistics: Predictive Analytics Software. Chicago, IL: SPSS, Inc.

Agriculture, C. D. o. 2009. *Noxious Weed List: Noxious Weed Management Program*. Accessed March 23 2009.

Agriculture, C. D. o. n.d. *Colorado Weeding Mapping*. Available at: http://www.colorado.gov/cs/Satellite?c=Page&cid=1167928184069&pagename=Agriculture-Main%2FCDAGLayout. Accessed April 27 2010.

Allen-Diaz, B., and J. Bartolome. 1998. Sagebrush-Grass Vegetation Dynamics: Comparing Classical and State-Transition Models. *Ecological Applications* 8:795 - 804.

Andreu, J., M. Vila, and P. Hulme. 2009. An Assessment of Stakeholder Perceptions and Management of Noxious Alien Plants in Spain. *Environmental Management* 43:1244 - 1255.

Baron, R. M., and D. A. Kenny. 1986. The Moderator-Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations. *Journal of Personality and Social Psychology* 51:1173 - 1182.

Berg, B. 2004. Qualitative Research Methods for the Social Sciences. Boston: Allyn and Bacon.

Bernard, H. (ED.) 2002. Research Methods in Anthropology: Qualitative and Quantitative Approaches. 224 - 230 p.

Bestelmeyer, B. T., J. R. Brown, K. M. Havstad, R. Alexander, G. Chavez, and J. E. Herrick. 2003. Development and use of state-and-transition models for rangelands. *Journal of Range Management* 56:114 - 126.

Biernacki, P., and D. Waldorf. 1981. Snowball Sampling: Problems and Techniques of Chain Referral Sampling. *Socilogical Methods and Research* 10:141 - 163.

Bradford, J., and W. Lauenroth. 2006. Controls over invasion of *Bromus tectorum:* The importance of climate, soil, disturbance and seed availability. *Journal of Vegetation Science* 17:693 - 704.

Braun, V., and V. Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3:77 - 101.

Briske, D. D., B. T. Bestelmeyer, T. K. Stringham, and P. Shaver. 2008. Recommendations for Development of Resilience-Based State-and-Transition Models. *Rangeland Ecology & Management* 61:359 - 367.

Briske, D. D., S. D. Fuhlendorf, and F. E. Smeins. 2003. Vegetation Dynamics on Rangelands: A Critique of the Current Paradigms. *The Journal of Applied Ecology* 40:601 - 614.

Brown, L. 1981. Innovation Diffusion: A New Perspective. New York: Methuen & Co.

Bryant, L., T. Roberts, D. Thompson, M. Sharpe, D. Unger, and P. Johnson. 1997. Memorandum of Understanding among the Bureau of Land Management USDS Forest Service USDA Natural Resources Conservation Service. USDA, United States Forest Service

USDI, Bureau of Land Management

USDA, Natural Resources Conservation Service. p. 1 - 3.

Center, N. P. W. R. 2003. *An Assessment of Exotic Plant Species of Rocky Mountain National Park*. Accessed April 1 2009.

Clements, F. 1936. Nature and Structure of the Climax. *Journal of Ecology* 24:252 - 284.

Cohen, J. 1988. Statistical power analysis for the behavioral sciences (2nd Edition). Hillsdale, N.J.: Lawrence Erlbaum Associates, Inc.

Coppock, D., and A. Birkenfeld. 1999. Use of livestock and range management practices in Utah. *Journal of Range Management* 52:7 - 18.

Corbin, J., and A. Strauss. 1990. Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology* 1:3 - 21.

CSREES. 2009. *Rangelands and Grasslands*. Accessed April 3 2009.

Davison, J., E. Smith, and G. Beck. 2007. Forestry: Cheatgrass and Wildfire. *In:* C. S. U. C. Extension [EDS.]. Fort Collins.

Didier, E., and M. Brunson. 2004. Adoption of Range Management Innovations by Utah Ranchers. *Journal of Range Management* 57:330 - 336.

Dillman, D. 2000. Mail and Internet Surveys: The Tailored Design Method. New York: Jouhn Wiley & Sons, Inc.

DiTomaso, J. 2000. Invasive weeds in rangelands: species, impacts, and management. *Weed Science* 48:255 - 265.

DiTomaso, J., R. Masters, and V. Peterson. 2010. Rangeland Invasive Plant Management. *Rangelands* 32:43 - 47.

Eviner, V., S. Hoskinson, and C. Hawkes. 2010. Ecosystem Impacts of Exotic Plants Can Feed Back to Increase Invasion in Western US Rangelands. *Rangelands* 32:21 - 31.

Fernandez-Gimenez, M., G. Ruyle, and S. McClaran. 2005. An Evaluation of Arizona Cooperative Extension's Rangeland Monitoring Program. *Rangeland Ecology & Management* 58:89 - 98.

Fowler, F. J. 2002. Survey Research Methods. Thousand Oaks: Sage Publications. 178 p.

Frasier, G., and R. Mack. 2009. Invasive Weeds on Range and Farmlands -- Problems, Causes, and Solutions: An Interview with Richard Mack. *Rangelands* 31:10 - 13.

Gosnell, H., and W. Travis. 2005. Ranchland Ownership Dynamics in the Rocky Mountain West. *Rangeland Ecology & Management* 58:191 - 198.

Graham, J., and J. Ackerfield. 2008. *Colorado State University Herbarium*. Accessed March 23 2009.

Grbich, C. 2007. Grounded Theory. Qualitative data analysis: An Introduction. Los Angles: Sage. p. 70 - 83.

Griffith, D. 1999. Economic Evaluation Procedures for Noxious Weed Management on Rangeland. *In:* R. Sheley and J. Petroff (EDS.). Biology and Management of Noxious Rangeland Weeds. Corvallis: Oregon State University Press. p. 44 - 56.

Hansen, A., R. Rasker, B. Maxwell, J. Rotella, J. Johnson, A. Wright Parmenter, U. Langner, C. W., L. R., and M. Kraska. 2002. Ecological causes and consequences of demographic change in the New West. *BioScience* 52:151 - 162.

Healy, C. 2001. *Drought fuels loss of U.S. western land to invasive grass and wildfires*. Available at: http://news.nationalgeographic.com/news/2001/06/0628_drought.html. Accessed May 20 2010.

Holechek, J. 2007. National Security and Rangelands. *Rangelands*:33 - 38.

Jerup, A. 2008. *Wyoming Weed & Pest Control Act Designated List*. Available at: http://www.wyoweed.org/statelist.html. Accessed April 12 2010.

Johnson, D., K. Davies, P. Schrder, and A. Chamberlain. 2009. 2007 Southeast Oregon Weed Management Survey: Ranchers' Perceptions of Weeds in Sagebrush Steppe Rangeland, The. *In:* U.-A. R. S. Oregon State University Extension Service, Eastern Oregon Agricultural Research Center [EDS.]. Burns.

Kelley, W. 2010.

Kennedy, C., and M. Brunson. 2007. Creating a Culture of Innovation in Ranching. *Rangelands*:35 -40.

Kenny, D. A. 2009. *Learn how you can do a meidiation analysis and output a text description of your results*. Available at: http://davidakenny.net/cm/mediate.htm#BK. Accessed July 25, 2010 2010.

Knapp, C., and M. Fernandez-Gimenez. 2009. Understanding Change: Integrating Rancher Knowledge Into State-and-Transition Models. *Rangeland Ecology & Management* 62:510 - 521.

Knapp, C., M. Fernandez-Gimenez, E. Kachergis, and A. Rudeen. 2010. Using Participatory Workshops to Integrate State-and-Transition Models Created With Local Knowledge and Ecological Data. Fort Collins: Colorado State University. p. 1 - 38.

Knapp, P. A. 1996. Cheatgrass (*Bromus tectorum* L) dominance in the Great Basin Desert. *Global Environmental Change* 6:37 - 52.

Kreuter, U., H. Amestoy, D. Ueckert, and M. W. 2001. Adoption of Brush Busters: Results of Texas County Extension Survey. *Journal of Range Management* 54:630 - 639.

Kreuter, U., J. Woodard, C. Taylor, and W. Teague. 2008. Perceptions of Texas Landowners Regarding Fire and Its Use. *Rangeland Ecology & Management* 61:456 - 464.

Lambert, D., P. Sullivan, R. Claassen, and L. Foreman. 2007. Profiles of US farm households adopting conservation-compatible practices. *Land Use Policy* 24:72 - 88.

Mack, R. 1981. Invasion of *Bromus tectorum* L. into Western North America: An Ecological Chronicle. *Agro-Ecosystems* 7:145 - 165.

Meyer, S., and E. Leger. 2010. Inbreeding, Genetic Variation, and Invasiveness: The Strange Case of *Bromous tectorum*. *Rangelands* 32:6 - 11.

Mosley, J., S. Bunting, and M. Manoukian. 1999. Cheatgrass. *In:* R. Sheley and J. Petroff (EDS.). Biology and Management of Noxious Rangeland Weeds. Corvallis: Oregon State University Press. p. 175 - 188.

NASS. 2009. *Table 46. Selected Operation and Operator Characteristics: 2007 and 2002*. Available at: http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_US_State_Level/st99_2_046_046.pdf. Accessed June 24 2010.

Natural Resources Conservation Service, U. 2010. *Plants Profile: County Distribution*. Available at: http://plants.usda.gov/java/county?state_name=Colorado&statefips=08&symbol=BRTE. Accessed April 27 2010.

Neuman, L. 2003. Social Research Methods: Qualitative and Quantitative Approaches. New York: Allan & Bacon.

Novak, S., and R. Mack. 1993. Genetic variation in *Bromus tectorum* (Poaceae): comparison between native and introduced populations. *Heredity* 71:167 - 176.

NRCS. 2004. Farm Bill 2002: Farm and Ranch Lands Protection Program Fact Sheet. *In:* U. Natural Resources Conservation Service [EDS.]: Natural Resources Conservation Service, USDA.

Peterson, R., and D. Coppock. 2001. Economics and Demographics Constrain Investment in Utah Private Grazing Lands. *Journal of Range Management* 54:106 - 113.

Pimentel, D., R. Zuniga, and J. Morrison. 2005. Update on the environmental and economic costs associated with alien - invasive species in the United States. *Ecological Economics* 52:273 - 288.

Preacher, K., and G. Leonardelli. 2003. *Calculation for the Sobel Test: An interactive calculation tool for mediation tests*. Available at: http://www.people.ku.edu/~preacher/sobel/sobel.htm. Accessed June 2 2010.

Rodriguez Iglesias, R., and M. Kothmann. 1997. Structure and causes of vegetation change in state and transition model application. *Journal of Range Management* 50.

Rogers, E. 1995. Diffusion of Innovations. New York: Free Press.

Rowan, R., and L. White. 1994. Regional differences among Texas rangeland operators. *Journal of Range Management* 47:338 - 343.

Rowan, R., L. White, and J. Conner. 1994. Understanding Cause/Effect Relationships in Stocking Rate Change over Time. *Journal of Range Management* 47:349 - 354.

Rowe, H., and C. Brown. 2008. Native Plant Growth and Seedling Establishment in Soils Influenced by *Bromus tectorum*. *Rangeland Ecology & Management* 61:630 - 639.

Rowe, H., M. Shinderman, and E. Bartlett. 2001. Change on the range. *Rangelands* 23:6 - 9.

Schachner, L., R. Mack, and S. Novak. 2008. *Bromus tectorum* (Poaceae) in midcontinental United States: population genetic analysis of an ongoing invasion. *American Journal of Botany* 95:1584 - 1595.

Selfa, T., R. Jussaume, and M. Winter. 2008. Envisioning agricultural sustainability from field to plate: Comparing producer and consumer attitudes and practices toward 'environmentally friendly' food and farming in Washington State, USA. *Journal of Rural Studies* 24:262 - 276.

Sell, R., D. Bangsund, and L. Leistritz. 1999. *Euphorbia esula:* perceptions by ranchers and land managers. *Weed Science* 47:740 - 749.

Smith, A., and W. Martin. 1972. Socioeconomic Behavior of Cattle Ranchers, with Implications for Rural Community Development in the West. 54:217 - 225.

Smith, M., and S. Enloe. 2006. Cheatgrass Ecology and Management in Wyoming. *In:* U. o. W. C. E. Office [EDS.]. Laramie. p. 2.

Sobel, M. E. 1982. Asymptotic Confidence Intervals for Indirect Effects in Structural Equation Models. *Sociological Methodology* 13:290 - 312.

Stephenson, G. 2003. The Somewhat Flawed Theoretical Foundation of the Extension Service. *Journal of Extension* 41.

Stewart, D., and P. Shamdasani. 1998. Focus Group Research: Exploration and Discovery. *In:* L. Bickman and D. Rog (EDS.). Handbook of Applied Social Research Methods. Thousand Oaks: Sage Publications. p. 505 - 526.

Strauss, A., and J. Corbin. 1990. Basics of Qualitative Research: Grounded Theory Procedures and Techniques. Newbury Park: Sage.

Stringham, T. K., W. C. Krueger, and P. Shaver. 2003. State and Transition modeling: An ecological process approach. *Journal of Range Management* 56:106 - 113.

Stringham, T. K., W. C. Krueger, and D. R. Thomas. 2001. Application of Non-Equilibrium Ecology to Rangeland Riparian Zones. *Journal of Range Management* 54:210 - 217.

Stubbendieck, J., S. Hatch, and L. Landholt. 2003. North American Wildland Plants: A Field Guide. Lincoln: University of Nebraska.

Suding, K. N., K. L. Gross, and G. R. Houseman. 2004. Alternative states and positive feedbacks in restoration ecology. *Trends in Ecology and Evolution* 19:46 - 53.

Talbert, C., R. Knight, and J. Mitchell. 2007. Private Ranchlands and Public Grazing in the Southern Rocky Mountains: Why the private land matters when we think about public lands grazing. *Rangelands*:5 - 8.

USBLS. 2009. *Occupational Outlook Handbook, 2010 - 11 Edition*. Available at: http://www.bls.gov/oco/ocos048.htm. Accessed July 17 2010.

USDA, N. R. C. S. 2010. *Plants Database: Plants Profile*. Available at: http://plants.usda.gov/java/county?state_name=Colorado&statefips=08&symbol=BRTE. Accessed June 27 2010.

USFS, U.-. 1989. An Analysis of the Land Base Situation in the United States: 1989 - 2040 General Technical Report RM - 181. *In:* U. S. F. S. U.S. Department of Agriculture [EDS.].

Vallentine, J. 1990. Grazing Management. San Diego: Academic Press, Inc.

Vaske, J. 2008. Survey Research and Analysis: Applications in Parks, Recreation and Human Dimensions. State College: Venture Publishing, Inc.

Vasquez, E., J. James, T. Monaco, and C. Cummings. 2010. Invasive Plants on Rangelands: A Global Threat. *Rangelands* 32:3 - 5.

Veckrey, D., and G. Hardy. 2008. Declared List of Weeds and Pest: Wyoming Weed and Pest Control Act of 1973 W.S. 11-5-102(a)(vii) and W.S. 11-5-102(a)(viii): 2008 Declared Species. Wyoming Weed and Pest Council and Wyoming Board of Agriculture.

Wallace, G., D. Theobald, T. Ernst, and K. King. 2008. Assessing the Ecological and Social Benefits of Private Land Conservation in Colorado. *Conservation Biology* 22:284 - 296.

Westoby, M., B. Walker, and I. Noy-Meir. 1989. Opportunistic Management for Rangelands Not at Equilibrium. *Journal of Range Management* 42:266 - 274.

Wilson, N. 2006. *Fact Sheet - Small Farm Living, Pasture Management Basics*. Available at: http://www.marioncountyfl.org/countyextension/pdf/ag_smfarmpasturemgmtpub.pdf. Accessed February 3, 2010.

Wyoming Pest Detection Program, U. 2009. *Cheatgrass*. Available at: http://uwadmnweb.uwyo.edu/capsweb/info.asp?p=11156. Accessed April 27 2010.

Young, J., and C. Clements. 2009. Cheatgrass: Fire and Forage on the Range. Reno: University of Nevada Press.

Appendix A: Focus Group Recruitment Script – Ranchers

Hello, my name is Windy Kelley. I am a graduate student at Colorado State University. I would like to talk with you regarding a research and extension project I am working on. This project will result in several land management decision-making tools. Do you have approximately 5 – 10 minutes right now?

[If yes, proceed.]

[If no, ask when a better time would be for you to call back. Thank you for your time, I look forward to speaking with you soon.]

Thank you. I'm contacting you because I hope that you will be able to refer me to individuals I can contact for our research. Our research includes separate focus groups for ranchers and natural resource professionals, with each focus group comprised of 8 – 12 individuals. The focus groups will be voluntary and are structured to encourage open dialogue among participants. In these focus groups we will be discussing specific rangeland resource issues and management practices and tools. The two main topics will be invasive plants, especially cheatgrass, and state and transition models. We also want to learn about what kinds of technical information ranchers need and how they prefer to receive the information.

As I mentioned earlier, I would like to request referrals of potential focus groups participants from you, specifically ranchers/producers. I want to invite a sample of potential participants who form a well-rounded representation of their population in your region. Ideally, this sample will include individuals who are leaders in the ranching/producing community as well as individuals who have not taken on a leadership role. Do you know of anyone you would recommend participating in the focus group?

[If yes, proceed.]

[If no, ask if they know of someone who can recommend potential focus group participants.]

To ensure I have accurate contact information for your referrals can you email or postal mail me their information?

[If yes, proceed.]

[If no, ask how they would prefer to provide the contact information.]

How would you prefer to provide me your referrals contact information?

[Let the key informant respond then provide one of the following accordingly.]

Email: wkelley@rams.colostate.edu
Postal Mail: Windy Kelley; Department of Forest, Rangeland, and Watershed Stewardship; 1472 Campus Delivery; Fort Collins, CO 80523

Thank you for your time and input today. Do you have any questions for me?

[If yes, answer questions then proceed.]

[If no, proceed.]

In the future, if you have questions regarding my research please do not hesitate to call me at (970) 491-3889. You can also contact the Principal Investigator for the study, Dr. Maria Fernandez-Gimenez at (970) 491-0409.

Lastly, would it be okay for me to contact you in the future regarding this project or related projects?

Thank you again for your time. Have a good day.

Appendix B: Focus Group Recruitment Script – Natural Resource Professionals

Hello, my name is Windy Kelley. I am a graduate student at Colorado State University. I would like to talk with you regarding a research and extension I am working on. This project will result in several land management decision-making tools. Do you have approximately 5 – 10 minutes right now?

[If yes, proceed.]

[If no, ask when a better time would be for you to call back. Thank you for your time, I look forward to speaking with you soon.]

Thank you. I'm contacting you because I hope that you will be able to refer me to individuals I can contact for our research. Our research includes separate focus groups for ranchers and natural resource professionals, with each focus group comprised of 8 – 12 individuals. The focus groups will be voluntary and are structured to encourage open dialogue between participants regarding their opinions and beliefs. In these focus groups we will be discussing their knowledge and opinions about specific rangeland resource issues and management practices and tools. We also want to learn about what kinds of technical information natural resource professionals need and how they prefer to receive the information.

As I mentioned earlier, I would like to request referrals of potential focus groups participants from you, specifically natural resource professionals. I want to invite a sample of potential participants who work as resource specialists and land managers. Positions include weed, range, and extension specialists. Do you know of anyone you would recommend participating in the focus group?

[If yes, proceed.]

[If no, ask if they know of someone who can recommend potential focus group participants.]

To ensure I have accurate contact information for your referrals can you email or postal mail me their information?

[If yes, proceed.]

[If no, ask how they would prefer to provide the contact information.]

How would you prefer to provide me your referrals contact information?

[Let the key informant respond then provide one of the following accordingly.]

Email: wkelley@rams.colostate.edu
Postal Mail: Windy Kelley; Department of Forest, Rangeland, and Watershed Stewardship; 1472 Campus Delivery; Fort Collins, CO 80523

Thank you for your time and input today. Do you have any questions for me?

[If yes, answer questions then proceed.]

[If no, proceed.]

In the future, if you have questions regarding my research please do not hesitate to call me at (970) 491-3889. You can also contact the Principal Investigator for the study, Dr. Maria Fernandez-Gimenez at (970) 491-0409.

Lastly, would it be okay for me to contact you in the future regarding this project or related projects?

Thank you again for your time. Have a good day.

Appendix C: Focus Group Invitation

Colorado State University

Knowledge to Go Places

Department of Forest, Rangeland, & Watershed Stewardship
Fort Collins, Colorado 80523-1472 USA
Telephone (970) 491-6911
FAX (970) 491-6754
http://www.cnr.colostate.edu/frws/

November XX, 2008

Dear Mr./Mrs./Ms. [Last Name]:

Colorado State University's Warner College of Natural Resources and the Bioagricultural Sciences and Pest Management Department are working on research and extension projects in Wyoming and Colorado that will provide new knowledge and land management tools for rangeland managers. To gain an understanding of land managers' knowledge, management practices, and information needs in your area we invite you to participate in a facilitated focus group on **[Insert Date, Time, and Location]**.

A focus group is a small group of people sampled about their opinions and beliefs through open discussion. During the focus group on **[Insert Date]** you will have the opportunity to discuss your knowledge and thoughts about specific rangeland resource issues, management practices, and decision-making tools. Two of the main topics in our discussion will be invasive plants and state and transition models—a decision-making tool for rangeland managers. We also want to learn about what kinds of technical information you need and how you prefer to get this information. The focus group will last 60 – 90 minutes and refreshments will be served.

Researchers are interested in your thoughts and experiences. There are no right or wrong answers to any of the questions. Participation in the focus group is completely voluntary. If at any time you decide you no longer want to participate you are welcome to refrain from comment. Your confidentiality will be maintained and no identifying characteristics will be revealed in any reports. We are unable to offer financial compensation to you. However, most participants find focus groups to be an enjoyable and informative opportunity to exchange ideas about topics of interest to all participants. Participation in this focus group is also a way to help ensure that our research and extension activities are directly relevant to and useful for land managers in your community.

Your participation is important to help us gain a better understanding of land managers' knowledge, needs, and preferences for information transfer. We hope you will be able to join us on **[Insert Date, Time, and Location]**. Please return the enclosed RSVP postcard by **[Insert Date]** indicating if you will be able to attend this focus group.
If you have questions about the study, please feel free to contact Windy Kelley, Graduate Research Assistant or Dr. Maria Fernandez-Gimenez, Principal Investigator. If you have

questions about your rights as a participant in this research, you may contact Janell Barker of the CSU Institutional Review Board at (970) 491-1655.

Thank you in advance for your time and consideration.

Sincerely,

Maria Fernandez-Gimenez, Ph.D.
Principal Investigator
Colorado State University
(970) 491-0409
gimenez@warnercnr.colostate.edu

Windy K. Kelley
Graduate Research Assistant
Colorado State University
(970) 491-3889
wkelley@rams.colostate.edu

Appendix D: Cover Letter for Focus Groups

Colorado State University

Knowledge to Go Places

Department of Forest, Rangeland, & Watershed Stewardship
Fort Collins, Colorado 80523-1472 USA
Telephone (970) 491-6911
FAX (970) 491-6754
http://www.cnr.colostate.edu/frws/

November XX, 2008

Dear Focus Group Participant:

Colorado State University's Warner College of Natural Resources and the Bioagricultural Sciences and Pest Management Department are working on two related research and extension projects. Each project will result in a land management decision-making tool.

We invite you to participate in a focus group, a small group of people sampled about their opinions and beliefs through open discussion. In this focus group you will be discussing your knowledge and opinions about specific rangeland resource issues, management practices, and decision-making tools. We also want to learn about what kinds of technical information you need and how you prefer to get this information. The focus group will last 60 – 90 minutes.

In accordance with U.S. Federal regulations, the Colorado State University Human Research Committee has reviewed and approved this study. Your participation in this study is voluntary and will remain completely confidential. If at any time you decide you no longer want to participate you are welcome to refrain from comment.

Please keep in mind there are no right or wrong answers to any of the questions and be considerate of others whose views may differ from your own. Researchers are interested in your thoughts and experiences. All participants are asked to keep this discussion confidential. With your permission we will voice record this focus group so researchers have an accurate record of the experiences, thoughts, and opinions shared in this meeting.

Please be aware there are no known risks or direct personal benefits associated with your participation in this study. Researchers will be happy to answer any questions about this study. You can also contact the Principal Investigator for the study, Dr. Maria Fernandez-Gimenez at (970) 491-0409 with any questions you have about the study. If you have questions about your rights as a participant in this research, you may contact Janell Barker of the CSU Institutional Review Board at (970) 491-1655.

Lastly, the next phase of this project will be a survey of randomly selected households. Please let us know if you have any objection to receiving such a survey and we will do our best to remove your name from our list of potential survey households. Thank you.

Sincerely,

Maria Fernandez-Gimenez, Ph.D.
Principal Investigator

Windy K. Kelley
Graduate Research Assistant

Colorado State University
(970) 491-0409
gimenez@warnercnr.colostate.edu

Colorado State University
(970) 491-3889
wkelley@rams.colostate.edu

Appendix E: Focus Group Script – Ranchers

Hello, my name is Windy Kelley. I am a graduate research assistant at Colorado State University. During the next 60 – 90 minutes you will be involved in a focus group, a small group sampled about their opinions and beliefs through open discussion.

I am working on two separate research and extension projects. Each project will result in a land management decision-making tool. The purpose of this focus group is to help us understand ranchers' knowledge and opinions about specific rangeland resource issues and management practices and tools. We are also interested in learning about what kinds of technical information you need and how you prefer to get this information.

I will be asking you about your knowledge, thoughts, and management practices related to invasive plants and state and transition models. Please take the time you need to answer my questions. I will let the group know when we have ten minutes left. Keep in mind your participation in this study is voluntary, if at anytime you decide you no longer want to participate you are welcome to refrain from comment.

Please be aware there are no known risks or direct personal benefits associated with your participation in this study. I am happy to answer any questions about the study. You can also contact the Principal Investigator for the study, Dr. Maria Fernandez-Gimenez at (970) 491-0409 with any question you may have about the study. If you have questions about your rights as a participant in this research, you may contact Janell Barker of the CSU Institutional Review Board at (970) 491-1655.

Before we begin, would it be okay if I voice record our discussion? I will also be taking some notes.

[Turn on voice recorder]

Please keep in mind there are no right or wrong answers to any of the questions I ask you. Please also keep in mind to be considerate of others whose views may differ from your own. I am interested in your personal thoughts and experiences.

First, I'd like to ask you some questions about invasive plant species on your management unit.

1) What are your concerns about invasive plants on your rangelands?
    a. What is the primary invasive plant species you are concerned about on your rangeland?
    b. Is cheatgrass a problem in your area?
    c. How big of a problem/concern is cheatgrass for you?

2) How does cheatgrass affect your ranch?
    a. What ecological impact(s) does cheatgrass have on the ecosystem?
    b. How does cheatgrass impact productivity of your operation?

3) In what other ways does cheatgrass affect your operation?

a. What economic impact(s) does cheatgrass have on your operation?

4) How do you manage cheatgrass on your ranch?
    a. Does management on private and public leased lands differ?

5) What are the biggest constraints/obstacles to managing invasive plants on your ranch?

Now, I'd like to ask you about another management tool, state and transition models.

6) What have you heard about state and transition models?

[If at least some participants have heard about state and transition models, proceed.]

7) How are you using state and transition models?

[If some or all participants have not heard about state and transition models, provide a brief explanation and example.]

8) What might be the benefits of state and transition models in helping you reach your ecological/land condition objectives for your ranch?

9) What benefits might state and transition models have in helping you reach your economic objectives?

10) What would make state and transition models a useful management tool for you?

Lastly, I'll ask you a few questions about where you get information about new management approaches and tools, as well as advances in natural resource science that could affect your ranch.

11) In general, how do you learn about new management tools and approaches?
    a. What are your specific sources of information about invasive plant management?
    b. What are your specific sources of information about state and transition models?

12) How would you prefer to get your information? Why?

Thank you for time and input today. Before we close, would you like to add anything? Thank you again for your participation.

Appendix F: Focus Group Script – Natural Resource Professionals

Hello, my name is Windy Kelley. I am a graduate research assistant at Colorado State University. During the next 60 – 90 minutes you will be involved in a focus group, a small group sampled about their opinions and beliefs through open discussion.

I am working on two separate research and extension projects. Each project will result in a land management decision-making tool. The purpose of this focus group is to help us understand natural resource professionals' knowledge and opinions about specific rangeland resource issues and management practices and tools. We are also interested in learning about what kinds of technical information you need and how you prefer to get this information.

I will be asking you about your knowledge, thoughts, and management practices related to invasive plants and state and transition models. Please take the time you need to answer my questions. I will let the group know when we have ten minutes left. Keep in mind your participation in this study is voluntary, if at any time you decide you no longer want to participate you are welcome to refrain from comment.

Please be aware there are no known risks or direct personal benefits associated with your participation in this study. I am happy to answer any questions about the study. You can also contact the Principal Investigator for the study, Dr. Maria Fernandez-Gimenez at (970) 491-0409 with any question you may have about the study. If you have questions about your rights as a participant in this research, you may contact Janell Barker of the CSU Institutional Review Board at (970) 491-1655.

Before we begin, would it be okay if I voice record our discussion? I will also be taking some notes.

[Turn on voice recorder]

Please keep in mind there are no right or wrong answers to any of the questions I ask you. Please also keep in mind to be considerate of others whose views may differ from your own. I am interested in your personal thoughts and experiences.

First, I'd like to ask you some questions about invasive plant species on your management unit.

12) What are your concerns about invasive plants on rangelands you manage?
    Additional probes:

    a. What are the primary invasive plant species you are concerned about on your rangelands?
    b. Is cheatgrass a problem in your area?
    c. How big of a problem/concern is cheatgrass for you?

13) How does cheatgrass affect the rangelands you manage?
    a. What ecological impacts have you observed from cheatgrass?

b. How does cheatgrass impact productivity of the rangeland(s) you manage?

14) In what other ways do invasive plants affect your agency or organization?
    a. What economic impact(s) does cheatgrass have on your organization?

4) How do you manage cheatgrass on your management unit(s)?
    a. What are the biggest constraints/obstacles to managing cheatgrass on your management unit(s)?

Now, I'd like to ask you about another management tool, state and transition models.

5) What have you heard about state and transition models?

[If at least some participants have heard about state and transition models, proceed.]

6) How are you using state and transition models now?

[If some or all participants have not heard about state and transition models, provide a brief explanation and example.]

7) What might be the benefits of state and transition models in helping you reach your ecological/land condition objectives for your management unit?

8) What benefits might state and transition models have in helping you reach your economic objectives?

9) What would make state and transition models a useful management tool for you?

Lastly, I'll ask you a few questions about where you get information about new management approaches and tools, as well as advances in natural resource science that could affect your agency.

10) In general, how do you learn about new management tools and approaches?
    a. What are your specific sources of information about invasive plant management?
    b. What are your specific sources of information about state and transition models?

11) How would you prefer to get your information? Why?

Thank you for time and input today. Before we close, would you like to add anything? Thank you again for your participation.

Appendix G: Pre-survey Letter – Ranchers and Natural Resource Professionals

Colorado State University

Knowledge to Go Places

Department of Forest, Rangeland, & Watershed Stewardship
Fort Collins, Colorado 80523-1472 USA
Telephone (970) 491-6911
FAX (970) 491-6754
http://www.cnr.colostate.edu/frws/

September XX, 2009

Mr./Ms./Mrs. First Name Last Name
Mailing Address
City, State, Zip Code

Dear Mr./Ms./Mrs. Last Name,

In about a week you will receive in the mail a request to fill out an important questionnaire. This questionnaire will help to inform two related research and extension projects being carried out with public and private partners in Colorado and Wyoming, including Colorado State University, Colorado State University Extension, and University of Wyoming Extension.

The questionnaire is about ranchers' and land managers' knowledge, management practices, and information needs related to grazing and rangeland management.

We are writing in advance because we have found that many people like to know ahead of time that they will be contacted. This questionnaire will help us to create tools useful to ranchers and land managers and to evaluate the effectiveness of our research and extension activities. The information you provide can help us to understand ranchers' and land managers' current knowledge, experiences, and opinions about specific management practices, which will help to inform the development of new land management decision-making tools.

Thank you in advance for your time and consideration. It's only with the generous help of people like you that our research and extension projects can be successful in informing future grazing and rangeland management decisions.

Sincerely,

Maria Fernandez-Gimenez, Ph.D.
Principal Investigator
Colorado State University
(970) 491-0409
Maria.Fernandez-Gimenez@colostate.edu

Windy K. Kelley
Graduate Research Assistant
Colorado State University
(970) 491-3889
wkelley@rams.colostate.edu

Appendix H: Survey Cover Letter – Ranchers

Colorado State University

Knowledge to Go Places

Department of Forest, Rangeland, & Watershed Stewardship
Fort Collins, Colorado 80523-1472 USA
Telephone (970) 491-6911
FAX (970) 491-6754
http://www.cnr.colostate.edu/frws/

September XX, 2009

Mr./Ms./Mrs. First Name Last Name
Mailing Address
City, State, Zip Code

Dear Mr./Ms./Mrs. Last Name,

We are writing to ask for your help in assisting us to understand ranchers' knowledge, management practices, and information needs about grazing and rangeland management. By completing the enclosed questionnaire, you can help researchers, and extension agents better understand your operation and develop decision-making tools and information sources targeted to the needs and interests of ranchers.

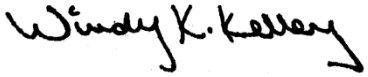
Specifically, the information you provide will help to inform two related research and extension projects being carried out by Colorado State University, CSU Extension, and University of Wyoming Extension that will result in new land management decision-making tools. Additionally, your responses to the enclosed questionnaire will help us evaluate the effectiveness of both projects in three or four years, when they are completed.

We ask that you please take the time to read and complete this questionnaire. Your answers and comments will be kept anonymous and confidential. Survey results will be reported in summary form so that individual responses can't be identified. Completion of this survey is voluntary. This is your opportunity to provide input to us about important grazing and rangeland management topics. Please feel free to share additional comments you might have in the margins or on the back of the questionnaire. If you prefer not to respond, please let us know by returning the blank questionnaire in the enclosed stamped envelope.

If you have any questions or comments about this study, we would be happy to talk with you. You can find our contact information below. If you have questions about your rights as a participant in this research, you may contact Janell Barker of the CSU Institutional Review Board at (970) 491-1655.

Thank you for your time and consideration.

Sincerely,



Maria Fernandez-Gimenez, Ph.D.
Principal Investigator

Windy K. Kelley
Graduate Research Assistant

Colorado State University
(970) 491-0409
Maria.Fernandez-Gimenez@colostate.edu

Colorado State University
(970) 491-3889
wkelley@rams.colostate.edu

Appendix I: Survey Cover Letter – Natural Resource Professionals

Colorado State University

Knowledge to Go Places

Department of Forest, Rangeland, & Watershed Stewardship
Fort Collins, Colorado 80523-1472 USA
Telephone (970) 491-6911
FAX (970) 491-6754
http://www.cnr.colostate.edu/frws/

September XX, 2009

Agency
Mr./Ms./Mrs. First Name Last Name
Title
Mailing Address
City, State, Zip Code

Dear Mr./Ms./Mrs. Last Name,

We are writing to ask for your help in assisting us to understand land managers' knowledge, management practices, and information needs about grazing and rangeland management. By completing the enclosed questionnaire, you can help researchers and extension agents to develop decision-making tools and information sources targeted to the needs and interests of land managers.

Specifically, the information you provide will help to inform two related research and extension projects being carried out by Colorado State University, CSU Extension, and University of Wyoming Extension that will result in new land management decision-making tools. Additionally, your responses to the enclosed questionnaire will help us evaluate the effectiveness of both projects in three or four years, when they are completed.

We ask that you please take the time to read and complete this questionnaire. Your answers and comments will be kept anonymous and confidential. Survey results will be reported in summary form so that individual responses can't be identified. Completion of this survey is voluntary. This is your opportunity to provide input to us about important grazing and rangeland management topics. Please feel free to share additional comments you might have in the margins or on the back of the questionnaire. If you prefer not to respond, please let us know by returning the blank questionnaire in the enclosed stamped envelope.

If you have any questions or comments about this study, we would be happy to talk with you. You can find our contact information below. If you have questions about your rights as a participant in this research, you may contact Janell Barker of the CSU Institutional Review Board at (970) 491-1655.

Thank you for your time and consideration.

Sincerely,

Maria Fernandez-Gimenez, Ph.D.

Windy K. Kelley

Principal Investigator
Colorado State University
(970) 491-0409
Maria.Fernandez-Gimenez@colostate.edu

Graduate Research Assistant
Colorado State University
(970) 491-3889
wkelley@rams.colostate.edu

Appendix J: Mail Survey – Ranchers

Grazing and Rangeland Management: A Survey for Ranchers

Photo courtesy of Emily Kachergis

Colorado State University
Knowledge to Go Places

University of Wyoming
Cooperative Extension Service

Colorado State University Extension

INTRODUCTION

This survey is about your knowledge, management practices, and information needs concerning cheatgrass (*Bromus tectorum*), an invasive non-native annual grass, and state and transition models, a decision-making tool for rangeland managers. Together with public and private partners in Colorado and Wyoming, Colorado State University is conducting two related research and extension projects that will result in new land management decision-making tools. Your survey responses will enable us to create useful tools and deliver them to ranchers in ways they prefer. For some questions you may not have an opinion or any prior knowledge. Please let us know this. Also, feel free to make comments in the margins. Your comments are appreciated and will be read.

Your comments will be kept confidential. Survey results will be reported in summary form so that individual responses can not be identified. The identification number on the back cover of this survey is for record keeping purposes only. If you have any questions about your rights as a survey respondent, you may contact Janell Barker of the CSU Institutional Review Board at (970) 491-1655.

Please note, information collected from this survey will be used to inform research and extension projects. The intent of this survey is not to promote products, programs, or organizations.

Thank you in advance for your time and consideration in completing this survey. Your input will help us and our partners better serve all Wyoming and Colorado ranchers into the future.

SECTION I: MANAGEMENT PRACTICES AND PROGRAMS

In the first section, we ask you a few questions to gain a better understanding of the nature of your ranching operation. Additionally, we are interested in learning about your grazing and land management practices, use of government programs, and experience with new business practices.

1) Approximately, what percentage of your ranching operation falls into each of the following land ownership categories? ***Write in the estimated percent.***

Private _____%	State Lands _____%
U.S. Forest Service _____%	Bureau of Land Management (BLM) _____%

Other (Please specify.) _____% _____

2) About how many private acres of land do you have in your ranching operation? ***Check one.***

Less than 100 acres	☐	250 – 499 acres	☐	1,000 – 4,999 acres	☐
100 – 249 acres	☐	500 - 999 acres	☐	5,000 acres or more	☐

3) As of July, 2009, about how many head of cattle, sheep, horses and other livestock did you have on your ranching operation? ***Please write in a number, write "0" if none.***

Cow-calf pairs_____	Sheep_____	Other (Please list.) _____
Dry cows _____	Goats _____	_____
Yearling (stocker) cattle _____	Horses _____	_____

4) What percent of your ranching operation's annual labor is supplied by the family? _____ %

5) About how many years have you managed this ranching operation? _____ years

6) In the last 5 years have you participated in any of the following programs with your ranching operation? ***Check one for each program.***

Land retirement conservation programs, for example, Conservation Reserve Program (CRP) or Wetland Reserve Program (WRP)	Yes ☐	No ☐
Working land conservation programs, for example, Environmental Quality Incentives Program (EQIP) or Conservation Security Program (CSP)	Yes ☐	No ☐
Wildlife habitat programs, for example, Partners, Landowner Incentive Program (LIP), or Ranching for Wildlife (RFW)	Yes ☐	No ☐
Agricultural land and grassland preservation programs, for example, Farm and Ranchlands Protection Program (FRPP), or Grassland Reserve Program (GRP)	Yes ☐	No ☐
Conservation easements	Yes ☐	No ☐

7) In the last 5 years have you carried out any of the following management practices on your ranching operation? ***Check all that apply.***

Rotational grazing ☐	Prescribed burning ☐	Reseeding ☐
Continuous, year-round grazing ☐	Mechanical brush removal ☐	Put in wildlife friendly fencing ☐
Low moisture supplements to distribute livestock, for example, Crystalyx ☐	Installed wildlife water development ☐	Used herd guard dog or other companion animal to deter predators ☐
Managed for sensitive plant or animal species (including threatened or endangered species) ☐	Holistic Resource Management, Savory grazing, or high intensity-short duration grazing ☐	Put in food plots (plant desirable plant species to distribute foraging) ☐
Grazed riparian areas for 30 to 40 days ☐	Put in erosion control structures ☐	Multiple species grazing ☐
Spring development ☐	Used a herder to manage livestock distribution ☐	Put in living fences ☐
Fenced stream banks or riparian areas ☐	Low-stress stock management ☐	Non-use of land (other than related to drought) ☐
Laid water pipeline ☐	Applied herbicides ☐	

8) In the last 5 years have you participated in or implemented any of the following business practices with your ranching operation? ***Check one for each program.***

Direct marketing of livestock products, for example, meat, wool, milk or cheese	Yes ☐	No ☐
Oil or gas leasing or extraction	Yes ☐	No ☐
Guiding services for hunting and fishing	Yes ☐	No ☐
Guiding services for bird watching and other types of wildlife viewing	Yes ☐	No ☐
Charged access fee for hunting, fishing, or wildlife viewing	Yes ☐	No ☐
Agri-tourism including rural tourism, such as a dude ranch	Yes ☐	No ☐
Received carbon off-set or carbon sequestration payments	Yes ☐	No ☐
Wind energy development	Yes ☐	No ☐
Geothermal energy development	Yes ☐	No ☐
Grass-fed or grass-finished beef, lamb, or goat	Yes ☐	No ☐
Certified organic beef, lamb, or goat	Yes ☐	No ☐
Bed & breakfast or other accommodations, for example, retreat facilities	Yes ☐	No ☐
Other (Please list.) _____ _____	Yes ☐	No ☐

9) **A person's decisions about whether to engage in new activities are usually based on many factors. We would like to know what influences <u>your</u> decision to <u>implement a new management tool or practice for your ranching operation.</u> Please indicate below to what degree each of the following factors influences your decision.** ***Circle one number for each factor.***

	Does Not Influence	Slightly Influences	Moderately Influences	Strongly Influences
Environmental benefits of the management practice	1	2	3	4
Potential for the management practice to benefit the local economy	1	2	3	4
Management practice will help reduce the spread of invasive weeds	1	2	3	4
Reliable scientific information exists to support the use of the management practice	1	2	3	4
Amount of time it takes for desired results from the management practice to be achieved	1	2	3	4
Amount of time desired results from the management practice will last	1	2	3	4
Impacts of the management practice on grazing capacity	1	2	3	4
Impacts of the management practice on wildlife habitat	1	2	3	4
Potential for direct financial gain from implementing the management practice	1	2	3	4

10) **In general, which of the following statements best describes your approach to engaging in new management practices or programs with your ranching operation?** ***Check one.***

I actively seek new management practices/programs beyond my local resources and I am willing to take financial risks to try these new practices/programs	☐
I seek new management practices/programs from my local resources and in general I am asked by members of the community for my opinion regarding new practices/programs	☐
I like to watch others and see how they do before adopting a new management practice/program, but I adopt before the average person	☐
Cautious, I adopt new management practices/programs after the majority of people have, generally due to economic necessity or increasing pressure from peers	☐
I tend to avoid new management practices/programs if possible, preferring to continue with what's worked in the past	☐

SECTION II: PERCEPTIONS AND MANAGEMENT OF CHEATGRASS (*Bromus tectorum*)

Cheatgrass (*Bromus tectorum*) is an invasive non-native annual grass that is causing problems in some regions of the West. In this section, we are interested in learning about your knowledge about and experiences with cheatgrass.

1) **The presence of cheatgrass and the degree to which it creates problems varies in different counties, regions, and states throughout the western United States. To what degree do you consider the presence of cheatgrass in your <u>county</u> a problem?** ***Circle one number.***

Not a Problem	Slight Problem	Moderate Problem	Extreme Problem
1	2	3	4

2) The following list contains some of the factors that may <u>contribute to the spread</u> of cheatgrass to new locations. For each of the following factors, please indicate to what degree you think it causes the spread of cheatgrass. ***Circle one number for each factor.***

	Not a Cause	A Minor Cause	A Moderate Cause	A Major Cause
Recreational activities, for example, hunting, hiking, etc.	1	2	3	4
Off-road vehicles, for example, OHVs or ATVs	1	2	3	4
Development activities, for example, equipment, roads, etc.	1	2	3	4
Livestock and wildlife movements	1	2	3	4
Wind or rain runoff	1	2	3	4
Crop or revegetation seed mixes contaminated with cheatgrass or feeding with contaminated hay	1	2	3	4

3) The following list contains some of the factors that may influence the <u>establishment and increase</u> of cheatgrass. For each of the following factors, please indicate to what degree you think it affects the successful establishment and growth of cheatgrass populations. ***Circle one number for each factor.***

	Not a Cause	A Minor Cause	A Moderate Cause	A Major Cause
Drought	1	2	3	4
Timing of rainfall or snow	1	2	3	4
Overgrazing by livestock or wildlife	1	2	3	4
Too little grazing by livestock or wildlife	1	2	3	4
Disturbance of soil or vegetation by development, for example, mineral extraction, residential development	1	2	3	4
Natural or prescribed fire	1	2	3	4
Fire suppression	1	2	3	4

4) Cheatgrass can affect the financial standing and environmental sustainability of a ranch in various ways. For each of the following <u>potential effects</u> of cheatgrass, please indicate how great a <u>concern</u> the plant is to you <u>personally</u>. ***Circle one number for each statement.***

	Not Concerned	Slightly Concerned	Moderately Concerned	Extremely Concerned
Causes loss of desirable plants	1	2	3	4
Reduces land value	1	2	3	4
Causes loss of wildlife habitat	1	2	3	4
Interferes with recreation	1	2	3	4
Increases fire frequency	1	2	3	4
Reduces livestock & wildlife forage	1	2	3	4
Reduces crop value	1	2	3	4
Increases soil erosion	1	2	3	4

5) In the following list of potential ecological and range management impacts of cheatgrass, please indicate which effects you have <u>personally experienced</u> on your ranching operation, and to <u>what degree.</u> ***Circle one number for each statement. If you have not experienced an impact, please select 'Have Not Experienced.'***

	Not a Problem	Slight Problem	Moderate Problem	Extreme Problem	Have Not Experienced
Loss of desirable plants for wildlife habitat	1	2	3	4	5
Loss of desirable plants for livestock forage	1	2	3	4	5
Forced alteration of management activities, for example, grazing duration	1	2	3	4	5
Reduced land value	1	2	3	4	5
Interfered with recreational activities, for example, hunting, hiking, etc.	1	2	3	4	5
Increased fire frequency	1	2	3	4	5
Reduced crop value	1	2	3	4	5
Increased soil erosion	1	2	3	4	5

6) Ranchers have tried a variety of management tools to try to eradicate cheatgrass or shift the dominance of cheatgrass infested areas to more native plants. Please indicate below how satisfied or dissatisfied you were with the results of the following management tools you have used to manage cheatgrass. ***Circle one number for each statement.***

	Completely Dissatisfied	Somewhat Dissatisfied	Somewhat Satisfied	Completely Satisfied	Have Not Tried
Prescribed fire	1	2	3	4	5
Application of an imazapic-based herbicide, for example, Plateau	1	2	3	4	5
Seeded a more desirable grass mix	1	2	3	4	5
Any combination of prescribed fire, herbicide application, or seeding	1	2	3	4	5
Increased stocking rate early in the spring to graze out cheatgrass	1	2	3	4	5
Shifted grazing to later in the fall or early winter to facilitate perennial plant growth	1	2	3	4	5
Other (Please list.) _____	1	2	3	4	5

7) **Ranchers may encounter constraints to managing cheatgrass on their ranching operation. In the following list, please indicate the constraints or barriers you have encountered to managing cheatgrass on your ranching operation.** ***Check Yes or No for each constraint.***

Lack of information about effective management tools to control cheatgrass	Yes ☐	No ☐
Cheatgrass is not a state listed noxious weed	Yes ☐	No ☐
Long-term treatment is not financially viable	Yes ☐	No ☐
Aerial application of herbicide by fixed wing aircraft is not allowed	Yes ☐	No ☐
Requirements associated with alternative grazing practices, for example, rotational grazing, are not feasible	Yes ☐	No ☐
Limited human resources/labor available	Yes ☐	No ☐
Other weeds are currently a higher priority to manage	Yes ☐	No ☐
Other (Please describe.) _____		

SECTION III: PERCEPTIONS AND USE OF STATE AND TRANSITION MODELS (STMs)

1) **The art and science of state and transition models have been developing for over a decade. Please circle the corresponding number for how familiar you were with the term or application of STMs prior to today.** ***Circle one number.***

I have never heard of STMs before today	I have heard about STMs, but I have not read or used one	I have read about STMs	I have used STMs
1	2	3	4

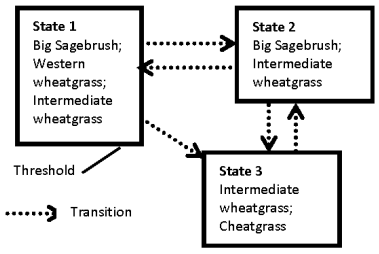


Figure 1. Example of a state and transition model diagram.

State and Transition Models (STMs) are a tool to visually display our current understanding of how specific types of land respond to different environmental events (such as drought and fire) and management practices (such as grazing, seeding, and shrub control). They can help managers identify the current ecological state of a specific piece of land and recognize the factors that could lead towards or away from the desired state for their management objectives. STMs can suggest potential indicators to use in measuring progress towards management objectives. They also provide a way to incorporate, organize, and share new knowledge gained through management experience or scientific studies. The USDA Natural Resources Conservation Service (NRCS) is the NRCS, BLM, and US Forest Service to assess and monitor rangelands.

PLEASE ANSWER THE FOLLOWING QUESTIONS TO THE BEST OF YOUR ABILITY.

2) **Based on what you know about STMs today, how might state and transition models help you reach your ecological/land condition objectives for your ranching operation? Please indicate to what degree you think each of the following would be a benefit of using STMs.** ***Circle one number for each potential benefit.***

	No Benefits	Slight Benefits	Moderate Benefits	Major Benefits	No Opinion
Better manage habitat for livestock and wildlife	1	2	3	4	5
Better manage nutrient needs for livestock and wildlife	1	2	3	4	5
Gain a better understanding of the ecological conditions and processes on my land	1	2	3	4	5
Increase plant species diversity	1	2	3	4	5
Shift plant community to a more desirable species composition	1	2	3	4	5
Retain soil or limit erosion potential	1	2	3	4	5
Other (Please list.) _____ _____	1	2	3	4	5

3) Land managers use STMs in different ways. In the following list of how land managers have used STMs, please indicate to what degree each description reflects your satisfaction with your use of STMs. ***If you have not tried to use STMs, please circle the number under 'Have Not Tried.' Circle one number for each statement.***

	Completely Dissatisfied	Dissatisfied	Satisfied	Completely Satisfied	Have Not Tried
Identify and assess the current state of my rangeland	1	2	3	4	5
Identify thresholds and how to avoid threats or seize opportunities to achieve or maintain a desired state	1	2	3	4	5
Assess or monitor the ecological condition of my rangeland	1	2	3	4	5
Develop a management plan	1	2	3	4	5
Identify management objectives	1	2	3	4	5
Identify potential actions to achieve my management objectives	1	2	3	4	5
Identify appropriate indicators to use in monitoring my rangeland	1	2	3	4	5
Evaluate the potential risks and benefits of specific management actions	1	2	3	4	5
Evaluate the feasibility or likely success of a potential management action	1	2	3	4	5
Understand how my rangeland came to be in its current state	1	2	3	4	5
Gain a better understanding of rangeland systems	1	2	3	4	5
Other (please specify) _____ _____	1	2	3	4	5

4) Based on what you know about STMs today, how might state and transition models help you reach your economic objectives for your ranching operation? ***Circle one number for each benefit.***

	No Benefits	Slight Benefits	Moderate Benefits	Major Benefits
Better manage habitat for livestock and wildlife	1	2	3	4
Better manage nutrient needs for livestock and wildlife	1	2	3	4
Increase livestock productivity	1	2	3	4
Increase pounds per acre of palatable forage	1	2	3	4
Increase pounds per acre of nutritious forage	1	2	3	4
Other (Please list.) _____ _____	1	2	3	4

5) **What would make state and transition models a more useful management tool for you?** ***Please provide a list or an explanation of how STMs could be made more useful.***

SECTION IV: INFORMATION NEEDS AND PREFERENCES

In this section, we are interested in learning where you get new information about cheatgrass and state and transition models. Additionally, we would like to know the types of information you want about these topics.

1) **Have you ever looked for information on cheatgrass management or state and transition models?** ***Check one number for each topic. If you answer 'no' for both, skip to question number 3.***

Cheatgrass management	Yes ☐	No ☐
State and transition models	Yes ☐	No ☐

2) **If you answered 'yes' to question number 1, what sources of information have you used?** ***Circle all that apply for both cheatgrass management and STMs or select 'Have Not Used this Source'.***

	Cheatgrass Management	State and Transition Models	Have Not Used this Source
County extension office or agent	1	2	3
Private companies or consultant	1	2	3
Local or regional trade magazine(s)	1	2	3
National trade magazine(s)	1	2	3
Scientific journal(s)	1	2	3
Environmental organization	1	2	3
Local or regional newspaper	1	2	3
County or city weed authority	1	2	3
Radio	1	2	3
State government agency, for example, State Forest Service, Wyoming Game & Fish or Colorado Division of Wildlife	1	2	3
Television	1	2	3
Federal government agency, for example, NRCS, USFS, BLM	1	2	3
Conferences	1	2	3
Internet websites	1	2	3
Advice from family, friends, and peers	1	2	3
Agricultural organizations, for example, Cattlemen's Association	1	2	3
Professional association, for example, Society for Range Management	1	2	3
Other (Please list.)_____ _____	1	2	3

3) **What information about cheatgrass management do you currently need or would you like to have?** ***Please select your top three choices.***

Herbicide safety	☐	Cheatgrass control options	☐
Herbicide effectiveness	☐	Proper use of control methods	☐
Livestock grazing strategies for cheatgrass control	☐	Getting started in the control of cheatgrass	☐
How cheatgrass spreads	☐	Biological controls	☐
When does it make economic sense to treat cheatgrass	☐	Groups and organizations dealing with cheatgrass management	☐
Time of year to treat cheatgrass	☐	Other (Please list.) _____ _____	☐

4) **What information about state and transition models do you currently need or would you like to have?** ***Please select your top three choices.***

Where to access STMs	☐	How to develop an ecological site description	☐
How to use STMs to meet my management objectives	☐	Where to find an existing ecological site description	☐
How to determine a threshold	☐	How are STMs developed	☐
How to use STMs to help make land management decisions	☐	What to do if there is no ecological site description for my type of land	☐
Benefits of using STMs over the more traditional range condition approach to rangeland assessment and monitoring	☐	Other (Please list.) _____ _____	☐

SECTION V: BACKGROUND

In this last section, we would like to know more about your ranching operation and your background. This information will only be used in making comparisons and will remain strictly confidential.

1) **Of your annual gross income, what percent comes from:** ***Write in your best estimate.***

Income from livestock _____ %

Income from crops _____ %

Income from wildlife _____ %

Income from other on-ranch sources (e.g. dude ranch) _____ %

Income from off-ranch sources _____ %

2) **What was the last year of school you completed?** ***Check one.***

Grade school	☐	
Some high school	☐	
Completed high school or GED	☐	
Some college or vocational/technical school	☐	
Completed 4 year college degree	☐	Major _____
Completed a graduate or professional degree (MS, PhD, MD, JD, DVM, etc.)	☐	Major _____

3) **When you are no longer operating your farm or ranch, which of the following best describes what you expect will happen to the operation?** ***Check one.***

It will be operated by my spouse	☐	It will be operated by individuals not involved with the current operation	☐
It will be operated by my children	☐	It will be converted to a non-farm use	☐
It will be operated by other relatives	☐	Don't know	☐
It will be operated by a non-relative who is currently involved with the ranch	☐		

4) **In which zip code area do you reside?** _____

5) **What is your gender?** ***Check one.***

Male ☐ Female ☐

6) **In which year were you born?** _____

7) **What is your approximate gross annual income?** ***Check one.***

Less than $19,999	☐	$80,000 - $199,999	☐	$800,000 - $999,999	☐
$20,000 - $49,999	☐	$200,000 - $499,999	☐	Between $1 million & $5 million	☐
$50,000 - $79,999	☐	$500,000 - $799,999	☐	Over $5 million	☐

Thank you for your help with this important study! Your participation is greatly appreciated. Please feel free to use the remaining space for any additional comments. If you are interested in receiving the survey results or participating in one of our workshops in your area, please check the appropriate box(s) below and provide your postal-mail address below. Thank you.

☐ Please send me a summary of the survey results when the study is complete.

☐ Please notify me of your workshops when they are in my area.

Please return your completed questionnaire in the enclosed envelope to:

CSU: WCNR Department FRWS
Attn. Windy Kelley
P.O. Box 150969,
Lakewood, CO 80215-096

Or

Phone: (970) 491-3889
Email: wkelley@rams.colostate.edu

Thank you for your time in completing this survey.
Your input is valuable and appreciated.
Thank you again.

Appendix K: Mail Survey – Natural Resource Professionals

Grazing and Rangeland Management: A Survey for Natural Resource Professionals

Photo courtesy of Emily Kachergis.

Colorado State University
Knowledge to Go Places

University of Wyoming
Cooperative Extension Service

Colorado State University
Extension

INTRODUCTION

This survey is about your knowledge, management practices, and information needs concerning cheatgrass (*Bromus tectorum*), an invasive non-native annual grass, and state and transition models, a decision-making tool for rangeland managers. Together with public and private partners in Colorado and Wyoming, Colorado State University is conducting two related research and extension projects that will result in new land management decision-making tools. Your survey responses will enable us to create useful tools and deliver them to land managers in ways they prefer. For some questions you may not have an opinion or any prior knowledge. Please let us know this. Also, feel free to make comments in the margins. Your comments are appreciated and will be read.

Your comments will be kept confidential. Survey results will be reported in summary form so that individual responses can not be identified. The identification number on the front cover of this survey is for record keeping purposes only. If you have any questions about your rights as a survey respondent, you may contact Janell Barker of the CSU Institutional Review Board at (970) 491-1655.

Please note, information collected from this survey will be used to inform research and extension projects. The intent of this survey is not to promote products, programs, or organizations.

Thank you in advance for your time and consideration in completing this survey. Your input will help us and our partners better serve all Wyoming and Colorado land managers into the future.

SECTION I: MANAGEMENT PRACTICES AND PROGRAMS

In the first section, we ask you a few questions to gain a better understanding of the nature of your position and responsibilities. Additionally, we are interested in learning about your grazing and land management practices and experience with new business practices.

1) **Which of the following best describes your position? If more than one selection applies, *check all that apply* and *circle the one that describes your primary responsibilities.***

Line officer ☐	Ranger program supervisor ☐	NEPA specialist/ID team leader ☐
Wildlife or fisheries biologist ☐	Soil scientist ☐	Weed specialist ☐
Hydrologist ☐	Ecologist/Botanist ☐	Other (Please specify.) _____ ☐
Range conservationist or specialist ☐	Monitoring specialist or coordinator ☐	_____ _____

2) **How many years have you worked with the agency/organization you work with now?** _____ years

3) **How many years have you been employed as a professional in a natural resource field?** _____ years

4) **In the last 5 years have you carried out any of the following management practices on your management area or units?** ***Check all that apply.***

Rotational grazing ☐	Prescribed burning ☐	Reseeding ☐
Continuous, year-round grazing ☐	Put in erosion control structures ☐	Put in wildlife friendly fencing ☐
Low moisture supplements to distribute livestock, for example, Crystalyx ☐	Installed wildlife water development ☐	Used herd guard dog or other companion animal to deter predators ☐
Managed for sensitive plant or animal species (including threatened or endangered species) ☐	Holistic Resource Management, Savory grazing, or high intensity-short duration grazing ☐	Put in food plots (plant desirable plant species to distribute foraging) ☐
Grazed riparian areas for 30 to 40 days ☐	Put in erosion control structures ☐	Multiple species grazing ☐
Spring development ☐	Used a herder to manage livestock distribution ☐	Put in living fences ☐
Fenced stream banks or riparian areas ☐	Low-stress stock management ☐	Non-use of land (other than related to drought) ☐
Laid water pipeline ☐	Applied herbicides ☐	

5) In the last 5 years have you allowed livestock permittees or leasees to conduct any of the following management practices on your management area or units? ***Check all that apply.***

Rotational grazing	☐	Prescribed burning	☐	Reseeding	☐
Continuous, year-round grazing	☐	Mechanical brush removal	☐	Put in wildlife friendly fencing	☐
Low moisture supplements to distribute livestock, for example, Crystalyx	☐	Installed wildlife water development	☐	Used herd guard dog or other companion animal to deter predators	☐
Managed for sensitive plant or animal species (including threatened or endangered species)	☐	Holistic Resource Management, Savory grazing, or high intensity-short duration grazing	☐	Put in food plots (plant desirable plant species to distribute foraging)	☐
Grazed riparian areas for 30 to 40 days	☐	Put in erosion control structures	☐	Multiple species grazing	☐
Spring development	☐	Used a herder to manage livestock distribution	☐	Put in living fences	☐
Fenced stream banks or riparian areas	☐	Low-stress stock management	☐	Non-use of land (other than related to drought)	☐
Laid water pipeline	☐	Applied herbicides	☐		

6) In the last 5 years have you allowed or implemented any of the following business practices on your management area or units? ***Check one for each program.***

Direct marketing of livestock products, for example, meat, wool, milk, or cheese	Yes ☐	No ☐
Oil or gas leasing or extraction	Yes ☐	No ☐
Guiding services for hunting and fishing	Yes ☐	No ☐
Guiding services for bird watching and other types of wildlife viewing	Yes ☐	No ☐
Charge access fee for hunting, fishing, or wildlife viewing	Yes ☐	No ☐
Agri-tourism including rural tourism, such as a dude ranch	Yes ☐	No ☐
Received carbon off-set or carbon sequestration payments	Yes ☐	No ☐
Wind energy development	Yes ☐	No ☐
Geothermal energy development	Yes ☐	No ☐
Grass-fed or grass-finished beef, lamb, or goat	Yes ☐	No ☐
Certified organic beef, lamb, or goat	Yes ☐	No ☐
Bed & breakfast or other accommodations, for example, retreat facilities	Yes ☐	No ☐
Other (Please list.) _____ _____	Yes ☐	No ☐

7) **A person's decisions about whether to engage in new activities are usually based on many factors. We would like to know what influences <u>your</u> decision to <u>implement a new management tool or practice for your management area or units.</u> Please indicate below to what degree each of the following factors influences your decision.** ***Circle one number for each factor.***

	Does Not Influence	Slightly Influences	Moderately Influences	Strongly Influences
Environmental benefits of the management practice	1	2	3	4
Potential for the management practice to benefit the local economy	1	2	3	4
Management practice will help reduce the spread of invasive weeds	1	2	3	4
Reliable scientific information to support the use of the management practice	1	2	3	4
Amount of time it takes for desired results from the management practice to be acheived	1	2	3	4
Amount of time desired results from the management practice will last	1	2	3	4
Impacts of the management practice on grazing capacity	1	2	3	4
Impacts of the management practice on wildlife habitat	1	2	3	4
Potential for direct financial gain from implementing the management practice	1	2	3	4

8) **In general, which of the following statements best describes your approach to engaging in new management practices or programs with your management area or units?** ***Check one.***

I actively seek new management practices/programs beyond my local resources and I am willing to take financial risks to try these new practices/programs	☐
I seek new management practices/programs from my local resources and in general I am asked by members of the community for my opinion regarding new practices/programs	☐
I like to watch others and see how they do before adopting a new management practice/program, but I adopt before the average person	☐
Cautious, I adopt new management practices/programs after the majority of people have, generally due to economic necessity or increasing pressure from peers	☐
I tend to avoid new management practices/programs if possible, preferring to continue with what's worked in the past	☐

SECTION II: PERCEPTIONS AND MANAGEMENT OF CHEATGRASS (*Bromus tectorum*)

Cheatgrass (*Bromus tectorum*) is an invasive non-native annual grass that is causing problems in some regions of the West. In this section, we are interested in learning about your knowledge about and experiences with cheatgrass.

1) **The presence of cheatgrass and the degree to which it creates problems varies in different counties, regions, and states throughout the western United States. To what degree do you consider the presence of cheatgrass in your <u>management area or units</u> a problem?** ***Circle one number.***

Not a Problem	Slight Problem	Moderate Problem	Extreme Problem
1	2	3	4

2) The following list contains some of the factors that may <u>contribute to the spread</u> of cheatgrass to new locations. For each of the following factors, please indicate to what degree you think it causes the spread of cheatgrass. ***Circle one number for each factor.***

	Not a Cause	A Minor Cause	A Moderate Cause	A Major Cause
Recreational activities, for example, hunting, hiking, etc.	1	2	3	4
Off-road vehicles, for example, OHVs, ATVs	1	2	3	4
Development activities, for example, equipment, roads, etc.	1	2	3	4
Livestock and wildlife movements	1	2	3	4
Wind or rain runoff	1	2	3	4
Crop or revegetation seed mixes contaminated with cheatgrass or feeding with contaminated hay	1	2	3	4

3) The following list contains some of the factors that influence the <u>establishment and increase</u> of cheatgrass. For each of the following factors, please indicate to what degree you think it affects the successful establishment and growth of cheatgrass populations. ***Circle one number for each factor.***

	Not a Cause	A Minor Cause	A Moderate Cause	A Major Cause
Drought	1	2	3	4
Timing of rainfall or snow	1	2	3	4
Overgrazing by livestock or wildlife	1	2	3	4
Too little grazing by livestock or wildlife	1	2	3	4
Disturbance of soil or vegetation by development, for example, mineral extraction, residential development	1	2	3	4
Natural or prescribed fire	1	2	3	4
Fire suppression	1	2	3	4

4) Cheatgrass can affect the financial standing and environmental sustainability of a management area or units in various ways. For each of the following <u>potential effects</u> of cheatgrass, please indicate how great a <u>concern</u> the plant is to your <u>agency</u>. ***Circle one number for each statement.***

	Not Concerned	Slightly Concerned	Moderately Concerned	Extremely Concerned
Causes loss of desirable plants	1	2	3	4
Reduces land value	1	2	3	4
Causes loss of wildlife habitat	1	2	3	4
Interferes with recreation	1	2	3	4
Increases fire frequency	1	2	3	4
Reduces livestock & wildlife forage	1	2	3	4
Reduces crop value	1	2	3	4
Increases soil erosion	1	2	3	4

5) **In the following list of potential ecological and range management impacts of cheatgrass, please indicate which effects you have experienced on your management area or units, and to what degree.** ***Circle one number for each statement. If you have not experienced an impact, please select 'Have Not Experienced.'***

	Not a Problem	Slight Problem	Moderate Problem	Extreme Problem	Have Not Experienced
Loss of desirable plants for wildlife habitat	1	2	3	4	5
Loss of desirable plants for livestock forage	1	2	3	4	5
Forced alteration of management activities, for example, grazing duration	1	2	3	4	5
Reduced land value	1	2	3	4	5
Interfered with recreational activities, for example, hunting, hiking, etc.	1	2	3	4	5
Increased fire frequency	1	2	3	4	5
Reduced crop value	1	2	3	4	5
Increased soil erosion	1	2	3	4	5

6) **Land managers have tried a variety of management tools to try to eradicate or shift the dominance of cheatgrass infested areas to more native plants. Please indicate below how satisfied or dissatisfied you were with the results of the following management tools you have used to manage cheatgrass.** ***Circle one number for each statement.***

	Completely Dissatisfied	Somewhat Dissatisfied	Somewhat Satisfied	Completely Satisfied	Have Not Tried
Prescribed fire	1	2	3	4	5
Application of an imazapic based herbicide, for example, Plateau	1	2	3	4	5
Seeded a more desirable grass mix	1	2	3	4	5
Any combination of prescribed fire, herbicide application, or seeding	1	2	3	4	5
Increased stocking rate early in the spring to graze out cheatgrass	1	2	3	4	5
Shifted grazing to later in the fall or early winter to facilitate perennial plant growth	1	2	3	4	5
Other (Please list.) _____	1	2	3	4	5

7) **Land managers may encounter constraints to managing cheatgrass on their management area or units. In the following list, please circle constraints or barriers you have encountered to managing cheatgrass.** ***Check yes or no for each constraint.***

Lack of information about effective management tools to control cheatgrass	Yes ☐	No ☐
Cheatgrass is not a state listed noxious weed	Yes ☐	No ☐
Long-term treatment is not financially viable	Yes ☐	No ☐
Aerial application of herbicide by fixed wing aircraft is not allowed	Yes ☐	No ☐
Requirements associated with alternative grazing practices, for example, rotational grazing, are not feasible	Yes ☐	No ☐
Limited human resources/labor available	Yes ☐	No ☐
Other weeds are currently a higher priority to manage	Yes ☐	No ☐

SECTION III: PERCEPTIONS AND USE OF STATE AND TRANSITION MODELS (STMs)

1) **The art and science of state and transition models have been developing for over a decade. The following are some of the ways STMs have been talked about and applied as a management tool. Please circle the corresponding number for how familiar you were with the term or application of STMs prior to today.** ***Circle one number.***

I have never heard of STMs before today	I have heard about STMs, but I have not read or used one	I have read about STMs	I have used STMs
1	2	3	4

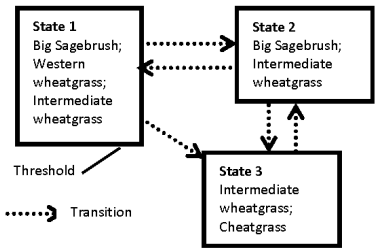


Figure 1. Example of a state and transition model diagram.

State and Transition Models (STMs) are a tool to visually display our current understanding of how specific types of land respond to different environmental events (such as drought and fire) and management practices (such as grazing, seeding, and shrub control). They can help managers identify the current ecological state of a specific piece of land and recognize the factors that could lead towards or away from the desired state for their management objectives. STMs can suggest potential indicators to use in measuring progress towards management objectives. They also provide a way to incorporate, organize, and share new knowledge gained through management experience or scientific studies. The USDA Natural Resources Conservation Service (NRCS) is the NRCS, BLM, and US Forest Service to assess and monitor rangelands.

PLEASE ANSWER THE FOLLOWING QUESTIONS TO THE BEST OF YOUR ABILITY.

2) **Based on what you know about STMs today, how might state and transition models help you reach your ecological/land condition objectives for your management area or units? Please indicate to what degree you think each of the following would be a benefit of using STMs.** ***Circle one number for each potential benefit.***

	No Benefits	Slight Benefits	Moderate Benefits	Major Benefits	No Opinion
Better manage habitat for livestock and wildlife	1	2	3	4	5
Better manage nutrient needs for livestock and wildlife	1	2	3	4	5
Gain a better understanding of the ecological conditions and processes on my management unit	1	2	3	4	5
Increase plant species diversity	1	2	3	4	5
Shift plant community to a more desirable species composition	1	2	3	4	5
Retain soil or limit erosion potential	1	2	3	4	5
Other (Please list.) _____ _____	1	2	3	4	5

3) Land managers use STMs in different ways. In the following list of how land managers have used STMs, please indicate to what degree each description reflects your satisfaction with your use of STMs. ***If you have not tried to use STMs, please circle the number under 'Have Not Tried.' Circle one number for each statement.***

	Completely Dissatisfied	Dissatisfied	Satisfied	Completely Satisfied	Have Not Tried
Identify and assess the current state of rangelands in my management area	1	2	3	4	5
Identify thresholds and how to avoid threats or seize opportunities to achieve or maintain a desired state	1	2	3	4	5
Assess or monitor the ecological condition of rangelands in my management area	1	2	3	4	5
Develop a management plan	1	2	3	4	5
Identify management objectives	1	2	3	4	5
Identify potential actions to achieve my management objectives	1	2	3	4	5
Identify appropriate indicators to use in monitoring rangelands	1	2	3	4	5
Evaluate the potential risks and benefits of specific management actions	1	2	3	4	5
Evaluate the feasibility or likely success of a potential management action	1	2	3	4	5
Understand how a specific rangeland area came to be in its current state	1	2	3	4	5
Gain a better understanding of rangeland systems	1	2	3	4	5
Other (please specify) _____ _____	1	2	3	4	5

4) Based on what you know about STMS today, what benefits might state and transition models have in helping you reach your economic objectives for your management area or units? ***Circle one number for each benefit.***

	No Benefits	Slight Benefits	Moderate Benefits	Major Benefits
Better manage habitat for livestock and wildlife	1	2	3	4
Better manage nutrient needs for livestock and wildlife	1	2	3	4
Increase livestock productivity	1	2	3	4
Increase pounds per acre of palatable forage	1	2	3	4
Increase pounds per acre of nutritious forage	1	2	3	4
Other (Please list.) _____ _____	1	2	3	4

5) **What would make state and transition models a more useful management tool for you?** ***Please provide a list and/or an explanation of how STMs could be made more useful.***

SECTION IV: INFORMATION NEEDS AND PREFERENCES

In this section, we are interested in learning where you get new information about cheatgrass and state and transition models. Additionally, we would like to know what type of information you want about these topics.

1) **Have you ever looked for information on cheatgrass management or state and transition models?** ***Check one number for each topic. If you answer 'no' for both, skip to question number 3.***

Cheatgrass management	Yes ☐	No ☐
State and Transition Models	Yes ☐	No ☐

2) **If you answered 'yes' to question number 1, what sources of information have you used?** ***Circle all that apply for both cheatgrass management and STMs or select 'Have Not Used this Source'.***

	Cheatgrass Management	State and Transition Models	Have Not Used this Source
County extension office or agent	1	2	3
Private companies or consultant	1	2	3
Local or regional trade magazine(s)	1	2	3
National trade magazine(s)	1	2	3
Scientific journal(s)	1	2	3
Environmental organization	1	2	3
Local or regional newspaper	1	2	3
County or city weed authority	1	2	3
Radio	1	2	3
State government agency, for example, State Forest Service, Wyoming Game & Fish or Colorado Division of Wildlife	1	2	3
Television	1	2	3
Federal government agency, for example, NRCS, USFS, BLM	1	2	3
Conferences	1	2	3
Internet websites	1	2	3
Advice from family, friends, and peers	1	2	3
Agricultural organizations, for example, Cattlemen's Association	1	2	3
Professional association, for example, Society for Range Management	1	2	3

Other (Please list.) _____

_____

3) **What information about cheatgrass management do you currently need or would you like to have?** ***Please select your top three choices.***

Herbicide safety	☐	Cheatgrass control options	☐
Herbicide effectiveness	☐	Proper use of control methods	☐
Livestock grazing strategies for cheatgrass control	☐	Getting started in the control of cheatgrass	☐
How cheatgrass spreads	☐	Biological controls	☐
When does it make economic sense to treat cheatgrass	☐	Groups and organizations dealing with cheatgrass management	☐
Time of year to treat cheatgrass	☐	Other (Please list.) _____ _____	☐

4) **What information about state and transition models do you currently need or would you like to have?** ***Please select your top three choices.***

Where to access STMs	☐	How to develop an ecological site description	☐
How to use STMs to meet my management objectives	☐	Where to find an existing ecological site description	☐
How to determine a threshold	☐	How are STMs developed	☐
How to use STMs to help make land management decisions	☐	What to do if there is no ecological site description, for my type of land	☐
Benefits of using STMs over the more traditional range condition approach to rangeland assessment and monitoring	☐	Other (Please list.) _____ _____ _____	☐

SECTION V: BACKGROUND

In this last section, we would like to know more about your background. This information will only be used in making comparisons and will remain strictly confidential.

1) **What was the last year of school you completed?** ***Check one.***

Grade school	☐	
Some high school	☐	
Completed high school or GED	☐	
Some college or tech school	☐	
Completed 4 year college degree	☐	Major _____
Completed a graduate or professional degree (MS, PhD, MD, JD, DVM, etc.)	☐	Major _____

2) **What is the name of the natural resource agency or organization where you work?** _____

3) **In which zip code area do you reside?** _____

4) **What is your gender?** ***Check one.***

Male ☐ Female ☐

5) **In which year were you born?** _____

Thank you for your help with this important study! Your participation is greatly appreciated. Please feel free to use the remaining space for any additional comments. If you are interested in receiving the survey results or participating in one of our workshops in your area, *please check the appropriate box(s) below and provide your postal-mail address below.* Thank you.

☐ Please send me a summary of the survey results when the study is complete.

☐ Please notify me of your workshops when they are in my area.

CSU: WCNR Department FRWS
Attn. Windy Kelley
P.O. Box 150969,
Lakewood, CO 80215-096

Or

Phone: (970) 491-3889
Email: wkelley@rams.colostate.edu

Thank you for your time in completing this survey.
Your input is valuable and appreciated.
Thank you again.

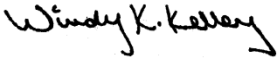
Appendix L: Follow-up Thank You and Reminder Postcard

Last week, a questionnaire about your knowledge, management practices, and information needs was mailed to you. This questionnaire is being sent to a sample of ranchers and land managers in Colorado and Wyoming with the intent to ensure your voice is heard in two research and extension projects which will both result in management decision making tools.

If you have already completed and returned the questionnaire to us, please accept our sincere thanks. If not, please do so as soon as possible. The success of this project depends on the willingness of people like you to respond. We are especially grateful for your help and believe your response will help us to develop useful rangeland management decisions making tools for all generations.

If you did not receive a questionnaire, or if it was misplaced, please call Windy Kelley at 970-491-3889 or email wkelley@rams.colostate.edu and we will get another one in the mail to you.

Sincerely,



Maria Fernandez-Gimenez, Ph.D.
Principal Investigator

Windy K. Kelley
Graduate Research Assistant

Appendix M: Replacement Survey Cover Letter

Colorado State University

Knowledge to Go Places

Department of Forest, Rangeland, & Watershed Stewardship
Fort Collins, Colorado 80523-1472 USA
Telephone (970) 491-6911
FAX (970) 491-6754
http://www.cnr.colostate.edu/frws/

September XX, 2009

Mr./Ms./Mrs. First Name Last Name
Mailing Address
City, State, Zip Code

Dear Mr./Ms./Mrs. Last Name,

About a month ago, we sent you a questionnaire that asked about your knowledge, management practices, and information needs about grazing and rangeland management. To the best of our knowledge, the questionnaire has not yet been returned.

We are writing again because of the importance of your questionnaire in assuring we get accurate results. Although we sent questionnaires to a large sample of ranchers throughout Colorado and Wyoming, it's only by hearing from everyone in the sample that we can be sure that the results are truly representative.

A few people have written or called to say they should not have received a questionnaire because they no longer own or manage rangelands in Colorado or Wyoming. If this situation applies to you, please let us know on the cover of the questionnaire and return it in the enclosed postage paid envelope, so that we can remove your name from the survey mailing list.

A comment on our survey procedures: We are partnering with the National Agricultural Statistics Services (NASS) to administer this survey. We provided them general guidelines for what type of operations (e.g., exclude feedlots) that we are interested in hearing from. They are the only ones that know who the survey was distributed to and they keep your contact information strictly confidential. The only information we will ever know is the identification number on the back cover of the questionnaire so that we have a way to organize our data. This number also helps NASS ensure individuals are removed from the contact list once the questionnaire is returned.

We hope that you will fill out and return the enclosed replacement questionnaire soon, but if for any reason you prefer not to answer it, please let us know by returning a note or the blank questionnaire cover in the enclosed stamped envelope.

Sincerely,

Maria Fernandez-Gimenez, Ph.D.
Principal Investigator
Colorado State University
(970) 491-0409
Maria.Fernandez-Gimenez@colostate.edu

Windy K. Kelley
Graduate Research Assistant
Colorado State University
(970) 491-3889
wkelley@rams.colostate.edu

Appendix N: Replacement Survey Cover Letter – Natural Resource Professionals

Colorado State University

Knowledge to Go Places

Department of Forest, Rangeland, & Watershed Stewardship
Fort Collins, Colorado 80523-1472 USA
Telephone (970) 491-6911
FAX (970) 491-6754
http://www.cnr.colostate.edu/frws/

September XX, 2009

Agency
Mr./Ms./Mrs. First Name Last Name
Mailing Address
City, State, Zip Code

Dear Mr./Ms./Mrs. Last Name,

About a month ago, we sent you a questionnaire that asked about your knowledge, management practices, and information needs about grazing and rangeland management. To the best of our knowledge, the questionnaire has not yet been returned.

We are writing again because of the importance of your questionnaire in assuring we get accurate results. Although we sent questionnaires to a large sample of land managers throughout Colorado and Wyoming, it's only by hearing from everyone in the sample that we can be sure that the results are truly representative.

A few people have written or called to say they should not have received a questionnaire because they are not responsible for monitoring, weed, rangeland, wildlife management, or extension activities in Colorado or Wyoming. If this situation applies to you, please let us know on the cover of the questionnaire and return it in the enclosed postage paid envelope, so that we can remove your name from the mailing list.

A comment on our survey procedures: We are partnering with the National Agricultural Statistics Services (NASS) to administer this survey. We provided them an extensive list of land managers throughout Wyoming and Colorado that we are interested in hearing from. They are the only ones that know who the survey was distributed to and they keep your contact information strictly confidential. The only information we will ever know is the identification number on the front cover of the questionnaire so that we have a way to organize our data. This number also helps NASS ensure individuals are removed from the contact list once the questionnaire is returned.

We hope that you will fill out and return the enclosed replacement questionnaire soon, but if for any reason you prefer not to answer it, please let us know by returning a note or the blank questionnaire cover in the enclosed stamped envelope.

Sincerely,

Maria Fernandez-Gimenez, Ph.D.
Principal Investigator
Colorado State University
(970) 491-0409

Windy K. Kelley
Graduate Research Assistant
Colorado State University
(970) 491-3889

Appendix O: Non-response Bias Script – Ranchers

For NASS Use:

ID #: _____

Section A ~ Introduction

Hello, my name is _____. I'm conducting a follow-up on a recent mail survey administered by Colorado State University, CSU Extension, and the University of Wyoming Extension.

1. About two months ago, a random sample of Wyoming and Colorado ranchers were mailed the survey asking questions about their knowledge, management practices, and information needs. Do you remember receiving the questionnaire?

□ **YES (Continue to 2)** □ **NO**

[If answer is "No"] It was sent in a large envelope. **[If respondent still says "no," check the mailing address we have for them. If that was incorrect, or respondents still maintains they did not receive a questionnaire, note "did not receive" – DNR – on data sheets.]** Thank you for your time.

2. According to our records, we did not receive a questionnaire back from you. **Move onto the next paragraph.**

3. Many of the land managers have returned their survey, but a part of any study is to provide an explanation for why some people did not return their survey. We need to know whether land managers who answered the survey differ in any significant way from land managers who didn't. Your responses will remain confidential and will only be associated with an identification number. If you can spare a few minutes, it would really help us if you could answer some quick questions. Do you have a few minutes to talk with me? □ **YES (Continue)** □ **NO**

[If answer is "no"] Thank you for your time. Have a {good day/evening}.

[If answer is "yes"] Thank you. To begin, a portion of the survey was about adoption of new management practices.

Section B ~ Operation

The first few questions will give us a better understanding of the nature of your ranching operation and your experience with new business practices.

1) **About how many private (deeded) acres of land do you have in your ranching operation? *Check one.***

Less than 100 acres	□	250 – 499 acres	□	1,000 – 4,999 acres	□
100 – 249 acres	□	500 - 999 acres	□	5,000 acres or more	□

2) **Approximately, what percentage of your ranching operation falls into each of the following categories?** ***Write in the estimated percent.***

Private (Deeded) _____%	State Lands _____%
U.S. Forest Service _____%	Bureau of Land Management (BLM) _____%

Other (Please specify.) _____%
_____

3) **What percent of your ranching operation's annual labor is supplied by the family?** _____ %

4) **About how many years have you managed this ranching operation?** _____ years

5) **In general, which of the following statements best describes your approach to engaging in new management practices or programs with your ranching operation?** ***Check one.***

Innovative:
[You seek new practices/programs beyond local resources AND you are willing to take financial risks.] ☐

Strongly Pro-active:
[You seek from local resources AND community members ask you for your opinion.] ☐

Pro-active:
[You watch others try new practices/programs AND see the results before adopting, BUT you adopt before the average person.] ☐

Cautiously Active:
[Generally, you adopt new practices/programs when necessary (i.e., economic necessity or pressure from peers.)] ☐

Observer:
[You avoid new practices/programs if possible and you prefer to continue with what has worked in the past.] ☐

Section C ~ Perceptions

The next question is about your perception of cheatgrass, a non-native annual grass.

1) **The presence of cheatgrass and the degree to which it creates problems varies in different counties, regions, and states throughout the western United States. To what degree do you consider the presence of cheatgrass in your county a problem?** ***Circle one number.***

Not a Problem	Slight Problem	Moderate Problem	Extreme Problem
1	2	3	4

The next question is about State and Transition Models. State and transition models are box and arrow diagrams that show how plant communities change with management, climate, or other disturbances.

2) The art and science of state and transition models have been developing for over a decade. Please indicate which of the following best describes your familiarity with the term and application of STMs. ***Circle one number.***

I have never heard of STMs before today	I have heard about STMs, but I have not read or used one	I have read about STMs	I have used STMs
1	2	3	4

SURVEY CONTINUES … GO TO NEXT PAGE

The next set of questions is about where you prefer to get new information about cheatgrass and state and transition models.

3) **Have you ever looked for information on cheatgrass management? *Check one.***

Cheatgrass management Yes ☐ No ☐

a. **[If respondent answers, yes, ask] Next, I am going to read a list of information sources. Please tell me when I say each source whether you have used it to find information about cheatgrass.**

County extension office or agent	Agricultural organizations, for example, Cattlemen's Association
Private companies or consultant	Federal government agency(s), for example, Conservation Services, USFS, BLM
Local or regional trade magazine(s)	Conferences
National trade magazine(s)	Internet websites
Scientific journal(s)	Advice from family, friends, and peers
Environmental organization	State government agency(s), for example, State Forest Service, Wyoming Game & Fish or Colorado Division of Wildlife
Local or regional newspaper(s)	Television
County or city weed authority	Professional association, for example, Society for Range Management
Radio	

SURVEY CONTINUES … GO TO NEXT PAGE

4) Have you ever looked for information on state and transition models? ***Check one.***

State and Transition Models Yes ☐ No ☐

a. **[If respondent answers, yes, ask]** Next, I am going to read a list of information sources. Please tell me when I read each source whether you have used it to find information about state and transition models.

County extension office or agent	Agricultural organizations, for example, Cattlemen's Association
Private companies or consultant	Federal government agency(s), for example, Conservation Services, USFS, BLM
Local or regional trade magazine(s)	Conferences
National trade magazine(s)	Internet websites
Scientific journal(s)	Advice from family, friends, and peers
Environmental organization	State government agency(s), for example, State Forest Service, Wyoming Game & Fish or Colorado Division of Wildlife
Local or regional newspaper(s)	Television
County or city weed authority	Professional association, for example, Society for Range Management
Radio	

Section D ~ Demographics

The following are the last set of questions I will ask you. This information will only be used in making comparisons and will remain strictly confidential.

1) What was the last year of school you completed? ***Check one.***

Grade school	☐	
Some high school	☐	
Completed high school or GED	☐	
Some college or tech school	☐	
Completed 4 year college degree	☐	Major _____
Completed a graduate or professional degree (MS, PhD, MD, JD, DVM, etc.)	☐	Major _____

2) When you are no longer operating your farm or ranch, which of the following best describes what you expect will happen to the operation? *Check one.*

It will be operated by my spouse	☐	It will be operated by individuals not involved with the current operation	☐
It will be operated by my children	☐	It will be converted to a non-farm use	☐
It will be operated by other relatives	☐	Don't know	☐
It will be operated by a non-relative who is currently involved with the ranch	☐		

3) In which zip code area do you reside? _____

4) What is your gender? *Check one.*

Male ☐ Female ☐

5) In which year were you born? _____

6) What is your approximate gross annual income? *Check one.*

Less than $19,999	☐	$80,000 - $199,999	☐	$800,000 - $999,999	☐
$20,000 - $49,999	☐	$200,000 - $499,999	☐	Between $1 million & $5 million	☐
$50,000 - $79,999	☐	$500,000 - $799,999	☐	Over $5 million	☐

Thank you for your help with this important study. Your participation is greatly appreciated. Are you interested in receiving the results or participating in one of the project's workshops in your area? *If yes, confirm the spelling of their first and last name and their mailing address.*

In the future, if you have any questions regarding this research please do not hesitate to call the Graduate Research Assistant for this project, Windy Kelley at (970) 491-3889. You can also contact the Principal Investigator for the study, Dr. Maria Fernandez-Gimenez at (970) 491-0409.

Thank you again for your time. Have a good {day/evening}.

Appendix P: Non-Response Bias Script: Natural Resource Professionals

For NASS Use:

ID #: _____

Section A ~ Introduction

Hello, my name is _____. I'm conducting a follow-up on a recent mail survey administered by Colorado State University, CSU Extension, and the University of Wyoming Extension.

1. About two months ago, a random sample of Wyoming and Colorado land managers were mailed the survey asking questions about their knowledge, management practices, and information needs. Do you remember receiving the questionnaire?
□ **YES (Continue to 2)** □ **NO**

[If answer is "No"] It was sent in a large envelope. **[If respondent still says "no," check the mailing address we have for them. If that was incorrect, or respondents still maintains they did not receive a questionnaire, note "did not receive" – DNR – on data sheets.]** Thank you for your time.

2. According to our records, we did not receive a questionnaire back from you. **Move onto the next paragraph.**

3. Many of the land managers have returned their survey, but a part of any study is to provide an explanation for why some people did not return their survey. We need to know whether land managers who answered the survey differ in any significant way from land managers who didn't. Your responses will remain confidential and will only be associated with an identification number. If you can spare a few minutes, it would really help us if you could answer some quick questions. Do you have a few minutes to talk with me? □ **YES (Continue)** □ **NO**

[If answer is "no"] Thank you for your time. Have a {good day/evening}.

[If answer is "yes"] Thank you. To begin, a portion of the survey was about adoption of new management practices.

Section B ~ Position

The first few questions will give us a better understanding of the nature of your position and responsibilities and your experience with new management practices.

6) **Which of the following best describes your position? If more than one selection applies, indicate all that apply and tell us which one describes your primary responsibilities.** ***Check all that apply and circle the one that describes their primary responsibilities.***

Line Officer	☐	Ranger program supervisor	☐	NEPA specialist/ID team leader	☐
Wildlife or fisheries biologist	☐	Soil scientist	☐	Weed specialist	☐
Hydrologist	☐	Ecologist/Botanist	☐	Other (Please specify.)	☐
Range conservationist or specialist	☐	Monitoring specialist or coordinator	☐		

7) How many years have you worked with the agency/organization you work with now? _____ years

8) How many years have you been employed as a professional in a natural resource field? _____ years

9) In general, which of the following statements best describes your approach to engaging in new management practices or programs? ***Check one.***

Innovative: [You seek new practices/programs beyond local resources AND you are willing to take financial risks.]	☐
Strongly Pro-active: [You seek from local resources AND community members ask you for your opinion.]	☐
Pro-active: [You watch others try new practices/programs AND see the results before adopting, BUT you adopt before the average person.]	☐
Cautiously Active: [Generally, you adopt new practices/programs when necessary (i.e., economic necessity or pressure from peers.)]	☐
Observer: [You avoid new practices/programs if possible and you prefer to continue with what has worked in the past.]	☐

Section C ~ Perceptions

The next question is about your perceptions of cheatgrass, a non-native annual grass.

3) The presence of cheatgrass and the degree to which it creates problems varies in different counties, regions, and states throughout the western United States. To what degree do you consider the presence of cheatgrass in your management area or units a problem? ***Circle one number.***

Not a Problem	Slight Problem	Moderate Problem	Extreme Problem
1	2	3	4

The next question is about State and Transition Models. State and transition models are box and arrow diagrams that show how plant communities change with management, climate or other disturbances.

4) The art and science of state and transition models have been developing for over a decade. Please indicate which of the following best describes your familiarity with State and Transition Models and their application. ***Circle one number.***

I have never heard of STMs before today	I have heard about STMs, but I have not read or used one	I have read about STMs	I have used STMs
1	2	3	4

SURVEY CONTINUES … GO TO NEXT PAGE

The next set of questions is about where you prefer to get new information about cheatgrass and state and transition models.

3) **Have you ever looked for information on cheatgrass management? *Check one.***

Cheatgrass management Yes ☐ No ☐

a. [If respondent answers, yes, ask] Next, I am going to read a list of information sources. Please tell me when I say each source whether you have used it to find information about cheatgrass.

County extension office or agent	**Agricultural organizations, for example, Cattlemen's Association**
Private companies or consultant	**Federal government agency(s), for example, Conser**vation Services, USFS, BLM
Local or regional trade magazine(s)	Conferences
National trade magazine(s)	Internet websites
Scientific journal(s)	Advice from family, friends, and peers
Environmental organization	State government agency(s), for example, State Forest Service, Wyoming Game & Fish or Colorado Division of Wildlife
Local or regional newspaper(s)	Television
County or city weed authority	Professional association, for example, Society for Range Management
Radio	

SURVEY CONTINUES … GO TO NEXT PAGE

4) Have you ever looked for information on state and transition models? *Check one.*

State and Transition Models Yes ☐ No ☐

a. [If respondent answers, yes, ask] Next, I am going to read a list of information sources. Please tell me when I say each source whether you have used it to find information about state and transition models.

County extension office or agent	Agricultural organizations, for example, Cattlemen's Association
Private companies or consultant	Federal government agency(s), for example, Conservation Services, USFS, BLM
Local or regional trade magazine(s)	Conferences
National trade magazine(s)	Internet websites
Scientific journal(s)	Advice from family, friends, and peers
Environmental organization	State government agency(s), for example, State Forest Service, Wyoming Game & Fish or Colorado Division of Wildlife
Local or regional newspaper(s)	Television
County or city weed authority	Professional association, for example, Society for Range Management
Radio	

Section D ~ Demographics

The following are the last set of questions I will ask you. This information will only be used in making comparisons and will remain strictly confidential.

7) What was the last year of school you completed? *Check one.*

Grade school	☐	
Some high school	☐	
Completed high school or GED	☐	
Some college or tech school	☐	
Completed 4 year college degree	☐	Major _____
Completed a graduate or professional degree (MS, PhD, MD, JD, DVM, etc.)	☐	Major _____

8) What is the name of the natural resource agency or organization where you work?

_____

9) In which zip code area do you reside? _____

10) What is your gender? *Check one.*

Male ☐ Female ☐

11) In which year were you born? _____

Thank you for your help with this important study. Your participation is greatly appreciated. Are you interested in receiving the results or participating in one of the project's workshops in your area? *If yes, confirm the spelling of their first and last name and their mailing address.*

In the future, if you have any questions regarding this research please do not hesitate to call the Graduate Research Assistant for this project, Windy Kelley at (970) 491-3889. You can also contact the Principal Investigator for the study, Dr. Maria Fernandez-Gimenez at (970) 491-0409.

Thank you again for your time. Have a good {day/evening}.