Bridging natural resource communication boundaries: Public perceptions of smoke from wildland fires and forest managers' perspectives of climate change science

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Authorization to Submit Dissertation

This dissertation of Jarod J. Blades, submitted for the degree of Doctor of Philosophy with a major in Natural Resources and titled BRIDGING NATURAL RESOURCE COMMUNICATION BOUNDARIES: PUBLIC PERCEPTIONS OF SMOKE FROM WILDLAND FIRES AND MANAGER PERSPECTIVES OF CLIMATE CHANGE SCIENCE has been reviewed in final form. Permission, as indicated by the signatures and dates given below, is now granted to submit final copies to the College of Graduate Studies for approval.

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Abstract

Land managers of the northern Rocky Mountains and south-central U.S. are challenged with numerous social and ecological changes, many of which are linked to climate change. The work presented here focuses on two important research gaps: 1) managers do not understand public opinions toward smoke from prescribed fires (a necessary forest management tool) or the factors that underlie public tolerance of smoke, and 2) managers lack specific information about anticipated local climate change effects and are unable to mitigate for them. This dissertation addresses this disconnect between the current needs of land managers and the supply of scientific information related to these topics.

The studies pertaining to public tolerance of smoke integrated components from the value-belief-norm theory, protection motivation theory, and conjoint analysis to explore the relationships between personal value orientations, beliefs about the outcomes of prescribed fire, actions that could mitigate personal impacts from smoke, contextual factors, and overall tolerance of smoke. Our regional survey findings suggest that, overall, the public is generally tolerant of smoke, though tolerance is influenced by beliefs about the benefits of Rx fire, agency trust, risk perceptions, and previous health impacts. The origin of the fire, level of advanced warning, and smoke duration also influenced tolerance.

Boundary organization and object theory served as the foundation for facilitating the transfer of climate change research and knowledge between academic researchers and resource managers. We conducted four workshops in the U.S. northern Rocky Mountains and applied multiple methods of inquiry (pre- and post-workshop interviews and questionnaires) to understand how workshops and climate science were perceived as useful and credible. We found that intention to use climate change science in forest management was positively predicted by usefulness, credibility, and organizational barriers. We discuss the importance of uncertainty, visualization, and best practices for effective boundary objects and organizations.

These studies contribute to understanding public perceptions and tolerance of smoke from forest fires, and provide a better understanding of how boundary organizations and objects are effective for communicating climate change science. Further, these studies demonstrate how multiple theoretical and methodological frameworks can be used in research to produce actionable outcomes.

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I would like to acknowledge the amazing group of faculty and students that represent the the National Science Foundation Integrative Graduate Education and Research Traineeship Program (IGERT) at the University of Idaho. This program is the reason I returned to graduate school and it has provided an exceptional learning experience. Thank you, Nilsa Bosque-Perez, project director, and Penny Morgan, my Northern Rockies team leader, for keeping our ship on course. I wish to thank Zion Klos and Kerry Kemp, my student team members, for sharing your friendship and professional growth with me. I truly believe we were able to maximize this interdisciplinary experience together and I will never forget it.

My thanks is due to Joint Fire Science Program for providing funding, and to the U.S. Forest Service, Bureau of Land Management, and multiple other agencies and stakeholder groups for providing personnel, participation, and other assistance for this research. Many people in the CSS Department contributed to my work and mental wellbeing, and I would particularly like to thank Ed, Nick, Julie, Chad, Spencer, Tessa, Melissa, Jesse, and Drew.

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Dedication

I dedicate this work to my parents, family, and especially to my beloved wife, Carissa, and two boys, Decker and Marshall

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Chapter I. General Introduction

The conifer forests of the northern Rocky Mountains and south-central U.S. are home to significant biodiversity and water resources, as well as diverse human communities and land uses, all of which are influenced by complex human and non-human factors. These regions are currently experiencing rapid and widespread social and ecological changes, many of which are interacting with climate change, subsequently resulting in compounded impacts that have not been experienced in the past. Climate change represents one of the greatest challenges to land management and society, as climatic shifts show potential to exceed the ability of many ecosystems to adapt naturally (Griesbauer, Green, & O'Neill, 2011). These regions are experiencing more high degree-days and prolonged droughts (Intergovernmental Panel on Climate Change, 2007), which are driving changes in water availability, increased drought stress to forests, susceptibility of forests to increased tree mortality, and increases in the number of large wildfires and smoke (Karl, Melillo, & Peterson, 2009; van Mantgem et al., 2009; Westerling, Hidalgo, Cayan, & Swetnam, 2006). Social changes have included transitioning community types from historically commodity-based (e.g., logging, ranching, and agriculture) towards amenity-based economies (Winkler, Field, Luloff, Krannich, & Williams, 2007). Both regions have experienced greater amenity-driven population and housing growth than other parts of the U.S., combined with greater population redistribution into the Wildland Urban Interface (WUI) (Hammer, Stewart, & Radeloff, 2009).

Land managers are tasked with addressing these complex social-ecological issues surrounding forest and fire management in the midst of continually changing land management priorities and regulatory restrictions. Nearly 10 years ago, there was a call for revising forest and wildfire management policy to promote a larger spectrum of active forest treatment strategies to mitigate wildfire risk by reducing fuels in the WUI and restoring historical fire behavior in wildlands

(Dombeck, Williams, & Wood, 2004). To that end, approximately 30 million acres of forest have been treated in the western U.S. since 2001 to reduce fuels and fire hazard on federal lands, with additional treatments on private and state lands (NWCG, 2009; Schoennagel, Veblen, & Romme, 2004).

Whereas land managers face many challenges, my research focuses on two crucial areas of concern with respect to wildland fires and relationships of climate change for both fire and water resources in these forests: 1) managers do not understand the diverse public opinions toward smoke from prescribed fires (a necessary forest management tool that is increasing in use) or the factors that underlie public tolerance of smoke, and 2) managers lack specific information about anticipated local climate change effects and are therefore unable to communicate effectively with the public about anticipated climate change impacts. Thus, a substantial disconnect remains between the current supply of scientific information related to local-scale climate change impacts, public tolerance of smoke from prescribed fires, and the information needs of managers in order to address these topics. This dissertation contains three manuscripts from research funded by two different sources.

Organization of Chapters

The manuscripts presented in Chapters II, III, and IV were designed to address the research gaps noted above. Chapters II and III were parter of a larger project funded by the Joint Fire Science Program (2010-1.3: 10-1-03-2) to answer the research question: How do cognitive factors and personal characteristics influence public tolerance of smoke and support for prescribed fire management activities? Chapter II was written as a framework for two manuscripts; the first will describe and compare public tolerance of smoke, level of smoke experience, perceptions of fire and smoke consequences, perceived vulnerability to smoke impacts, trust in fire managers, personal value orientations, and individual sociodemographic characteristics between urban and rural communities, communities that vary in their level of preparedness for forest fires, and region. The second paper will explore how overall tolerance of smoke and prescribed fire management support differ as a function of these variables. The target journal for these papers will be *Society and Natural Resources*.

Chapter III builds off of Chapter II and describes the conjoint approach we used to "decompose" selected contextual factors (i.e., fire origin, smoke duration, health impacts, and type of advanced warning) that may influence public tolerance of smoke from wildland and prescribed fires. It compares these findings to traditional approaches to understanding attitudes that ask respondents to rate each factor independently. The target journal for this paper will be the *International Journal of Wildland Fire*.

Chapter IV represents a co-authored manuscript that was written by the northern Rockies interdisciplinary research team. I participated in the Integrative Graduate Education and Research Traineeship (IGERT), which is an interdisciplinary doctoral research and education program funded by the National Science Foundation. The goal of this program is to "catalyze a cultural change in graduate education" through "collaborative research that transcends traditional disciplinary boundaries"(National Science Foundation, 2013). My participation in the program involved a broad-based interdisciplinary education, gaining experience in integrating interdisciplinary knowledge, and an opportunity to work in an interdisciplinary faculty/student research team. Funding for this work was also provided by the Joint Fire Science Program's Graduate Research Innovation (GRIN) Award.

As an interdisciplinary group of graduate students and faculty from the University of Idaho's College of Natural Resources, we aimed to find a climate change problem that addressed issues of social-ecological systems resilience and integrated our team disciplines of social psychology, forest ecology, and physical hydrology. Our northern Rockies team, composed of three PhD students (eventually four), was initially given a broad problem-focus area related to natural resource issues in Idaho and western Montana, such as increases in large-scale forest fires, increased rates of forest mortality, changes in winter snowpack and water availability, and changes in regional social dynamics. Eventually, we found common ground in our interests of science communication, biophysical climate change impacts, and adaptation-based land management. Focusing on applied aspects, we identified as a problem the general lack of understanding of climate change information among community leaders and land managers. We felt we could help bridge the gap between the research and land management worlds. Chapter IV describes how we drew upon multiple theoretical frameworks to evaluate the effectiveness of interactive climate change workshops and modeling tools for influencing participants' beliefs about climate change science credibility, salience, and legitimacy, as well as intention to use climate change science in management decisions. The target journal for Chapter IV will be *Science Communication*.

Chapter V discusses the overall conclusions from the entire body of work. Consideration is also given to limitations that existed for each of the chapters and an overall description of trustworthiness, validity, and reliability as it pertains to these chapters. Lastly, I discuss future research avenues that could be pursued in light of the work presented here.

Ethical Considerations

We ensured participant confidentiality through multiple steps to protect human subjects. I completed the National Institutes of Health online training and received the Protecting Human Subjects certificate. The University of Idaho Institutional Review Board (IRB) reviewed and approved each study (Appendix A). Participant names and contact information were kept confidential in a password protected file on my computer. Participant information was coded into a non-descript number system that allowed for retrieval of contact information when necessary.

Returned surveys and interview notes were kept in a secure location. All correspondence with study participants clearly explained confidentiality. No actual names or detailed descriptions of participants were used in any written or verbal communications concerning this study.

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Chapter II. USING AN EXPANDED RISK PERCEPTION THEORY TO PREDICT PUBLIC TOLERANCE OF SMOKE FROM FOREST FIRES

Introduction

Smoke from forest fires can limit forest management actions because of down-wind impacts. Public controversy can result from the vast distances smoke disperses over residential, work, recreation, and transportation areas. Pyne, Andrews, and Laven (1996) aptly describe why fires burning in one region can result in smoke becoming an issue across county, state, and national lines: "no other aspect of fire carries its effects so far from the site, no other is so visible to the public or threatens public health, no other is subject to such regulation by outside agencies, and no other so threatens to compromise programs of routine prescribed fire" (p. 554). Forest managers and officials need to understand the diverse public opinions toward smoke from forest fires; however, very limited research has been conducted specifically on this topic. Hence, forest and fire managers are largely uncertain about society's willingness to tolerate smoke in the short-term from prescribed fires in order to obtain long-term benefits, such as future community protection from large fires (Potter, Rorig, Strand, Goodrick, & Olson, 2007).

Our study, funded by the Joint Fire Science Program in the United States, integrated components from the value-belief-norm theory (Stern, 2000) and protection motivation theory (Rogers & Prentice-Dunn, 1997) to answer the research question: How do cognitive factors and personal characteristics influence public tolerance of smoke and support for prescribed (Rx) fire management activities? Results may provide land managers, fire professionals, community leaders, and policy makers who set air quality standards for prescribed burning with a clearer framework to develop more effective public communication strategies that align with local and regional perspectives.

This chapter was written as a framework for two manuscripts, one that describes and compares the two study regions and communities with regards to their level of preparedness for fire, type (urban or rural), smoke experience, perceptions of fire and smoke consequences, perceived vulnerability to impacts, trust in fire managers, individual characteristics, and overall tolerance of smoke. The second manuscript will describe how path analytic models were used to explore tolerance of smoke and management support as a direct function of beliefs and individual characteristics, and indirectly as a function of personal value orientations and agency trust. The justification and findings of both papers are integrated in the single chapter, which will serve as the final report to the funding agency.

A Perfect Storm: Population Growth, Land Management, and Air Quality Regulation

Historically, smoke as an air pollutant has been understood as an unavoidable consequence of naturally ignited fires or the result of necessary human actions; humans on every continent have carried out burning that resulted in smoke (Riebau & Fox, 2010). In recent times, smoke has continued to be an occasional but expected reality of living in parts of the U.S. – whether from burning agricultural fields, wildfires, understory burning, or winter inversions that trap smoke from the burning of wood for home heating, vehicle exhaust, and other air pollutants in valley bottoms. However, increases in wildfire activity, coupled with changing social dynamics, are resulting in different and greater societal impacts than in the past (NRDC, 2013). Smoke can create short and long-term health problems, notably for smoke-sensitive populations, including children, the elderly, and those with existing health conditions (Environmental Protection Agency, 2008; Molina & Molina, 2004). In terms of health care costs, it was estimated for one California fire that the average cost of illness was $9.50 per exposed person per day (Richardson, Champ, & Loomis, 2012), and each person was willing to pay on average $84.42 to avoid smoke exposure symptoms for a day. Smoke also affects public transportation and causes numerous accidents every year (Sandberg, Ottmar, Peterson, & Core, 2002). Increased development within the wildland–urban interface (WUI) has exacerbated smoke impacts (Hammer, Stewart, & Radeloff, 2009; United States Forest Service, 2001). Clearly, there are many ways that smoke from fires can adversely affect residents at individual, community, and regional levels.

Land and fire managers are tasked with addressing these complex social-ecological issues surrounding smoke management in the midst of continually changing land management priorities and regulatory restrictions (Haines, Busby, & Cleaves, 2001). Air quality regulations began tightening during a time when forest fuel reduction and Rx burning were increasing as management tools (Riebau & Fox, 2001), and this tension persists. Based on updated research on health impacts from fine particulates, the 2006 revision of the National Ambient Air Quality Standards (NAAQS) lowered the 24-hour standard for fine particulate matter ($PM_{2.5}$ are tiny particles or droplets in the air that are 2.5 microns or less in width) from 65 to 35 µg m^3. In the spring of 2013, the primary annual arithmetic mean for $PM_{2.5}$ was again lowered from 15 µg m^3 to 12 µg m^3 to reflect the latest studies. The primary standard is intended to protect human health. The NAAQS for ozone, which is part of smoke emissions, may also be reduced in the near future (Riebau & Fox, 2010). Lowering the NAAQS standards creates new nonattainment areas (especially near national forests, parks and wildlife refuges), increased challenges for conducting Rx fires, leads ti more instances of air quality violations, and causes greater administrative and planning workloads for wildand fire management agencies (Environmental Protection Agency, 2013; Riebau & Fox, 2010). Land and fire managers face considerable challenges in meeting forest health and air quality standards concurrently.

Theoretical Framework and Hypotheses

Responding to calls for more comprehensive models (Absher & Vaske, 2007), this study drew on a range of theoretical frameworks and empirical findings to develop a model of public tolerance for smoke (Figure 1). The primary foundation is a family of theories of attitude structure and function, which posit that specific attitudes (e.g., tolerance of smoke) are influenced by general attitudes and value orientations (Dietz, Fitzgerald, & Shwom, 2005; Rohan, 2000; Stern, 2000), as explained below. We approached public tolerance of smoke through the integration of several concepts: 1) forest values and beliefs about the benefits of prescribed burning (from value-belief-norm theory), 2) self-protection and perceptions of threat and coping (from protection motivation theory), 3) trust in land and fire managers, and 4) individual characteristics (e.g., knowledge, past experience with smoke, preparedness, and sociodemographic characteristics).

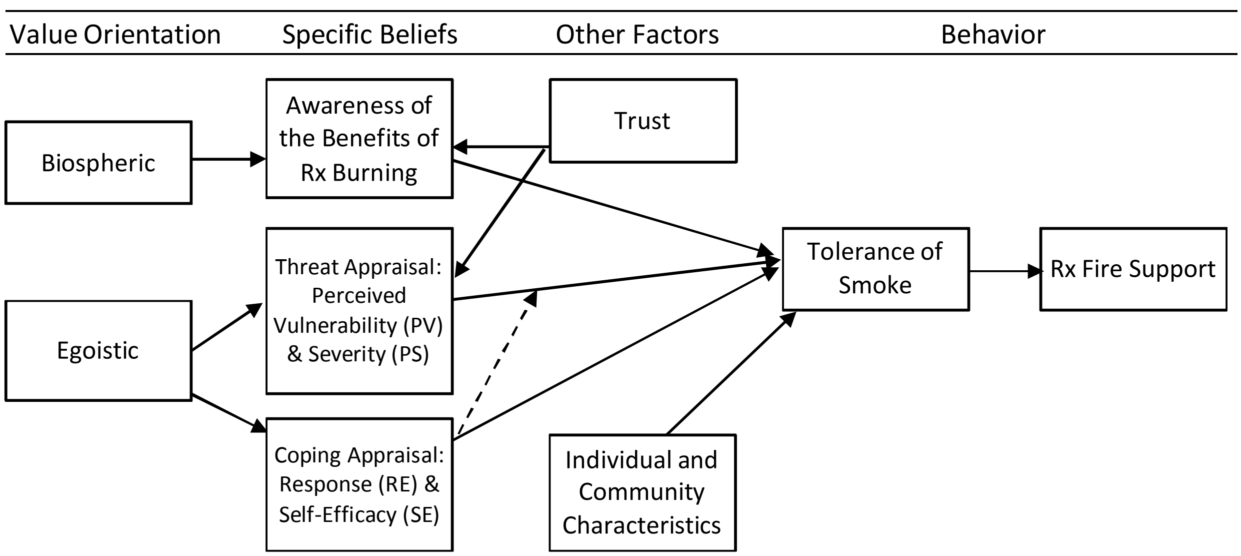

Figure 1. Conceptual framework of respondent tolerance of smoke and support for Rx fire. The dashed line indicates a moderating effect.

Value orientations have been the foundation of many theories in psychology, such as work by Rokeach (e.g., 1973) and Schwartz (1992, 1994). Although the definition and measurement of values have been extensively researched and debated, two primary values were used in this study as antecedents of environmental concern: egoistic personal values and biospheric forest values (De Groot & Steg, 2007; Stern, Dietz, & Guagnano, 1995; Stern, 2000). For this study, we were interested in the relationship between personal values and specific beliefs about Rx fire and smoke.

The value-belief-norm theory (VBN) suggests that personal value orientations are fundamental to understanding and predicting behaviors, such as tolerance of smoke and support for prescribed fire management (Stern, 2000). People with biospheric values focus more on the interests of non-human species and the biosphere (De Groot & Steg, 2007). For fire and smoke management, biospheric value considerations often relate to the potential impact of fire and smoke on biophysical or ecological aspects of the forest, such as forest health and wildlife habitat. Conversely, people operating from egoistic value orientations try to maximize personal outcomes (De Groot & Steg, 2007). For this study, maximizing personal outcomes meant considering the impacts of smoke on personal health, property, aesthetics, recreation, traffic, and lifestyle. The effect of these value orientations on tolerance is indirect, being mediated by specific beliefs about the impact of some outcome (e.g., smoke) on objects of value.

The protection motivation theory (PMT; Rogers & Prentice-Dunn, 1997) suggests that an individual's decision to act in response to a threat (e.g., smoke) results from considering the likelihood and severity of the risk (i.e., perceived vulnerability, PV, and perceived severity, PS), in combination with beliefs about the possibility of coping with the adverse consequences (i.e., self-efficacy, SE, and response efficacy, RE). For this study, threat appraisal is considered the additive relationship of PV and PS associated with smoke impacts from wildland fire, and coping appraisal is the additive relationship of SE (ability to avoid smoke impacts) and RE (the effectiveness of taking such actions) (e.g., staying indoors, purchasing an air purifier, or leaving town). In our model, egoistic value orientations are hypothesized (per the value-belief-norm theory) to relate to these beliefs.

Trust is an important yet complex and fragile component of public land management. Trust in agencies influences public tolerance of smoke because trust is related to perceptions of risk and beliefs about prescribed fire. Public acceptance of prescribed fire is often related to the degree to which people trust the implementing agency (Fried, Gatziolis, Gilless, Vogt, & Winter, 2006; Vogt, Winter, & Fried, 2005). For some people, there is a positive relationship between agency trust and the perceived benefits of using prescribed burning (e.g., it saves money, restores natural conditions, improves wildlife habitat, or protects a community from future fires) (Winter, Vogt, & McCaffrey, 2004). For others, the threat of an escaped fire is a primary concern and may be associated with low agency trust (e.g., Absher et al., 2009; Blanchard & Ryan, 2007; Brunson & Evans, 2005; Hunter et al., 2007; Weisshaupt et al., 2005; Winter et al., 2004). We hypothesized that agency trust, beliefs about the positive outcomes of Rx fire, and personal risk perceptions all can influence a person's tolerance of smoke, with trust operating via specific beliefs.

Beyond the cognitive aspects of public tolerance of smoke mentioned above (value orientations, threat appraisal, coping appraisal, and trust), we also compared how different types of communities (i.e., urban and rural), the level of community preparedness for fire, previous experience with fire and smoke, and sociodemographic characteristics influenced tolerance of smoke. Although urban areas can be intensely affected by smoke, the risks to property and viewsheds may be quite different than those of WUI areas. We also hypothesized that the level of community preparedness (e.g., communities that have completed and implemented a Community Wildfire Protection Plan) will influence tolerance of smoke (discussed further in study area descriptions below). Our study aimed to explore the relationships between public tolerance of smoke and community (level of preparedness, urban or rural) or sociodemographic characteristics, in conjunction with the cognitive aspects described above.

It is logical that past experience influences public tolerance of smoke. People with more wildland fire experience, permanent (as opposed to seasonal)WUI residents, and individuals who have worked in natural resource-related fields have been documented to be more accepting of forest treatments and subsequently smoke (Blanchard & Ryan, 2007; Vogt et al., 2005; Winter et al., 2006). Florida residents, for example, are accustomed to prescribed fire practices due to extensive experience, and subsequently support their use (Loomis, Bair, & González-Cabán, 2001). Similarly, in one study, Montana residents claimed to be more tolerant of prescribed fire smoke because they had experienced severe wildfire smoke the previous summer and viewed prescribed burning as an effective technique for reducing catastrophic wildfire risk and smoke (Weissenhaupt et al., 2005). However, it is unclear if experience with smoke is the same as experience with fire. It appears that the type of experience (e.g., severity of adverse consequences or perceived benefits from fire), in part, influence beliefs about how severe the next fire will be, and is suspected to be important in determining attitudes toward smoke.

The literature related to public perceptions of smoke from forest fires has illustrated how tolerance for smoke may vary greatly across cognitive, contextual, and community gradients – and the underlying reasons for such variations are not always clear. The model presented here explores tolerance of smoke as a direct function of beliefs (awareness of benefits, threat appraisal, and coping appraisal), individual characteristics, and community characteristics, and indirectly as a function of value orientations and agency trust (Figure 1; Table 1).

Table 1. Summary of research questions and supporting hypotheses

Overarching Research Question: How do cognitive factors and personal characteristics influence public tolerance of smoke and support for prescribed (Rx) fire management activities?	
Supporting RQs	**Hypotheses**
RQ1. How do value orientations relate to specific beliefs about forest fires and smoke?	*Hypothesis 1 (H1)*: A stronger biospheric value orientation will predict a higher awareness of the positive consequences associated with fire and smoke. *H2*: A stronger egoistic value orientation will lead to increased awareness of the adverse consequences of smoke.
RQ2. How do specific beliefs about the consequences of smoke and agency trust relate to	*H3*: Increased perceptions of the benefits of using prescribed fire to improve forest health will increase tolerance of smoke. *H4*: Increased threat appraisal of smoke effects will decrease tolerance for smoke. *H5*: Increased coping appraisal will increase tolerance for smoke.

tolerance of smoke?	*H6*: Perceived response efficacy will moderate the effect of threat appraisal on tolerance. *H7*: Higher levels of agency trust will be associated with a higher awareness of the positive consequences associated with fire and smoke. *H8:* Higher levels of agency trust will be associated with lower perceived vulnerability to smoke impacts.
RQ3. How do community type, preparedness for fire, past experience with smoke, and sociodemographics relate to tolerance of smoke?	*H9*: Rural residents will be more tolerant of smoke than urban residents. *H10*: Rural residents will be more aware of the relationship between smoke and forest health. *H11*: People who have had been adversely affected by smoke in the past will be less tolerant of smoke than people who have not been affected by smoke. *H12*: Residents in WUI communities that are more prepared for fire will be more tolerant of smoke and fuels management than those that are not prepared.

Methods

Study Areas and Communities

This study focused on two regions (Figure 2): the U.S. northern Rocky Mountains (Idaho and Montana; NORO) and the south-central U.S. (east Texas and western Louisiana; SOUTH). Both regions have forest health concerns, increases in wildfire activity, and changing social dynamics that have resulted in more substantial wildland fire and smoke issues than in the past (USDA Forest Service, 2009; Winkler et al., 2007). Many communities historically reliant on resource commodities (e.g., logging, ranching, and agriculture) have been transitioning towards amenity-based economies (Winkler et al., 2007), and smoke can inhibit many outdoor activities. Both regions have experienced greater amenity-driven population and housing growth than other parts of the U.S., combined with greater population redistribution into WUI areas (Hammer et al., 2009). Idaho and Texas ranked in the top five states for relative population growth since 2000 (U.S. Census Bureau, 2010). Though there are some similarities, there are also important variations between the two regions (Table 2), such as fire return intervals, the type and amount of prescribed fire use, size of metropolitan areas, and ethnicity.

Figure 2. Study areas overview map

Table 2. Comparison of the study regions.

	U.S. Northern Rocky Mountains Forests		Southern Pine Forests
Historic fire return interval	5 – 150+ years		2 – 5 years
Prescribed fire use type[1]	slash reduction and wildland fire use		understory burning
Prescribed fire treated acres in 2010[2]	ID and MT = 64,000		TX = 160,000
Most populous metropolitan area [3] (within city limits; metropolitan area)	Boise, ID (205,671; 616,500) Missoula, MT (66,788; 109,299)		Houston (2,100,000; almost 6,000,000)
Race and Ethnicity (statewide)[3]	Idaho White: 89% African-American: <1% Hispanic: 11%	Montana White: 89% African-American: <1% Hispanic: 3%	Texas White: 70% African-American: 12% Hispanic: 38%[3]

Sources: [1] Haines, Busby, & Cleaves, 2001; [2] NIFC, 2011; [3] U.S. Census Bureau, 2011 – these values do not total 100% because other ethnicities exist in the regions (e.g., Native Americans), and Hispanic can be listed in combination with other race/ethnicities.

U.S. Northern Rocky Mountains

The mixed conifer forests of the U.S. northern Rocky Mountains are home to globally significant biodiversity, as well as diverse human communities and land uses, all of which are influenced by complex human and non-human factors. This region has been experiencing rapid social and ecological changes. Ecological changes include increased fuel loading, tree mortality, higher potential for insect establishment and spread, and subsequently larger and more severe wildfires and smoke levels (Westerling et al., 2006; Morgan et al., 2008; USFS, 2009). Several recent fire seasons were among the most severe in the past half-century (Gorte, 2006). Future projections for the region include more high degree-days and prolonged droughts, which are anticipated to drive changes in water availability, increased drought stress in forests, susceptibility of forests to increased tree mortality, and increases in the number of large wildfires and smoke (van Mantgem et al., 2009; Westerling et al., 2006). The U.S. northern Rocky Mountains have proven to be particularly vulnerable to increased fires associated with climate change, as evidenced by an 1100 percent increase in the number of large fires (> 1000 acres) and a 3500 percent increase in the area burned since 1970, accounting for more than half of all western fires and total area burned

(Westerling, 2008). Increases in wildfire and prescribed fire in the region are anticipated to be accompanied by substantial increases in human exposure to smoke and associated management issues, notably for those with existing health issues that are sensitive to smoke (McCaffrey & Olsen, 2012).

We hypothesized that the level of community preparedness for wildfire may be related to public tolerance of smoke. Every county in Idaho and Montana has completed a County Wildfire Protection Plan (CWPP), but the level of follow-through on management actions and *actual* preparedness for fire varies greatly by community within each county. For example, many CWPPs were written prior to the passage of Healthy Forests Restoration Act of 2003, and some have not been updated to comply with the CWPP guidelines stipulated in the Act. Current wildfire risk status is not documented in many CWPPs, nor is there a current record of planned and completed fuel reduction projects. Other factors affecting community preparedness for fire included the level of coordination between wildfire and structural fire fighters, paid versus unpaid volunteer firefighters, presence of a WUI committee, and amount of funding obtained for fuel reduction projects. All of these factors were taken into consideration when selecting and classifying each community as WUI more-prepared, WUI less-prepared, or urban (non-WUI). These considerations for community preparedness for fire are also true in the south-central U.S.

South-central U.S. (East Texas and Western Louisiana)

Climate change models project that Gulf Coast states will have less rainfall in winter and spring compared with northern states in the region, and the frequency, duration, and intensity of droughts are likely to continue increasing (Karl, Melillo, & Peterson, 2009). Continued warming in all seasons across the Southeast is anticipated through the end of the century. June of 2011 was the hottest June ever recorded in Texas and the fourth hottest month ever recorded in Texas (NOAA, 2011). As expected, more intense and severe wildfires have accompanied the increases in temperatures, drought, southern pine beetle outbreaks, and erratic weather (Karl et al., 2009). Similar to the northern Rocky Mountains, the increase in wildfire and prescribed fire use, accompanied by increases in smoke, has occurred at the same time as population increases and amenity migration into the WUI.

Prescribed burning in south-central forests has been a regular annual occurrence to address increased fuel loads, primarily near communities-at-risk. For example, in the Sam Houston National Forest, 50 miles north of Houston, the U.S. Forest Service has burned an average of 30,000 acres per year since 2004, which is 20 percent of the total area (USFS, 2010). In general, residents in the south-central U.S. have more experience with Rx fire and associated smoke than other parts of the country because the practice is more commonly used and accepted on federal, state, and private lands in this region – even in the presence of increasing constraints from urban expansion, air quality regulations, and liability for smoke intrusions and escaped fires (Fried et al., 2006; Haines et al., 2001). Nevertheless, smoke resulting from prescribed burning is an ongoing concern for land managers and community residents alike.

The smoke management issues associated with the region between Houston, the Texas National Forests and western Louisiana are particularly challenging because of the large variation in social conditions (e.g., income levels, education, land ownership) and divergent levels of public tolerance of smoke from fires. As of 2012, all of the counties near Houston and the Texas National Forests were in some stage of completing a CWPP, which illustrated an awareness and concern about wildfire in the region. Houston is the largest city in the state of Texas and was listed as an ozone non-attainment area by the Environmental Protection Agency, adding to the complexity of air quality and forest fire management in the region. Suburban and exurban areas surrounding Houston have rapidly expanded towards the Texas National Forests and western Louisiana. Many

Houston residents have migrated into smaller rural towns and planned communities adjacent to the National Forests, consistent with the national trends reported in Hammer et al. (2009). The amenity-migration trends from Houston have resulted in complex WUI community mosaics similar to many western communities (e.g., as reported in Paveglio et al., 2009).

Studying these two regions allows us to identify similarities and differences between public perceptions and tolerance of smoke across large and representative regions of the U.S. that are increasingly dealing with smoke management issues from forest fires.

Sampling Design

A quantitative design was chosen based on a desire to generalize findings to the populations of the study regions (Creswell, 2009). Communities from the NORO and SOUTH were stratified into three community types (selection process described further below): 1) WUI communities that are more-prepared for fire (WUIMP); 2) WUI communities that are less-prepared for fire (WUILP); and (3) urban areas not located in the WUI, but that have a high potential to be impacted by smoke. Communities were selected through a review of CWPP literature in each county of the two regions. In each CWPP we explored when the plan was completed, whether mitigation activities/projects had been identified, whether the activities/projects had been completed, if a WUI committee had been formed, how active the WUI committee was, and whether the CWPP had been updated since the original document.

Our team held a meeting with the primary authors of nearly all of the CWPPs in the NORO to discuss communities that met each classification. We also consulted with local land and fire managers to discuss communities that met each classification. Further, in the fall 2011 a web-based exploratory questionnaire was emailed to more than 200 fire managers, land managers, and community leaders from each region, asking them to nominate study communities based on our preparedness classification. Responses from the exploratory questionnaire were compiled and the 18 communities that received the most nominations in the two regions, in combination with recommendations with CWPP authors, were selected (Table 3). Follow-up phone calls were conducted with managers and land managers in both regions in the fall of 2011 to ensure that the communities met our criteria. We also consulted with the smoke research team from The Ohio State and Oregon State Universities to discuss our community selection criteria against their focus group findings.

Table 3. Northern Rocky Mountains and South-central U.S. survey communities.

Northern Rocky Mountains Study Area	
More Prepared: Communities near fire-prone lands that *have* actively prepared for fire	
Name	**Justification**
Missoula, MT (outlying WUI areas only)	Missoula has a second generation CWPP. An active WUI organization coordinates fire activities between city, rural, volunteer, state agency, and U.S. Forest Service fire departments. Significant fuels reduction work has been done on both private and public lands. Residents within the WUI on the outskirts of town were targeted.
Salmon, ID	The Lemhi County WUI committee is very active and has an up-to-date CWPP. There is a county biomass collaborative and grants had been secured for fuels treatment. There is good coordination between community firefighting and wildfire fighting operations. Moose Creek Estates (certified Firewise) had conducted shaded fuel breaks around the community.
Ketchum and Hailey, ID	The CWPP is current; the WUI Committee is active; there is good interagency cooperation regarding fire planning and mitigation; citizens are aware and knowledgeable about fire. Recent fires have increased community engagement and fire awareness. Communities dealt with smoke from forest fires on a regular basis.
Less Prepared: Communities near fire-prone lands that *have not* actively prepared for fire	
Bitterroot Valley, MT	Several communities, notably Victor, MT, have been identified as resistant to fire planning and mitigation efforts. This study included Hamilton, Corvallis, and Stevensville to increase sample size.
Sun Valley and Bellevue, ID	Local residents are resistant to fire planning and mitigation efforts, and not engaged in CWPP planning.
Idaho City, ID	The community is located in a region of high fire risk, and has inadequate personnel resources to address planning needs.
Urban (non-WUI) Area: Communities with high potential to be *impacted by smoke*	
Boise, ID	All are urban communities regularly impacted by smoke, but most residents do not live in the WUI adjacent to forested lands. Residents were targeted who did not live within the WUI.
Coeur d' Alene, ID	
Kalispell, MT	
South-Central U.S. Study Area	
More Prepared: Communities near fire-prone lands that *have* actively prepared for fire	
Name	**Justification**
Huntsville, TX	The city official participated in the development of the CWPP. The city fire chief has a good working relationship with Texas Forest Service and the US Forest Service. The community has pursued grants and reduced fuels within city limits. The leadership of the city was very

	engaged in fuels reduction.
Crockett, TX	The community has completed a CWPP. There are active school programs and a heightened awareness because both state and federal fire management entities are present in the community.
Spring Ridge, LA	This community has completed a CWPP and recent fuels reduction projects.
Less Prepared: Communities near fire-prone lands that *have not* actively prepared for fire	
Elkins Lake and Sunset Lake, TX	These retirement communities had not experienced recent wildfire, but were located in an area of very high risk. Forest thinning and Rx burning projects were planned for 2010 – 2015.
Diboll, TX	This former timber products town is surrounded by former industrial lands and National Forests with high wildfire risk. The county had a CWPP in progress.
Groveton, TX	This community nearly evacuated during 2010 fires. It was not well prepared and had not completed a CWPP.
Goldonna, LA	These communities completed a CWPP but had not completed any projects identified in the plan.
Pitkin CDP, LA	
Ashland Village, LA	
Urban (non-WUI) Area: Community with high potential to be *impacted by smoke*	
The Woodlands, TX	All are urban communities regularly impacted by smoke, but most residents do not live in the WUI adjacent to forested lands. Residents were targeted who did not live within the WUI.
Conroe, TX	
Livingston, TX	
Alexandria, LA	

We desired a random sample of 200 completed questionnaires from each of the 18 communities (i.e., 3,600 total completed questionnaires). This sample size was necessary to satisfy the recommendations for factor analysis (Kline, 2011). Participant names, addresses and phone numbers were purchased from Survey Sampling International (SSI, www.surveysampling.com).

We followed a modified version of Dillman's Total Design Method (Dillman, Smyth, & Christian, 2009) to ensure maximum participation. To reduce the time and effort requirements for each participant, an initial letter was mailed to participants notifying them about the study and providing internet address where they could complete the questionnaire online. A reminder postcard was sent 15 days after the initial mailing that again pointed the participants to the questionnaire internet address. A physical questionnaire was mailed three weeks later to anyone who had not completed the questionnaire online. Participants were enrolled in a lottery for one of six $250 gift certificates as an incentive for completing the questionnaire. We conducted 100 telephone interviews with randomly selected non-respondents in each region to assess potential bias between responders and non-responders (Creswell, 2009). Non-respondents were asked a few key questions from our study, such as their support for prescribed fire practices, opinions about the potential outcomes of prescribed fire, tolerance of smoke from prescribed fire, and demographic characteristics. Refer to Appendices B – F for all participant correspondence materials and the survey instrument.

Measurements

The questionnaire had four primary sections related to 1) values, beliefs, and attitudes; 2) tolerance of smoke; 3) Rx fire management support; and 4) sociodemographic characteristics. Most measures used a 7-point Likert-type scales (see Appendix E for the instrument). The online survey was constructed and administered using Qualtrics software (Qualtrics, Inc., http://qualtrics.com/). Pilot testing of the questionnaire was conducted with three undergraduate classes at the University of Idaho in September and October of 2011 to ensure that questions were understandable and that response burden was not too great.

Values, beliefs, attitudes, and perceptions

The measures of value orientations followed the Value-Belief-Norm framework (VBN) for measuring egoistic and biospheric values (Stern, 2000; De Groot & Steg, 2007; De Groot & Steg, 2008), and were also informed by Schwartz's (1992) universal values scale and Absher and Vaske's (2009) measures of forest-specific values. Altruistic values (consideration for other people) are also a component of the VBN framework, but were not measured in this study because altruistic values were not considered by the research team to be a logical or strong predictor of public tolerance of smoke.

Specific beliefs about the beneficial and adverse consequences of smoke from fires were assessed through measures of concern about different biospheric (5 items) and egoistic (5 items) topics. Participants were asked to indicate how concerned they were about risks associated with smoke and wildland fire (modified questions from Bowker, 2008; Thapa et al., 2006; Vogt et al., 2005; Winter et al., 2004; 2006). Subjective threat appraisal (perceptions of vulnerability and severity) of smoke impacts were assessed through a multi-item measure focused on personal and family health, property, recreation and tourism, fish and wildlife, drinking water, aesthetics, occupation, transportation, and school recess. Coping appraisal (RE and SE) was measured with questions about the perceived effectiveness and ability to complete various risk-reduction behaviors, such as staying indoors, using heating or air conditioning to filter indoor air quality, or temporarily leaving the area. Responses were given on a 7-point scale of (-3) strongly disagree to (+3) strongly agree.

Trust was defined in terms of competence, defined as the extent to which the respondents trust the ability of forest fire managers to effectively manage smoke and fire, and credibility, defined as the ability to provide information about smoke and fire (Absher & Vaske, 2011; Absher, Vaske, & Shelby, 2009). Responses were given on a 7-point scale of (-3) strongly disagree to (+3) strongly agree.

Tolerance of Smoke

Respondent tolerance of smoke was measured with a question about tolerance of smoke from four fire sources (prescribed fire, prescribed-natural fire, slash pile burning following a fuels reduction project, and a lightning-caused wildfire[1]). Respondents rated their tolerance on a 7-point scale of (-3) very intolerant to (+3) very tolerant.

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[1] **Wildland Fire (wildfire)** - Any nonstructural fire that occurs in forests, rangelands, grasslands, or other wildland setting (other than prescribed fire). When we refer to wildfires in this chapter, we specifically mean fires in forests. **Prescribed Fire** - Any fire ignited by land managers to meet specific forest resource management objectives. **Prescribed-Natural Fire** - Any fire that is naturally ignited (e.g., lightning) that is managed to meet specific forest resource management objectives**. Slash Pile Burning** - The burning of branches, tops, and other woody material that are piled up after a logging activity or forest fuel reduction project.

Support for Rx Fire Use as a Forest Management Tool

Public support for Rx fire management was measured using modified questions from Absher et al. (2009). These asked respondents to indicate their level of agreement with fire management statements (5 items). Two of the items asked respondents to consider Rx fire and smoke tradeoffs, such as "forest managers should periodically burn underbrush and debris in forests near my community, even though it results in periodic smoke."

Sociodemographic Characteristics

Sociodemographic measures included age, education level, gender, income, race/ethnicity, residency status, and political orientation. Respondents were also asked about their previous experience with fire and smoke within the last 3 years and exposure to information about smoke, prescribed fire, and fuels reduction.

Data Analysis

The quantitative analysis of the survey responses included descriptive statistics, item-reduction using exploratory factor analysis, comparison of means using T-tests and analysis of variance, and path analytic modeling. Multi-item measures were investigated for multiple dimensions and reduced to scales using factor analysis and a Cronbach's alpha reliability coefficient with a cutoff level of 0.70 or greater (Field, 2005; Vogt, 2005). Maximum likelihood estimation with an oblique direct oblimin rotation was used to rotate the factors while allowing them to correlate, which is common in naturalistic and human research (Field, 2005; Raykov & Marcoulides, 2011). Analysis of variance was used to determine whether smoke tolerance varies among sub-populations (2 regions and 3 community preparedness types).

Path analysis (PA) is a multivariate analysis where causal relationships among several variables are represented with diagrams showing the paths along which causal influences travel (Klem, 1995; Vogt, 2005). PA is an extension of multiple regression where regression is conducted over a set of variables and multiple dependent variables can be present in the model. Results of a PA, called "path coefficients," reflect the magnitude and statistical significance of each relationship, while holding all others constant. This study used PA to explore tolerance of smoke as a direct function of beliefs and individual characteristics, and indirectly as a function of values and trust (Figure 1). PA allows for the exploration of mediator variables, which act as both dependent and independent variables. Mediator variables allow for the quantification of indirect relationships (i.e., indirect effects), which are predicted to exist between a set of variables (e.g., values, trust, beliefs about Rx fire, and tolerance of smoke). Calculation of indirect effects allows for more nuanced understandings of the antecedents of respondent tolerance of smoke. For example, trust may not directly influence tolerance of smoke, but rather indirectly influences beliefs about the benefits of Rx fire, which directly influence tolerance. Indirect effects are calculated as the product of the direct effects. Both direct and indirect effects are interpreted as regression coefficients. Dummy variables were used to control for particular predictors (e.g., community type, region, gender, race, political orientation) to explore whether path relationships differed based on these identified moderating variables.

Results

This section begins with a description of the sample characteristics for the Northern Rocky Mountains (NORO) and south-central U.S. (SOUTH), then provides descriptive and comparative statistics for each variable by region and community type (i.e., urban/rural, and level of preparedness for wildland fire), and lastly describes the results of path analytic model and hypothesis testing.

Characteristics of the Samples

Respondents from both regions were typically older (> 60 years old) white males who were permanent residents of their community, and had lived there more than 5 years (Table 4). About half had completed a four-year college or advanced degree. Politically, the majority of respondents considered themselves conservative, and the SOUTH sample was more conservative than the NORO sample. Less than 20 percent of respondents had any employment or income sources related to forests. About half of the respondents reported household incomes of $60,000/year.

Table 4. Descriptive statistics for sociodemographic characteristics

Socio-Demographic Characteristic	Region	Socio-Demographic Metric		% of Respondents
Age	**NORO** (n=1488)	Mean=63 Years Median=56 Years Range= 18-94	18-29 30-49 50-59 60+	1 15 23 61
	SOUTH (n=350)	Mean=60 Years Median=56 Years Range= 18-94	18-29 30-49 50-59 60+	2 23 22 53
Gender	**NORO** (n=1482)		Male Female	73 27
	SOUTH (n=345)		Male Female	70 30
Residency	**NORO** (n=1498)		Permanent Part-time	98 2
	SOUTH (n=350)		Permanent Part-time	98 2
Years lived in community	**NORO** (n=1493)		Less than 1 year 1-5 Years More than 5 years	<1 6 94
	SOUTH (n=350)		Less than 1 year 1-5 Years More than 5 years	0 11 89
Employment or any source of income related to forests	**NORO** (n=1488)		Yes No	19 81
	SOUTH (n=345)		Yes No	15 85

Education level	**NORO** (n=1493)	Less than a high school degree	2
		High school degree or GED	11
		Some college or post-high school training	22
		Two-year technical or associate degree	11
		Four-year college degree (BA/BS)	31
		Advanced degree (MS, JD, MD, Ph.D.)	23
	SOUTH (n=352)	Less than a high school degree	4
		High school degree or GED	16
		Some college or post-high school training	25
		Two-year technical or associate degree	9
		Four-year college degree (BA/BS)	24
		Advanced degree (MS, JD, MD, Ph.D.)	21
Household income	**NORO** (n=1386)	Less than $20,000 per year	10
		$20,001 to $40,000	22
		$40,001 to $60,000	23
		$60,001 to $80,000	16
		$80,001 to $100,000	11
		$100,001 to $120,000	7
		more than $120,000	10
	SOUTH (n=319)	Less than $20,000 per year	8
		$20,001 to $40,000	24
		$40,001 to $60,000	18
		$60,001 to $80,000	14
		$80,001 to $100,000	12
		$100,001 to $120,000	11
		more than $120,000	13
Ethnicity	**NORO** (n=1538)	White/Caucasian	94
		Black/African-American	<1
		Hispanic, Latino, or Spanish Origin	<1
		American Indian or Alaska Native	2
		Asian	1
		Native Hawaiian or Other Pacific Islander	<1
		Other or Unknown	1
	SOUTH (n=375)	White/Caucasian	81
		Black/African-American	6
		Hispanic, Latino, or Spanish Origin	2
		American Indian or Alaska Native	3
		Asian	1
		Native Hawaiian or Other Pacific Islander	<1
		Other or Unknown	2
Political orientation	**NORO** (n=1469)	Liberal (0-2)	29
		Neither (3)	24
		Conservative (4-6)	47

	SOUTH (n=346)	Liberal (0-2) Neither (3) Conservative (4-6)	12 20 68

NORO Sample

The first round of initial letters and postcards resulted in 466 returned by the postmaster due to bad addresses or deceased residents, lowering the sample size to 5,457 (Table 5). We received 1,538 completed questionnaires total, for an overall response rate of 28%. Of those, 967 were completed online after the first and second rounds, and 577 were completed paper surveys after the third round. The total population size for all sample communities was 362,350 at the time the questionnaire was sent (U.S. Census, 2010), and 1,538 total returned questionnaires resulted in a margin of error of 2.49% at a 95% confidence level, shown in Table 5 (Scheaffer, Mendenhall, & Ott, 2006). The sample size and margins of error for each community preparedness type (i.e., level of preparedness for fire) were also acceptable. The robustness of this sample allows for statistical analysis and inferences at regional and community levels.

Table 5. NORO and SOUTH sample characteristics summary

Stratification	Population	Sample	Completed Surveys	Response Rate (%)	Margin of Error (%)*
NORO					
Urban (non-WUI)	269,735	1,887	481	25	4.46
WUI more prepared	80,559	1,732	500	29	4.37
WUI less prepared	12,056	1,838	557	30	4.06
Regional Total	362,350	5,457	1,538	28	2.49
SOUTH					
Urban (non-WUI)	205,875	1,969	108	5	9.43
WUI more prepared	72,401	1,949	122	6	8.87
WUI less prepared	13,173	2,259	146	6	8.07
Regional Total	291,449	6,172	376	6	5.05

* Margins of error calculated at a 95% confidence interval.

SOUTH Sample

The first round of initial letters and second round of reminder postcards resulted in 244 returned by the postmaster due to bad addresses or deceased, lowering my sample size to 6,172 (I oversampled to compensate for the number of bad addresses received in the NORO sample). I received 376 completed questionnaires total, for an overall response rate of 6%. Of those, 199 were completed online surveys after the first and second rounds, and 177 were completed paper surveys after the third round. My total population size for all sample communities was 291,449 at the time the questionnaire was sent (U.S. Census, 2010), so 376 total returned questionnaires results in a margin of error of 5.05% at a 95% confidence level (Table 5). The regional margin of error is acceptable based on the sample size; however, the margins of error for each community preparedness type were slightly beyond the typical limits of acceptable error (Scheaffer et al., 2006). Therefore, caution was taken when making statistical inferences or comparative conclusions from the community preparedness groupings.

Assessment of Non-response Bias

To assess potential response bias, we conducted brief telephone interviews with 100 randomly selected non-respondents, evenly divided among both region and community types. Non-respondents were asked about their support for prescribed fire practices, opinions about the potential outcomes of prescribed fire, tolerance of smoke from prescribed fire, and demographic characteristics. In both regions, no significant differences were found between the responders and non-responders regarding their support for prescribed fire practices, opinions about the potential outcomes of prescribed fire, or tolerance of smoke from prescribed fire (Table 6). In both regions, respondents were more educated than non-responders, and in the south, respondents were significantly more likely to be permanent residents than non-responders were. Overall, these findings indicated that respondents in each region had similar opinions and characteristics as their population.

Table 6. Non-response bias assessment for NORO and SOUTH

NORO					
Question*	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**SE Difference**
Support for Rx fire management practices	-.34	1569	.73	-.08	.22
Tolerance of smoke from Rx fire	-.68	1577	.50	-.18	.26
Awareness that forest health will improve with the use of Rx fire	-.84	1548	.40	-.20	.23
Age	-.22	1533	.83	-.43	1.94
Highest level of education	2.52	1536	**.01**	.54	.21
Permanent or part-time resident	-.01	1544	.99	.00	.02
Years lived in community	-1.78	1539	.07	-.07	.04
SOUTH					
Question*	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**SE Difference**
Support for Rx fire management practices	1.59	411	.11	.38	.24
Tolerance of smoke from Rx fire	.68	418	.50	.17	.249
Awareness that forest health will improve with the use of Rx fire	1.85	408	.07	.42	.23
Age	.60	396	.55	1.35	2.25
Highest level of education	3.92	398	**.00**	.92	.23
Permanent or part-time resident	-2.09	397	**.04**	-.06	.03
Years lived in community	-1.91	397	.06	-.09	.04

*The scale for the firest three items was -3 to +3

Knowledge about Wildland Fire and Smoke

Knowledge was measured by asking respondents to indicate (yes/no) if they had heard or read about the use of prescribed fire (Rx fire), smoke impacts associated with forest fires, the use of prescribed-natural fire, and the need to reduce forest fuels near their respective community. Overall, the percentage of respondents that reported having read or heard about these practices was very high for both regions and in all community types (Table 7). Respondents from the NORO reported significantly more exposure to information on all of these topics than the SOUTH. In both regions, knowledge pertaining to the use of prescribed fire and prescribed-natural fire for improving forest health was greater than knowledge about potential smoke impacts and the need to reduce forest fuels near communities. Surprisingly, WUI less prepared (WUILP) communities in the NORO knew slightly more about smoke impacts and fuels reduction than WUI more prepared (WUIMP) or urban non-WUI (non-WUI) communities. The overall high level of exposure to information related to wildland fire, Rx fire, and smoke impacts is consistent with findings from previous studies that have demonstrated the public's informed and often sophisticated level of knowledge related to wildland fire and forest health issues (e.g., McCaffrey & Olsen, 2012).

Table 7. Summary of respondents' exposure to information about wildland fire and smoke (knowledge; % Yes)

Strata	**K1**	**K2**	**K3**	**K4**
	(%)			
NORO Total	98	87	97	88
Urban	98	87	97	87
Rural	97	89	97	91
Preparedness				
Non-WUI	97	83	97	82
WUI MP	98	88	97	89
WUI LP	98	90	97	92
Community Type Chi-square	1.2	11.0	.28	23.37
p	.55	**<.01**	.87	**<.001**
SOUTH Total	88	76	89	65
Urban	88	79	90	68
Rural	88	74	88	64
Preparedness				
Non-WUI	86	77	90	70
WUI MP	86	79	88	60
WUI LP	92	73	87	66
Community Type Chi-square	3.1	1.4	.2	2.4
p	.21	.50	.91	.30
Regional Chi-square*	59.5	29.3	45.5	107.3
p	**<.001**	**<.001**	**<.001**	**<.001**

*Chi-square values were substantially impacted by the large sample sizes. All values are quite high.
K1: Have you heard/read about the use of prescribed fire?
K2: have you heard/read about the potential impacts of smoke from forest fires [wildfires and Rx fire]?
K3: have you heard/read about managing or using wildfire [naturally ignited fire] to improve forest health?
K4: Have you heard/read about the need to reduce forest fuels near your community?

Experience with Smoke and Fire

Respondent experiences with smoke from Rx fire, wildfire, or an unknown source was measured by asking whether they (or family members) had suffered smoke effects related to health, discomfort, property damage, road closures, and evacuations. An additional item asked whether a fire had occurred near their home in the previous three years.

A large majority of respondents from both regions (NORO > 80%, SOUTH> 65%) and all community types reported that they had experienced some type of impact from smoke from wildland fires in the past three years (Tables 8-11). In the NORO, one-third of respondents said they had suffered some type of personal health effect from smoke, which is twice as many as in the SOUTH (13%). NORO respondents also reported three times as many instances of personal and family health impacts and discomfort from wildfire smoke than SOUTH respondents. Among those with a health effect, a significantly larger proportion were reported in rural and WUI communities than urban areas, notably WUILP communities. Rx fire caused nearly twice as many SOUTH respondents (14%) to experience road closures than NORO respondents (8%), which is consistent with the higher level of Rx fire use in the SOUTH. Lightning ignited wildfires caused more road closure experiences in the NORO than in the SOUTH, likely due to significantly more experience with wildfire in the NORO during the previous three years.

Rural NORO residents, notably in WUILP communities, had more experience with Rx fire in the past three years than other community types. WUILP communities in both regions also experienced more Rx fire smoke impacts related to personal and family health, discomfort, property impacts, and road closures (Table 8). In the SOUTH, non-WUI and WUIMP communities near urban centers reported more experience with wildfire and smoke impacts related to roads, family property, and evacuations than WUILP.

Table 8. Percent of respondents who had experienced any impact from forest fire smoke or personal health effects

Strata		Have you experienced any impacts from wildland fire smoke? (Exp1-7 any source)	Have you suffered personal health effects from wildland fire smoke? (Exp 1 any source)
		% yes	% yes
NORO	**Total**	83	29
	Urban	82	27
	Rural	87	34
	Chi-square	4.1	5.0
	p	**.02**	**.02**
Preparedness			
	Non-WUI	69	17
	WUI MP	89	29
	WUI LP	88	38
	Community Type Chi-square	82	56.1
	p	**<.01**	**<.01**
SOUTH	**Total**	67	13
	Urban	71	14
	Rural	64	12
	Chi-square	ns	ns
	p	ns	ns
Preparedness			
	Non-WUI	66	16
	WUI MP	70	11
	WUI LP	65	12
	Community Type Chi-square	.81	1.1
	p	**.67**	**.51**
	REGION Chi-square	44.7	39.9
	p	**<.01**	**<.01**

Table 9. Percent of respondents who had **experienced smoke impacts from Rx fire** in the previous 3 years

Strata	EXP1 Health	EXP2 Discomfort	EXP3 Property	EXP4 Roads	EXP5 Family Property	EXP6 Family Health	EXP7 Evac	EXP8 Past 3 Years
	% yes							
NORO Total	10	18	1	8	2	11	1	18
Urban	8	15	<1	8	2	9	1	15
Rural	15	28	2	11	3	19	2	29
Chi-square	14.5	28.2	7.3	4.5	ns	23.7	ns	12.2
p	**<.01**	**<.01**	**.02**	**.03**	ns	**<.01**	ns	**<.01**
Preparedness								
Non-WUI	5	11	<1	6	1	6	1	8
WUI MP	8	16	1	10	2	9	1	17
WUI LP	14	24	1	8	4	17	1	29
Community Type Chi-square	25.5	32.0	ns	ns	ns	32.5	ns	44.3
p	**<.001**	**<.001**	ns	ns	ns	**<.001**	ns	**<.001**
SOUTH Total	5	16	1	14	2	5	1	18
Urban	4	11	<1	8	3	5	1	15
Rural	5	19	<1	18	1	5	1	21
Chi-square	ns	4.3	ns	7.8	ns	ns	ns	ns
p	ns	**.02**	ns	**<.01**	ns	ns	ns	ns
Preparedness								
Non-WUI	2	9	0	8	2	5	2	9
WUI MP	3	11	1	8	2	3	0	13
WUI LP	8	24	1	22	1	6	2	30
Community Type Chi-square	ns	13.7	ns	14.4	ns	ns	ns	22.9
p	ns	**.001**	ns	**.001**	ns	ns	ns	**<.001**
REGION Chi-square	9.5	ns	ns	10.6	ns	13.3	ns	ns
p	**.001**	ns	ns	**.001**	ns	**<.001**	ns	ns

EXP1: Have you suffered personal health effects from smoke?
EXP2: Have you experienced discomfort from smoke?
EXP3: Have you suffered personal property damage due to smoke?
EXP4: Have you experienced a road closure or delay due to smoke?
EXP5: Have your friends, family, or neighbors suffered property damage from smoke?
EXP6: Have your friends, family, or neighbors suffered personal health effects from smoke?
EXP7: Have you evacuated your home or office due to smoke?
EXP8: A forest fire has occurred near my home in the past 3 years.

Table 10. Percent of respondents who had **experienced smoke impacts from wildfire** in the previous 3 years

Strata	EXP1 Health	EXP2 Discomfort	EXP3 Property	EXP4 Roads	EXP5 Family Property	EXP6 Family Health	EXP7 Evac	EXP8 Past 3 Years
	% yes							
NORO Total	24	58	2	40	12	34	5	63
Urban	22	55	2	40	11	32	4	59
Rural	29	70	3	41	13	39	7	79
Chi-square	5.5	19.8	ns	ns	ns	5.2	4.2	22.7
p	**.01**	**<.01**	ns	ns	ns	**.01**	**.03**	**<.01**
Preparedness								
Non-WUI	12	36	1	27	8	18	2	29
WUI MP	24	66	2	49	13	34	8	79
WUI LP	33	70	3	43	14	46	5	80
Community Type Chi-square	57.9	141.0	7.1	50.2	11.6	87.4	20.1	216.6
p	**<.001**	**<.001**	**.03**	**<.001**	**.003**	**<.001**	**<.001**	**<.001**
SOUTH Total	8	23	2	35	19	12	5	50
Urban	9	26	3	41	26	13	8	64
Rural	6	21	2	30	13	10	2	39
Chi-square	ns	ns	ns	4.3	11.3	ns	6.4	22.4
p	ns	ns	ns	**.03**	**<.01**	ns	**.01**	**<.01**
Preparedness								
Non-WUI	9	23	2	35	15	7	2	46
WUI MP	8	25	2	43	30	16	11	66
WUI LP	6	22	3	28	12	11	2	40
Community Type Chi-square	.75	.36	1.1	7.2	15.1	4.2	14.1	18.7
p	.69	.85	.57	**.03**	**.001**	1.2	**.001**	**<.001**
REGION Chi-square	48.6	144.9	.04	3.6	12.8	70.0	.15	18.2
p	**<.001**	**<.001**	.48	**.03**	**<.001**	**<.001**	.40	**<.001**

EXP1: Have you suffered personal health effects from smoke?
EXP2: Have you experienced discomfort from smoke?
EXP3: Have you suffered personal property damage due to smoke?
EXP4: Have you experienced a road closure or delay due to smoke?
EXP5: Have your friends, family, or neighbors suffered property damage from smoke?
EXP6: Have your friends, family, or neighbors suffered personal health effects from smoke?
EXP7: Have you evacuated your home or office due to smoke?
EXP8: A forest fire has occurred near my home in the past 3 years.

Table 11. Percent of respondents who had **experienced smoke impacts and didn't know the source of the smoke** in the previous 3 years

Strata	EXP1 Health	EXP2 Discomfort	EXP3 Property	EXP4 Roads	EXP5 Family Property	EXP6 Family Health	EXP7 Evac	EXP8 Past 3 Years
	% yes							
NORO Total	5	12	1	4	3	10	1	5
Urban	4	13	1	5	3	9	1	5
Rural	4	8	1	2	3	14	1	4
Chi-square	ns	6.1	ns	6.1	ns	5.9	ns	ns
p	ns	**<.01**	ns	**<.01**	ns	**.01**	ns	ns
Preparedness								
Non-WUI	4	15	1	7	3	7	<1	6
WUI MP	5	11	1	3	3	12	<1	3
WUI LP	6	10	1	3	4	12	1	5
Community Type Chi-square	.93	6.8	.07	13.7	.86	8.6	3.8	2.5
p	.63	**.03**	.96	**<.01**	.65	**.01**	.15	.28
SOUTH Total	4	11	1	4	3	8	1	6
Urban	6	10	2	4	4	8	1	6
Rural	2	11	1	4	2	9	1	6
Chi-square	ns	ns	ns	ns	ns	ns	ns	ns
p	ns	ns	ns	ns	ns	ns	ns	ns
Preparedness								
Non-WUI	7	13	0	4	5	8	2	6
WUI MP	3	12	3	6	3	8	1	5
WUI LP	1	9	1	3	1	8	0	7
Community Type Chi-square	6.1	1.0	2.7	1.7	2.3	.002	2.6	.48
p	**.05**	.61	.26	.43	.32	.99	.27	.79
REGION Chi-square	.93	.12	1.4	.11	.04	.14	.09	.68
p	.21	.40	.19	.44	.50	.13	.50	.24

EXP1: Have you suffered personal health effects from smoke?
EXP2: Have you experienced discomfort from smoke?
EXP3: Have you suffered personal property damage due to smoke?
EXP4: Have you experienced a road closure or delay due to smoke?
EXP5: Have your friends, family, or neighbors suffered property damage from smoke?
EXP6: Have your friends, family, or neighbors suffered personal health effects from smoke?
EXP7: Have you evacuated your home or office due to smoke?
EXP8: A forest fire has occurred near my home in the past 3 years

Opinions about Smoke Regulations

We asked study participants about their opinions related to smoke and air quality regulations. Fewer than half of the residents in both regions agreed with the statement that smoke from prescribed fires should be included in the Environmental Protection Agency's (EPA) air quality limits for their state. People from the SOUTH agreed more than people from the NORO that Rx fire smoke should be included in EPA air quality regulations (Table 12). Further, 40-percent of respondents in the SOUTH also agreed with the statement that Rx fire smoke should be exempt from state smoke management requirements and guidelines. Non-WUI residents in the NORO agreed significantly more with Rx fire smoke being exempted from state regulation than WUI residents, and agreed less that smoke should be included in EPA limits. The opposite was true in the SOUTH, where WUI residents agreed more with Rx fire smoke being exempted from state regulation than WUI residents, and agreed less that smoke should be included in EPA limits, although there were no significant differences.

Table 12. Respondent perceptions of federal and state regulations pertaining to smoke.

Strata		Smoke from Rx fires should be included in the Environmental Protection Agency's air quality limits for your state.	Prescribed fire smoke should be exempt from the State Smoke Management requirements and guidelines.
		% yes	% yes
NORO	**Total**	47	29
	Urban	47	28
	Rural	47	31
	Chi-square	ns	ns
Preparedness			
	Non-WUI	42	34[a]
	WUI MP	49	26[b]
	WUI LP	50	27[b]
SOUTH	**Total**	36	40
	Urban	38	37
	Rural	35	41
	Chi-square	ns	ns
Preparedness			
	Non-WUI	34	34
	WUI MP	36	43
	WUI LP	37	40
	REGION Chi-square	18.5**	35.7**

** $p < .01$, *$p < .05$
[a,b,c] Values with different superscripts in the same column and within the strata grouping are significantly different at the $p < .05$ level.

Community Preparedness for Wildland Fire

Respondents were asked how prepared for wildfire they thought their community was as a whole (1-6 or don't know). A second question asked whether their community or county had completed a Wildfire Protection Plan (CWPP) (yes, no, don't know). The majority of respondents in the NORO (60%) and the SOUTH (68%) didn't know if their community had a CWPP (Table 13). About one-fifth of the respondents in the NORO (16%) and SOUTH (18%) reported that they didn't know about their community's level of preparedness for fire.

Most people in both regions reported that their communities were somewhat prepared to prepared for wildland fire (Table 13). Respondents in the NORO perceived their communities as slightly more prepared for wildland fire than people in the SOUTH. The WUI communities in the NORO perceived themselves to be slightly more prepared than people in non-WUI communities, whereas people from SOUTH WUILP communities felt less prepared than those from non-WUI and WUIMP communities did. Significantly fewer NORO non-WUI respondents thought that their community had a CWPP than WUI communities.

Table 13. Respondent perceptions of community preparedness for forest fire

Strata		**How prepared for forest fire is your community as a whole?** (1, not prepared at all – 6, very prepared, or dk)	**Does your community or county have a Wildfire Protection Plan?** (yes, no, dk)
		mean	% yes
NORO	**Total**	4.6	38
	Urban	4.6	37
	Rural	4.6	42
	Chi-square	ns	ns
Preparedness			
	Non-WUI	4.5[a]	32[a]
	WUI MP	4.7[b]	45[b]
	WUI LP	4.6[ab]	37[ab]
SOUTH	**Total**	4.2	26
	Urban	4.4	28
	Rural	4.0	23
	Chi-square	12.35*	8.56*
Preparedness			
	Non-WUI	4.2[ab]	23
	WUI MP	4.5[a]	28
	WUI LP	4.0[b]	26
	REGION	*t* = 6.0**	Chi-square = 35.7**

** p < .01, *p < .05

[a,b,c] Values with different superscripts in the same column and within the strata grouping are significantly different at the *p* < .05 level.

Total: Regions combined

Urb: Non-WUI

MP: More Prepared for Forest Fire

LP: Less Prepared for Forest Fire

Personal Value Orientations

Personal value orientations were measured by asking respondents to rate (-3 to +3) the level of importance of biospheric and egoistic value statements pertaining to their personal lives. Not surprisingly, people from all communities in both regions considered biospheric and egoistic value orientations to be important; however, in the SOUTH, people reported slightly (though significantly) stronger biospheric and egoistic value orientations than people in the NORO (Table 14). People in Urban communities consistently reported higher biospheric values than people in rural communities. People from WUILP communities in both regions had slightly lower biospheric values than people in WUIMP and non-WUI.

Rural communities in the SOUTH, notably WUILP, significantly agreed more than urban communities with the egoistic value statements that the primary role of forests today is to provide timber and wood products, grazing lands, minerals, jobs, and income (Table 14). Respondents from the SOUTH also felt more strongly than those from the NORO that their personal health comes first. In the NORO, all communities, notably WUI communities, agreed slightly more than SOUTH communities did with the egoistic value statement that the primary role of forests today is to provide places to play and recreate.

Table 14. Mean respondent biospheric and egoistic personal value orientations by region and community type.

	Item	NORO						SOUTH						REGION
		Total	Urban	Rural	Preparedness			Total	Urban	Rural	Preparedness			
					Urb	MP	LP				Urb	MP	LP	*t*
		% Importance						% Importance						
Biospheric	The environment should be protected and nature should be preserved.	1.9	2.0	1.8	2.0	2.1	1.8	2.0	2.1	2.0	2.1	2.1	1.9	ns
	We should have unity with nature and fit into forest processes.	1.3	1.3	1.1	1.3	1.4	1.2	1.5	1.6	1.5	1.7	1.5	1.4	-2.9**
	I have an obligation to respect the earth and be at harmony with other species.	1.6	1.7	1.4	1.6	1.8	1.5	1.9	1.9	1.8	1.9	1.9	1.8	-2.8**
	Pollution should be prevented to protect nature.	1.5	1.5	1.4	1.6	1.5	1.4	1.8	1.9	1.8	1.8	1.8	1.8	-4.2**
Egoistic	The primary role of forests today is to provide places to play and recreate.	0.8	0.8	0.8	0.7	0.9	0.8	0.7	0.7	0.7	1.0	0.6	0.6	ns
	The primary role of forests today is to provide timber and wood products, grazing lands, and minerals for people.	0.8	0.8	0.8	0.9	0.7	0.8	1.2	1.0	1.4	1.0[a]	0.9[a]	1.6[b]	-4.5**
	My personal health comes first (not being sick physically or mentally).	1.6	1.5	1.6	1.5	1.6	1.6	1.9	1.9	1.9	1.9	1.8	2.0	-4.7**
	The primary role of forests today is to produce jobs and income.	0.3	0.3	0.4	0.4	0.2	0.4	0.7	0.5	0.8	0.4[a]	0.4[a]	1.1[b]	-3.6**

** p < .01, *p < .05

[a,b,c] Values with different superscripts in the same row and region are significantly different at the *p* < .05 level.

Total: Regions combined

Urb: Non-WUI

MP: More Prepared for Wildland Fire

LP: Less Prepared for Wildland Fire

Scale was -3 to +3

Awareness of the Benefits of Prescribed Fire

Study respondents were asked to indicate their level of agreement (-3 to +3) with statements about the potential outcomes of Rx fire. People from both regions highly recognized the benefits of Rx fire in forests (Table 15). Respondents agreed most with the statement that “prescribed fire reduces the amount of excess fuels,” and agreed least with the statement “forest health will improve if we use more prescribed fire.” The high level of recognition of the role of fire and benefits of Rx fire from our study has been well established in the fire literature (e.g., Jacobson, Monroe, & Marynowski, 2001; Ryan & Wamsley, 2008; Toman, Shindler, & Brunson, 2006; Vining & Merrick, 2008).

In the NORO, WUILP residents were significantly less aware of the benefits of Rx fire than WUIMP and non-WUI residents. SOUTH residents were slightly more willing than NORO residents to trade-off the short-term impacts of Rx fire smoke for the benefits of reduced future risk of large wildfires (and associated hazardous smoke impacts that come with large fires) (Table 15). SOUTH communities also significantly agreed more than NORO residents did with the statement that smoke from prescribed fire is an unavoidable outcome of improving forest health. The SOUTH rural WUI respondents were typically slightly more aware of Rx benefits than urban residents.

Table 15. Mean respondent **awareness of the benefits of Rx fire** by region and community type.

Item	NORO						SOUTH						REGION
	Total	Urban	Rural	Preparedness			Total	Urban	Rural	Preparedness			*t*
				Urb	MP	LP				Urb	MP	LP	
	mean (SE range 0.05-0.08)						mean (SE range 0.1-0.15)						
Prescribed fire reduces the amount of excess fuels	1.9	1.9	1.8	2.0^{a}	1.9^{a}	1.7^{b}	1.9	1.9	2.0	1.8	2.0	2.0	ns
Prescribed fire restores the forest to a more natural condition	1.4	1.5	1.4	1.6^{a}	1.5^{a}	1.3^{b}	1.6	1.4	1.7	1.5	1.5	1.7	ns
Prescribed fire improves wildlife habitat	1.4	1.5	1.3	1.6^{a}	1.6^{a}	1.2^{b}	1.3	1.2	1.4	1.1	1.4	1.4	ns
Prescribed fire near my community reduces the risk of large wildfires in the future and associated hazardous smoke impacts	1.6	1.7	1.5	1.9^{a}	1.7^{a}	1.4^{b}	1.9	1.8	2.0	1.8	1.9	2.0	-3.33**
Forest health will improve if we use more prescribed fire	1.3	1.3	1.2	1.5^{a}	1.4^{a}	1.1^{b}	1.5	1.3	1.6	1.3	1.4	1.6	ns
The negative consequences of smoke from prescribed fire are an unavoidable outcome of improving forest health	1.0	1.1	0.9	1.2^{a}	1.1^{a}	0.9^{b}	1.3	1.2	1.4	1.2	1.3	1.5	-2.93**

** p < .01, *p < .05

^{a,b,c} Values with different superscripts in the same row and region are significantly different at the $p < .05$ level.

Total: Regions combined

Urb: Non-WUI

MP: More Prepared for Wildland Fire

LP: Less Prepared for Wildland Fire

Scale was -3 to +3

Threat Appraisal

The section describes the results of the two dimensions of threat appraisal: perceptions of vulnerability (PV) and perceptions of severity (PS). The constructs PV and PS were measured by asking respondents to rate (-3 to +3) how likely (PV) and severe (PS) the impacts from smoke would be from a forest fire near their community.

Overall, PV regarding smoke from wildland fire was near the midpoint of neutral in both the NORO and the SOUTH (Table 16). Similarly, overall PS was near neutral in the NORO and SOUTH (Table 17). These results suggest that respondents in both regions did not generally have strong opinions about the likelihood and severity of smoke impacts from wildland fire. However, exploring individual items and community types did reveal some interesting differences. In NORO communities, potential smoke impacts on recreation/tourism, scenery, and school recess/outdoor sports elicited the highest scores for PV and PS. In the SOUTH, scenery and recess/sports impacts were also of greater concern than other items, but significantly less so than in the NORO.

Respondent PV and PS were significantly higher in NORO WUILP communities than other community types. Conversely, in SOUTH communities, non-WUI residents were slightly more concerned about smoke impacts than people from other communities were. For the most part, SOUTH communities perceived the effects of smoke to be equivocal for most items, except regarding smoke impacts to school recesses, where non-WUI residents thought impacts would be more severe than people from WUI communities.

Table 16. Mean respondent **perceptions of vulnerability** to smoke impacts by region and community type

	NORO						SOUTH						REGION
	Total	Urban	Rural	Preparedness			Total	Urban	Rural	Preparedness			
				Urb	MP	LP				Urb	MP	LP	t
Item	mean (SE .07-.08)						mean (SE .08-.19)						
Loss of recreation and tourism opportunities	1.3	1.3	1.5	1.0^{a}	1.5^{b}	1.5^{b}	-0.1	0.3	-0.4	0.6^{a}	0.0^{b}	-0.6^{b}	14.0**
Negative impact to my health	0.4	0.4	0.5	0.0^{a}	0.5^{b}	0.7^{b}	0.1	0.1	0.2	0.6^{a}	-0.1^{b}	0.0^{ab}	2.6**
Injury or death of wildlife in the area	0.3	0.3	0.1	0.3	0.2	0.3	0.4	0.6	0.2	0.8^{a}	0.5^{ab}	0.0^{b}	ns
Property damage from smoke	-0.9	-0.9	-0.9	-1.1^{a}	-0.9^{ab}	-0.8^{b}	-0.4	-0.1	-0.5	0.0^{a}	-0.3^{ab}	-0.7^{b}	-5.9**
Water contamination due to ash	-0.2	-0.1	-0.2	-0.3	-0.2	0.0	-0.4	-0.2	-0.5	0.1^{a}	-0.6^{b}	-0.5^{ab}	2.1*
Negative scenery impacts	1.3	1.2	1.3	1.1^{a}	1.2^{a}	1.5^{b}	0.5	0.7	0.3	0.7	0.7	0.2	7.9**
Negative impact to my family's health	0.3	0.2	0.3	-0.1^{a}	0.3^{b}	0.5^{b}	0.0	0.1	-0.1	0.3	-0.1	-0.2	2.4*
Negative impact to my occupation	-1.5	-1.5	-1.4	-1.8^{a}	-1.5^{ab}	-1.3^{b}	-1.5	-1.4	-1.6	-1.4	-1.7	-1.6	ns
Negative impact to my travel - road closures and/or car accidents	-0.3	-0.3	-0.4	-0.6^{a}	-0.2^{b}	-0.3^{b}	0.0	0.1	-0.1	0.3^{a}	0.0^{ab}	-0.3^{b}	-3.1**
Negative impact to school recess and outdoor sports	1.0	0.9	1.1	0.5^{a}	1.1^{b}	1.2^{b}	0.4	0.6	0.3	0.9^{a}	0.4^{ab}	0.0^{b}	5.7**

** $p < .01$, * $p < .05$

[a,b,c] Values with different superscripts in the same row and region are significantly different at the $p < .05$ level.

Urb: Non-WUI

MP: More Prepared for Wildland Fire

LP: Less Prepared for Wildland Fire

Scale was -3 to +3

Table 17. Mean respondent **perceptions of severity** to smoke impacts by region and community type

Item	NORO						SOUTH						REGION
	Total	Urban	Rural	Preparedness			Total	Urban	Rural	Preparedness			
				Urb	MP	LP				Urb	MP	LP	*t*
	mean (SE .04-.07)						mean (SE .09-.18)						
Loss of recreation and tourism opportunities	0.8	0.7	0.9	0.3^{a}	0.9^{b}	1.0^{b}	-0.1	0.1	-0.3	0.1	-0.2	-0.3	10.4**
Negative impact to my health	-0.1	-0.1	0.1	-0.4^{a}	-0.1^{b}	0.2^{c}	-0.1	-0.1	0.0	0.1	-0.2	-0.1	ns
Injury or death of wildlife in the area	-0.3	-0.3	-0.3	-0.3	-0.4	-0.2	0.0	0.1	0.0	0.2	-0.1	0.0	-3.1**
Property damage from smoke	-1.1	-1.1	-1.1	-1.1	-1.1	-0.9	-0.6	-0.5	-0.6	-0.3	-0.7	-0.6	-5.6**
Water contamination due to ash	-0.7	-0.7	-0.7	-0.9^{a}	-0.7^{ab}	-0.6^{b}	-0.7	-0.6	-0.7	-0.3	-0.9	-0.7	ns
Negative scenery impacts	0.4	0.3	0.6	0.0^{a}	0.3^{b}	0.7^{c}	-0.3	-0.1	-0.4	-0.1	-0.2	-0.4	6.1**
Negative impact to my family's health	-0.1	-0.1	0.0	-0.4^{a}	-0.2^{b}	0.2^{c}	-0.2	-0.1	-0.2	0.1	-0.3	-0.3	ns
Negative impact to my occupation	-1.7	-1.7	-1.6	-1.9^{a}	-1.8^{a}	-1.4^{b}	-1.6	-1.5	-1.6	-1.6	-1.7	-1.5	ns
Negative impact to my travel - road closures and/or car accidents	-0.7	-0.7	-0.7	-0.9^{a}	-0.6^{b}	-0.5^{b}	-0.2	-0.1	-0.2	0.1	-0.3	-0.3	-5.3**
Negative impact to school recess and outdoor sports	0.4	0.3	0.6	-0.1^{a}	0.4^{b}	0.7^{c}	0.0	0.0	0.0	0.5a	-0.2b	-0.1b	3.5**

** $p < .01$, * $p < .05$

[a,b,c] Values with different superscripts in the same row and region are significantly different at the $p < .05$ level.

Total: Regions combined

Urb: Non-WUI

MP: More Prepared for Wildland Fire

LP: Less Prepared for Wildland Fire

Scale was -3 to +3

Coping Appraisal

The section describes the results of the two dimensions of coping appraisal, response efficacy (RE) and self-efficacy (SE). The constructs RE and SE were measured by asking respondents to rate (-3 to +3) how effective a list of actions would be for coping with smoke (RE), and how likely it was that they would take action (SE).

The suggested ways of coping with smoke from forest fires were found, overall, to be only slightly effective in both the NORO and the SOUTH (Table 18). In both regions, respondents said that the most effective ways of coping with smoke were to keep one's windows and doors closed and stay indoors as much as possible. The SOUTH respondents perceived the suggested ways of coping with smoke (both staying at home or leaving home) to be more effective than respondents in the NORO (Table 18), and the SOUTH residents were also more likely than NORO residents to complete the actions that involved staying in the home (Table 19).

People from both regions agree that leaving one's home or the area is an effective way to cope with smoke. In the NORO, WUIMP residents felt more strongly than WUILP or non-WUI residents that that leaving town would be more effective than going to someone else's house. NORO urban residents were less likely to leave home than WUI residents. Regardless of how effective respondents believed leaving town would be for escaping smoke effects (RE), residents from both regions reported that they were unlikely to actually leave (Table 19).

Table 18. Mean respondent **perceptions of response efficacy** to smoke impacts by region and community type

	NORO						SOUTH						REGION
	Total	Urban	Rural	Preparedness			Total	Urban	Rural	Preparedness			
				Urb	MP	LP				Urb	MP	LP	
Item	mean (SE .04-.07)						mean (SE .09-.18)						t
Run your furnace or air conditioner to filter the air in your home.	-0.4	-0.4	-0.4	-0.3	-0.4	-0.5	0.1	0.2	0.0	0.3	0.1	-0.1	-4.7**
Leave town until the smoke clears.	1.2	1.2	1.1	0.9^{a}	1.5^{b}	1.1^{a}	0.9	0.8	0.9	1.1	0.9	0.7	2.7**
Remain indoors as much as possible.	1.3	1.3	1.3	1.3	1.2	1.3	1.3	1.4	1.2	1.4	1.5	1.2	ns
Keep your furnace fresh air intake closed.	0.1	0.0	0.1	0.0	0.1	0.1	0.7	1.0	0.6	0.7	0.9	0.6	-6.7**
Go to someone else's house or different location in town.	-0.5	-0.5	-0.3	-0.2^{a}	-0.7^{b}	-0.5^{b}	0.6	0.8	0.5	0.6	0.9	0.4	-9.6**
Purchase and use an indoor air purifier.	0.4	0.4	0.4	0.3	0.4	0.5	0.4	0.4	0.4	0.4	0.5	0.4	ns
Leave town and stay at a hotel paid by the agency conducting the prescribed fire.	1.0	1.0	1.1	1.0	1.1	1.0	1.3	1.2	1.3	1.1	1.2	1.4	ns
Keep your windows and doors closed.	1.4	1.4	1.4	1.5	1.4	1.4	1.6	1.6	1.6	1.5	1.5	1.7	-2.0*

** $p < .01$, *$p < .05$

^{a,b,c} Values with different superscripts in the same row and region are significantly different at the $p < .05$ level.

Total: Regions combined

Urb: Non-WUI

MP: More Prepared for Wildland Fire

LP: Less Prepared for Wildland Fire

Scale was -3 to +3

Table 19. Mean respondent **perceptions of self-efficacy** towards smoke impacts by region and community type

	NORO						SOUTH						REGION
	Total	Urban	Rural	Preparedness			Total	Urban	Rural	Preparedness			
				Urb	MP	LP				Urb	MP	LP	
Item	mean (SE .01-.20)						mean (SE .01-.20)						*t*
Run your furnace or air conditioner to filter the air in your home.	-0.7	-0.7	-0.8	-0.5	-0.8	-0.8	0.4	0.5	0.3	0.5	0.5	0.2	-8.6**
Leave town until the smoke clears.	-1.1	-1.1	-1.0	-1.4[a]	-0.9[b]	-1.1[ab]	-0.6	-0.6	-0.6	-0.4	-0.6	-0.7	-4.3**
Remain indoors as much as possible.	1.1	1.1	1.3	1.1	1.0	1.2	1.4	1.4	1.4	1.7	1.3	1.3	-3.1**
Keep your furnace fresh air intake closed.	-0.5	-0.5	-0.3	-0.4	-0.6	-0.4	0.6	0.6	0.6	0.6	0.5	0.7	-8.3**
Go to someone else's house or different location in town.	-1.6	-1.6	-1.6	-1.4[a]	-1.7[b]	-1.7[b]	-0.3	-0.3	-0.3	-0.3	-0.1	-0.4	-12.5**
Purchase and use an indoor air purifier.	-0.8	-0.8	-0.8	-1.0[a]	-0.8[ab]	-0.6[b]	-0.5	-0.5	-0.5	-0.4	-0.5	-0.7	-2.2*
Leave town and stay at a hotel paid by the agency conducting the prescribed fire.	-0.6	-0.6	-0.6	-0.6	-0.6	-0.6	0.2	0.2	0.3	0.3	0.2	0.2	-6.8**
Keep your windows and doors closed.	2.2	2.2	2.3	2.2	2.1	2.3	2.2	2.2	2.2	2.3	2.3	2.1	ns

** p < .01, *p < .05

[a,b,c] Values with different superscripts in the same row and region are significantly different at the *p* < .05 level.

Total: Regions combined

Urb: Non-WUI

MP: More Prepared for Wildland Fire

LP: Less Prepared for Wildland Fire

Scale was -3 to +3

Trust in Forest Fire Managers

Respondents were asked to rate (-3 to +3) their level of agreement with statements about the extent to which they trust the ability of forest fire managers to effectively manage wildland fire and smoke (i.e., competence), and the extent to which they trust that forest fire managers provide adequate information about wildland fire and smoke (i.e., credibility). In the NORO, the highest level of competence was attributed to forest fire managers' ability to protect private property. In the SOUTH the highest competence rating was given to managers' ability to use Rx fire effectively. In both regions, the lowest competency rating was given to managers' ability to manage smoke. The lowest credibility rating in both regions was managers providing timely information regarding smoke (Table 20).

Respondents from the SOUTH believed that forest fire managers were more trustworthy than NORO respondents did, and they had slightly more confidence in the ability of fire managers to manage wildfires, use Rx fires effectively, manage the associated smoke, and protect private property (Table 20). In the NORO, WUILP respondents found fire managers to be less competent and credible overall than WUIMP and non-WUI communities did. The SOUTH respondents were very consistent in their perceptions of high competence and credibility of forest fire managers, regardless of community type.

Table 20. Mean respondent **trust in forest fire managers' competency and credibility** by region and community type.

Item	NORO						SOUTH						REGION
	Total	Urban	Rural	Preparedness			Total	Urban	Rural	Preparedness			
				Urb	MP	LP				Urb	MP	LP	*t*
	mean (SE .04-.12)						mean (SE .07-.12)						
Competency: Effectively manage smoke	0.3	0.3	0.0	0.8^{a}	0.2^{b}	-0.2^{c}	1.2	1.3	1.1	1.4	1.3	1.0	-9.4**
Competency: Protect private property when conducting a prescribed fire	1.4	1.5	1.3	1.7^{a}	1.5^{b}	1.2^{c}	1.7	1.8	1.7	1.7	1.8	1.7	-3.5**
Competency: Use prescribed fire effectively	1.2	1.2	0.9	1.6^{a}	1.1^{b}	0.8^{c}	1.8	1.9	1.8	1.9	1.9	1.7	-7.1**
Competency: Manage and control wildfires effectively	0.8	0.9	0.5	1.3^{a}	0.8^{b}	0.3^{c}	1.6	1.7	1.6	1.6	1.7	1.6	-8.0**
Competency: Protect private property during a wildfire	1.5	1.5	1.4	1.6^{a}	1.6^{a}	1.3^{b}	1.5	1.5	1.5	1.4	1.6	1.5	ns
Credibility: The best available information on smoke issues	1.1	1.1	0.9	1.3^{a}	1.1^{b}	0.9^{b}	1.4	1.5	1.4	1.6	1.5	1.3	-3.9**
Credibility: Enough smoke information to decide what actions I should take	1.1	1.1	1.0	1.3^{a}	1.1^{ab}	0.9^{b}	1.5	1.6	1.4	1.7	1.5	1.2	-3.9**
Credibility: The best available information about prescribed fire	1.2	1.2	1.1	1.4^{a}	1.2^{a}	0.9^{b}	1.5	1.6	1.4	1.7	1.5	1.3	-3.4**
Credibility: Timely information regarding smoke	0.9	1.0	0.8	1.2^{a}	0.9^{ab}	0.7^{b}	1.3	1.4	1.3	1.5	1.5	1.1	-4.2**
Credibility: Information about safety related to wildfire	1.4	1.5	1.3	1.6^{a}	1.5^{a}	1.2^{b}	1.5	1.6	1.5	1.8	1.6	1.2	ns

** $p < .01$, * $p < .05$

^{a,b,c} Values with different superscripts in the same row and region are significantly different at the $p < .05$ level.

Total: Regions combined, Urb: Non-WUI, MP: More Prepared for Wildland Fire, LP: Less Prepared for Wildland Fire

Scale was -3 to +3

Tolerance of Smoke from Wildland Fire

We asked participants to consider experiencing smoke in their community from different fire sources, and then rate (-3 to +3) how tolerant or intolerant they would be of the smoke. Participants were asked to only consider the fire source. Overall, respondents were somewhat tolerant of smoke from all sources in both regions (Table 21). Respondents in the NORO were most tolerant of smoke from wildfires caused by lightning. In the SOUTH, respondents were equally as tolerant of smoke from Rx fire as they were of smoke from lightning caused wildfire. Prescribed-natural fire and slash pile burning from forest fuel reduction were the least tolerated sources of smoke in both regions. In the NORO, WUILP communities were significantly less tolerant of smoke from all sources than WUIMP and non-WUI communities.

Support for Rx Fire Management

Support for Rx fire management was measured by asking respondents to rate (-3 to +3) their level of agreement with statements about the use of Rx fire in forest management. Support for Rx fire overall was moderately high (Table 22). In both regions, respondents showed the strongest agreement for the statement, “the use of prescribed fire is appropriate, so long as smoke health impacts are minimal in my community,” followed closely by “forest managers should periodically burn underbrush and debris in forests near my community, even though it results in periodic smoke.” Respondents in the SOUTH disagreed more with the statements that Rx fire is too dangerous and the health effects are too great to use it. Respondents in the SOUTH agreed more with the trade-off statement, “forest managers should periodically burn underbrush and debris in forests near my community, even though it results in periodic smoke.” In the NORO, non-WUI communities were always more supportive of Rx fire use than WUILP communities.

Table 21. Mean **respondent tolerance of smoke** by region and community type

Item	NORO						SOUTH						REGION
	Total	Urban	Rural	Preparedness			Total	Urban	Rural	Preparedness			
				Urb	MP	LP				Urb	MP	LP	*t*
	mean (SE 0.01-0.1)						mean (SE 0.01-0.1)						
Smoke from a **prescribed fire** that is ignited by land managers to achieve forest health objectives.	0.8	0.9	0.6	1.1[a]	0.9[a]	0.5[b]	1.2	1.1	1.2	1.1	1.1	1.2	-3.4**
Smoke from a **prescribed-natural fire** / wildland fire that is unintentionally started (e.g., lightning) but allowed to burn to achieve forest health objectives.	0.8	0.9	0.6	1.2[a]	0.9[b]	0.5[c]	1.1	1.0	1.1	1.0	1.1	1.0	ns
Smoke from **slash pile burning** following a forest fuel reduction project (thinning).	0.7	0.8	0.6	0.9[a]	0.8[a]	0.5[b]	.9	0.9	0.8	0.9	0.9	0.8	ns
Smoke from a **wildfire** that was started by lightning.	1.2	1.3	1.0	1.5[a]	1.3[a]	0.9[b]	1.2	1.1	1.2	1.1	1.1	1.2	ns

** p < .01, *p < .05

[a,b,c] Values with different superscripts in the same row and region are significantly different at the $p < .05$ level.

Total: Regions combined

Urb: Non-WUI

MP: More Prepared for Wildland Fire

LP: Less Prepared for Wildland Fire

Scale was -3 to +3

Table 22. Mean **respondent support for Rx fire management** by region and community type

Item	NORO						SOUTH						REGION
	Total	Urban	Rural	Preparedness			Total	Urban	Rural	Preparedness			
				Urb	MP	LP				Urb	MP	LP	*t*
	mean (SE 0.01-0.1)						mean (SE 0.01-0.1)						
The use of prescribed fire is appropriate, so long as smoke health impacts are minimal in my community.	1.8	1.8	1.6	1.9^{a}	1.8^{ab}	1.6^{b}	1.9	1.9	1.8	1.7	1.9	1.9	ns
Prescribed fire should not be used because of the potential health problems from smoke in my community.	-1.3	-1.4	-1.2	-1.5^{a}	-1.4^{a}	-1.1^{b}	-1.1	-1.1	-1.1	-0.8	-1.2	-1.2	2.4*
Prescribed fire is too dangerous to be used in forests near my community.	-1.4	-1.5	-1.3	-1.6^{a}	-1.5^{ab}	-1.2^{b}	-1.1	-1.0	-1.2	-0.9	-1.0	-1.4	2.9**
All fires near my community, regardless of origin, should be put out as soon as possible.	-.6	-0.6	-0.5	-0.9^{a}	-0.7^{ab}	-0.3^{b}	-.5	-0.3	-0.6	0.0	-0.6	-0.7	ns
Forest managers should periodically burn underbrush and debris in forests near my community, even though it results in periodic smoke.	1.4	1.4	1.4	1.6^{a}	1.5^{ab}	1.3^{b}	1.6	1.4	1.8	1.3^{a}	1.6^{ab}	1.9^{b}	-2.1*

** p < .01, *p < .05

^{a,b,c} Values with different superscripts in the same row and region are significantly different at the *p* < .05 level.

Total: Regions combined

Urb: Non-WUI

MP: More Prepared for Wildland Fire

LP: Less Prepared for Wildland Fire

Scale was -3 to +3

Model Testing

This section goes beyond descriptive and comparative statistics for individual variables into the results of data reduction using factor analysis, model building and testing using path analytic models, and hypothesis testing.

Data Reduction – Factor Analysis

Exploratory factor analysis (EFA) was performed on the raw data to determine whether a single or multiple dimensions of the construct exist. The pattern matrix from the direct oblimin rotation with pairwise deletions is reported with a description of the resulting factor(s).

Personal Value Orientations

The EFA conducted for the eight personal value orientation items revealed two distinct dimensions present in both the NORO and SOUTH (Table 23). These two dimensions were consistent with biospheric and egoistic value orientations. Two egoistic items ("the primary role of forests today is to provide places to play and recreate", and "my personal health comes first") were not included in the egoistic factor because the items loaded more strongly on the biospheric factor and would have reduced the reliability of the biospheric factor if included. Good reliability was demonstrated by both biospheric (NORO α= .78, SOUTH α= .85) and egoistic (NORO α= .83, SOUTH α= .80) dimensions, and the items were combined into two factors by calculating the mean of the items that reliably loaded on each dimension.

Awareness of the Benefits of Rx Fire

The EFA conducted for the six personal value orientation items revealed one distinct dimension present in both the NORO and SOUTH (Table 24). Good reliability was demonstrated (NORO α= .93, SOUTH α= .91) and the items were combined into a single factor.

Table 23. Summary of exploratory factor analysis results for **biospheric and egoistic value orientations.**

Item	NORO		SOUTH	
	Factor Loadings (pattern matrix)			
	Biospheric n=1493	Egoistic n=1492	Biospheric n=352	Egoistic n=351
I have an obligation to respect the earth and be at harmony with other species	**.81**	-.18	**.83**	-.20
We should have unity with nature and fit into forest processes	**.79**	-.12	**.82**	-.12
Pollution should be prevented to protect nature	**.75**	-.01	**.82**	-.09
The environment should be protected and nature should be preserved	**.74**	-.25	**.79**	.05
The primary role of forests today is to provide places to play and recreate*	.51	.26	.53	.19
My personal health comes first (not being sick physically or mentally)*	.50	.33	.55	.22
The primary role of forests today is to provide timber and wood products, grazing lands, and minerals for people	-.06	**.89**	.01	**.89**
The primary role of forests today is to produce jobs and income	-.13	**.88**	-.02	**.90**
Factor means (scale -3 to 3)	1.58	0.56	1.81	0.94
SE	0.03	0.04	0.05	0.07
Cronbach's alpha	0.78	0.83	0.85	0.80
Eigenvalue	3.1	1.7	3.3	1.7
% Variance explained	38.9	21.5	41.7	21.5

*Two items were not included in either factor because they loaded across factors
Bolded items loaded well on a single dimension and were combined into the factor

Table 24. Summary of exploratory factor analysis results for the **awareness of benefits of prescribed fire**

Item	NORO	SOUTH
	Factor Loadings (component matrix)	
Forest health will improve if we use more prescribed fire	0.90	0.91
Prescribed fire restores the forest to a more natural condition	0.90	0.81
Prescribed fire near my community reduces the risk of large wildfires in the future and associated hazardous smoke impacts	0.89	0.86
Prescribed fire improves wildlife habitat	0.88	0.81
Prescribed fire reduces the amount of excess fuels	0.87	0.79
The negative consequences of smoke from prescribed fire are an unavoidable outcome of improving forest health	0.77	0.76
Factor means (scale -3 to 3)	1.46	1.58
Standard deviation	0.03	0.06
Cronbach's alpha	0.93	0.91
Eigenvalue	4.6	4.1
% Variance explained	76.2	68.5

Threat Appraisal

The EFA conducted for the 10 PV items revealed two dimensions present in the NORO (Table 25). The two dimensions appeared to differentiate between perceptions of vulnerability to recreation and transportation, and perceptions of non-recreation vulnerabilities. However, the overall correlation between these two dimensions was somewhat high (r= 0.60), and all 10 PV items demonstrated high inter-item reliability (α= .85). Our intent in this study was not necessarily to understand the underlying dimensions of PV, but rather to understand overall PV, how it combines with PS to create overall threat appraisal, and how threat appraisal relates to public tolerance of smoke from wildland fires. Therefore, based on the moderately high correlation and high inter-item reliability for the two PV dimensions, we decided to create one single composite dimension of PV. The EFA conducted for the 10 PV items for the SOUTH revealed one distinct dimension present (Table 25). Good reliability was demonstrated (α= .90) and the items were combined into a single factor.

The EFA conducted for the 10 PS items revealed one dimension present in the NORO and the SOUTH (Table 26). Good reliability was demonstrated (NORO α= .90, SOUTH α= .93) and the items were combined into a single factor. Following the guidelines suggested by protection motivation theory (Rogers & Prentice-Dunn, 1997), the PV and PS factors were summed to create a final factor of Threat Appraisal (range of -6 to +6).

Coping Appraisal

The EFAs conducted for the 8 RE and SE items revealed two distinct dimensions present in the NORO and SOUTH (Table 27 and 28). One dimension described actions that required the respondent to stay home and cope with smoke, such as “keep your windows and doors closed” and “run your furnace or air conditioner to filter the air in your home.” The second dimension included items that would require respondents to leave their home in order to cope with smoke, such as "leave town until the smoke clears" and "go to someone else's house or different location in town." Moderate to good reliability was demonstrated by both the "stay home" (RE: NORO α= .66, SOUTH α= .60; SE: NORO α= .63, SOUTH α= .69) and "leave home" (RE: NORO α= .67, SOUTH α= .72; SE: NORO α= .65, SOUTH α= .74) dimensions, and the items were combined into two factors for each region. Following the guidelines of protection motivation theory (Rogers & Prentice-Dunn, 1997), the RE and SE were summed to create factors of Stay Home and Leave Home Coping Appraisal (ranges of -6 to +6).

Table 25. Summary of exploratory factor analysis results for **perceptions of vulnerability**

	NORO		SOUTH
	Factor Loadings (pattern matrix)		
Item	PV Non-Rec	PV Rec/Trans	PV
Property damage from smoke	**0.84**	-0.15	0.80
Negative impact to my occupation	**0.79**	-0.18	0.60
Water contamination due to ash	**0.64**	0.11	0.81
Negative impact to my travel - road closures and/or car accidents	**0.60**	0.14	0.71
Injury or death of wildlife in the area	**0.57**	0.16	0.74
Negative impact to my family's health	**0.54**	0.34	0.81
Negative impact to my health	**0.49**	0.32	0.69
Loss of recreation and tourism opportunities	-0.04	**0.77**	0.58
Negative scenery impacts	-0.02	**0.76**	0.70
Negative impact to school recess and outdoor sports	0.23	**0.60**	0.78
Factor means (scale -3 to 3)	0.16		-0.10
SE	0.03		0.07
Cronbach's alpha	0.85		0.90
Eigenvalue	4.1		5.3
% Variance explained	41.5		53.4

Bolded items loaded well on a single dimension and were combined into the factor

Table 26. Summary of exploratory factor analysis results for **perceptions of severity**

	NORO	SOUTH
Item	Factor Loadings (component matrix)	
Loss of recreation and tourism opportunities	0.67	0.71
Negative impact to my health	0.79	0.80
Injury or death of wildlife in the area	0.73	0.83
Property damage from smoke	0.74	0.83
Water contamination due to ash	0.72	0.84
Negative scenery impacts	0.70	0.81
Negative impact to my family's health	0.80	0.84
Negative impact to my occupation	0.66	0.69
Negative impact to my travel - road closures and/or car accidents	0.72	0.77
Negative impact to school recess and outdoor sports	0.73	0.81
Factor mean (scale -3 to 3)	-0.30	-0.30
SE	0.03	0.07
Cronbach's alpha	0.90	0.93
Eigenvalue	5.3	6.3
% Variance explained	52.4	63.0

Table 27. Summary of exploratory factor analysis results for **perceived response efficacy**

	NORO		SOUTH	
	Factor Loadings (pattern matrix)			
Item	RE – Stay Home	RE – Leave Home	RE – Stay Home	RE – Leave Home
Keep your windows and doors closed	**0.76**	0.21	**0.77**	0.25
Remain indoors as much as possible	**0.69**	-0.10	**0.72**	0.13
Keep your furnace fresh air intake closed	**0.68**	-0.05	**0.66**	-0.05
Run your furnace or air conditioner to filter the air in your home	**0.57**	0.01	**0.62**	-0.20
Purchase and use an indoor air purifier*	0.47	-0.30	0.03	0.48
Leave town until the smoke clears	-0.10	**-0.84**	-0.17	**0.84**
Leave town and stay at a hotel paid by the agency conducting the prescribed fire	-0.03	**-0.82**	0.04	**0.77**
Go to a someone else's house or different location in town	0.15	**-0.60**	0.37	**0.73**
Factor means (scale -3 to 3)	0.60	0.60	1.2	0.9
SE	0.03	0.04	0.06	0.08
Cronbach's alpha	0.66	0.67	0.60	0.72
Eigenvalue	2.58	1.43	2.8	1.6
% Variance explained	32.2	17.8	34.7	20.0

* Item eliminated because it did not load well on either dimension
Bolded items loaded well on a single dimension and were combined into the factor

Table 28. Summary of exploratory factor analysis results for **perceived self-efficacy**

	NORO		SOUTH	
	Factor Loadings (pattern matrix)			
Item	SE – Stay Home	SE – Leave Home	SE – Stay Home	SE – Leave Home
Run your furnace or air conditioner to filter the air in your home	**0.69**	-0.14	**0.56**	0.47
Keep your windows and doors closed	**0.67**	-0.13	**0.87**	0.26
Keep your furnace fresh air intake closed	**0.64**	0.14	**0.57**	0.05
Remain indoors as much as possible	**0.59**	0.26	**0.81**	-0.04
Purchase and use an indoor air purifier*	0.40	0.28	0.07	-0.14
Leave town until the smoke clears	-0.03	**0.79**	-0.03	**0.81**
Go to a someone else's house or different location in town	0.04	**0.77**	-0.20	**0.79**
Leave town and stay at a hotel paid by the agency conducting the prescribed fire	-0.02	**0.76**	0.28	**0.77**
Factor means (scale -3 to 3)	0.60	0.60	1.2	0.9
SE	0.03	0.04	0.06	0.08
Cronbach's alpha	0.66	0.68	0.65	0.74
Eigenvalue	2.58	1.43	1.6	2.5
% Variance explained	40.17	19.0	54.8	31.9

* Item eliminated because it did not load well on either dimension
Bolded items loaded well on a single dimension and were combined into the factor

Trust in Forest Fire Managers

The EFA conducted for the 10 agency trust items revealed two distinct dimensions present in both the NORO and SOUTH that aligned with the dimensions of competency and credibility (Table 29). However, the overall correlation between competency and credibility was high (r= 0.71) and all 10 trust items demonstrated high inter-item reliability (NORO α= .95, SOUTH α= .95). Our intent in this study was not necessarily to understand the underlying dimensions of trust, but rather to understand trust overall and how it relates to public tolerance of smoke from wildland fires. Therefore, based on the high correlation and high inter-item reliability for the two dimensions, we decided to create one single composite dimension of trust.

Tolerance of Smoke from Wildland Fire and Support for Rx Fire Management

The EFA conducted for the four tolerance items revealed one distinct dimension present in both the NORO and SOUTH (Table 30). Good reliability was demonstrated (NORO α= .90, SOUTH α= .89) and the items were combined into a single tolerance factor. The EFA conducted for the five Rx management support items revealed one distinct dimension present in both the NORO and SOUTH (Table 31). Good reliability was demonstrated (NORO α= .83, SOUTH α= .89) and the items were combined into a single tolerance factor. A summary of all factors is provided in Table 32.

Table 29. Summary of exploratory factor analysis results for **trust in forest fire managers**

	NORO		SOUTH	
	Factor Loadings (pattern matrix)			
Item	Credibility	Competency	Credibility	Competency
Trust Credibility: Provide enough smoke information to decide what actions I should take	**0.99**	-0.06	**0.90**	0.06
Trust Credibility: Provide timely information regarding smoke	**0.94**	-0.02	**0.95**	0.02
Trust Credibility: Provide the best available information on smoke issues	**0.93**	0.00	**0.92**	0.02
Trust Credibility: Provide the best available information about prescribed fire	**0.88**	0.05	**0.98**	-0.03
Trust Credibility: Provide information about safety related to wildfire	**0.80**	0.10	**0.94**	-0.02
Trust Competence: Protect private property when conducting a prescribed fire	-0.04	**0.91**	0.20	**0.66**
Trust Competence: Protect private property during a wildfire	-0.09	**0.90**	-0.02	**0.93**
Trust Competence: Manage and control wildfires effectively	0.02	**0.86**	0.11	**0.82**
Trust Competence: Use prescribed fire effectively	0.11	**0.82**	-0.11	**0.99**
Trust Competence: Effectively manage smoke	0.17	**0.66**	0.00	**0.88**
Factor means (scale -3 to 3)	1.1		1.5	
SE	0.04		0.03	
Cronbach's alpha	0.95		0.95	
Eigenvalue	7.9		8.4	
% Variance explained	78.9		84.2	

Table 30. Summary of exploratory factor analysis results for **respondent tolerance of smoke.**

	NORO	SOUTH
Item	Factor Loadings (component matrix)	
Smoke from a prescribed fire that is ignited by land managers to achieve forest health objectives.	**.91**	**.91**
Smoke from a prescribed-natural fire / wildland fire that is unintentionally started (e.g., lightning) but allowed to burn to achieve forest health objectives.	**.91**	**.91**
Smoke from slash pile burning following a forest fuel reduction project (thinning).	**.84**	**.88**
Smoke from a wildfire that was started by lightning.	**.83**	**.79**
Factor means (scale -3 to 3)	0.9	1.1
Standard deviation	1.5	1.5
Cronbach's alpha	0.90	0.89
Eigenvalue	3.1	3.0
% Variance explained	76.2	76.1

Table 31. Summary of exploratory factor analysis results for **Rx fire management support.**

	NORO	SOUTH
Item	Factor Loadings (component matrix)	
Prescribed fire is too dangerous to be used in forests near my community. (reverse coded)	**.86**	**.81**
Prescribed fire should not be used because of the potential health problems from smoke in my community.	**.84**	**.84**
Forest managers should periodically burn underbrush and debris in forests near my community, even though it results in periodic smoke.	**.74**	**.73**
All fires near my community, regardless of origin, should be put out as soon as possible. (reverse coded)	**.70**	**.79**
The use of prescribed fire is appropriate, so long as smoke health impacts are minimal in my community.	**.70**	**.67**
Factor means (scale -3 to 3)	0.9	1.1
Standard deviation	1.5	1.5
Cronbach's alpha	0.90	0.89
Eigenvalue	3.1	3.0
% Variance explained	76.2	76.1

Table 32. Summary of all factors from exploratory factor analysis by region and community type

	NORO						SOUTH						REGION
	Total	**Urban**	**Rural**	**Preparedness**			**Total**	**Urban**	**Rural**	**Preparedness**			
				Urb	**MP**	**LP**				**Urb**	**MP**	**LP**	***t***
FACTOR	*mean*$^{+}$						*mean*$^{+}$						
Biospheric Value Orientations	1.6	1.6	1.4	1.6^{ab}	1.7^{a}	1.5^{b}	1.8	1.9	1.8	1.9	1.8	1.7	-3.5**
Egoistic Value Orientations	0.6	0.5	0.6	0.6	0.5	0.6	0.9	0.8	1.1	0.7^{a}	0.7^{a}	1.4^{b}	-4.3**
Awareness of the Benefits of Rx Fire	1.5	1.5	1.4	1.6^{a}	1.5^{a}	1.3^{b}	1.6	1.5	1.7	1.5	1.6	1.7	ns
Threat Appraisal	-0.1	-0.2	-0.0	-0.6^{a}	-0.1^{b}	0.3^{c}	-0.4	-0.2	-0.6	0.1^{a}	-0.5^{ab}	-0.7^{b}	2.1*
Coping Appraisal	0.3	0.3	0.4	0.3	0.3	0.3	1.3	1.3	1.2	1.4	1.4	1.1	-9.0**
Trust – All items	1.1	1.1	0.9	1.4^{a}	1.1^{b}	0.8^{c}	1.5	1.6	1.5	1.6	1.6	1.4	-5.6**
Tolerance of Smoke	0.9	0.9	0.7	1.2^{a}	1.0^{a}	0.6^{b}	1.1	1.0	1.1	1.0	1.1	1.1	ns
Support of Rx Fire Management	1.3	1.3	1.1	1.4^{a}	1.3^{a}	1.0^{b}	1.3	1.1	1.2	.9	1.2	1.3	ns

** $p < .01$, *$p < .05$

^{a,b,c} Values with different superscripts in the same row and region are significantly different at the $p < .05$ level.

$^{+}$The standard errors for all values ranged from 0.1 to 0.2

Total: Regions combined

Urb: Non-WUI

MP: More Prepared for Wildland Fire

LP: Less Prepared for Wildland Fire

Scales for threat and coping appraisal are -6 to 6, all others are -3 to 3

Correlational Analysis

Bivariate correlational analysis was conducted for the entire sample (both regions) and revealed significant relationships among some of the main variables discussed above, though the majority indicated non-significant weak relationships with *r*-values less than 0.50 (see Appendix Q for full correlation table). Many of the significant yet small correlations were considered spurious due to the large sample size of the study. Public tolerance of smoke from wildland fire was most positively correlated with Rx fire management support (r= .52), awareness of the benefits of Rx burning (r= .53), trust in forest fire managers (r= .37), and the participants' level of education (r= .17). Tolerance of smoke was negatively correlated with threat appraisal (r= -.42), negative experience with personal health effects (r= -.29), and family health effects (r= -.19) from smoke. Rx fire management support followed the same positive and negative correlational trends with the other variables as tolerance of smoke.

Path Analytic Models

Path analytic models were used because they allowed for the exploration of more than one dependent variable simultaneously in our model, and allow us to test the magnitude and statistical significance of the predicted relationships across the set of variables (refer back to Figure 1 for the proposed path model). Three models were evaluated: model 1 used the combined dataset that included both regions, model 2 used the NORO sample, and model 3 used the SOUTH sample. Each model was initially tested using 22 total variables (single questions) and factors (EFA composite variables) (Appendix Q). The maximum likelihood estimation converged on an admissible solution for each initial path model with all of the variables included (Kline, 2011); however, the global and localized fit indices indicated that the initial models displayed extremely poor overall fit (i.e., significant X^2 test, Comparative Fit Index (CFI) < 0.90, Root Mean Squared Error of Approximation

(RMSEA) > 0.05 with an upper confidence interval greater than 0.08, and Standardized Root Mean Square Residual (SRMR) > 0.08) (Barrett, 2007; Kenny & McCoach, 2003; Kline, 2011).

To obtain acceptable fit for each model, non-significant variables were removed and the models were estimated again. In the SOUTH model, the direct paths from trust in forest fire managers to threat appraisal and tolerance of smoke were non-significant and removed to improve model fit. However, the overall fit of all three models was still considered unacceptable based on the fit indices noted above. Investigation of the modification indices (MI) suggested that two areas of localized ill fit were observed and that direct paths needed to be added from awareness of Rx fire benefits to threat appraisal (negative relationship), and from previous health experience with smoke to threat appraisal (positive relationship). These modifications were logical and the two additional paths were added to each model. Inspection of the standardized residuals (an indication of how well the model variances and covariance matrix fit the observed variance and covariance matrix) demonstrated that localized fit was acceptable, as no residuals above the 2.58 (z-score) significance level were present. After the models had been trimmed and MIs addressed, the overall fit of each model was considered acceptable (Table 33). The significant X^2 tests for each model and high values of RMSEA (and the upper confidence interval bound) for models 2 and 3 were considered acceptable because it has been documented that samples larger than 200 will nearly always yield a significant X^2 result (Barrett, 2007; Kline, 2011), and RMSEA is considered positively biased (i.e., tends to be artificially large) when the model degrees of freedom are small (Kenny & McCoach, 2003). Other modification indices were explored but did not suggest logical additional variable relationships and recommended correlated errors between dependent and independent variables; therefore, no further modifications were made to the models.

Table 33. Global fit indices for Model 1: Combined Regions, Model 2: NORO, and Model 3: SOUTH.

	df	X^2	Prob. of X^2	CFI	RMSEA (90CI)	SRMR	R^2
Model 1: Combined	7	48.6	< .01	.99	.05 (.04-.07)	.03	.37
Model 2: NORO	7	50.2	< .01	.98	.06 (.05-.08)	.03	.41
Model 3: SOUTH	10	19.7	< .01	.98	.07 (.04-.11)	.03	.24

Path diagrams for model 1 (Figure 3; combined regions), model 2 (Figure 4; NORO), and model 3 (Figure 5; SOUTH) represent the predicted relationship between beliefs about public trust in forest fire managers, Rx fire (threat appraisal and awareness of the benefits of Rx burning), individual characteristics (previous health experience with smoke and highest level of education achieved) and public tolerance of smoke. These figures are the graphical equivalent of a set of regression equations that relate the dependent and predictor variables (Kline, 2011). Each straight line with a single-headed arrow represents a path and points in the proposed direction of causality. Standardized path coefficients (the number immediately above or below the single-headed arrow) are interpreted as the expected change in standard deviation (SD) units of the dependent variable given a one SD increase in the predictor variable, while controlling for the direct effects of other variables. The curved double-headed arrows on the left side of the model indicate correlations between pairs of predictor variables. The number within the curved double-headed arrow indicates the strength of the correlation between the two variables. The number next to the circles adjacent to each dependent variable indicate the disturbance, or standardized residual variance, associated with that dependent variable.

Model 1: Combined Regions

Public trust in forest fire managers accounted for 27% of the variance in public awareness of the benefits of Rx fire (Figure 3), where a one SD increase in trust predicted a 0.44 increase in awareness of Rx fire benefits. Public trust in forest fire managers, experience with health effects from smoke, and awareness of Rx fire benefits accounted for 13% of the variance in threat appraisal. A one SD increase in trust predicted a -0.17 decrease in threat appraisal, holding past experience constant. The indirect effect of trust on threat appraisal was nearly as strong as the direct effect, where the respondent's threat appraisal decreased by -0.15 SDs for every one SD increase on trust via its prior effects on awareness of Rx fire benefits (Table 34). A one SD increase in past health effect experience predicted a 0.29 increase in threat appraisal, holding trust constant.

The strongest predictors of public tolerance of smoke were the direct effects of awareness of Rx fire benefits (β = 0.44) and threat appraisal (β = -0.19), and the total effect (direct and indirect effects) of trust in fire managers (β = 0.30). The total effect of trust on tolerance of smoke is 0.30, meaning that the respondent's tolerance of smoke improves by 0.30 standard deviations for every one standard deviation increase in trust, which was a combination of the direct effect of trust (β = 0.06) and indirect effects via awareness of Rx fire benefits and threat appraisal (β = 0.24). The total effect of trust on tolerance of smoke was therefore largely mediated by awareness of Rx fire benefits and threat appraisal. The respondent's personal health experience with smoke (β = -0.15) was partially mediated by threat appraisal, and education (β = 0.10) had the smallest effects on tolerance of smoke. Public tolerance of smoke explained 25% of the variance in overall support for Rx fire management actions, where one SD increase in tolerance of smoke predicted a 0.50 increase in Rx fire management support.

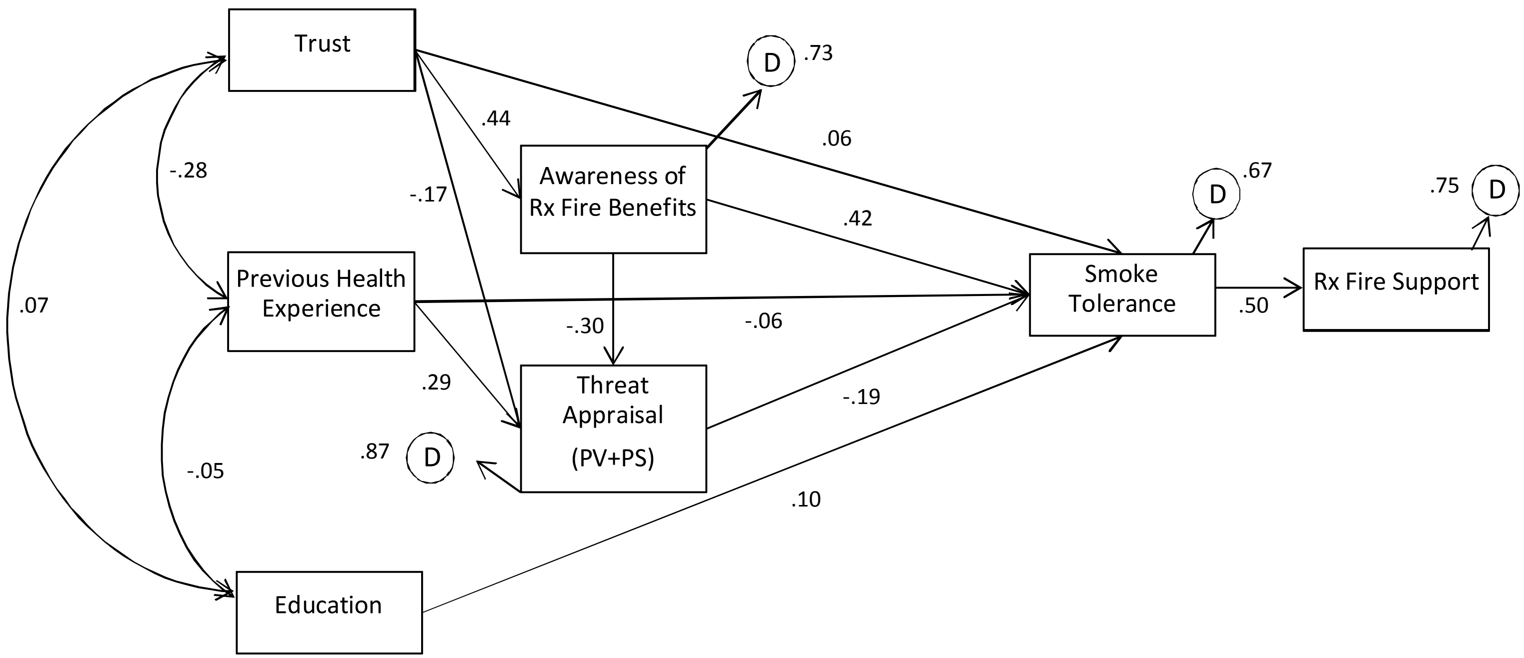

Figure 3. Combined regions final path measurement model. Numbers associated with single-headed arrows are standardized path coefficients. Numbers associated with curved double-headed arrows are correlations. The numbers next to the disturbance circles are the residuals associated with a dependent variable. All path coefficients are significant at the $p < 0.01$ level.

Table 34. Effect decomposition table for the final combined region path model of smoke tolerance and Rx fire support

Causal Variables	**Endogenous Variables**			
	Awareness of Rx Fire Benefits	**Threat Appraisal**	**Tolerance of Smoke**	**Rx Fire Support**
Trust				
Direct effect	0.44	-0.17	0.06	
Total Indirect effects		-0.15	0.24	0.37
Total effect	0.44	-0.32	0.30	0.37
Experienced Personal Health Effects from Smoke				
Direct effect		0.29	-0.06	
Total Indirect effects			-0.09	-0.13
Total effect		0.29	-0.15	-0.13
Awareness of Rx Fire Benefits				
Direct effect		-0.30	0.42	
Total Indirect effects			0.06	0.58
Total effect		-0.30	0.48	0.58
Threat Appraisal				
Direct effect			-0.19	
Total Indirect effects				-0.23
Total effect			-0.19	-0.23
Education				
Direct effect			0.10	
Total Indirect effects				0.13
Total effect			0.10	0.13
Tolerance of Smoke				
Direct effect				0.50
Total Indirect effects				
Total effect				

Model 2: NORO

Among NORO respondents, public trust in forest fire managers accounted for 28% of the variance in public awareness of the benefits of Rx fire (Figure 4), where a one SD increase in trust predicted a 0.46 increase in awareness of Rx fire benefits. Public trust in forest fire managers, experience with health effects from smoke, and awareness of Rx fire benefits accounted for 16% of the variance in threat appraisal. A one SD increase in trust predicted a -0.21 decrease in threat appraisal, holding past experience constant. The indirect effect of trust on threat appraisal was nearly as strong as the direct effect, where the respondent's threat appraisal decreased by -0.15 standard deviations for every one standard deviation increase on trust via its prior effects on awareness of Rx fire benefits. A one SD increase in past health effect experience predicted a 0.31 increase in threat appraisal, holding trust constant.

Similar to the combined model, the strongest predictors of public tolerance of smoke were the direct effects of awareness of Rx fire benefits (β = 0.42) and threat appraisal (β = -0.19), and the total effect of trust in fire managers (β = 0.36) (Table 35). The total effect of trust on tolerance of smoke was partially mediated by awareness of Rx fire benefits and threat appraisal (β = 0.27). Respondent personal health experience with smoke (β = -0.11, partially mediated by threat appraisal) and education (β = 0.10) had the smallest effects on tolerance of smoke. Public tolerance of smoke explained 28% of the variance in overall support for Rx fire management actions, where one SD increase in tolerance of smoke predicted a 0.50 increase in Rx fire management support.

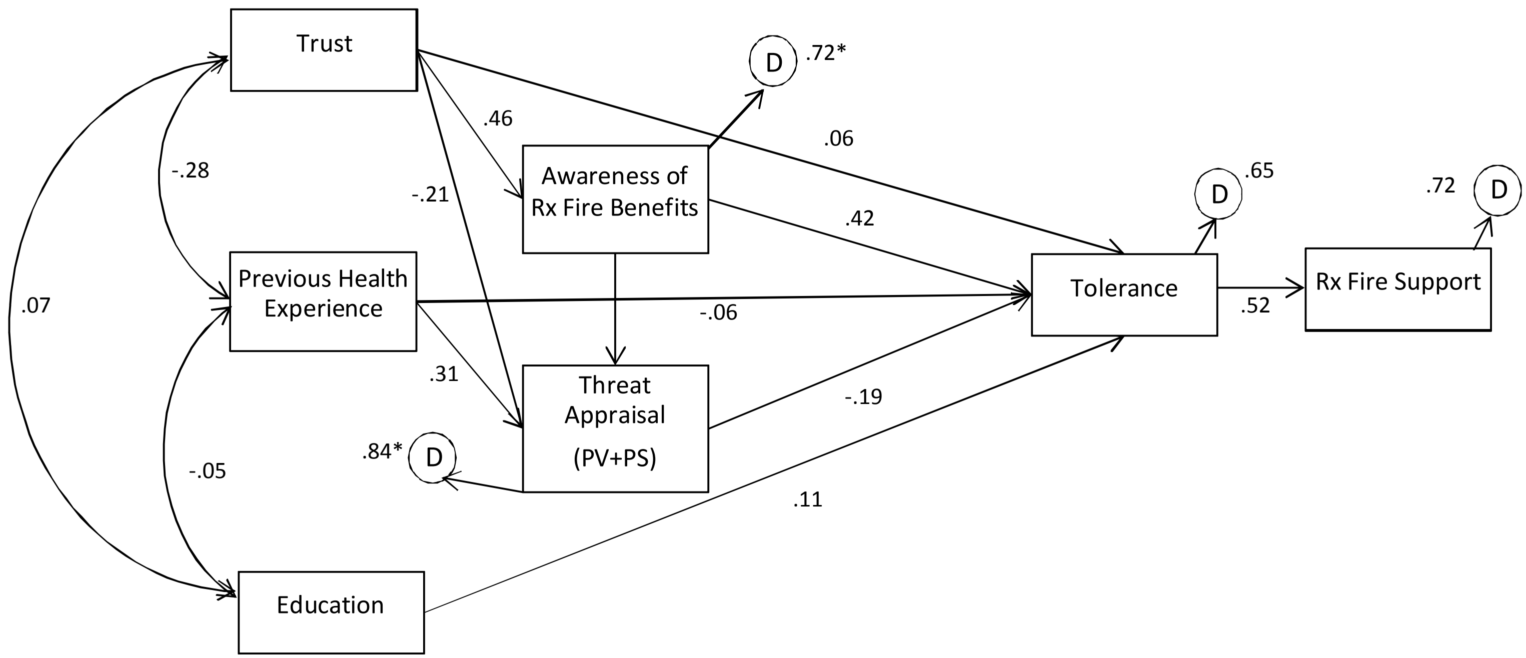

Figure 4. NORO final path measurement model. Numbers associated with single-headed arrows are standardized path coefficients. Numbers associated with curved double-headed arrows are correlations. Numbers within circles are the residuals associated with a dependent variable. All path coefficients are significant at the $p < 0.01$ level.

Table 35. Effect decomposition table for the final NORO path model

Causal Variables	Endogenous Variables			
	Awareness of Rx Fire Benefits	Threat Appraisal	Tolerance of Smoke	Rx Fire Support
Trust				
Direct effect	0.46	-0.21	0.07	
Total Indirect effects			0.26	0.41
Total effect	0.46	-0.21	0.36	0.41
Experienced Personal Health Effects from Smoke				
Direct effect		0.31	-0.06	
Total Indirect effects			-0.05	-0.14
Total effect		0.31	-0.11	-0.14
Awareness of Rx Fire Benefits				
Direct effect		-0.27	0.42	
Total Indirect effects			0.05	0.57
Total effect		-0.27	0.47	0.57
Threat Appraisal				
Direct effect			-0.19	
Total Indirect effects				-0.22
Total effect			-0.19	-0.22
Education				
Direct effect			0.10	
Total Indirect effects				0.13
Total effect			0.10	0.13
Tolerance of Smoke				
Direct effect				0.52
Total Indirect effects				
Total effect				0.52

Model 3: SOUTH

Among SOUTH respondents, public trust in forest fire managers accounted for 26% of the variance in public awareness of the benefits of Rx fire (Figure 5), where a one SD increase in trust predicted a 0.36 increase in awareness of Rx fire benefits. Experience with health effects from smoke and awareness of Rx fire benefits accounted for 16% of the variance in threat appraisal. A one SD increase in past health effect experience predicted a 0.25 increase in threat appraisal, holding trust constant. The respondent's threat appraisal decreased by -0.15 standard deviations for every one standard deviation increase on trust via its prior effects on awareness of Rx fire benefits.

The strongest predictors of public tolerance of smoke were the direct effect of threat appraisal (β = -0.19) and the total effect of awareness of Rx fire benefits (β = 0.47) (Table 36). The difference of model 3 with the previous two models is that trust is no longer one of the stronger predictors of tolerance of smoke (β = 0.14). The total effect of awareness of Rx fire benefits on tolerance of smoke was partially mediated by threat appraisal (β = 0.08). The respondent's personal health experience with smoke (β = -0.08, fully mediated by threat appraisal) and education (β = 0.10) had the smallest effects on tolerance of smoke. Public tolerance of smoke explained 19% of the variance in overall support for Rx fire management actions, where one SD increase in tolerance of smoke predicted a 0.43 increase in Rx fire management support.

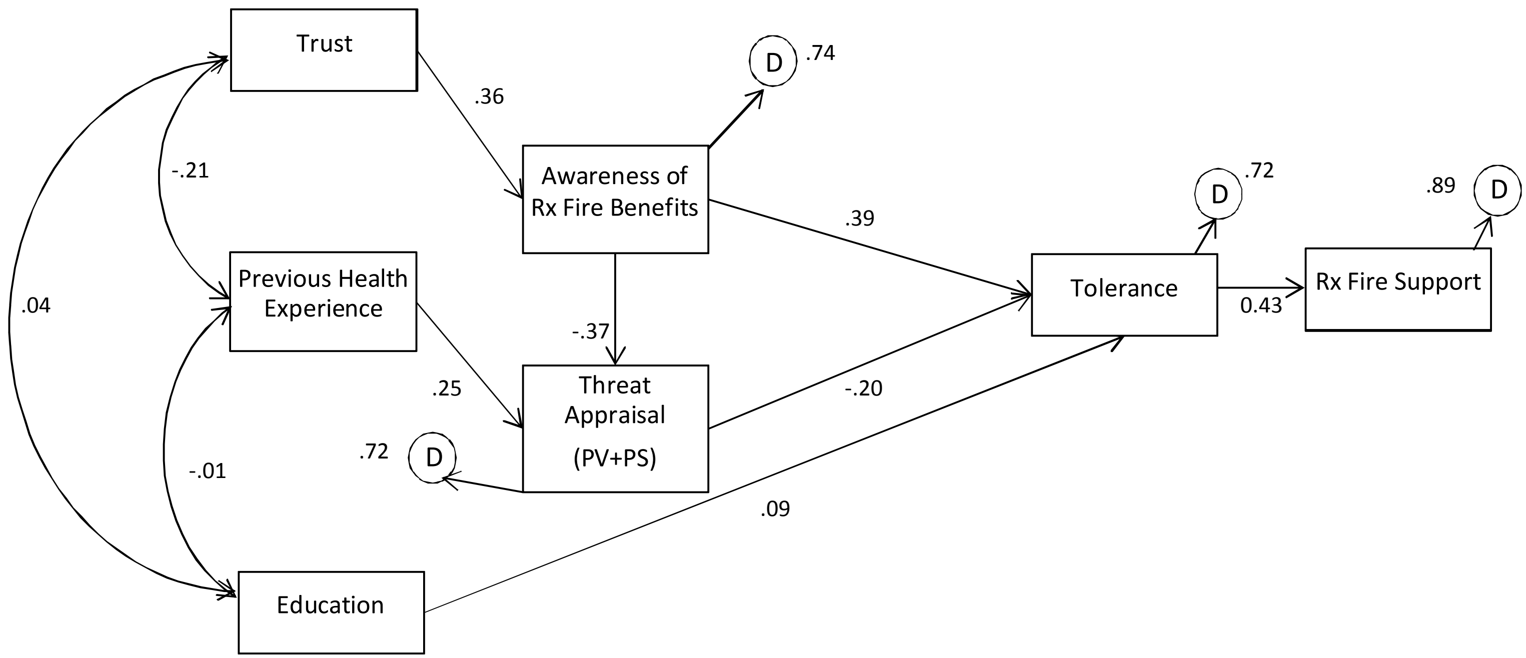

Figure 5. SOUTH final path measurement model. Numbers associated with single-headed arrows are standardized path coefficients. Numbers associated with curved double-headed arrows are correlations. Numbers within circles are the residuals associated with a dependent variable. All path coefficients are significant at the *p* < 0.01 level.

Table 36. Effect decomposition table for the final SOUTH path model.

Causal Variables	Endogenous Variables			
	Awareness of Rx Fire Benefits	Threat Appraisal	Tolerance of Smoke	Rx Fire Support
Trust				
Direct effect	0.36	ns	ns	
Total Indirect effects	ns		0.14	0.22
Total effect	0.36	ns	0.14	0.22
Experienced Personal Health Effects from Smoke				
Direct effect		0.25	ns	
Total Indirect effects			-0.08	-0.16
Total effect		0.25	-0.08	-0.16
Awareness of Rx Fire Benefits				
Direct effect		-0.37	0.39	
Total Indirect effects			0.08	0.61
Total effect		-0.37	0.47	0.61
Threat Appraisal				
Direct effect			-0.20	
Total Indirect effects				-0.27
Total effect			-0.20	-0.27
Education				
Direct effect			0.09	
Total Indirect effects				0.12
Total effect			0.09	0.12
Tolerance of Smoke				
Direct effect				0.43
Total Indirect effects				
Total effect				0.43

16 non-significant variables: Biospheric and egoistic value orientations, response and self-efficacy, trust, and all sociodemographic variables other than EDU.

Hypothesis Testing

This study proposed three research questions and 12 associated hypotheses (see Table 1). A detailed matrix of the statistical evaluation used to confirm or reject each hypothesis can be found in Appendix R. The first research question asked how value orientations relate to specific beliefs about forest fires and smoke. The positive relationship between value orientations (biospheric and egoistic) and specific beliefs about the consequences of smoke was not supported by the findings of this study.

Research question two and associated hypotheses explored the relationships between specific beliefs about the consequences of smoke, agency trust, and public tolerance of smoke. Findings suggested that increased perceptions of the benefits of using prescribed fire to improve forest health will increase tolerance of smoke (H3). It was also established that increased levels of perceived vulnerability and perceived severity (i.e., threat appraisal) of smoke effects decrease tolerance for smoke (H4). Agency trust was found to be an important positive predictor of awareness of Rx fire benefits (H7) and negative predictor of smoke threat appraisal in the NORO and combined samples (H8). However, in the SOUTH, trust was not a significant predictor of threat appraisal, so the hypothesis was partially supported overall. The hypothesized positive relationship between respondent coping appraisal on tolerance of smoke (H5) was not supported, and a moderating relationship between coping appraisal and threat appraisal was not significantly detected in any of the models while controlling for other factors.

The third research question explored how aspects of community type, preparedness for fire, past experience with smoke, and sociodemographic characteristics influenced public tolerance of smoke. We did not find support for the hypotheses that rural residents would be more tolerant of smoke from wildland fires (H9) and aware of the benefits of Rx fire (H10) than urban residents. It was found that respondents in both regions who had experienced health effects from wildland fire smoke in the past were less tolerant of smoke (H11) than people who had not experienced health effects from smoke. However, this finding was not fully consistent with other types of experience with smoke impacts in the past (e.g., property, transportation, evacuation). In the SOUTH there was not a significant difference in tolerance based on those previous experiences with smoke impacts. In the NORO, WUI communities that were more prepared for wildland fire were significantly more tolerant of smoke than WUI communities that were less prepared for fire (H12), and subsequently more supportive of Rx fire management activities as well (H13). In the SOUTH, a difference was not detected in the level of tolerance of smoke and community preparedness for fire; however, non-WUI communities were slightly more supportive of Rx fire than WUILP communities.

Discussion

Explaining Public Tolerance of Smoke

Overall, respondents from both regions and all stratifications were somewhat tolerant of smoke from forest fires. This is consistent with previous research that has suggested that smoke from wildland fire is not a major concern for the majority of the public (Blanchard & Ryan, 2007; Brunson & Shindler, 2004; McCaffrey & Olsen, 2012; Shindler & Toman, 2003). The path analytic models for the NORO and SOUTH consistently identified the predictors of public tolerance of smoke as being trust in forest fire managers (Hypothesis 7; H7), threat appraisal of smoke impacts (perceptions of vulnerability and severity) (H4), awareness of the benefits of Rx burning (H3), previous health experience with smoke (H11), and level of completed education. The strongest predictors of public tolerance of smoke from wildland fires were being aware of Rx fire benefits and trust in fire managers. Previous research has established clear linkages between knowledge, attitude, and acceptability of forest treatments (e.g., Fried et al., 2006; Winter et al., 2006), where knowledge of a management practice is positively correlated with attitudes toward it (Absher et al., 2009; Fried et al., 2006; McCaffrey, 2006; Ryan & Wamsley, 2008; Shindler & Toman, 2003; Winter et al., 2006). Our findings suggest that the same holds true for public tolerance of smoke from wildland fires. Individuals and communities can become more tolerant of smoke and supportive of management if they fully understand its necessity to improve forest health and reduce community risk.

The linkage between trust in forest fire managers and public support for Rx fire practices has also been well established (Fried et al., 2006; Vogt, Winter, & Fried, 2003; Vogt et al., 2005). We found that, overall, the public trusts forest fire managers to competently use Rx fire and provide adequate information about fire and smoke. This finding is not surprising because the government is well established as the preferred source of information about fire and tends to rank highest in terms of trustworthiness (Absher & Vaske, 2011; McCaffrey & Olsen, 2012; Shindler, Toman, & McCaffrey, 2009). Our findings are also consistent with research that has shown a positive relationship between agency trust and beliefs about the benefits of using Rx fire (Winter et al., 2004). Our findings demonstrate that this positive relationship is also associated with higher tolerance for smoke from wildland fires. One notable finding was that the lowest competency and credibility ratings, although still positive values, were fire managers' ability to manage and provide timely information regarding smoke. This suggests that, although trust is high, there is room for improvement regarding communication with the public about smoke management issues, and specifically the timing at which communication takes place. The public's desire for advanced warning about potential smoke impacts and issues has been recently documented by Blades et al. (2012), and is an issue worthy of further study. Further, the importance of advance warning systems related to wildland fire and smoke has been an increasing topic of interest for the fire management community, evidenced by a recent call for research about the effectiveness of public warning and evacuation systems, and public perceptions about the need for warning or evacuation systems (Joint Fire Science Program, 2013).

Threat appraisal (i.e., perceptions of vulnerability and severity) had a significant and negative relationship with smoke tolerance. A significant factor of threat appraisal was previous adverse health experience with smoke. This shows that, although the public is generally tolerant of smoke from wildland fires, it can be a very large concern for individuals who have had negative health experiences with smoke in the past. Several other studies have consistently found that approximately one-third of the public has high levels of concern about smoke from Rx fire (Bowker et al., 2008; McCaffrey, Moghaddas, & Stephens, 2008), and it is often specifically related to health impacts (Brunson & Evans, 2005; Jacobson et al., 2001; Loomis et al., 2001; Ryan & Wamsley, 2008). Further, previous negative experiences with fire have been shown to negatively influence attitudes toward Rx fire. For example, Brunson and Evans (2005) found that following an escaped Rx fire in Utah, nearly half of the respondents indicated that the fire had a negative impact on how they felt about prescribed fire and managers' ability to control prescribed burns. Considering the large percentage (30%) of households containing a family member who is sensitive to smoke (McCaffrey, 2006), and the percentage of respondents we found who have actually been affected by smoke in the past (21% overall), it is logical that concerns about health impacts from smoke can significantly decrease the public's tolerance of smoke. Areas that have experienced high amounts of smoke impacts in the past can be expected to have lower tolerance for smoke from prescribed fire than areas that have had little exposure to smoke.

Health issues related to smoke will likely increase as baby-boomers enter retirement ages and amenity migration to the WUI continues. Older residents will have increasingly more health concerns. The elderly have unique needs, beliefs, and circumstances that need to be proactively and strategically addressed during all natural hazard situations, including smoke from wildland fires (Rosenkoetter, Covan, Cobb, Bunting, & Weinrich, 2007). Clearly, the relationships between previous heath experience with smoke, beliefs about threats related to smoke, and the influence of agency trust should be a primary consideration when communicating with the public about smoke from wildland and Rx fires.

The final path analytic models demonstrated that people who were more tolerant of smoke were in turn more supportive of Rx fire practices. It was very encouraging to find that the strongest variables shaping public tolerance of smoke (i.e., beliefs about the benefits of Rx fire and level of agency trust) are the same variables that have been shown to shape public acceptance of Rx fire (see synthesis by McCaffrey & Olsen, 2012). Overall, the path models did a moderate job of explaining one-fourth to nearly one-half of public tolerance of smoke and support for Rx fire practices (R^2 range from 0.24 to 0.41), yet at least 60% of the variance remains unexplained. Nevertheless, this model provides managers with a solid framework from which to shape public engagement strategies based on building and maintaining agency trust and reinforcing beliefs about the ecological and community protection benefits of Rx fire practices, while also being sensitive and proactive about regional and community perceptions of smoke impacts, namely related to health impacts.

The Limited Roles of Personal Value Orientations and Coping Appraisal

Respondents in this study ascribed high levels of importance to biospheric values and moderate importance to egoistic values. Other research has demonstrated that biospheric value orientations and concern for environmental issues are related to attitudes towards policy and environmental management (Absher et al., 2009; De Groot & Steg, 2007; De Groot & Steg, 2008; Dietz, Dan, & Schwom, 2007). In our study, the relationship between personal value orientations and specific beliefs about the consequences of smoke (i.e., benefits of Rx fire, threat appraisal, coping appraisal) was not supported (H1 and H2).

Our findings are consistent with the Winter et al. studies (2004, 2006) who found that respondents in diverse regions in the U.S. reported strong biospheric values and believed that Rx fire practices could improve conditions for wildlife and help restore forests to a more natural condition. We also found moderately strong respondent biospheric values (NORO m= 1.6, SOUTH m= 1.8) and awareness of the benefits of Rx fire (NORO m= 1.5, SOUTH m= 1.6), yet there was a weak, non-significant correlation between them (NORO r= 0.09, SOUTH r= -.04).

Respondents in the NORO valued forests as places to play and recreate, whereas people from the SOUTH valued forests more for timber, minerals, jobs, and income. However, biospheric values were considered stronger than egoistic values in both regions, which was consistent with a Florida study that found respondent concerns about the harm to wild animals from Rx fire (biospheric values) were greater than concerns about personal health problems from smoke, which are egoistic values (Jacobson et al., 2001). Clearly, personal value orientations and beliefs about Rx fire were important to respondents in the NORO and SOUTH; however, we detected a non-significant relationship between values and beliefs about the benefits of Rx fire, threat appraisal, coping strategies, and tolerance of smoke.

Our study also considered the relationship of coping behaviors for smoke and public tolerance of smoke. Previous research has found that individuals, particularly those who are sensitive to air pollution, will take averting measures when the air pollution levels are high (Bresnahan, Dickie, & Shelby, 1997). Other research has suggested that when large wildfire events are publicized and smoke is clearly visible, individuals will take measures to avoid smoke impacts from wildfires (Kochi, Donovan, Champ, & Loomis, 2010). In our study, we found that residents of the SOUTH agreed more that coping behaviors were effective than NORO residents. However, overall coping measures and the likelihood of completing those actions were not considered an important topic by respondents in both regions (overall coping $m = 0.5$), and exhibited a non-significant relationship to public tolerance of smoke. The lack of effect of coping appraisal was perplexing, but may further reinforce that the majority of the public in this study does not consider smoke from forest fires to be a major concern, and therefore the need to cope with smoke is also not a salient topic.

Encouraging Results for Managers

Overall, we found the results of this study to be very encouraging for fire managers because respondents from both regions were well informed about the benefits of Rx fire and issues related to smoke, generally tolerant of smoke from all sources, trusting of fire managers, and highly supportive of Rx burning practices – even given that a large majority of participants had experienced some type of impact from forest fire smoke during the previous three years. Further, concerns about smoke impacts (i.e., threat appraisal) were very low in both regions. These findings are consistent with the national population surveys conducted by Bowker et al. (2008) that suggested widespread public acceptance of Rx fire across the country, and a growing body of research that is establishing that overall smoke concerns may not be as problematic as previously anticipated (e.g., Blanchard & Ryan, 2007; Brunson & Shindler, 2004; Cortner, Field, Jakes, & Buthman, 2003; McCaffrey, 2004; McCaffrey & Olsen, 2012; Shindler & Reed, 1996). A notable exception is residents who have experienced negative health impacts from smoke. Overall, the public appears to be well aware of forest health issues and the need for taking action. A recent review of the fire science literature found that more than 80 percent of public respondents are accepting of some level of Rx fire use, and consistently identify "no action" as the least preferred choice (McCaffrey & Olsen, 2012). Our findings suggest that people are generally willing to trade-off the short-term impacts of smoke from Rx fire for the long-term benefits of forest health and community protection, and possibly avoiding longer-duration and more severe smoke from large wildfires when Rx fires are not done.

Focus on WUI Less-Prepared Communities in the NORO

Residents from NORO WUILP communities were significantly less aware of the benefits of Rx fire, more concerned about smoke impacts, less trusting of agency fire managers, less tolerant of smoke, and less supportive of Rx fire use than WUIMP and non-WUI residents were. That is not to say that these communities were not aware of the Rx fire benefits, concerned about smoke impacts, trusting of agency fire managers, tolerant of smoke, or supportive of Rx fire use – they were just less so than WUIMP and non-WUI residents. Thus, this could highlight a need in the NORO for increasing public communication in less-prepared communities regarding the use of Rx fire as a means to improve forest health and reduce the risk of large wildfires near their communities, even though it will temporarily result in short-term smoke impacts.

Residents from the NORO, most notably in WUILP communities, were concerned about potential smoke impacts on recreation/tourism, scenery, and school recess/outdoor sports more than all other potential smoke impacts. This is logical because many NORO communities have shifted from logging, mining, and ranching communities towards amenity-based economies that rely heavily on recreation and tourism (Winkler et al., 2007). This has been combined with amenity-migration and population redistribution from urban areas into the WUI (Hammer et al., 2009). Summer and fall in the NORO represent peak tourism seasons, which are most heavily affected by fire and smoke impacts. Many of the communities that participated in this study represent destination locations for tourism. Clearly, communities that rely on amenities for their economic base would perceive the impacts to recreation, tourism, and outdoor activities to be greater than communities that do not rely as heavily on amenities. Fire managers should recognize this during the fire season and proactively communicate with rural, recreation-based communities, about upcoming Rx fire season activities and potential smoke impacts depending on fire location and under varying dispersion scenarios.

Policy Implications

Although we found that the public is generally tolerant of smoke from various sources, there were mixed findings about public perceptions about the role of federal and state regulations pertaining to smoke from Rx fires. People in the SOUTH were more supportive than people in the NORO of excluding Rx fire smoke from EPA air quality regulations and state smoke management requirements and guidelines. Residents in the SOUTH have been using Rx fire as a forest management tool much longer than the NORO, which has historically been focused on fire suppression. Residents from the SOUTH also had a higher coping appraisal than residents in the NORO, meaning they thought the methods suggested for coping with smoke were effective and were more likely to complete the actions. As such, the culture of fire use and coping with smoke in the SOUTH contributed to respondents being more tolerant of smoke from Rx fires than NORO residents. Not surprisingly, the SOUTH's familiarity and perceived necessity for using Rx fire likely explains why people there support exempting Rx fire smoke from federal and state smoke regulations more so than NORO residents.

Urban residents in the NORO (non-WUI) tended to agree more with Rx fire smoke being exempted from state and federal regulation than WUI residents. This may be, in part, because urban respondents do not typically experience the greatest concentrations of smoke since they are farther away. Residents living in the WUI are likely aware that they will be exposed to more smoke from Rx fires if the smoke is exempt from regulations. Urban residents probably experience less smoke from Rx fires since those fires are under "controlled" conditions. The times the urban residents get smoke are when there are large, uncontrolled wildfires. Thus, it is logical that urban residents would support deregulating Rx fire smoke in order to reduce the probability of larger wildfires – the source of the smoke they experience.

Conclusions

The goals of this study were to understand how cognitive factors and personal characteristics influence public tolerance of smoke from wildland fires. Specifically, we aimed to explore public tolerance of smoke as function of personal value orientations, specific beliefs about Rx fire, trust of forest fire managers, and individual characteristics. The path analytic models explained public tolerance of smoke and support for Rx fire practices as primarily a direct function of specific beliefs about the benefits of Rx fire and indirectly as a function of trust in fire managers. This is consistent with the findings of a relatively large body of existing research related to public acceptability of Rx fire and provides a solid foundation for reinforcing and building upon the high level of trust in fire managers and beliefs about the benefits of Rx fire for improving forest health and protecting communities. Public appraisal of threats from potential smoke impacts was also a direct predictor of smoke tolerance and can be used as a tool to tailor specific messages in both regions to address public concerns in the NORO and SOUTH. Previous adverse health experience with smoke was direct predictor of threat appraisal and smoke tolerance, demonstrating the importance of understanding at-risk segments of the population who may be at risk of smoke impacts or have experienced adverse effects in the past.

Overall, the findings of this study are encouraging for fire and resource managers because respondents from both regions were well informed about the benefits of Rx fire and issues related to smoke, generally tolerant of smoke from all sources, trusting of fire managers, and highly supportive of Rx burning practices. Further, concerns about smoke impacts (i.e., threat appraisal) were very low. Overall, the public is generally well informed about forest health issues and supports taking action. Our findings suggest that people are generally willing to trade-off the short-term impacts of smoke from Rx fire for the long-term benefits of forest health and community protection.

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Chapter III. Deconstructing Public Preferences and Tradeoffs about Smoke from Wildland and Prescribed Fires using Conjoint Analysis

Introduction

Smoke from forest fires can result in public controversy and impair forest management as a result of smoke dispersion over residential, commercial, recreational, and transportation areas. Many parts of the U.S. are experiencing more impacts from forest fire smoke due to increases in wildfire activity and more people living in the wildland-urban interface (WUI) and rural areas (Hammer, Stewart, & Radeloff, 2009; United States Forest Service, 2001). Smoke is a particularly salient concern because it can create short and long-term health problems, notably for smoke-sensitive populations, including children, the elderly, and those with existing health conditions (Environmental Protection Agency, 2008; Molina & Molina, 2004). Clearly, there are many ways that smoke from wildland fires can impact residents at individual, community, and regional levels.

In the center of these issues are natural resource and fire managers, who are tasked with the additional challenges of navigating ever-changing land management priorities and regulatory restrictions (Haines, Busby, & Cleaves, 2001). Air quality regulations in the U.S. have been tightening during a time when forest fuel reduction projects and prescribed (Rx) burning are needed more than ever. Lowering National Ambient Air Quality Standards (NAAQS) has created new nonattainment areas (especially near National Forests, Parks and Wildlife Refuges), increased challenges for conducting Rx fires, raised the number of air quality violations, and expanded the administrative and planning workloads for wildand fire management agencies (Environmental Protection Agency, 2013; Riebau & Fox, 2010). Land and fire managers face considerable challenges in meeting forest health and air quality standards concurrently.

Understanding the diverse public opinions toward smoke from wildland and prescribed fires is important for managers and public officials, yet a paucity of research has been conducted specifically on this topic. This study, funded by the Joint Fire Science Program, aimed to understand the factors that underlie public tolerance of smoke from prescribed (Rx) fires. This paper uses conjoint analysis, and compares a univariate rating method, in order to deconstruct how context-specific factors and trade-offs affect public tolerance of smoke from forest fires.

Why Use Conjoint Analysis?

Typical multivariate studies have participants rate causal variables individually, often using these ratings in regression models that "compose" the association between independent variables and a dependent variable (e.g., tolerance of smoke). However, people are not always able to reliably weight the separate features of a complete smoke scenario (Orme, 2005). The conjoint approach presented here required study participants to evaluate complete and realistic smoke scenarios, comprised of multiple contextual variables simultaneously, which were then "decomposed" to estimate the independent variable preference structure.

Conjoint analysis, also known as stated preference analysis, is a multivariate technique developed specifically to understand how respondents develop preferences for any type of object and what trade-offs each person is willing to make (Hair, Black, Babin, & Anderson, 2010). The conjoint technique was developed in the 1960s and 70s (Green & Rao, 1971) and was eventually applied to environmental topics, the first being an economic evaluation of visibility impairments at Mesa Verde and Great Smoky Mountains National Parks (Rae, 1983). It is based on the assumption that people develop preferences by combining separate pieces of a particular scenario. For example, when considering the purchase of a chainsaw, one might focus on the key attributes of cost, brand, size, chain specifications, and warranty. Before purchasing the saw, it may seem that brand and size are the most important attributes in a chainsaw. However, after entering the store and seeing how expensive chainsaws are, one might focus more on cost and warranty than brand and size. Thus, when looking at the chainsaws one is making simultaneous tradeoffs about the choice that may, or may not, match what was originally considered as preferable prior to making the choice. In this study, conjoint analysis was used to understand public tolerance of smoke from forest fires based on different attributes that occur when a person experiences smoke from a wildland fire at home or in the community. Similar to the chainsaw example, one might consider health impacts to be the most important aspect of tolerance of smoke from wildland fires; however, other variables may rise to a larger level of importance (e.g., the source of the smoke or advanced warning prior to a Rx fire) when considering a whole scenario where tradeoffs are required.

In this study, we compared a univariate rating task with our multivariate conjoint task to determine whether the different approaches yield similar findings. Previous studies have contrasted conjoint techniques with univariate rating or univariate ranking tasks and found mixed results. Several studies from the health field have found that conjoint and univariate tasks yielded similar results for the most important attribute (e.g., Bridges, Lataille, Buttorff, White, & Niparko, 2012), but the order of importance of other attributes varied considerably across studies (Pignone et al., 2012). Other heath studies have found differences between conjoint analysis and Likert-type univariate ratings, where conjoint analysis was more effective at describing the magnitude of differences between the attributes (Johnson et al., 2006; Ryan et al., 2001). To our knowledge, this study represents the first comparison between univariate and conjoint techniques in a natural resources setting.

Key Variables in the Context of Smoke

Our primary consideration was the selection of key contextual factors likely to influence opinions about whether or not the smoke from forest fire is tolerable (Hair et al., 2010; Louviere, Hensher, & Swait, 2000). For example, smoke that lasts a few hours from a lightning-caused wildfire may be considered more tolerable than smoke that lasts 24 hours from a prescribed fires. It was also crucial to use the fewest possible variables to reduce participation burden (see methods and sampling design). The variables used in this study were carefully selected based on feedback from many sources, including 1) recommendations from collaborating smoke researchers (Olsen and Toman, personal communication) who had recently conducted focus groups on the topic, 2) existing research on key factors that influence public opinions about forest fire, 3) previous conjoint studies related to natural resources and fire (e.g., Kneeshaw, Vaske, Bright, & Absher, 2004), and 4) pilot testing with three undergraduate classes at the University of Idaho in 2011. Four key variables (fire origin, advanced warning, smoke duration, and health effects) were identified from these sources and explored relative to their influence on public tolerance of smoke from wildland fire (Table 37). Several other variables were considered at the beginning of the process (e.g., fire management strategy, forest recovery, and outdoor recreation impact) but were eliminated or merged into other variables (e.g., smoke intensity and visibility merged into health effects) based on feedback during the selection process described here.

Table 37. Attributes and levels used for the conjoint survey questions

Attribute	**Levels**
Fire Origin	Wildfire (lightning caused or unintentional)
	Prescribed-natural Fire (wildland fire use)
	Prescribed Fire
Smoke Duration in Community	Up to 6 hours
	Up to 2 days
	Longer than 2 days
Health Effects	Moderate (Extremely sensitive individuals may experience respiratory symptoms)
	Unhealthy for Sensitive Groups (Increasing likelihood of respiratory symptoms and breathing discomfort in sensitive groups)
	Very Unhealthy for Everyone (Substantial risk of respiratory effects in the general population)
Advanced Warning	None (no advanced warning)
	Public Service Announcement (A message is broadcasted on the local radio or TV news, or in the local newspaper)
	Personal Phone Call (agency personnel give you a call)

Research has shown that the ***origin of a fire*** can influence public support for fire management practices (Gardner, Cortner, Widaman, & Stenberg, 1985; Kneeshaw et al., 2004) and tolerance of the resulting smoke (Weisshaupt, Carroll, Blatner, Robinson, & Jakes, 2005). Forest fires are ignited by lightning or by humans. Human-caused ignitions may occur by accident or carelessness (e.g., escaped campfire, sparks from vehicles, or arson), or they may be ignited intentionally and contained by forest managers to achieve forest health objectives (i.e., prescribed fire). Forest managers may also choose to allow lightning-caused fires to burn (rather than suppress them) to achieve forest health objectives, which is called prescribed-natural, management-ignited, or wildland fire use. We asked respondents to consider the origin of a fire when deciding how tolerant they are of smoke.

Previous research has suggested that the frequency and magnitude of seasonal fire activity can be a driving influence in regional differences in support for prescribed fire practices (Loomis, Bair, & González-Cabán, 2001). It was intuitive that the duration of time that a person has been exposed to smoke (i.e., ***smoke duration***) would influence tolerance of smoke. The duration of smoke exposure can have cascading effects related to public health, recreation and tourism, school activities, and transportation.

The potential ***health effects*** from smoke were suspected to be strongly related to smoke tolerance. Kneeshaw et al. (2004) found that respondents living within or near three western U.S. national forests rated air quality concerns (i.e., health) as a consistent factor for supporting full suppression of fires. In a Florida study, the majority of respondents said that protecting air quality (i.e., health) was more important than the ecological benefits of prescribed burning. A review of four studies by McCaffrey (2006) found that up to 30% of respondents lived in a household where a member had a health issue that could be affected by smoke. Clearly, health effects are an important consideration for public tolerance of smoke.

Focus groups conducted by Olsen and Toman (2011) identified the importance of ***advanced warning*** when discussing smoke-related impacts. There has been a recent call for a better understanding of public perceptions of advanced warning systems related to natural hazards, such as hurricanes and fires (Gladwin, Willoughby, Lazo, Morrow, & Peacock, 2009; Joint Fire Science Program, 2013). To our knowledge, this topic has never been explored in relation to the acceptability of fire management or tolerance of smoke. Advanced warning systems alert individuals and communities about the potential threat of smoke in order for them to act in sufficient time and in an appropriate manner to reduce the possibility of injury, loss of life, property damage, and loss of livelihoods (Bridge, 2010).

In this study we aimed to determine the public preference structure for tolerance of smoke based on the source of the fire, duration that smoke was present in the community, associated health impacts, and type of advanced warning. We also compared tolerance of smoke across regions (northern Rocky Mountains and south-central U.S.), the level of community preparedness for wildland fire (non-WUI, WUIMP, WUILP), urban or rural residents, gender (men, women), and whether the respondent had experienced previous adverse health effects from smoke from wildland fire (Health-yes, Health-no). Further, we aimed to compare the conventional univariate method of rating these variables individually versus evaluating all attributes simulatneously using a conjoint approach.

Methods

Study Areas and Communities

This study focused on two regions: the U.S. northern Rocky Mountains (Idaho and western Montana; NORO) and the south-central U.S. (east Texas and western Louisiana; SOUTH). In both regions, forest health concerns, increases in wildfire activity, and changing social dynamics have resulted in wildland fire and smoke issues not present in the past (United States Forest Service, 2009; Winkler, Field, Luloff, Krannich, & Williams, 2007). Many communities historically reliant on resource commodities (e.g., logging, ranching, and agriculture) have been transitioning towards amenity-based economies (Winkler et al., 2007). Both regions have experienced greater amenity-driven population and housing growth than other parts of the U.S., combined with greater population redistribution into WUI areas (Hammer et al., 2009). Idaho and Texas ranked in the top five states for relative population growth since 2000 (U.S. Census Bureau, 2010). Though there are some similarities, there are also important variations between the two regions, such as fire return intervals, the type and amount of prescribed fire use, size of metropolitan areas, and ethnicity.

U.S. Northern Rocky Mountains

This region has been experiencing rapid ecological changes, such as increased fuel loading, tree mortality, higher potential for insect establishment and spread, and subsequently larger and more severe wildfires and smoke levels (Morgan, Heyerdahl, & Gibson, 2008; Westerling, 2008; Westerling, Hidalgo, Cayan, & Swetnam, 2006). Increases in forest fires in the region (both wild and Rx) will clearly result in more frequent human exposure to smoke and associated management issues.

Every county in Idaho and Montana has completed a County Wildfire Protection Plan (CWPP), but the level of *actual* preparedness for fire varies greatly by community within each county. For example, many CWPPs were written prior to the passage of Healthy Forests Restoration

Act of 2003, and some have not been updated to comply with the CWPP guidelines stipulated in the Act. Current wildfire risk status was not documented in many CWPPs, nor is there a current record of planned and completed fuel reduction projects. Other factors affecting community preparedness for fire include the level of coordination between wildfire and structural fire fighters, paid versus unpaid volunteer firefighters, presence of a WUI committee, and amount of funding obtained for fuel reduction projects. All of these factors were taken into consideration when selecting and classifying each community as urban non-WUI (non-WUI), WUI more-prepared (WUIMP), or WUI less-prepared (WUILP).

South-central U.S. (East Texas and Western Louisiana)

Gulf Coast states are anticipated to be affected by climate change in the form of less rainfall in winter and spring, and the frequency, duration, and intensity of droughts are likely to continue increasing (Karl, Melillo, & Peterson, 2009). More intense and severe wildfires have accompanied the increases in temperatures, drought, southern pine beetle outbreaks, and erratic weather (Karl et al., 2009). Similar to the NORO, increases and amenity migration into the WUI, coupled with more frequent wild and Rx fires, will lead to more instances of people experiencing impacts from smoke.

Prescribed burning in south-central forests has been a regular annual occurrence to address increased fuel loads, primarily near communities-at-risk. In general, residents in south-central U.S. have more experience with Rx fire and associated smoke than other parts of the country because the practice is more commonly used and accepted on federal, state, and private lands in this region – even in the presence of increasing constraints from urban expansion, air quality regulations, and liability for smoke intrusions and escaped fires (Fried, Gatziolis, Gilless, Vogt, & Winter, 2006; Haines et al., 2001). Nevertheless, smoke resulting from prescribed burning is an ongoing and primary concern for land managers and community residents alike.

Sampling Design

A quantitative design was chosen based on a desire to generalize findings to the populations of the study regions (Creswell, 2009). Communities from the NORO and SOUTH were stratified into three community types (selection process described further below): 1) WUI communities that are more-prepared for fire (WUIMP); 2) WUI communities that are less-prepared for fire (WUILP); and (3) urban areas not located in the WUI, but that have a high potential to be impacted by smoke (non-WUI). Communities were selected through a review of CWPP literature in each county of the two regions. In each CWPP we explored when the plan was completed, whether mitigation activities/projects had been identified, whether the activities/projects had been completed, if a WUI committee had been formed, activity level of the WUI committee, and whether the CWPP had been updated since the original document. Our team held a meeting with the primary authors of nearly all of the CWPPs in the NORO to discuss communities that met each classification. We also consulted with local land and fire managers to discuss communities that met each classification. Further, a web-based exploratory questionnaire was emailed to over 200 fire managers, land managers, and community leaders from each region, asking them to nominate study communities based on our preparedness classification. Follow-up phone calls were conducted with managers and land managers in both regions in the fall of 2011 to ensure that the communities selected met our criteria. We also consulted with our smoke research team collaborators in the larger Joint Fire Science Project who are at The Ohio State and Oregon State Universities to discuss our community selection criteria against their focus group findings.

We desired a random sample of 200 completed questionnaires from each of the 18 communities (i.e., 3,600 total completed questionnaires). This minimum sample size was necessary to satisfy the recommendations for conjoint analysis (see Measurements and Data Analysis below)

(Hair et al., 2010; Kline, 2011; Orme, 2006). Participant names, addresses and phone numbers were purchased from Survey Sampling International (2011).

We followed a modified version of Dillman's Total Design Method (Dillman, Smyth, & Christian, 2009) to ensure maximum participation. To reduce the time and effort requirements for each participant, an initial letter was mailed to participants notifying them about the study and providing an internet address where they could complete the questionnaire online. A reminder postcard was sent 15 days after the initial mailing that again pointed the participants to the questionnaire internet address. A physical questionnaire was mailed three weeks later to anyone who had not completed the questionnaire online. Participants were enrolled in a lottery for one of six $250 gift certificates as an incentive for completing the questionnaire. We conducted 100 telephone interviews with randomly selected non-respondents in each region to assess potential bias between responders and non-responders (Creswell, 2009). Non-respondents were asked a few key questions from our study, such as their support for prescribed fire practices, opinions about the potential outcomes of prescribed fire, tolerance of smoke from prescribed fire, and demographic characteristics. Refer to Appendices B – F for all participant correspondence materials and the survey instrument.

Conjoint Measurements

Conjoint analysis required respondents to simultaneously consider the attributes of hypothetical fire and smoke scenarios and make tradeoffs (Hair et al., 2010; Kneeshaw et al., 2004; Shooter & Galloway, 2010). When the respondents evaluated the descriptions of each set of scenarios, we were able to decompose the responses and understand the relative importance (i.e., utility or part-worth) of each attribute that contributed to their overall tolerance of smoke. Relative importance scores are standardized percentages that describe how significant each attribute is (i.e., importance) in a person's overall tolerance of smoke.

There are a variety of formats used for conjoint studies, including rating, ranking, and choice-based methods – each with its own distinct advantages and disadvantages (Hair et al., 2010; Louviere et al., 2000). In the rating format, respondents are asked to compare and rate several scenarios based on preference. In a ranking format, the survey asks individuals to compare and order the scenarios. In the choice-based format, respondents are simultaneously shown two or more scenarios and asked to choose the most preferred alternative. For this study we used the rating method, where respondents were presented with combinations of fire and smoke attributes and asked to rate their tolerance of each scenario. We selected the rating method to reduce participant burden (the amount of time and mental effort required for each task) and to promote a slower and more careful consideration of each scenario and its associated attributes (Louviere et al., 2000). Ranking was not used because it would have required the simultaneous consideration of nine scenarios and 36 attribute levels, which would be difficult to cognitively sort out and rank in a meaningful way. A choice-based approach was not used because it would have required a minimum of two scenarios for 9 questions, so each participant would have evaluated at least 18 total scenarios. Further, choice-based approaches have been described as being more useful for situations where consumers are making choices and evaluating the attributes very quickly (e.g., purchasing toothpaste) (Louviere et al., 2000), whereas we desired our participants to read and consider each scenario slowly and carefully – simulating a more realistic encounter with fire and smoke. Each participant's perceived level of smoke tolerance was directly measured in relation to each conjoint scenario on a 7-point Likert-type scale of tolerance (-3= very intolerant, 3= very tolerant; Figure 6).

Smoke Scenario 1

- There is no advanced warning about anticipated smoke
- The smoke is from a prescribed-natural fire
- The smoke would be very unhealthy for everyone (see picture 3 on separate included page)
- The smoke will be present for up to 2 days

How tolerant (accepting) are you of the above scenario?

Very Intolerant			Neutral			Very Tolerant
-3	-2	-1	0	1	2	3

Figure 6. Example from the survey that shows the four attributes comprising a full scenario and the tolerance rating scale.

We used an orthogonal fractional factorial design for this survey, meaning that each attribute and level was independent and that only a subset of the possible scenario combinations was used (Hair et al., 2010; Vogt, 2005). A fractional factorial design was preferred because a full factorial design of our four attributes with three levels each would have required each respondent to evaluate 81 scenarios (3^4 scenarios). The orthogonal fractional factorial design reduced the respondent burden by decreasing the total number of scenarios to be evaluated (Hair et al., 2010; Kneeshaw et al., 2004). The basic model of this conjoint analysis was additive and linear, meaning that smoke tolerance was assumed to be the sum of each attribute, with a linear relationship between the attribute levels and smoke tolerance (e.g., as smoke health effects decrease, tolerance would increase in a linear fashion). A limitation of the additive linear fractional design was that it only allowed for the estimation of main effects (i.e., direct effects of each independent variable on the dependent variable), with the assumption that the interaction effects among the attributes were not significantly different than zero, or if significant would account for very little of the explained variance (Louviere et al., 2000). Thus, the main effects of this conjoint model were limited by omitted variable bias, but the bias was anticipated to be minimal.

The fractional subset of fire and smoke scenarios was generated from the 81 total potential scenarios (full factorial) using SPSS Conjoint (SPSS, 2005) and was an optimal design, meaning that it was orthogonal and balanced the same number of levels per factor. Hair et al. (2010) suggest the number of scenarios to be evaluated by each survey respondent should be as follows:

$$\text{Minimum number of scenarios} = \text{Total number of levels across all factors} - \text{Number of factors} + 1$$

Based on the above equation, each respondent evaluated nine scenarios in our survey (12 levels − 4 attributes + 1). A full-profile method was used to create each scenario, meaning that each scenario used one level from each attribute (Table 38). The advantage of a full profile was that it provided a realistic description of each scenario and a more explicit portrayal of trade-offs among the attributes (Hair et al. 2010). The most important aspect of a full-profile task is that it encouraged respondents to evaluate each scenario individually (Huber, 1997). We found that realistically depicting the fire and smoke scenarios verbally was challenging; therefore, a representative and standardized series of real images of varying smoke levels was included in each survey.

Table 38. Fractional factorial array of scenarios used in the survey

Scenario Number	**Attribute Combinations**			
	Smoke Origin	**Smoke Duration**	**Health Effects from Smoke**	**Advanced Warning**
1	Prescribed-natural	Moderate - up to 3 days	Unhealthy for Everyone	None
2	Prescribed-natural	Long - more than 3 days	Moderate	Public Service Announcement
3	Prescribed Fire	Short - 6 hours	Unhealthy for Everyone	Public Service Announcement
4	Prescribed Fire	Long - more than 3 days	Unhealthy for Sensitive Populations	None
5	Prescribed Fire	Moderate - up to 3 days	Moderate	Personal Phone Call
6	Natural (lightning or unintentional)	Long - more than 3 days	Unhealthy for Everyone	Personal Phone Call
7	Natural (lightning or unintentional)	Short - 6 hours	Moderate	None
8	Prescribed-natural	Short - 6 hours	Unhealthy for Sensitive Populations	Personal Phone Call
9	Natural (lightning or unintentional)	Moderate - up to 3 days	Unhealthy for Sensitive Populations	Public Service Announcement

Data Analysis

Each respondent was modeled separately, and the part-worths were viewed for each respondent and aggregated into community types and regions (Hair et al., 2010). Model goodness-of-fit was evaluated for each individual using the Pearson's correlation coefficient between observed and expected tolerance. Respondent tolerance of smoke was assessed by calculating the mean utility scores for each level of the attributes: fire origin, advanced warning, smoke duration, and associated health effects. The magnitude and polarity (positive or negative) of each utility score indicated the relative influence of each attribute level on the mean smoke tolerance ratings. For example, the positive utility scores associated with fires that originated from lightning indicated that the attribute level increased the respondent's overall mean tolerance of smoke (constant + level utility score). Conversely, the negative utility scores associated with prescribed fire indicated that the factor level decreased the respondent's mean tolerance of smoke (constant - level utility score). Utility scores can be added together (plus the constant) to determine the predicted smoke tolerance rating. Relative importance scores were computed by calculating the range of utility scores for each attribute and then dividing it by the total range in utility values across all attributes (Hair et al., 2010). Paired sample t-tests were used to evaluate differences in mean acceptability ratings between the levels of each attribute.

Conjoint analyses was conducted separately and compared by region (NORO and SOUTH), level of community preparedness for wildland fire (non-WUI, WUIMP, WUILP), urban or rural, gender (men, women), and whether the respondent had experienced previous adverse health effects from smoke from wildland fire (Health-yes, Health-no).

Results and Discussion

Overall, about one quarter of the respondents in each grouping were removed from the analysis because they did not answer one or all of the conjoint scenario questions (failing to evaluate the minimum number of 9 scenarios) or provided the same rating value for all of the scenarios, resulting in no variance to evaluate (Table 39). In the NORO, elimination of these responses resulted in samples that were larger than the recommended minimum of 200 responses per group necessary for reliable parameter estimates in conjoint analysis (Hair et al., 2010; Orme, 2005), and all data groupings were carried forward for analysis. In the SOUTH, the smaller regional sample size (*n*= 375) resulted in many of the groups failing to meet the recommended minimum of 200 responses for conjoint analysis and subsequently dropped from analysis due to unreliable/unstable parameter estimates. Conclusions and comparisons drawn from the SOUTH sample were therefore only discussed at the regional level.

Table 39. Summary of sample characteristics by region, community preparedness, urban or rural, gender, and prior experience with health effects from forest fire smoke

	Responses	No Variance	Missing Values	Skipped Question	Total Removed	% Total Removed	Usable Sample
NORO Sample							
Region Total	1542	119	85	205	409	26	1133
UNWUI	481	28	21	40	89	19	392
WUIMP	502	26	21	52	99	20	403
WUILP	556	39	21	64	124	22	432
Urban	1243	70	50	118	238	19	1005
Rural	296	23	13	38	74	25	222
Men	1085	62	37	102	201	19	884
Women	397	26	12	54	92	23	305
Health – Y	442	35	14	58	107	24	335
Health – N	1100	58	49	98	205	19	895
SOUTH Sample							
Region Total	375	26	22	48	96	26	279
UNWUI	110*	-	-	-	-	-	-
WUIMP	120*	-	-	-	-	-	-
WUILP	145*	-	-	-	-	-	-
Urban	163*	-	-	-	-	-	-
Rural	212	2	7	14	23	11	189
Men	243	17	10	30	57	23	186
Women	102*	-	-	-	-	-	-
Health – Y	48*	-	-	-	-	-	-
Health – N	327	21	18	38	77	24	250

*Groupings that had fewer than 200 responses did not meet the minimum sample size recommendation for conjoint analysis and were not carried forward. Note: No variance meant that the respondent answered each conjoint scenario question with the same rating value, resulting in no variance to analyze. Missing values meant that the respondent failed to answer one or more of the conjoint scenario questions, failing to meet the nine-scenario minimum. Skipped question meant that the respondent did not provide any answers for the conjoint scenario questions. The usable sample value was the amount of responses carried forward for conjoint analysis for each grouping.

Utility Scores of the Attribute Levels

Respondent tolerance of smoke was assessed by calculating the mean utility scores for each level of the attributes: fire origin, advanced warning, smoke duration, and associated health effects (Tables 40 and 41). All mean differences between levels of each attribute were statistically significant (p<.01). Overall, respondents from both regions and all groups were somewhat tolerant to very tolerant of smoke from forest fires (range of the mean constant values was 1.14 – 2.12). All mean tolerance ratings were positive values, except one, where respondents had previously experienced a negative health effect from smoke and the smoke levels of the scenario were unhealthy for everyone (NORO *m* = -0.05, Total *m* = -0.07, slightly intolerant). This is consistent with previous research that has suggested that smoke from forest fires is not a major concern for the majority of the public (Blanchard & Ryan, 2007; Brunson & Shindler, 2004; Shindler & Toman, 2003), but can be a very salient issue for individuals who have an existing health condition that is aggravated by smoke (e.g., asthma or heart disease) or have experienced a previous smoke impact to their health (McCaffrey, 2006; McCaffrey & Olsen, 2012).

The respondents' preference structures related to fire origin, advanced warning, smoke duration, and health effects were surprisingly stable between both regions and among all other groupings (Tables 40 and 41). Respondents were significantly more tolerant of smoke that came from lightning caused fires (overall *m*= 2.40) than smoke from prescribed-natural (overall *m*= 1.69) or prescribed fires (overall *m*= 1.40). This is somewhat contrary to previous work by Weisshaupt et al. (2005), who conducted focus groups in Spokane, WA, and Missoula, MT, and found that participants were more accepting of smoke from prescribed fires than smoke from lightning-caused wildfires. The discrepancy between the Weisshaupt et al. findings and our study could be in part due to data collection methods (focus group deliberations with a self-selected sample versus a large representative regional public survey) and participant bias due to previous smoke experience (i.e., some focus group participants had experienced substantial wildfire smoke the previous summer and viewed prescribed forest burning as an effective fuels reduction technique that reduced catastrophic wildfire risk and smoke). Our study, with a regional and random sampling approach, is likely more representative of the public's greater tolerance of smoke from lightning-caused wildfires than smoke from prescribed and prescribed-natural fires. Higher tolerance of smoke from lightning-caused fires is likely due, in part, to the fact that lightning-caused fires are a natural occurrence where the responsibility for subsequent smoke cannot be attributed to human

Table 40. Tolerance of smoke utility scores and mean ratings by region and community preparedness.

Attribute	Level	Region total		UNWUI		WUIMP		WUILP	
		Utility	Mean Rating	Utility	Mean Rating	Utility	Mean Rating	Utility	Mean Rating
NORO Sample									
Fire Origin	Natural (lightning or unintentional)	0.62	2.45	0.63	2.63	0.60	2.52	0.61	2.29
	Prescribed-natural (wildland fire use)	-0.15	1.68	-0.16	1.84	-0.13	1.79	-0.15	1.53
	Prescribed Fire	-0.47	1.36	-0.48	1.52	-0.48	1.44	-0.46	1.22
Advanced Warning	None	-0.54	1.29	-0.62	1.38	-0.54	1.38	-0.48	1.20
	Public Service Announcement	0.13	1.96	0.16	2.16	0.15	2.07	0.10	1.78
	Personal Phone Call	0.41	2.24	0.46	2.46	0.39	2.31	0.37	2.05
Smoke Duration in Community	Short - 6 hours	-0.33	1.50	-0.29	1.71	-0.35	1.57	-0.34	1.34
	Moderate - up to 3 days	-0.65	1.18	-0.58	1.42	-0.70	1.22	-0.68	1.00
	Long - more than 3 days	-0.98	0.85	-0.86	1.14	-1.05	0.87	-1.03	0.65
Health Effects	Moderate	-0.47	1.36	-0.51	1.49	-0.47	1.45	-0.44	1.24
	Unhealthy for Sensitive Populations	-0.94	0.89	-1.02	0.98	-0.95	0.97	-0.88	0.81
	Unhealthy for Everyone	-1.41	0.42	-1.52	0.48	-1.42	0.50	-1.31	0.37
	Constant	1.85		2.00		1.92		1.68	
	Goodness of Fit*	0.99		0.99		0.99		0.99	
SOUTH Sample									
Fire Origin	Natural (lightning or unintentional)	0.39	2.12	-	-	-	-	-	-
	Prescribed-natural (wildland fire use)	-0.11	1.62	-	-	-	-	-	-
	Prescribed Fire	-0.28	1.45	-	-	-	-	-	-
Advanced Warning	None	-0.60	1.13	-	-	-	-	-	-
	Public Service Announcement	0.15	1.88	-	-	-	-	-	-
	Personal Phone Call	0.45	2.17	-	-	-	-	-	-
Smoke Duration in Community	Short - 6 hours	-0.27	1.45	-	-	-	-	-	-
	Moderate - up to 3 days	-0.55	1.18	-	-	-	-	-	-
	Long - more than 3 days	-0.82	0.91	-	-	-	-	-	-
Health Effects	Moderate	-0.51	1.22	-	-	-	-	-	-
	Unhealthy for Sensitive Populations	-1.01	0.71	-	-	-	-	-	-
	Unhealthy for Everyone	-1.52	0.21	-	-	-	-	-	-
	Constant	1.73	-	-	-	-	-	-	-
	Goodness of Fit*	0.99		-	-	-	-	-	-

TOTAL Sample									
Fire Origin	Natural (lightning or unintentional)	0.57	2.40	0.59	2.55	0.58	2.47	0.55	2.23
	Prescribed-natural (wildland fire use)	-0.14	1.69	-0.15	1.81	-0.13	1.76	-0.14	1.54
	Prescribed Fire	-0.43	1.40	-0.44	1.52	-0.45	1.44	-0.41	1.27
Advanced Warning	None	-0.55	1.28	-0.64	1.32	-0.56	1.33	-0.47	1.21
	Public Service Announcement	0.14	1.97	0.17	2.13	0.16	2.05	0.09	1.77
	Personal Phone Call	0.42	2.25	0.47	2.43	0.40	2.29	0.38	2.06
Smoke Duration in Community	Short - 6 hours	-0.32	1.51	-0.29	1.67	-0.33	1.56	-0.33	1.35
	Moderate - up to 3 days	-0.63	1.20	-0.58	1.38	-0.66	1.23	-0.66	1.02
	Long - more than 3 days	-0.95	0.88	-0.86	1.10	-1.00	0.89	-0.98	0.70
Health Effects	Moderate	-0.48	1.35	-0.51	1.45	-0.48	1.41	-0.45	1.23
	Unhealthy for Sensitive Populations	-0.95	0.88	-1.02	0.94	-0.95	0.94	-0.91	0.77
	Unhealthy for Everyone	-1.43	0.40	-1.52	0.44	-1.43	0.46	-1.36	0.32
	Constant	1.83		1.96		1.89		1.68	
	Goodness of Fit*	0.99		0.99		0.99		0.99	

Scale rating for the dependent variable, tolerance of smoke, ranged from -3 = ‘‘very intolerant’’ through 0= ‘‘neutral’’ to 3= ‘‘very tolerant.’’ * The goodness-of-fit statistic is the Pearson’s correlation between predicted and observed tolerance ratings. All level values within an attribute are significantly different at the *p*<.001 level. Many cells are blank because they did not meet the minimum sample size requirement.

Table 41. Tolerance of smoke utility scores and mean ratings by urban or rural residence, gender, and prior experience with health effects from forest fire smoke

Attribute	Level	Urban		Rural		Men		Women		Health – Y*		Health – N	
		Utility	Mean Rating	Utility	Mean Rating	Utility	Mean Rating	Utility	Mean Rating	Utility	Mean Rating	Utility	Mean Rating
NORO Sample													
Fire Origin	Natural (lightning or unintentional)	0.61	2.45	0.65	2.60	0.61	2.51	0.63	2.46	0.57	1.75	0.63	2.75
	Prescribed-natural (wildland fire use)	-0.14	1.70	-0.19	1.76	-0.14	1.76	-0.17	1.66	-0.15	1.03	-0.15	1.97
	Prescribed Fire	-0.47	1.37	-0.46	1.49	-0.48	1.42	-0.46	1.37	-0.42	0.76	-0.49	1.63
Advanced	None	-0.54	1.30	-0.52	1.43	-0.53	1.37	-0.61	1.22	-0.46	0.72	-0.58	1.54

Warning	Public Service Announcement	0.14	1.98	0.12	2.07	0.14	2.04	0.13	1.96	0.12	1.30	0.14	2.26
	Personal Phone Call	0.41	2.25	0.40	2.35	0.39	2.29	0.49	2.32	0.33	1.51	0.44	2.56
Smoke Duration	Short - 6 hours	-0.32	1.52	-0.36	1.59	-0.32	1.58	-0.34	1.49	-0.35	0.83	-0.32	1.80
	Moderate - up to 3 days	-0.64	1.20	-0.72	1.23	-0.65	1.25	-0.69	1.14	-0.70	0.48	-0.64	1.48
	Long - more than 3 days	-0.96	0.88	-1.08	0.87	-0.97	0.93	-1.03	0.80	-1.05	0.13	-0.95	1.17
Health Effects	Moderate	-0.47	1.37	-0.47	1.48	-0.46	1.44	-0.51	1.32	-0.41	0.77	-0.49	1.63
	Unhealthy for Sensitive Populations	-0.94	0.90	-0.94	1.01	-0.92	0.98	-1.02	0.81	-0.82	0.36	-0.99	1.13
	Unhealthy for Everyone	-1.42	0.42	-1.41	0.54	-1.38	0.52	-1.53	0.30	-1.23	**-0.05****	-1.48	0.64
	Constant	1.95		1.84		1.90		1.83		1.18		2.12	
	Goodness of Fit*	0.99		0.99		0.99		0.99		0.99		0.99	
SOUTH													
Fire Origin	Natural (lightning or unintentional)	-	-	0.35	2.06	0.38	2.19	-	-	-	-	0.37	2.24
	Prescribed-natural (wildland fire use)	-	-	-0.10	1.60	-0.13	1.68	-	-	-	-	-0.11	1.76
	Prescribed Fire	-	-	-0.25	1.45	-0.25	1.56	-	-	-	-	-0.27	1.60
Advanced Warning	None	-	-	-0.53	1.17	-0.63	1.18	-	-	-	-	-0.60	1.27
	Public Service Announcement	-	-	0.10	1.81	0.19	2.00	-	-	-	-	0.15	2.02
	Personal Phone Call	-	-	0.42	2.13	0.44	2.25	-	-	-	-	0.45	2.32
Smoke Duration in Community	Short – 6 hours	-	-	-0.29	1.41	-0.26	1.55	-	-	-	-	-0.28	1.59
	Moderate – up to 3 days	-	-	-0.58	1.12	-0.53	1.28	-	-	-	-	-0.55	1.32
	Long – more than 3 days	-	-	-0.88	0.82	-0.79	1.02	-	-	-	-	-0.83	1.04
Health Effects	Moderate	-	-	-0.51	1.19	-0.49	1.32	-	-	-	-	-0.53	1.34

	Unhealthy for Sensitive Populations	-	-	-1.02	0.68	-0.98	0.83	-	-	-	-	-1.05	0.82
	Unhealthy for Everyone	-	-	-1.53	0.17	-1.47	0.34	-	-	-	-	-1.58	0.29
Constant		-	-	1.70	-	1.81		-	-	-	-	1.87	-
Goodness of Fit*		-	-	0.99	-	0.99	-	-	-	-	-	0.99	-
TOTAL													
Fire Origin	Natural (lightning or unintentional)	0.59	2.42	0.53	2.37	0.57	2.45	0.58	2.36	0.57	1.71	0.58	2.64
	Prescribed-natural (wildland fire use)	-0.14	1.69	-0.15	1.69	-0.14	1.74	-0.15	1.63	-0.15	0.99	-0.14	1.92
	Prescribed Fire	-0.45	1.38	-0.37	1.47	-0.44	1.44	-0.43	1.35	-0.41	0.73	-0.44	1.62
Advanced Warning	None	-0.56	1.27	-0.53	1.31	-0.55	1.33	-0.59	1.19	-0.47	0.67	-0.58	1.48
	Public Service Announcement	0.15	1.98	0.11	1.95	0.15	2.03	0.11	1.89	0.13	1.27	0.14	2.20
	Personal Phone Call	0.42	2.25	0.41	2.25	0.40	2.28	0.48	2.26	0.34	1.48	0.44	2.50
Smoke Duration in Community	Short – 6 hours	-0.31	1.52	-0.33	1.51	-0.31	1.57	-0.33	1.45	-0.34	0.80	-0.31	1.75
	Moderate – up to 3 days	-0.62	1.21	-0.66	1.18	-0.63	1.25	-0.66	1.12	-0.68	0.46	-0.62	1.44
	Long – more than 3 days	-0.94	0.89	-1.00	0.84	-0.94	0.94	-0.99	0.79	-1.02	0.12	-0.93	1.14
Health Effects	Moderate	-0.48	1.35	-0.49	1.35	-0.47	1.41	-0.52	1.26	-0.40	0.74	-0.50	1.56
	Unhealthy for Sensitive Populations	-0.95	0.88	-0.97	0.87	-0.93	0.95	-1.03	0.75	-0.81	0.33	-1.00	1.06
	Unhealthy for Everyone	-1.43	0.40	-1.46	0.38	-1.40	0.48	-1.55	0.23	-1.21	**-0.07****	-1.51	0.55
Constant		1.83		1.84		1.88		1.78		1.14		2.06	
Goodness of Fit*		0.99		0.99		0.99		0.99		0.99		0.99	

Scale rating for the dependent variable, tolerance of smoke, ranged from -3 = ‘‘very intolerant’’ through 0= ‘‘neutral’’ to 3= ‘‘very tolerant.’’ * The goodness-of-fit statistic is the Pearson’s correlation between predicted and observed tolerance ratings. All level values within an attribute are significantly different at the *p*<.001 level. Many cells are blank because they did not meet the minimum sample size requirement. ** These are the only instances where the mean smoke tolerance rating was a negative value.

management decisions. Moreover, people recognize that often little can be done to reduce smoke from these fires. Conversely, smoke from prescribed and prescribed-natural fires is the result of a deliberate management decision, which provides a target for public frustrations and blame related to smoke impacts. Regardless, these findings suggest that the public is generally tolerant of smoke from forest fires, irrespective of the source, which mirrors previous research (Blanchard & Ryan, 2007; Brunson & Shindler, 2004; Shindler & Toman, 2003).

Respondents from both regions were clear that advanced warning about potential smoke impacts was important. Respondents preferred a personal phone call warning about smoke (*m*= 2.25) significantly more than a public service announcement (*m*= 1.97), or receiving no advanced warning at all (*m*= 1.28). This finding is consistent with an online nationwide survey pertaining to Americans' greatest public safety concerns, which found that one in four Americans said they would prefer to be notified about an emergency situation by a personal telephone call or by television announcement (Federal Signal, 2010). Advance warning systems related to forest fire and smoke have been a topic of increasing interest for the fire management community, evidenced by a recent call for more research about the effectiveness of public warning and evacuation systems, and public perceptions about the need for warning or evacuation systems (Joint Fire Science Program, 2013). Our study represents a key empirical example from two regions of the U.S. that demonstrates the salience of advance warning systems in the eyes of the public; this is perhaps one of the most important considerations for public tolerance of smoke and public support for prescribed fire management.

Not surprisingly, respondents were more tolerant of smoke that stayed in town for a shorter duration than smoke that was present for longer durations. Smoke present for up to 6 hours (the shortest duration) was significantly more preferred (*m*= 1.51) than smoke that lasted for

3 days (*m*= 1.20) or longer (*m*= 0.88). Similarly, and not surprisingly, smoke with moderate health effects was significantly more preferred (*m*= 1.35) than smoke that was unhealthy for sensitive groups (*m*= 0.88) or generally unhealthy for everyone (*m*= 0.40).

Based on these findings, the optimal scenario given the respondents and attributes of this study were a lightning caused fire where the health effects were low, smoke did not last long in town, and residents received an advanced warning phone call notifying them to be aware of potential smoke and air quality concerns resulting from the fire.

Although the utility scores within each attribute followed a similar pattern, regardless of how the data were grouped, there are a few interesting findings that emerged related to previous experience with health effects from smoke, gender, and community preparedness for fire. Participants who had previously experienced adverse health effects from smoke from forest fire reported significantly lower smoke tolerance and had lower mean rating values for all attribute levels than participants who had not experienced adverse health effects from smoke from forest fire (Table 41). Previous adverse experiences with prescribed fire have been shown to have lasting negative effects on perceptions of prescribed fire. For example, following an escaped prescribed fire in Utah, nearly half of the respondents indicated that the fire had a negative impact on how they felt about prescribed fire, and increased their concerns about whether prescribed fire would reach their property or places they cared about (Brunson & Evans, 2005). Other research related to fire and smoke has suggested that nearly one-third of U.S. households consider smoke from forest fire to be a major issue because of health concerns and/or the presence of household members with a health issue affected by smoke (Brunson & Evans, 2005; Jacobson, Monroe, & Marynowski, 2001; Loomis et al., 2001; McCaffrey, 2006; McCaffrey & Olsen, 2012; Shindler & Toman, 2003). Thus, it is logical that a person who has experienced previous adverse impacts from forest fire smoke would be less tolerant of smoke than people without previous adverse impacts from forest fire smoke. However, the differences were small (<15%), and even those who had experienced previous adverse health effects from smoke had a mean tolerance of smoke that was greater than zero for all but one condition.

Several studies have discussed the important relationships among space, community, and culture that define a WUI community and their level of preparedness for wildland fire (Bowker et al., 2008; Jakes et al., 2007; Jakes, Fish, Carr, & Blahna, 1998; Paveglio, Jakes, Carroll, & Williams, 2009). Knowledge and understanding of current fire and smoke issues is linked to the culture of a community, and can influence tolerance of smoke and support for forest treatments. Shindler and Toman (2003) found that the more people knew about mechanical thinning or prescribed burning the greater the level of support for these practices. It is logical that a community that is more prepared for wildland fire would be more aware of forest management objectives and smoke issues, leading to a greater tolerance of smoke than residents in communities that are less prepared for fire and less aware of the role of fire in forest management. However, in our study the differences were small and not statistically significant. We also did not observe significant differences between urban and rural communities (Table 41). Previous research has suggested that an urban and rural divide exists due to differing value orientations and economies. However, our findings are consistent with a growing body of literature that suggests that communities can be a mosaic of varying interests and do not fit within traditional typologies (Racevskis & Lupi, 2006), notably within the WUI (Paveglio, Jakes, Carroll, & Williams, 2009).

Other research related to fire has found that women were more concerned than men about the potential adverse effects of prescribed fire near their homes, and subsequently less supportive of the use of prescribed fire (Lim, Bowker, Johnson, & Cordell, 2009; Ryan & Wamsley, 2008). The utility scores between gender were not statistically significant in our study, and the differences between men and women were less than 3% for all items.

Relative Importance of the Attributes

The conjoint relative importance values are the averaged importance ratings across all respondents and sum to 100% within each stratification (Table 42). In the NORO, the origin of the fire was consistently the most important factor (>30%), followed by advanced warning (25-28%), health effects from smoke (21-24%), and lastly the duration of the smoke in the community (17-21%). In the SOUTH, advanced warning (29%) was slightly more important than the fire origin (28%), health effects from smoke (25%), and the duration of the smoke (19%). The relative importance value patterns were very stable across data stratifications in both regions (Table 42).

Two surprises emerged from the relative importance findings: 1) advanced warning was consistently perceived to be more important than negative health effects and smoke duration, and 2) there were somewhat similar relative importance percentages among the four attributes, regardless of data stratification (Table 42). Given previous research that has documented the importance of existing health conditions and concern for smoke (e.g., Brunson & Evans, 2005; McCaffrey, 2006; McCaffrey & Olsen, 2012; Shindler & Toman, 2003), we anticipated that health effects would be one of the more important attributes influencing public tolerance of smoke. However, the relative importance range of 21-24% we found for health effects is a sizable margin of overall public tolerance of smoke. Clearly, health effects are a prominent concern; however, it is interesting, and carries important fire management implications, that advanced warning was consistently more important than health effects. Stated another way, the public as a whole is more interested in advanced warning about potential smoke in their community than the actual health impacts associated with smoke. This result could be associated with the fact that advanced warning

Table 42. Relative importance values for each attribute by region, community type, gender, and prior experience with health effects from smoke

Attribute	Total	non-WUI	WUIMP	WUILP	Urban	Rural	Men	Women	Health – Y	Health – N
	Mean % Importance									
NORO Sample										
Fire Origin	32	31	32	33	34	32	33	30	32	33
Advanced Warning	27	28	26	26	26	27	26	27	27	25
Smoke Duration	19	17	20	20	19	19	19	19	18	21
Health Effects	22	24	22	21	21	23	22	23	23	21
Total	100	100	100	100	100	100	100	100	100	100
SOUTH Sample										
Fire Origin	28	-	-	-	-	27	27	-	-	27
Advanced Warning	29	-	-	-	-	28	30	-	-	29
Smoke Duration	19	-	-	-	-	19	19	-	-	19
Health Effects	25	-	-	-	-	26	25	-	-	25
Total	100	100	100	100	100	100	100	100	100	100
Total Sample										
Fire Origin	31	31	31	32	31	31	32	30	33	31
Advanced Warning	27	28	27	26	27	27	27	27	25	28
Smoke Duration	19	17	20	20	19	19	19	19	21	18
Health Effects	23	24	22	22	23	23	22	23	21	23
Total	100	100	100	100	100	100	100	100	100	100

allows people to prepare or evacuate before smoke is present, thereby mitigating or avoiding the potential adverse health effects. For example, a personal phone call to community residents who are known to have existing health conditions, or a public service announcement, would alert residents to the smoke threat and allow them to take precautionary measures within their residence (e.g., close doors and windows, use air purifiers), plan to limit outdoor activities during the anticipated smoke presence in their community, or evacuate the area until the smoke threat has subsided. The desire for two-way, personal interaction when receiving information about potential fire or smoke information is consistent with previous research that has shown less public preference for one-way information sharing (McCaffrey & Olsen, 2012; Toman, Shindler, & Brunson, 2006).

The second surprise was that the relative importance values consistently ranged between approximately 20-35% importance, without a clear polarization among the attributes. This is not consistent with most other conjoint studies that have involved rating full-profile scenarios. A 20-year review of conjoint studies found that it was common for participants to clearly focus on a small number of attributes, resulting in high importance values, while the others had almost zero importance (Huber, 1997). That was not the case in our study. One explanation might be that our study participants were weighing the nine conjoint scenarios rather equally, and were not strongly targeting particular smoke attributes. This may be because: 1) the attribute levels were not clearly understood or differentiated by participants (e.g., short duration of smoke (6-hours) was not considered different from the long duration (greater than 3 days), or 2) the public did not find the attributes of smoke, or smoke in general, to be a salient concern. Previous research has suggested that for the overall public, smoke may not be a major concern (Blanchard & Ryan, 2007; Brunson & Shindler, 2004; McCaffrey & Olsen, 2012; Shindler & Toman, 2003), and as we have noted, general tolerance was high among our respondents.

Contrasting the Multivariate Conjoint and Univariate Techniques

We thought it important to contrast our multivariate conjoint approach with a univariate approach for determining the relative importance of the four smoke attributes (origin, duration, advanced warning, health effects) to determine whether the assessment method affected interpretations about attribute importance. Thus, a separate survey question, apart from the conjoint analysis, asked participants to rate the relative importance of each of the four independent conjoint attributes by allocating 100 points across them (Table 43). This task prompted participants to consider each attribute individually, rather than evaluating their tolerance of full scenarios (i.e., conjoint). Interestingly, in the univariate approach in both regions and across all stratifications, participants consistently identified health effects as the most important attribute (41-53%). In the NORO, the second most important attribute was smoke duration in the community (19-23%), followed by the fire origin (16-21%), and lastly advanced warning (12-18%). In the SOUTH, advanced warning and duration were rated as the second most important attribute (15-22%), with fire origin least important (13-15%). There was a clear difference between this univariate approach and the multivariate conjoint approach, notably the reversed importance of health effects and smoke duration with fire origin and advanced warning.

Our findings are consistent with some previous research from the health fields that have compared the two techniques and found that they produced different results (e.g., Ryan et al., 2001). In a comparison of multiple methods, Johnson et al. (2006) found that conjoint analysis allowed for a more accurate depiction of participant preferences. However, comparisons between these two approaches is worthy of future study to examine whether differences widely exist between the univariate and multivariate conjoint approaches in natural resource settings, or whether the findings are isolated to this study and topic.

Table 43. Self-reported univariate importance of each smoke attribute by region, community type, gender, and prior experience with health effects from smoke

Attribute	Total	UNWUI	WUIMP	WUILP	Urban	Rural	Men	Women	Health – Y	Health – N
	Mean % Importance									
NORO Sample										
Fire Origin	20	21	20	18	20	19	20	20	16	21
Advanced Warning	16	18	15	15	16	17	16	16	12	17
Smoke Duration	21	19	22	23	21	22	22	21	23	21
Health Effects	43	41	43	44	43	41	43	44	49	41
Total	100	100	100	100	100	100	100	100	100	100
SOUTH Sample										
Fire Origin	14	14	13	15	13	15	14	15	11	14
Advanced Warning	20	21	22	17	21	18	21	18	15	21
Smoke Duration	19	19	19	19	19	19	19	19	21	19
Health Effects	47	46	46	49	47	47	48	48	53	46
Total	100	100	100	100	100	100	100	100	100	100
Total Sample										
Fire Origin	19	19	19	17	19	18	19	18	15	18
Advanced Warning	17	19	16	15	16	17	16	16	12	18
Smoke Duration	20	19	21	21	20	20	20	21	22	20
Health Effects	45	43	44	47	45	45	45	45	51	44
Total	100	100	100	100	100	100	100	100	100	100

Conclusions

Overall, our findings suggest that the public is generally tolerant of smoke from wildland and prescribed fires, and may not consider smoke to be a major issue of concern – based on the high tolerance scores and minimal differentiation in the smoke attributes and scenarios. However, in the conjoint analysis, participants consistently reported that receiving advanced warning about the potential presence of smoke in their community was of primary importance. This is a topic worthy of further study and fire management consideration because it is one aspect of Rx fires that managers can address regarding improvements in public outreach. Further, people prefer personal forms of communication, such as a phone call, rather than general public service announcements or no warning at all. Prescribed fires do not always go as planned. Weather conditions may change, fuel conditions may be different than assumed, and fire behavior may be erratic. Public communication plans about smoke are recommended as part of Rx fire management standard operating procedures, but they do not always occur and could be more widespread and proactive. Addressing advanced warning in a more proactive way would also help develop procedures for identifying and working with individuals and population segments that have existing health conditions or are sensitive to smoke. With many of today's more sophisticated fire behavior and meteorological models, there may also be cases where fire managers can provide advanced warnings for some communities that will be experiencing smoke from prescribed-natural fires and large wildfires in the region.

Research related to other natural hazards, such as hurricanes, has highlighted the importance of understanding the public's preferences related to early warning systems (Lazo, Waldman, Morrow, & Thacher, 2010). Similarly, future research should focus on achieving a better understanding of public attitudes and preferences for advanced warnings related to smoke from forest fires. Agencies and organizations that interface with natural hazards, including forest fire and smoke, have recently been calling for a better understanding of warning systems (Gladwin et al., 2009; Joint Fire Science Program, 2013). Research about hurricane hazards found that residents were most willing to pay for advanced warning systems that would alert them about the projected timing, magnitude, and location of impacts (Lazo et al., 2010). Advanced warning about smoke could provide similar metrics related to the projected timing and locations of smoke impacts, as well as the potential health impacts that could result from smoke concentrations. Modern society allows urban and rural community residents to receive information from multiple high-speed sources via the internet, cell phones, and network, satellite, and cable television. In addition to understanding public attitudes towards advanced warning systems, future research related to creating fire-adapted communities should focus on information sources for advanced warning, community dissemination channels, and the structure, format, and timing of warnings.

The goal of this study was to use a conjoint approach to deconstruct how context-specific factors and trade-offs affect public tolerance of smoke from forest fires. Comparing our multivariate conjoint approach to a univariate approach demonstrated that the two techniques can produce varying results, and that our conjoint approach was an effective tool for examining trade-offs and preferences related to public tolerance of smoke from forest fires.

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Chapter IV. FOREST MANAGERS RESPOND TO INTERDISCIPLINARY CLIMATE CHANGE SCIENCE: EVALUATING THE CENTRAL CONSTRUCTS OF BOUNDARY OBJECTS AND ORGANIZATIONS

Introduction

Climate change represents one of the greatest challenges to land management and society. It is expected to alter the mountainous ecosystems of the U.S. northern Rocky Mountains and affect the people who depend on them for ecosystem services and livelihoods. The U.S. Forest Service (USFS) will not fulfill its mission to promote sustainability without integrating climate change impacts into management plans and actions (U.S. Department of Agriculture Forest Service, 2008). With rapid biophysical changes already occurring in these forests, the USFS and other stakeholders are increasingly seeking to understand and mitigate the effects of a changing climate on public lands. Effective action depends on understanding regional and local implications of climate science and open and reasoned discussions about current research and potential mitigation actions among researchers, land managers, and other stakeholders (Dietz, 2013; Hall, Wilson, & Newmann, 2012; Luskin, Fishkin, & Jowell, 2002; Parkins & Mitchell, 2005).

In the fall of 2012, our interdisciplinary research team of biophysical and social scientists conducted a series of climate change workshops (CCWs) focused on conveying locally relevant information on shifts in forest ecosystems due to changing climate. The CCWs facilitated the exchange of current climate change knowledge across research and management boundaries in the U.S. northern Rocky Mountains. Our CCWs were designed to bring abstract concepts of climate impacts to regional and local scales through the synthesis of historical empirical data and the visualization of future forest and water modeling.

To assess how participants' beliefs about climate change science credibility, salience, legitimacy, and behavioral intention changed from before to after the CCWs, we applied a rigorous pre-test/post-test, mixed methods approach. Drawing upon multiple frameworks, we evaluated the effectiveness of the boundary objects and organization. We contribute to both theory and practice of boundary objects and organizations by carefully attending to each of the factors posited as leading to more effective outcomes. Additionally, we incorporated ideas from social learning theory to develop activities likely to enhance collective understanding in the application of science to practice, including visualization techniques.

Background of Boundary Organization and Boundary Object Theory

The process by which research communities establish relationships with the worlds of land management and policy is commonly referred to as boundary work (Clark et al., 2010; Gieryn, 1983). Boundaries are symbolic distinctions that categorize objects, people, practices, and even time and space (Lamont & Molnár, 2002). Many boundaries reflect unique ways of understanding and approaching management between different social sectors and disciplines. Boundaries have been addressed in two ways: though the concept of boundary objects and as boundary organizations.

Boundary organization theory offers one approach to understanding and enhancing interactions between specific groups or organizations that lie on the boundary between worlds. Boundary organizations -- institutions or settings that facilitate knowledge and information exchange among scientists, decision-makers, and land managers -- can facilitate a multi-directional flow of information between science and management at multiple scales (Cash & Moser, 2000). The primary assumptions of boundary organizations set forth by Guston (2001) are: 1) they exist at the frontier of the science and management communities but are accountable to both; 2) they involve participation by land managers/policymakers and researchers, as well as professionals who mediate between them; and 3) they provide opportunities for the co-production of boundary objects, which are “objects that live in multiple social worlds and which has different identities in each" (Star & Griesemer, 1989, p. 409). In the context of climate change, research specific to boundary organizations and objects is relatively new.

Guston (2001) and Miller (2001) identified the importance of creating incentives for the production of boundary objects, involving key participant institutions (scientific and management communities), and maintaining lines of accountability to both scientists and managers. In a separate line of work (but related to boundary organization theory), boundary object theory originated with Star and Griesemer's (1989) study of a museum classification system as a boundary object. Research on boundary objects describes them as hybrid, flexible, and portable tools that help people from multiple sectors negotiate knowledge transfer between the science, management, and policy realms (Cutts, White, & Kinzig, 2011; White et al., 2010). Boundary objects link different sets of diverse interests, and they can be physical or virtual entities that promote cohesive working relationships. Therefore, boundary objects can be constructed differently depending on the work or informational needs of different social groups or worlds that are creating, using, and modifying them.

Boundary objects include decision support systems, scenarios, and GIS technology (e.g., Girod, Wiek, Mieg, & Hulme, 2009; Harvey & Chrisman, 1998; White et al., 2010). Model-based decision support tools have become popular as boundary objects that connect natural resource sciences and decision-makers, because models can provide a common means for visualizing complex information (White et al., 2010). Transforming abstract numeric and verbal data into imagery can greatly reduce the risk of confusion while honoring the inherent human preference for visual information (Al-Kodmany, 2002). We defined our boundary organization as the CCW as a whole, and the boundary objects were the climate change modeling tools used during the CCW.

Despite the interest in and promise of boundary organizations and objects, the different types, natures, and effects of boundary objects in natural resource management are poorly understood (White, 2011). Their flexibility and lack of common classification have prompted efforts to create standardized sets of constructs to define and measure boundary objects (Cutts et al., 2011; White et al., 2010). Cash et al. (2003) identified three elements integral to linking knowledge and action for environmental decision-making: credibility, salience, and legitimacy. ***Credibility*** involves the scientific adequacy of the technical evidence and arguments. This has been qualitatively assessed in terms of perceived scientific accuracy, validity, technical evidence, data quality, calculations, and visual display (White et al., 2010). ***Salience*** (or usefulness) is the perception of whether the boundary object has the ability to meet the needs of decision-makers. ***Legitimacy*** reflects the perceptions that the production of information and technology has been respectful of the divergent values and beliefs of stakeholders, unbiased in its conduct, and fair in its treatment of views and interest. In our study, these constructs were evaluated in terms of both the CCW organization and individual boundary objects. We also desired to explore how institutional factors influence the likelihood of using climate change science in land management decisions.

Institutional environments affect the capacity of using climate change science in land management. Agency policies, directives, diverse priorities, time, funding, politics, litigation, and the perception of limited discretion in decision making are a few potential organizational barriers that may supplant the previously described variables related to boundary objects and organizations (Archie, Dilling, Milford, & Pampel, 2012; Jantarasami, Lawler, & Thomas, 2010; Wright, 2010). Organizational factors are likely have a direct causal impact on behavior. The more barriers a person perceives is anticipated to result in a lower likelihood of intending to use climate change research in land management.

Our rigorous pre- and post-workshop interviews and questionnaires were designed to evaluate the effect of the boundary organization and objects, and explore the hypothesized relationships between the factors that predict likelihood to use climate science in forest management. The specific hypotheses we tested were:

H1: Perceptions of (a) the usefulness and (b) the credibility of climate change science will significantly increase as a result of participating in the CCWs.

H2: Higher perceived credibility will be associated with higher perceived usefulness of climate change science in management decisions.

H3: Higher perceived usefulness will be associated with higher intention to use climate change science in future work.

H4: Higher perceived organizational barriers will be associated with (a) lower perceived usefulness of and (b) lower intention to use climate change science in management decisions.

H5: Participation in the CCW will result in a positive overall evaluation of the credibility, salience, and legitimacy of the boundary organization.

The methods section will begin with a description of how our CCWs and climate change modeling tools were designed to meet the theoretical assumptions and best practices of boundary organizations and objects, followed by a description of the mixed-methods study design, measurements, and analysis framework.

Methods

Workshops as Boundary Organizations

The overall CCW represented a boundary organization existing at the frontier between the science and management communities and involved participation by actors from both communities (Guston, 2001). Our CCWs met the assumptions of boundary organizations because: 1) the workshops were conducted with USFS personnel (including decision-makers), university researchers, and regional collaborative group members; and 2) the tools used in the CCW were developed and used by professionals from both the scientific and land management worlds. The visualization and modeling tools used during the CCWs represented boundary objects and were designed to facilitate the exchange of climate change research (Figure 7).

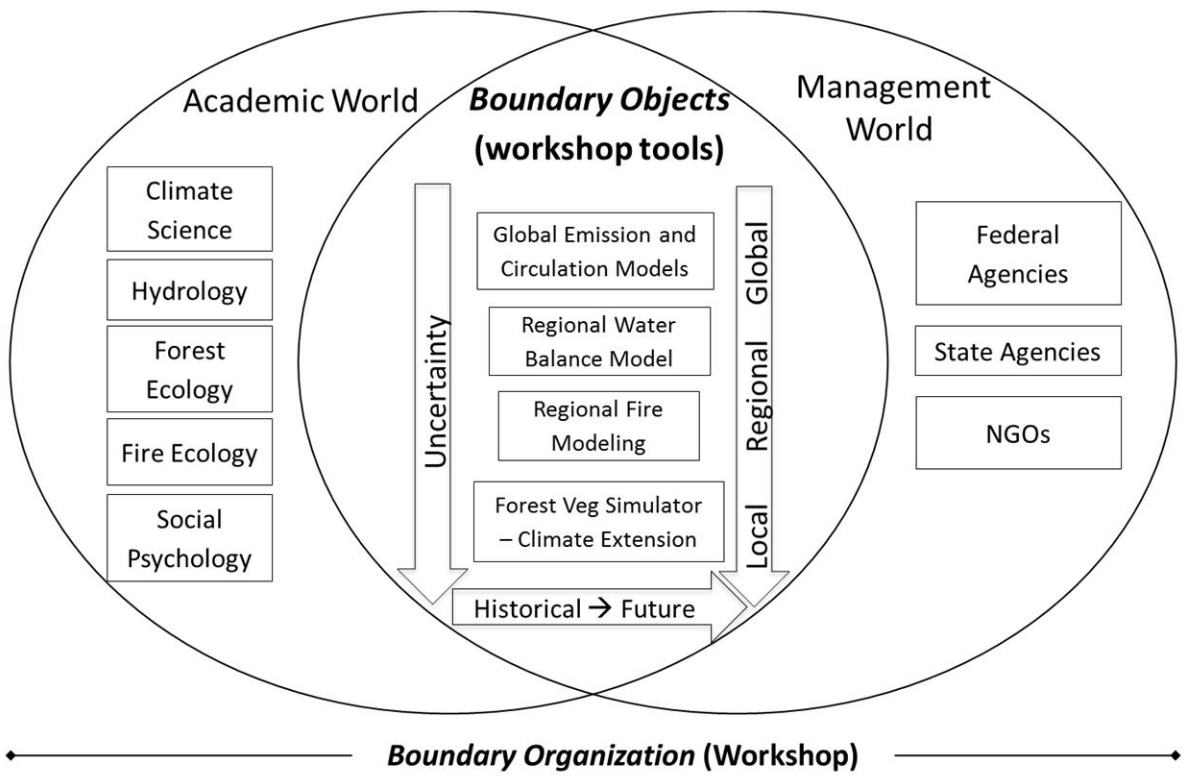

Figure 7. Conceptual diagram of the climate change workshops (CCWs), boundary organization, that linked research and management worlds. The boxes on the left, academic world, are the disciplines represented by our interdisciplinary research team. The boxes on the right in the management world represent the diversity of stakeholders present at the CCWs. The boxes in the center represent the CCW tools that were evaluated as boundary objects. The large arrows show that the boundary objects spanned global, regional, and local spatial scales, historical and future temporal scales, and that uncertainty was present at all scales and compounds when transitioning from global to local and historical to future.

Although there has been limited documentation of specific variables, structures, and processes of boundary organizations (Parker & Crona, 2012), the management culture (inter-personal relationships between participants and boundary organizations) has been identified as a key consideration (Crona & Parker, 2011). This was an important concern for our CCWs, where the university research team made many efforts to establish and nurture relationships with potential participants. Careful planning helped to ensure that the design, organization, and convening of the CCWs served both our purpose and the needs of our participants (Heierbacher, 2010; McCoy & Scully, 2002).

Recognizing human limitations related to information processing, cognitive load, numeracy, and attention span, we took careful consideration regarding how we designed and presented climate change information during the workshops (Figure 8). We capitalized on the importance of visualizing climate change trends and impacts to summarize a large amount of complex information and make the information locally relevant (e.g., Al-Kodmany, 2002; Lipkus, 2007; O'Neill & Nicholson-Cole, 2009; Sheppard, 2005). Because humans possess a limited capacity to receive and use complex information (Lang, 2000; Sylwester & Cho, 1992/3), we prioritized visualizations that were simple (listed below), but that would hold attention and promote careful consideration. Visualization is an important part of the boundary object for conveying uncertainty in complex information in a way that participants could process (MacEachren, Robinson, & Hopper, 2005).

The CCW tools represented and satisfied the assumptions of boundary objects because each tool can be freely used by different actors in different locations, they model and predict future scenarios, they explain the meaning and significance of climate change effects in forests of the northern Rocky Mountains, and they provide a foundation for climate change discussions among people from different disciplines and sectors. The boundary objects went through integration

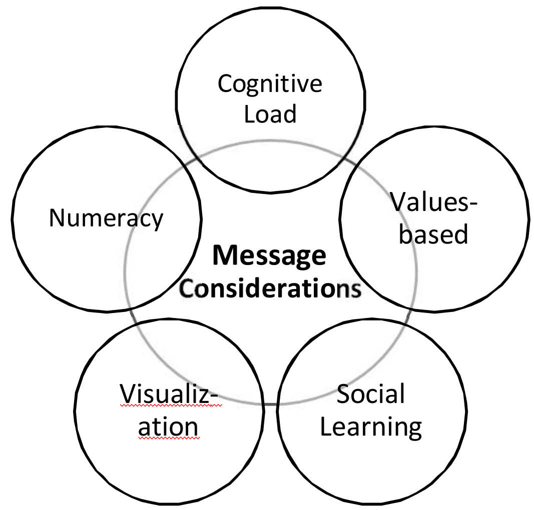

Figure 8. Climate change message considerations for the workshops.

and coproduction between our research team (the scientific community) and managers (USFS and forest collaborative groups). The final boundary objects represented diverse information, compiled at different scales:

1. *Global Scale*: An overview of global climate, historically (in both a geologic and contemporary context) and future projections, including a review of the greenhouse effect and historical $C0_2$ concentrations. For future projections, we provided an introduction to global circulation models (GMCs) and emission scenarios and discussed the relative uncertainty of each. This section provided the global and atmospheric considerations necessary to understand the practical workings and limitations of the input data needed for the models described below.
2. *Regional-Scale Water Resources*: Historical data provided examples of how temperature, precipitation, snowpack, streamflow, and stream temperature have changed within the region over the past century (Klos et al., 2014). Future projections showed how these systems may continue to change (UW-CIG, 2012). A regional hydroclimatic model was used to create 3D visualizations of potential changes in snowpack accumulation and flood risk in the regional and local landscapes surrounding the CCW locations. Additionally, river-scale

streamflow models provided insight about potential regional and local changes in timing and amount of in-stream water availability (UW-CIG, 2012).

3. *Regional-Scale Forest and Fire Ecology*: Regional vegetation models were used to project future tree species and biome distributions of the northern Rocky Mountains based on climate envelope modeling (Rehfeldt, Crookston, Warwell, & Evans, 2006; Rehfeldt, Ferguson, & Crookston, 2008). Climatic fire models were used to visualize projected increases in area burned in the western U.S. (Littell, 2011), increasing fire season length, and days with high fire danger ratings. These models demonstrated how climate shifts in precipitation and temperature could link to forest vegetation and wildfire regimes.
4. *Local-Scale Vegetation Simulations*: The Climate Extension to the Forest Vegetation Simulator (Climate-FVS) (Crookston, Rehfeltd, Dixon, & Weiskittel, 2010) was developed to provide forest managers a tool for considering climate change effects at the forest stand level. Working closely with the model developers and stakeholders from each CCW forest, a combination of forest type, elevations, and time scales was selected for evaluating a series of management regimes under a climate change scenario. The modeling was used to determine when particular tree species would not be able to regenerate due to unsuitable climate. Further, effects of different management regimes (e.g., prescribed fire, mechanical thinning, or a combination) were simulated to evaluate the increase or decrease in resilience of these species throughout time under anticipated climate change.

In addition to the boundary object variables described above, we recognized the need to employ best practices related to active/collaborative learning and small group processes during the CCWs (Bonwell & Eison, 1991; Cohen, 1994; Daniels & Walker, 1996; Michael, 2006). We desired workshop participants to be actively engaged with the opportunity to work together in small groups and articulate their understanding and opinions to others (Rivard & Straw, 2000). Thus, we created opportunities for participants, under semi-structured facilitation, to carefully reflect upon the climate change science, consider how it might be useful in land management, and identify where gaps exist.

According to boundary organization theory, successful exchange of the climate change information during the CCWs was more likely to occur if the workshops and modeling tools were perceived as credible, salient, and legitimate by the participants. These factors provided a framework for evaluating the boundary objects and organizations (legitimacy was not evaluated for the boundary objects used during the CCW because the models were designed specifically for climate, water, vegetation, and fire science disciplines, and therefore were not intended to be applicable to all agency natural resource disciplines). Specifically, we assessed the extent to which our boundary objects and organization, were perceived as credible and salient. Then, through regression analysis, we assessed whether these factors, as well as organizational barriers, predicted participants' intentions to use climate change science in management practice.

Design and Sampling

We employed a mixed sequential equal status design (Leech & Onwuegbuzie, 2009; Onwuegbuzie & Collins, 2007) to triangulate quantitative and qualitative data in the evaluation of our CCW boundary organization and objects. Qualitative interviews provided depth and richness to our understanding of the utility of climate change science in land management, while quantitative surveys permitted us to establish the magnitude of relationships among constructs.

The CCWs were quasi-experiments because the participants were self-selected (i.e., lacked random assignment) and we did not attempt to isolate the effects of the pre-test or use a control group; otherwise they had similar purposes and structural attributes to experiments (Creswell, 2009; Graziano & Raulin, 2009). Our interrupted time series design involved pre-test measures (i.e., interviews and questionnaires), a treatment (i.e., the workshop), and post-test measures (i.e., questionnaires and interview).

We purposefully selected individuals who satisfied multiple criteria (listed below) to maximize our understanding of the effectiveness of our CCWs (Creswell, 2009; Onwuegbuzie & Collins, 2007; Teddlie & Yu, 2007). Using a snowball sampling approach, we asked participants to recommend other participants, including both climate change accepters and deniers (Creswell, 2009). The sample frame involved selecting U.S. National Forests that were: 1) located within the northern Rocky Mountains (Idaho and Montana); 2) contained a steep elevation gradient with a diversity of forest types; 3) were identified as being sensitive to substantial temperature and precipitation changes (Klos, Link, & Abatzoglou, in revision); and 4) had local and regional forest collaborative groups of citizens who were engaged with USFS activities.

For each CCW location, participants were selected from three strata: forest managers/ decision makers and planners (e.g., fire management officers, district rangers, interdisciplinary team leaders, National Environmental Policy Act document editors), forest ecologists (e.g., silviculturists, foresters, fire ecologists), and water resource specialists (e.g., hydrologists, fisheries biologists, riparian ecologists). These strata represented the main natural resource and climate change topics presented during the CCWs (forest, fire, and water resources) and included individuals who regularly work with land management documents that incorporate climate change science. A target of 25 participants at each CCW location (100 total) was chosen to detect a moderate (Cohen, 1988), one-tailed relationship between our constructs of interest with 0.80 power at the 5% level of significance (Onwuegbuzie & Leech, 2004). Though by quantitative survey standards this is a relatively small sample for correlational or comparative designs (Bartlett, Kotrlik, & Higgins, 2001), small samples are appropriate for exploratory research and mixed method quasi-experiments (Onwuegbuzie & Collins, 2007; Onwuegbuzie & Leech, 2004).

To reach theoretical saturation through our interviews we followed the recommendations of Onwuegbuzie and Collins (2007) to include at least three participants per subgroup in a quasi-experimental mixed methods design. Guest, Bunce, and Johnson (2006) found that the majority of themes reach saturation with the completion of 12 interviews. Therefore, because this study involved CCWs in four locations with three disciplinary strata, we conservatively aimed to conduct pre- and post-workshop interviews with 12 people at each location, and 16 in each disciplinary stratum (48 total pre-post interviews).

Interview and Survey Content

The telephone interviews and online questionnaires both addressed the variables discussed in the introduction, but the interviews were less structured, allowing for probing and elaboration (Morse & Richards, 2002). Each participant was generally asked the same questions in the same order, with some variation in probing questions based on initial responses. Pre-workshop questions pertained to the primary focus of the study, following the theoretical model of Figure 9, such as "how useful is climate change science in the work you do?" Probing questions related to these included, "what about that particular research makes it useful or impedes is usefulness?" Post-workshop interview questions asked participants to evaluate how their thinking changed regarding the credibility and salience of climate change science in their work based on the boundary objects presented at the CCWs. We also asked participants to evaluate the overall credibility, salience, and legitimacy of the CCWs.

For the self-administered written questionnaires, participants had the option of taking the pre-workshop survey either online prior to the actual CCW date, or on site prior to the start of the CCW. All CCW participants were encouraged to complete a written or online survey at the conclusion of each CCW. To ensure maximum participation, we followed a modified version of Dillman's Total Design Method that included an initial email notifying participants that they would receive a request to complete an online survey, an email with a survey link (the electronic survey was deployed using Qualtrics), a follow-up reminder email, and personal phone calls to those who had not completed the survey (Dillman, Smyth, & Christian, 2009). Refer to Appendices H - P for all participant correspondence materials, the survey instrument, and interview instrument.

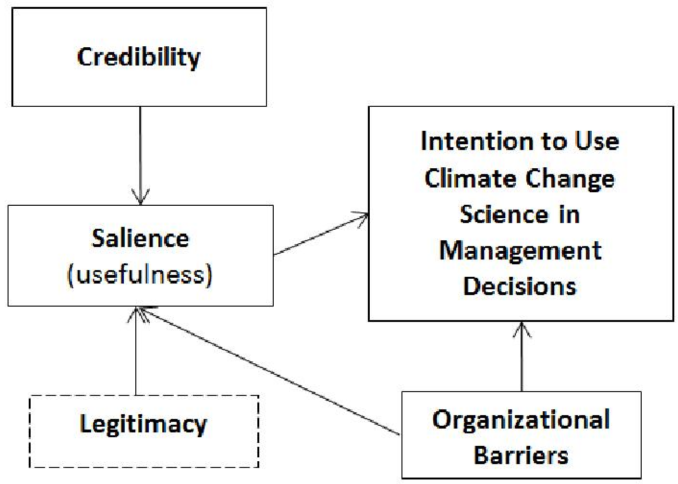

Figure 9. Integrated model of boundary variables, organizational barriers, and the intention to use climate change research in land management decisions. The dotted line indicates that legitimacy was only measured for the CCW boundary organization (not the boundary objects).

The pre-workshop questionnaire had nine sets of questions. Most questions had 5- or 7-point Likert-type response options. The first section asked questions about the salience (i.e., usefulness) and credibility of climate change science that were adapted from previous boundary object work (Cutts et al., 2011; Jacobs, Garfin, & Buizer, 2009; White et al., 2010). Questions were also asked about potential barriers to addressing climate change in their work (Wright, 2010). A final section asked participants about their disciplinary expertise, years worked in the northern Rocky Mountains, highest level of education obtained, gender, and political orientation.

The post-workshop questionnaire had six sets of questions, including the questions from the pre-workshop questionnaire pertaining to the usefulness and credibility of climate change science. An additional section asked participants to evaluate the credibility, salience, and legitimacy of the entire CCW (Buizer, Jacobs, & Cash, 2010; Cash, 2001; Crona & Parker, 2011; Guston, 2001; Miller, 2001; Parker & Crona, 2012).

Interview and Survey Data Analysis

All interviews were digitally recorded with permission and transcribed verbatim. Analysis of the interview data followed a team-based strategy to developing a codebook guide (Boeije, 2002; MacQueen, McLellan, Kay, & Milstein, 2002; Ryan & Bernard, 2003). An initial list of parent nodes included categories of anticipated themes based on our theoretical framework and interview protocol. After the parent codes were defined, the research team reviewed the codebook and discussed any discrepancies in code interpretations. Using the team-developed parent nodes, two team members coded each interview. The process continued until each coding category had a definition, an example, and rules for application. The acceptable level of reliability was set at Cohen's kappa > .80 (Krippendorff, 2004), which was achieved after four rounds of coding. After reliability was established, one coder applied codes to all the interview text and codes were attached to text in NVivo (Appendix P).

Our team also established rapport with the participants through prolonged engagement, such as multiple phone conversations, so that they felt comfortable to provide honest and candid answers. A research journal was kept by all members of the research team during the interview process to track responses and events, allowing us to identify any outside events that could have affected interpretation of a participant's interview (Shenton, 2004).

Survey responses were analyzed using the Statistical Package for the Social Sciences (SPSS, 2010) to reduce multi-item measures to indices using factor analysis (direct oblimin rotation) with a Cronbach's alpha reliability coefficient cutoff level of 0.70 or greater (Field, 2005; Kline, 2011). Paired sample T-tests were used to determine whether variables of interest changed from pre- to post-test, and one-way analysis of variance was used to determine whether the variables of interest varied by discipline or location. Ordinary least squares (OLS) regressions were used to test the relationships presented in Figure 9 (Barker et al., 1994; Graziano & Raulin, 2007). We used Baron and Kenny's (1986) process for testing the mediating effect of salience/usefulness on the relationships of credibility and organizational barriers to behavioral intention.

Results

A total of 97 people participated in the four CCWs; however, for this paper we only analyzed responses from 61 participants who completed all of the pre-test and post-test quantitative measures (61= Missoula: 19, Grangeville: 15, Boise: 16, and McCall: 11). We also collected 60 pre-workshop interviews and 35 post-workshop interviews. Substantially fewer post-workshop interviews were collected because severe winter conditions and conflicting agency training prevented the attendance of 25 people that had been pre-interviewed. Analysis revealed few differences related to participants' specific discipline and workshop location (see Appendix S for supplemental data tables specific to discipline and location). Therefore, the findings presented here combine all four CCW locations and disciplines into one sample. Quantitative findings are presented in conjunction with selected qualitative interview excerpts to provide richness and context.

Credibility of Climate Change Boundary Objects

Participants found global and regional climate change science to be significantly more credible than local (forest stand-level) climate change science both before (t_{52}= 6.9, p< .01) and after (t_{57}= 6.8, p< .01) participating the CCWs. Interestingly, the credibility of both historical data (t_{55}= 3.9, p< .01) and projected/modeled data (t_{55}= 4.3, p< .01) increased to a similar degree as a result of the CCWs. Many participants commented that the historical data we presented made them more aware that climate change is currently affecting forests they manage, not just something that will happen in the future. One manager remarked how the CCW made her aware that climate change modeling that illustrates impacts "certainly needs to play a bigger role…because the time frames are a lot quicker than I was thinking going into the workshop. Yes, we certainly need to start using that in all of our decision making processes" (Manager 4, Boise).

The interview data reflected the important role of scale in determining whether participants felt the boundary objects were credible. Participants often said that the climate change science needed to be used for management at the scale that the data represented, and that often mismatches occur. Discussions about the local-scale modeling, both before and after the CCWs, often described an overall lack of confidence in modeling predictions at smaller, project-level scales. For example, one water resources specialist noted before the CCWs that "one of the biggest problems I have with [models is the] validity…it is so out of whack…no way you can say that's going to happen on that acre of ground, on that thirty-meter pixel." He then further described his frustration with the use of models after the CCW by saying, "the data that you used at that broad level, you can't take that same data and take it down right to [a local] scale" (Water/Physical 1, McCall). Though skepticism about the credibility of local-scale modeling was commonly observed before and after the CCWs, participants did indicate that these types of models were helpful for exploring different management actions and illustrating climate change impact trends at regional scales – illustrating that sometimes a negative relationship existed between credibility and usefulness. That is, participants may have thought the credibility of local-scale vegetation modeling was low, but that they were still useful for exploring management alternatives.

Further, many participants shared after the CCWs that they were more "convinced of the water [science], the hydrologic side of it that was presented, and less [convinced] on the terrestrial side" (Water/Physical 10, Missoula), suggesting that the water resources modeling was perceived to be more credible than the vegetation modeling. This was further explained by a forest manager in terms of the landscape and model complexity inherent in vegetation simulation modeling. He reflected that “the regional [hydrologic modeling] was the most helpful because getting down to the forest level [vegetation modeling] is more microclimate driven… it’s harder to transition down to the smaller vegetative scale” (Water/Physical 7, Grangeville). Model complexity and spatial scale were clearly influencing perceptions of boundary object credibility.

A Grangeville participant described how “there’s a lot of skepticism and skeptics [about climate change science]…that’s what I perceive as the biggest challenge both internally and externally…there’s a lot of perspectives” (Vegetation/Fire5, Grangeville). However, after participating in the CCW, the same participant reflected that “I could see where [the CCW tools] could be incorporated. It relates to that best available science factor.” This suggests that the participant felt that the CCW influenced her perceptions of the credibility of the climate change science presented and classified it as “best available science,” which is a requirement for all federal and state land management documents. In other words, some participant attitudes improved about the defensibility and credibility of climate change science, even in the presence of internal and external skeptics.

Salience/Usefulness of Climate Change Boundary Objects

Before the CCWs, participants recognized the utility of climate change science for the work they do, especially for long-term land use planning (Table 44). However, many participants attended our CCWs because they wanted a better understanding of the local- and regional-scale context of climate change science including tools that they could consistently use agency-wide. Participation in the CCW increased ratings for four of the five “usefulness” survey questions. Additionally, salience/usefulness items on the post-test all had mean values >1.0, suggesting that the boundary objects were perceived as useful (Table 44).

Interviews indicated that participation in the CCW and exposure to boundary objects helped participants see how climate change science could be applied to land management decisions. For example, before the CCW, one participant noted that he had “yet to see a user friendly tool that is easily accessible,” but after the CCW, he reflected that “being able to look at the models and kind of see the trend” was “really useful” (Water/Physical 8,). The information was something he could share with his crew and “get them thinking in the direction we are going.”

In the post-test survey, participants were asked to evaluate the usefulness of different spatial scales of climate change science presented at the workshops. Overall, the regional-scale water (m= 2.2), vegetation, and wildland fire research (m= 2.2) was considered to be significantly more useful than global-scale (m= 1.4, t_{61}= 8.5, p< .01) and local-scale (m= 1.9, t_{61}= 4.1, p< .01) climate change science (Table 44).

Interviews shed light on why participants viewed climate change science as more useful at regional scales, and more difficult to use at smaller project-level scales where the landscape is varied and uncertainty in the models increases. For example, a forest ecologist summarized his view that “every time you step down [in scale] you have to carry the uncertainty from the level above and how that compounds” (Vegetation/Fire 9, Missoula). After the CCWs, many participants observed that climate change science is more salient for landscape-scale planning efforts, specifically describing the usefulness of the qualitative nature of the science for establishing “desired conditions in our forest plans” (Vegetation/Fire3, Missoula). Not surprisingly, the usefulness of climate change science was inherently connected to participant perceptions of climate change science credibility.

Table 44. Pre-test, post-test, and change of overall usefulness, credibility, organizational barriers, and behavioral intention

Const-ruct	Items*	N	Pre test	SE	Post test	SE	Mean Change	SE	Paired T-test (*p*)
Credibility	Global and regional climate change science is credible.	60	2.0	0.1	2.1	0.1	0.2	0.1	0.13
	Local (forest stand-level) climate change science is credible.	52	0.9	0.2	1.2	0.2	0.3	0.2	0.11
	Historical data and calculations used in climate change science are credible.	56	1.5	0.2	2.1	0.1	0.6	0.2	**0.00**
	Projected/modeled future data and calculations used in climate change science are credible.	56	1.0	0.2	1.6	0.1	0.6	0.1	**0.00**
	I consider science about climate change impacts to be defensible when a decision is challenged or appealed.	55	1.1	0.2	1.5	0.1	0.4	0.2	**0.03**
	FACTOR - Credibility	61	1.2	0.1	1.7	0.1	0.5	0.1	**<0.01**
Usefulness PRE-POST	Climate change science is useful in my work.	61	2.0	0.1	2.1	0.1	0.1	0.1	0.33
	Climate change science is useful in long-term land use planning.	58	2.3	0.1	2.4	0.1	0.2	0.1	0.16
	Climate change science is useful for specific management projects.	60	1.5	0.2	1.7	0.1	0.3	0.1	**0.04**
	FACTOR – Usefulness in general for planning	60	1.9	0.1	2.1	0.1	0.2	0.1	**0.05**
	Models that simulate future vegetation scenarios are useful in land management.	58	1.6	0.1	1.5	0.1	-0.1	0.2	0.51
	Models that simulate future precipitation patterns are useful in land management.	59	1.5	0.2	1.7	0.1	0.2	0.2	0.29
	FACTOR – Usefulness of models that are resource specific	59	1.6	0.1	1.6	0.1	0.0	0.1	0.99
Usefulness POST Only	The global climate change information is useful for land management (modeling and emission scenario information).	60			1.4	0.1			
	The regional climate and water research is useful for land management.	61			2.2	0.1			
	The regional vegetation and fire research is useful for land management.	59			2.2	0.1			
	The local-scale forest vegetation and climate simulations are useful for land management.	58			1.9	0.1			
Org Barriers	Funding is a constraint for addressing climate change in my work.	60	1.2	0.2					
	Time is a constraint for addressing climate change in my work.	59	1.5	0.2					
	The politics of climate change are a constraint for using the science in my work.	59	0.5	0.2					
	FACTOR – Organizational Barriers	61	1.1	0.2					
Behavioral Intention	I plan to use climate change science in future work that I do.	61	2.0	0.1	1.9	0.1	-0.1	0.1	0.56
	I plan to use *global* climate change science in future work that I do.	58			1.1	0.2			
	I plan to use the *regional climate and precipitation* research in future work that I do.	61			2.0	0.1			
	I plan to use the *regional vegetation and fire* research in future work that I do.	58			1.7	0.1			
	I plan to use the *local-scale forest vegetation and climate simulations* in future work that I do.	55			1.4	0.1			

*Scale values were -3 strongly disagree to 3 strongly agree

Organizational Barriers to Using Climate Change

Participants agreed that using climate change science in land management was consistent with their organizations' mission and within their job descriptions. However, the interviews revealed that, until recently, climate change has not been considered a high-priority topic when compared to other natural resource issues, such as special status species, wildland fire, or noxious weeds. Organizational factors were clearly a factor for using climate change science in management decisions. Workshop participants generally agreed that the organizational barriers of time, funding, and politics are a constraint for using climate change science in their work (Table 44). One participant noted that "so many times here [at] the district level you're caught in the deadlines or time frames and [to] get [a] project put out at [a] particular time, you don't have the time to build in all the literature and to track [climate change research], that is if you have any other kind of life (laughing)" (Water/Physical 9, Grangeville). The same participant then went on to describe how the CCW helped address barriers of time, because "having somebody…collecting the information is very useful… You realize there are things out there that will be quite helpful"; she further reflected that the CCW "gave me somewhere to go for the information that I need to back, scientifically back, what I am saying in my documents."

Intention to Use Climate Change Boundary Objects

Prior to the workshops, participants agreed that they plan to use climate change science in future work, and that opinion did not significantly change as a result of participating in the CCWs. However, after the CCW, participants reported that they were significantly more likely to use the regional climate change boundary objects related to water (m= 2.0), vegetation, and fire (m= 1.7) than the global models (m= 1.1, t_{72}= 7.4, p< .01) and local-scale vegetation simulations (m= 1.4, t_{70}= 5.0, p< .01). This was reflected during many of the interviews; for example, one water resources specialist noted before the CCW that he has seen it used "on broad scale but not on smaller scale, not on project level stuff." After the CCW he described how higher-level agency direction may influence the use of climate change science: "there is a lot of talk on how you could use [Climate-FVS], and there's a lot of interest that, I think we just don't have a real good handle on how to use it as an agency, except on a very broad regional scale" (Water/Physical5, McCall). This was consistent with our findings related to the usefulness of climate change science – that it is more useful, and more likely to be used, at regional scales.

Model Testing for Boundary Objects

Data Reduction – Factor Analysis

The exploratory factor analysis (EFA) conducted for the five usefulness items revealed two dimensions with good reliability in both the pre-test and post-test (Table 45): 1) general usefulness of climate change science for planning, and 2) the usefulness of models that simulate future vegetation and precipitation. Using indices computed as the mean of items loading cleanly on each factor, participant perceptions of the usefulness of climate change science for planning significantly increased as a result of participating in the CCWs (t_{60}= 1.9, p= 0.05), but perceptions of the usefulness of models did not increase (Table 44).

The EFA conducted for the five credibility items revealed single reliable dimensions in both the pre-test and post-test (Table 46), so the mean of the items was computed. Perceptions of credibility significantly increased because of participating in the CCWs (t_{60}= 4.01, p< 0.01). The EFA conducted for the three organizational barriers items revealed a single dimension with high reliability (Table 47), so a single factor was computed. Table 48 displays the bivariate correlations among the computed indices. The strongest correlates of behavioral intention to use climate change science, for both the pre-test and post-test, were usefulness and credibility. The strongest correlates of usefulness, for both the pre-test and post-test, were credibility and organizational barriers.

Table 45. Summary of exploratory factor analysis results for the **usefulness** of climate change science.

Item	Factor Loadings (pattern matrix)			
	PRE-TEST		POST-TEST	
	Usefulness in General n=58	Usefulness of Models n=59	Usefulness in General n=60	Usefulness of Models n=56
Climate change science is useful in my work.	**0.81**	-0.01	**0.97**	-0.22
Climate change science is useful in long-term land use planning.	**0.81**	0.16	**0.82**	0.20
Climate change science is useful for specific management projects.	**0.93**	-0.10	**0.74**	0.24
Models that simulate future vegetation scenarios are useful in land management.	-0.03	**0.97**	0.14	**0.82**
Models that simulate future precipitation patterns are useful in land management.	0.04	**0.94**	-0.07	**0.93**
Factor means (scale -3 to 3)	1.89*	1.58	2.07*	1.58
SE	0.12	0.14	0.10	0.11
Cronbach's alpha	0.82	0.91	0.82	0.76
Eigenvalue	2.76	1.30	2.89	1.11
% Variance explained	55.23	26.07	57.88	22.10

*Significant increase from pre-test to post-test at the *p*<.05 level

Table 46. Summary of exploratory factor analysis results for the **credibility** of climate change science.

Item	Factor Loadings (pattern matrix)	
	PRE-TEST n=50	POST-TEST n=54
Global and regional climate change science is credible.	0.81	0.74
Local (forest stand-level) climate change science is credible.	0.77	0.61
Historical data and calculations used in climate change science are credible.	0.82	0.67
Projected/modeled future data and calculations used in climate change science are credible.	0.87	0.77
I consider science about climate change impacts to be defensible when a decision is challenged or appealed.	0.89	0.71
Factor means (scale -3 to 3)	1.24*	1.70*
SE	0.13	0.09
Cronbach's alpha	0.89	0.70
Eigenvalue	3.46	2.45
% Variance explained	69.26	49.02

*Significant increase from pre-test to post-test at the *p*<.05 level

Table 47. Summary of exploratory factor analysis results for **organizational barriers** that could be a constraint for addressing climate change.

Item	Factor Loadings (pattern matrix) PRE-TEST n=57
Funding is a constraint for addressing climate change in my work.	0.87
Time is a constraint for addressing climate change in my work.	0.88
The politics of climate change are a constraint for using the science in my work.	0.73
Factor means (scale -3 to 3)	1.07
SE	0.17
Cronbach's alpha	0.76
Eigenvalue	2.07
% Variance explained	69.01

Table 48. Correlation matrix (Pearson's *r*) for the pre-test (below the diagonal) and post-test (above the diagonal) factors used in the multiple regressions.

	Factors	1.	2.	3.	4.	5.	Mean	SE
1.	Behavioral Intention	**1.00**	.81**	.35**	.55**	.35**	1.63	0.12
2.	Usefulness	.79**	**1.00**	.38**	.61**	.54**	2.07	0.09
3.	Usefulness of Models	.38**	.31**	**1.00**	.38**	0.11	1.58	0.11
4.	Credibility	.55**	.47**	.55**	**1.00**	0.22	1.69	0.09
5.	Organizational Barriers	.48**	.49**	.29*	0.24	**1.00**	1.07	0.17
	Mean	1.98	1.89	1.58	1.24	1.07		
	SE	0.13	0.12	0.14	0.13	0.17		

*Correlation is significant at the 0.05 level, **Correlation is significant at the 0.01 level
Note: The pre-test value for organizational barriers was used for correlations during both the pre-test and post-test (it was only measured during the pre-test).

Regression Analysis of Usefulness and Behavioral Intention

We used ordinary least squares linear regressions to explore relationships between the independent variables (perceived credibility and organizational barriers) and the dependent variables of salience/usefulness and behavioral intention at both time periods (see Figure 9). Baron and Kenny's (1986) approach to determining mediation was followed, using five sequential regression models (Table 49). Credibility and organizational barriers were significant predictors of perceived usefulness during both the pre-test and post-test (Model 1). Next, we independently regressed intention to use climate change science on usefulness (Model 2), credibility (Model 3), and organizational barriers (Model 4). Each of these yielded a significant positive relationship, with usefulness for planning explaining nearly two-thirds, and credibility explaining one-third, of the variance in intention. Surprisingly, the positive relationship between organizational barriers and intention was the opposite of the negative relationship we had hypothesized.

Lastly, we ran a multiple regression that examined the relationship of all of the predictor variables on behavioral intention (Model 5). Usefulness for planning and credibility remained significant predictors of intention for the pre-test, and usefulness for planning was the only significant predictor of intention for the post-test. The direct effect of credibility on intention weakened in the final pre-test model and disappeared in the post-test model after adding the mediator usefulness. The direct effect of organizational barriers on intention was independently a significant predictor of usefulness (Model 4), but that effect also disappeared in the final models with the addition of the usefulness mediator. These findings suggest that the effect of credibility and organizational barriers on behavioral intention is largely mediated by perceived usefulness.

Table 49. Linear regression results for usefulness of climate change science (pre-test and post-test).

	Pre-test				**Post-test**			
	β	*t*	*Adj. R^2*	*F*	*β*	*t*	*Adj. R^2*	*F*
DV: Usefulness (in general)								
Model 1:			0.32	10.27**			0.54	24.44**
Usefulness of Models	-0.01	-0.08			0.16	1.65		
Credibility	0.38	2.96**			0.46	4.74**		
Organizational Barriers	0.39	3.43**			0.42	4.63**		
DV: Behavioral Intention								
Model 2:			0.63	101.10**			0.65	114.04**
Usefulness	0.80	10.10**			0.81	10.70**		
Model 3:			0.29	25.64**			0.29	25.81**
Credibility	0.55	5.06**			0.55	5.08**		
Model 4:			0.22	17.86**			0.11	8.11**
Organizational Barriers	0.48	4.23**			0.35	2.85**		
Model 5:			0.66	29.18**			0.65	28.88**
Usefulness	0.63	6.60**			0.82	7.11**		
Credibility	0.21	2.11*			0.06	0.63		
Organizational Barriers	0.12	1.33			-0.11	-1.20		
Usefulness of Models	0.04	0.42			0.03	0.35		

* Significant at the $p < .05$ level, ** Significant at the $p < .01$ level. $\alpha = .05$

Evaluation of the CCW Boundary Organization

Participants were asked during the post-test to rate their level of agreement with 19 statements related to the usefulness, credibility, and legitimacy of the CCWs as a whole (i.e., *boundary organization* – these are different than the measures of usefulness and credibility described above for boundary objects) (Table 50). Participants agreed that the CCWs were salient/useful overall. While high scores for the first two items were expected, given our use of models and information dissemination, it was encouraging that participants largely agreed that the CCWs made science more useful for management purposes. Many participants commented on the local saliency of the CCW, pointing out that "[the CCW brought] everyone up to date as far as climate change science goes, especially for the [northern Rocky Mountains] rather than just a global picture. It was more about our area of concern and interest… I wasn't aware of those types of data and projections that in the past…. [the CCW] added more precision" (Manager 1, Missoula).

The CCWs enhanced climate change science credibility by translating complex science and meeting science needs with data from multiple sources, and many participants commented they learned during the CCW. One person said, "there were some specific intricacies that I didn't fully understand. I felt I learned something… [such as] increasing in intensity of spring rainfall... and the visual 3D depiction of rain and snowfall" (Manager 6, Missoula). Nearly all participants commented that allowing participants to process the information in small group discussions was a valuable part of their CCW experience. One participant said, "we had a good discussion at our table concerning the uncertainty of making projections, as to what species will be where, [and] how to manage a forest in the future. I was able to talk about that with the folks, and maybe even firm up my opinion about how to deal with that" (Hydro 1, McCall). Participants disagreed with the statement that the presentations at the CCWs were too detailed, but it was often expressed that participants desired more time to reflect on the new information being presented.

Table 50. Evaluation of the CCWs as a boundary organization

	Items	Mean (n=61)	SE
Usefulness (Salience)	There was a clear dissemination strategy for workshop information and outcomes.	2.2	1.7
	The workshop encouraged the use of models and tools for linking science and decision making.	2.0	0.8
	The workshop helped to understand how research could be used in decisions being made.	1.8	0.9
	Scientific information and results were translated for practical use.	1.8	1.0
Credibility	Information needs were connected with sources of information.	2.0	0.9
	The small group discussions helped me understanding the presented information.	1.8	1.4
	The workshop added value by combining data and information from multiple sources.	1.8	1.0
	The workshops helped identify the underlying assumptions of the information presented.	1.6	1.1
	The presentations were too detailed – too much information was presented	-1.5	1.2
	There was adequate time to reflect on new information.	1.1	1.4
Legitimacy	Active listening took place during the Q&A and small group sessions.	2.6	0.9
	It was easy for participants to speak openly.	2.3	0.6
	Different opinions were welcome.	2.3	0.6
	I was comfortable talking about any concerns or disagreements.	2.2	0.7
	The workshop created a forum for individuals who otherwise would not have occasion to work together on these topics.	1.9	0.9
	The workshop helped participants engage in productive debate.	1.7	1.1
	The workshop was accountable to both resource specialists and decision-maker needs and interests.	1.6	1.4
	The workshop promoted information exchange between scientists, agency and interested stakeholders.	1.4	1.1
	Diverse disciplines and interests were not represented at the workshop.	-0.7	1.6

Scale values: -3 strongly disagree to 3 strongly agree

Legitimacy was defined as the presentation of information and technology in a manner that is respectful of stakeholders' divergent values and beliefs, unbiased in conduct, and fair in its treatment of views and interest. Participants reported the highest level of agreement with the legitimacy questions. They felt comfortable to share openly, that diverse opinions were welcome, and that they were being heard. Participants felt that an important aspect of the CCWs was that they created a space for scientists, agency personnel, and interested stakeholders who otherwise would not have occasion to work together to engage in productive debate. Many participants commented on the two-way exchange of information; for example, one participant appreciated the forum's goal to "both to share information… and engage with people that are using it and get more feedback" (Manager/Planner 2, Missoula). The application of workshop best practices and careful consideration of science communication resulted in a positive evaluation of the CCW experience.

Discussion

We evaluated the effectiveness of boundary objects (i.e., workshop components) and a boundary organization (i.e., the overall workshops) for influencing workshop participants' attitudes towards the usefulness of climate change science. We gained a greater understanding of boundary work variables, organizational barriers, and intention to use climate change science for management decisions at various spatial and temporal scales, using multiple methods of inquiry.

The Effectiveness of Boundary Objects

We found support for several of our hypotheses related to the boundary objects. Similar to the case study by Cutts, White, and Kinzing (2011), we found that participant perceptions of the usefulness (H1a) and credibility (H1b) of climate change science significantly increased because of participating in the CCWs. Positive relationships were also observed between credibility and usefulness (H2), and between usefulness and intention to use climate change science in future work (H3). Our data provided rich context about how participation in the CCW influenced (or did not influence) perceptions of salience and credibility at different spatial scales. Prior to the CCWs, many participants indicated that climate change science was most useful for long-term land use planning and regional scale management decisions (e.g., forest plans), rather than fine-scale specific forest projects (e.g., plot-level thinning projects), and the CCW did not have a significant impact on this perception. Participant comfort with using climate change science at regional scales may be due, in part, to current agency guidance for using climate change science at that scale (Dillard, 2008; U.S. Department of Agriculture Forest Service, 2010), suggesting that direction from upper-level management may have influenced participant perceptions of the usefulness and credibility of climate change science during the CCW. However, interviews suggested other reasons about why participants may have favored the regional-scale climate change boundary objects.

Nearly all interviewees indicated a preference for the regional scale hydrologic modeling, where they were able to witness animation of projected changes in the rain/snow transition zones for the forests they manage. This hydrologic modeling was also consistently rated as more useful and credible than global and local-scale modeling on the surveys. The primary difference between the regional hydrologic modeling and the other types of modeling used during the CCW (i.e., regional vegetation shifts, wildland fire area burned, and stand-level vegetation simulations) was that it used direct measures of climate in which projected changes in temperature were used to predict rain versus snow. This was more credible than the vegetation and fire modeling because it relied on a small number of simple variables that were easy to comprehend and had less uncertainty. Credibility decreased with models that were based on factors further away from direct measures of climate, such as those for vegetation and fire, because there were more variables, more complex relationships among variables, and more uncertainty involved. This finding is consistent with other studies which have shown that natural resource managers prefer simple and direct measures of climate (i.e., precipitation, temperature, and snowpack) are the most useful climate for their work (Klos et al., in review).

The visualization and animated aspects of the hydrologic modeling were captivating and powerful. They simplified, summarized, and made the information locally relevant to the CCW participants, consistent with other literature on climate change visualization (e.g., Al-Kodmany, 2002; Lipkus, 2007; O'Neill & Nicholson-Cole, 2009; Sheppard, 2005). The animated sequence allowed participants to focus their attention on climate change impacts within the forests they manage, consider those impacts against other important resources of the region (e.g., big game crucial winter range and Canada lynx habitat), and then process the information in a deliberative small group discussion. The benefits of this approach were consistent with research that has shown that interactivity enhances visualization, notably when used in a carefully designed workshop setting that uses small breakout groups (Schroth, Hayek, Lange, Sheppard, & Schmid, 2011). Similarly, Cutts et al. (2011) highlighted the importance of Geographic Information Systems (GIS), maps, and scientist-guided discussions as being effective boundary objects. This dynamic engagement was not possible with the other types of boundary objects presented at the CCWs, so it is not possible to determine whether the greater credibility of regional hydrologic models was due solely to the visualization or simplicity of the models. Thus, future research should compare the effect of visualizations from models differing in complexity and associated uncertainty to gain a better understanding of effects of visualization on perceptions of credibility and usefulness.

Beyond considerations of visualization and model complexity, there was also clear evidence of a scale mismatch between participant needs related to climate change science and perceptions of the credibility and usefulness of the climate change science we presented. For example, prior to the CCWs, interviewees expressed that climate change science was not useful because it addressed scales that were too broad for forest management, and they desired more local-scale information. After the CCWs, the scale mismatch existed in the opposite direction; although the local-scale climate change science was presented, participants preferred the regional scale modeling. In post-CCW interviews, it was common to hear about challenges related to the uncertainty and assumptions associated with the local-scale vegetation modeling (e.g., the selected types of forest treatments, timing of the treatments, fire disturbances, and reestablishment rate), which people thought reduced the utility for management decisions. Sometimes the local-scale vegetation modeling was credible but not useful because it was accurate for a small parcel of land but did not capture larger landscape variability. Other times the information was described as not credible but still useful; the landscape variability was not captured (lacks credibility) but the model was still considered useful for exploring and comparing land management alternatives. The CCWs revealed a participant preference for boundary objects that provided coarse representations of climate change impacts, such as the hydrologic spatial model that illustrated relative shifts in rain/snow zones, rather than quantitative predictive boundary objects, such as the local-scale vegetation simulations. Many people expressed a desire for local-scale predictive modeling, but said that the complexity and uncertainty was too great to use it as a prescriptive management tool.

These findings related to scale suggest that tradeoffs existed between the usefulness and credibility of climate change modeling at different spatial scales. This is consistent with the findings of White et al. (2010), who found that trade-offs existed between boundary object variables (i.e., credibility sacrificed for increased usefulness) when workshop participants evaluated a complex system dynamics model. The CCWs were effective for helping to define the usefulness of climate change science at different scales and determining which scales were more useful, which is a desirable function of an effective boundary organization (Cash, 2001; Guston, 2001). As climate change science becomes increasingly more accurate and precise over time, future research should track perceptions of its credibility and salience at different spatial and temporal scales.

Organizational Barriers Overcome by Boundary Objects

Although nearly all CCW participants agreed that climate change science should be used in forest management, participants also strongly agreed that time, funding, and politics act as constraints for addressing climate change in their work. The interviews consistently indicated that agency personnel have a full plate of work expectations, and that climate change was yet another responsibility on top of many other higher priority topics. These findings are consistent with other work regarding barriers to using current science in natural resource management (Archie et al., 2012; Jantarasami et al., 2010; Wright, 2010), where a large majority of respondents agreed that time and politics acted as barriers to using the "best available science" in management decisions.

Because of these consistent findings about organizational barriers, we initially hypothesized that higher levels of perceived organizational barriers (time, funding, and politics) would be associated with lower perceived usefulness of climate change science (H4a) and with lower intention to use climate change science in management decisions (H4b). However, neither hypothesis was supported by our findings. In fact, a positive relationship existed between organizational barriers and the usefulness and intention to use climate change science. This finding might be explained by feedback we received from CCW participants throughout the entire research process: no one has the time or ability to collect, interpret, and summarize the vast amount of climate change science available, which is why the CCW was desired as a mechanism to achieve those purposes. The pre-CCW interviews commonly demonstrated this need, and nearly all of the post-CCW interviews commented on how this need was met by the CCWs. This finding was also reflected in the post workshop questionnaire results, where nearly all participants agreed that during the CCW, scientific information and results were translated for practical use. This overcame the barriers of time and funding that would be necessary to gather and synthesize climate change information independently.

Alternatively, if the barriers are related to politics, more credible climate change science may be the solution to political barriers. Regardless, the positive relationship between organizational barriers and intention to use climate change science was perplexing and worthy of further investigation.

A Hybrid Boundary Organization-Object

Prior work has consistently identified the need for boundary organizations to exist as an institution (Cash, 2001; Guston, 2001; White, 2011; White, Corley, & White, 2008), implying some form of long-term relationship between actors from differing worlds of a boundary organization. However, such institutions require high levels of investment and resources from all participants.

There is often a need for short-term partnerships that provide rapid science delivery and deliberation between scientists and land managers/decision makers. Thus, we aimed to explore the effectiveness of a hybrid boundary organization-object positioned in the overlapping space of scientific research and natural resource management and decision-making. Further, it is also common to lack the necessary funding that would accommodate a long-term consistent relationship or institution. Thus, we explored how well the CCWs, representing a short-term organization but also a knowledge transfer tool, could achieve the goals and purposes of a long-term institutional organization. Our findings suggest that the CCWs were effective for satisfying the overarching constructs of salience, credibility, and legitimacy, and facilitated a multi-directional flow of information. Participant feedback expressed that the CCWs served the crucial roles of meeting agency desires for linking climate change science with information sources, translating the practical uses of the information, and creating opportunities for deliberation that would otherwise be unlikely between the diverse participants. Participants also agreed that the workshop encouraged the use of models and tools (i.e., boundary objects) for linking science and decision-making, and considered the tools accountable to their needs. These findings are consistent with literature specific to the necessary functions of a boundary organization (Buizer et al., 2010; Cash, 2001; Guston, 2001; Miller, 2001). Participants clearly felt that the CCWs facilitated knowledge and information exchange among scientists, land managers, and decision-makers.

Despite the positive response, there are limitations to conducting a one-day workshop, as opposed to establishing a long-term institution. A central finding of Cash et al. (2003) was that a long-term perspective and commitment to managing boundaries between scientists and decision-makers was more effective for linking knowledge to action. We acknowledge the generally slow impact of ideas on practice, and are curious whether participation in our one-day CCW provided enough time to process the workshop information and link it with day-to-day forest management practices. Participants only slightly agreed that there was adequate time to reflect on new information, but many also stated during the interviews that if the workshop had been longer than one day, participation would not have been possible given time constraints. This finding is not altogether surprising because agency personnel consistently report that time is a major limiting factor for collecting, reflecting on, and using cutting edge science (e.g., Wright, 2010). In order to understand the impact of CCWs on actual forest management practices, future research should focus on the longitudinal effect of short-term workshops designed for rapid science delivery on actual subsequent forest management decisions.

Conclusions

Our intent when designing this study was to address disconnects between the supply of academic research related to climate change impacts and the needs of forest managers for regional- and local-scale information pertinent for decisions. Our findings suggest that the CCWs were effective for the rapid delivery of climate change science in a setting that capitalized on the use of visualization and interactive participation. Perceptions of the usefulness and credibility of climate change science increased, which were found to be significant predictors of behavioral intention to use climate change science in land management decisions.

We designed the CCWs to serve as research-management partnerships aimed at integrating climate change science and management. The CCW participants reflected that, overall, the CCWs were salient, credible, legitimate, and considered to be time well spent and worth the agency investment. The need for ongoing research-management partnerships that synthesize and translate climate change science, such as the CCWs, is imperative in the face of increasing organizational barriers that constrain agency specialists from adequately addressing climate change in natural resource management decisions.

This study represents a unique and rigorous empirical evaluation of boundary objects and hybrid boundary object-organizations. The use of multiple methods of inquiry revealed the primary importance of scale, model complexity, uncertainty, and visualization when designing, implementing, and evaluating climate change boundary objects. Our findings suggest that boundary objects that use direct measures of climate (i.e., temperature and precipitation) at a regional scale are considered more useful and credible than boundary objects that are more complex, use indirect measures, and estimate local-scale climate impacts within ecological systems. Further, the visualization and animated aspects of the boundary objects were important to focus participant attention on climate change impacts within the geographic areas that participants manage.

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Chapter V. General Conclusions

The studies of my dissertation were built on the fact that forests of the U.S. are changing at a remarkable rate due to disturbances (e.g., wildfire and infestation). Many of those changes are linked to changes in the climate. Forest managers recognize the need to reduce fuel loads on thousands of forest acres to improve forest health and protect burgeoning WUI communities. However, forest managers struggle to address these changes for several reasons. Two challenges addressed in my studies were: 1) a lack of understanding of public perceptions and tolerance of smoke from wildland and prescribed (Rx) fires; and 2) little available scientific information about climate change impacts on forests at a local-level. Thus, the goals of my dissertation research were derived from two larger studies aimed at understanding how cognitive factors, personal characteristics, and community characteristics influence public tolerance of smoke from wildland and prescribed fires (Chapter II); using a conjoint approach to deconstruct how context-specific factors and trade-offs affected public tolerance of smoke (Chapter III); and exploring how forest manager attitudes toward and intention to use climate change science in management decisions were influenced by participation in interactive workshops (Chapter IV).

The findings from our smoke tolerance study are encouraging for fire and resource managers because respondents were well informed, generally tolerant of smoke, trusting of fire managers, and highly supportive of Rx burning practices. Further, concerns about smoke impacts, particularly health impacts, were low. There were surprisingly few differences between rural and urban residents, prepared and unprepared communities, or the northern Rocky Mountains and south-central U.S. regions.

Our path analytic models did a reasonably good job explaining public tolerance of smoke and support for Rx fire practices as primarily a positive function of specific beliefs about the benefits of Rx fire (e.g., improves forest health and protects the community) and indirectly a function of trust in fire managers. To a lesser extent, previous adverse experience with health impacts from smoke was found to influence respondent appraisal of threats from smoke, which in turn was also a direct predictor of smoke tolerance. These findings provide a solid foundation for reinforcing and building upon the high level of trust in fire managers and beliefs about the benefits of Rx fire for improving forest health and protecting communities. The findings of this study, particularly related to threat appraisal, can be used to tailor specific public messages in both regions that address public concerns about smoke, such as concerns about recreation and tourism impacts in the northern Rocky Mountains.

In the conjoint analysis study, participants consistently reported the importance of receiving advanced warning about the potential impacts of smoke in their community. People prefer to receive personal forms of communication, such as a phone call, rather than general public service announcements or no warning at all. This work also demonstrated the importance of understanding and effectively communicating with segments of the population that are at risk from smoke impacts or have experienced adverse effects in the past. Our findings suggest that people are generally aware of the need to manage forests using Rx fire, and are willing to trade-off the short-term impacts of smoke from Rx fire for the long-term benefits of forest health and community protection.

In the separate but related study reported in Chapter IV, our intent was to address disconnects between the overwhelming supply of climate change science at national and global scales and the demand requirements of forest managers for regional- and local-scale information pertinent for forest-specific decisions. We found that our climate change workshops (CCW; i.e., boundary organization) and modeling tools (i.e., boundary objects) were effective for the rapid delivery of climate change science in a setting that capitalized on the use of visualization and small group deliberation. The CCWs increased participant perceptions of the usefulness and credibility of climate change science, which were important predictors of participants' intention to use climate change science in land management decisions. The CCW participants reflected that, overall, the CCWs were salient, credible, legitimate, and time well spent for receiving the best available climate change science specific to their region and forests. We found that in the context of climate change, where uncertainty is prevalent, boundary objects that use fewer variables and direct measures of climate (e.g., temperature and precipitation) at a regional scale are more likely to be perceived as useful and credible than boundary objects that are more complex, use indirect measures, and estimate climate impacts within ecological systems at local or global scales.

Overall, these studies represented a unique and rigorous empirical evaluation of public tolerance of smoke from forest fires and the effectiveness of boundary organizations and objects for communicating climate change science to forest managers. Ideally, this work provides a greater theoretical understanding of these phenomena and represents actionable science that is useful to the land management community.

Consideration of Study Limitations

Public Perceptions and Tolerance of Smoke

Understanding public perceptions and tolerance of smoke and climate change science communication, like many cognitive processes, is a complicated endeavor influenced by many factors. We selected predictor variables for these studies based on existing theoretical and empirical research; however, it is possible that other important factors were not included in the models, as evidenced by the unexplained variance in our models. The selection of variables to be included in our study was discussed with other members of the research team and diverse forest professionals. Ultimately, the models performed reasonably well, indicating that many of the chosen predictors were appropriate, but additional variables could be explored further in future research, such as community fire risk, specific types of existing health conditions, and fire history surrounding each community. Also, many paths were not significant in our models, which should help focus future research on the topic.

Other limitations of the smoke tolerance study pertain to errors in the sample purchased from the provider, Survey Sampling International. Approximately 15% of the sample contained incorrect or missing information and an unknown, but small number of contacts did not receive the questionnaire materials. We believe these errors were minimal because Survey Sampling International has been used for many natural resource studies and we worked closely with their regional representatives to explore how potential sample biases could be reduced. We conducted a brief telephone interview with 100 randomly selected non-respondents from each region (divided evenly among the community types). We found no statistical differences between responders and non-responders for questions related to tolerance of smoke from different sources, support for prescribed fire management, and public awareness of the benefits of prescribed fire – which is consistent with other studies related to public perceptions of wildland fire (Brunson & Shindler, 2004; Kneeshaw, Vaske, Bright, & Absher, 2004). However, respondents were more educated and older than non-respondents, which is also consistent with previous studies (Blanchard & Ryan, 2007; Vining & Merrick, 2008).

The response rate for our NORO sample (28%) was at the lower end of the 30-45% that has been generated by similar studies (Absher & Vaske, 2007; Blanchard & Ryan, 2007; Brunson & Shindler, 2004). However, the response rate for the SOUTH sample was much lower and limited the types of statistical analyses and inferences we were able to make. Survey response rates have been declining over time, notably for online surveys (Dillman, Smyth, & Christian, 2009), but this low response rate was suspected to be associated with other factors. Our mailing envelopes displayed the logo of the University of Idaho, which is located more than 1,000 miles from Texas or Louisiana. This likely resulted in confusion or suspicion by residents of these southern states, and perhaps many surveys being thrown away without opening. We had established local collaborators with the U.S. Forest Service and Texas Forest Service, and might have received a higher response rate had we originated the mailings from a local address, using a local agency logo and relying on the source credibility of these agencies (although this may have resulted in unforeseen bias as well). Another possibility could have been to use a representative from a regional university.

Another potential explanation for the lower SOUTH response rate could have been the extremely rural nature of the sample and limited accessibility to internet services. We might have potentially alleviated this if we had mentioned in the first mailing that a paper version would follow in a few weeks, but we did not want to discourage people from completing the survey online because they preferred to wait for a paper version. Other factors that could have contributed to lower response rates include the length of the survey (a 16-page booklet) and the participant burden and fatigue that it may have invoked. To address this issue, future studies could isolate which key variables are important for public tolerance of smoke and which were extraneous.

Conjoint Analysis

Several different types of conjoint analysis techniques can be applied to different research contexts. We chose a "full profile" rating method because it represented the least amount of burden for participants (in an already large survey), and required participants to work slowly and carefully consider each scenario individually rather than quickly choosing between multiple scenarios (Hair, Black, Babin, & Anderson, 2010). The rationale for our conjoint approach and how it compares to other methods is discussed in more detail in Chapter IV; however, it is worth noting that had we decided to pursue a choice-based conjoint rather than a rating method, we might have seen a larger spread between the utility scores and relative importance values. This would likely have been a result of the participants making a faster simplified decision when comparing multiple scenarios. It has been shown that comparing multiple scenarios in a more-complex design forces participants to simplify the task by focusing more on the most important attribute(s), which could have led to more differentiation in the attributes than we observed. Nevertheless, our intent was not to determine which attributes were most important in a rapid choice situation (e.g., purchasing toothpaste in a store); instead, we desired careful consideration of each attribute and scenario. Another potential limitation of our approach was that it did not allow for the investigation of interaction effects between the attributes. However, previous research has demonstrated that direct effects typically account for more than 80% of the variance in the dependent variable (Hair et al., 2010). Given that this was the first exploratory study using conjoint analysis in this context, we were satisfied with focusing on direct effects. Therefore, we are confident in our approach using the full-profile rating method.

An interesting finding from our conjoint study was the lack of differentiation between the attributes (i.e., the relative importance percentages were tightly grouped). The interpretation we provided in Chapter III was that this may corroborate our findings in Chapter II – the public is generally tolerant of smoke – and therefore were not strongly focusing on any particular conjoint attribute over the others. Another noteworthy interpretation might be that our participants were not strongly differentiating between the attribute levels. For example, the levels identified for health effects from smoke were 1) moderate, 2) unhealthy for sensitive groups, and 3) very unhealthy for everyone. These levels were selected based on recommendations from air quality experts and represented levels that receive public attention during smoke events. However, participants may have had a hard time interpreting the difference between a moderate impact and impacts that are very unhealthy for everyone. In the mind of a participant, any level of health impact could have been important. The same could have been true for smoke duration – any duration could have been important. If this was the case, participants may have focused less on health impacts and duration (both may have been identified as important regardless of level) and focused more on the origin of the fire and the type of advanced warning. This could account for fire origin and advanced warning being the two attributes identified as being the most important. The future research section below discusses options for addressing this in subsequent studies.

The results of the conjoint and separate univariate rating exercises raised our attention to the possibility of a primacy effect. The primacy effect is a cognitive bias where a participant pays more attention to the information that was presented first than information presented later (Cohen, Swerdlik, & Sturman, 2010). For example, a participant who reads a long list of words may be more likely to focus attention on the words from the beginning than words in the middle. A primacy effect could have occurred for smoke origin and advanced warning in the conjoint technique because these attributes were presented first in each scenario description, and our conjoint results identified these two attributes as the most important. Similarly, in the univariate rating exercise that directly followed the conjoint, health impact and smoke duration were presented first, and our results identified these two attributes as the most important. This raised the question about whether the sequence in which the information was presented in both techniques potentially biased the participants' responses – the primacy effect. Future studies should consider randomizing the order in which the attributes are presented in order to account for a potential sequencing and primacy effect. Other future considerations for conjoint studies related to public tolerance of smoke are discussed in the future research section below.

The IGERT Experience and Communicating Climate Change Science with Forest Managers

Participation in the Integrative Graduate Education and Research Traineeship (IGERT) was a unique experience that was full of rewards and challenges. Existing pedagogical frameworks for interdisciplinary problem-solving, such as Klein (1990) and Repko (2008), were incorporated into our academic curriculum for student education. However, unlike cases discussed in these existing frameworks, the specific research problem to be addressed was not given a starting point, and remained undecided at the beginning of our team's PhD education. Instead, creating the focus of the problem was meant to be an iterative decision process between students and faculty over the first year of the program. To develop and focus our research problem, we embarked on a two-week tour with our advising faculty to learn more about the region, talk with local community members and land managers to learn what concerned them the most, and explore how our skills and time could best address a problem related to the resilience of their social-ecological systems. Throughout our first year as students, we continued to listen, read, discuss, and iterate through one problem to the next. During the process, disciplinary boundaries were overcome as we learned what constituted valid methods, results, and conclusions within our different disciplinary silos. Daily interaction and mutual coursework provided space for continuous discourse as we developed, refined, researched, and may times "scrapped" our research problem. Topics were often abandoned because one or more members of the team felt the focus was not inclusive enough of their respective interests. Simultaneously, what defined our individual disciplines was also changing as we further defined our personal career interests. After considerable back-and-forth, with ideas as broad as "holistic system-scale questions looking at metrics of social-ecological resilience," we honed in on the more refined topic of "local-scale climate change communication" in a deliberative workshop setting.

Similar to all quasi-experimental designs that involve an interactive workshop setting, several limitations existed. First is a discussion of our sampling bias. Our CCW participants were purposively recruited from Federal land management agencies and collaborative groups that are associated with them. Our recruitment capabilities, research team size, and budget did not allow us to recruit a representative sample from all land management agencies in Idaho and Montana. We focused on the U.S. Forest Service Climate Change Scorecard (U.S. Department of Agriculture Forest Service, 2011) as the main incentive for recruiting Forest Service agency personnel to participate. Further, our participants were partially self-selected (Graziano & Raulin, 2009), meaning that although we did contact them about our upcoming workshops, they ultimately decided whether to participate or not. Self-selection can make it difficult to interpret and generalize our findings because the sample may have been biased towards people who are climate change believers that were actively engaged with the topic and not representative of general agency personnel. We attempted to mitigate this sampling bias by contacting all relevant Forest Service employees associated with water resources, forest ecology, silviculture, fire ecology, planners, and upper management within the forests we were targeting. Not only did we encourage them to attend, but we also asked them to encourage climate skeptics to attend. Further, we asked upper management to strongly encourage their forest staff to attend in an effort to satisfy the evaluation criteria of the Climate Change Scorecard that every forest was required to complete.

Our research team included a finite number of people, disciplines, and funding, which limited the disciplinary focus of our CCWs, the number of CCWs we could conduct, and the number of participants we could feasibly recruit and manage at each CCW. Our CCWs were focused towards climate science, water resources, forest ecology, silviculture, and fire ecology. It would have been ideal to have more research support in other disciplinary areas, notably forest insect infestation and social impacts from climate change. Another point of interest was the potential effect of our different presentation styles on the effectiveness of the boundary objects at different scales. The climate change science presented by an animated and gregarious speaker may have been better received than information from a presenter who spoke fast, did not engage the audience, and used technical scientific jargon. We addressed this challenge by conducting pilot sessions in front of live audiences to standardize our approach, presentation styles, and the flow of the CCWs.

Trustworthiness, Validity, and Reliability

Trustworthiness, validity, and reliability were important considerations for each manuscript in this body of work. Trustworthiness is an overarching qualitative framework that is the counterpart to the quantitative concepts of validity and reliability. Trustworthiness has been defined by four concepts that have similar concepts in the quantitative world: credibility (internal validity), transferability (external validity/generalizability), dependability (reliability), and confirmability (Guba, 1981; Shenton, 2004).

Credibility and internal validity generally refer to the methodological soundness or appropriateness – that we measured what was intended to be measured (Creswell, 2009). Extensive literature review took place with regard to the theoretical foundation of the constructs and variables being measured, but also empirical studies that operationalized and verified their validity. The lines of questioning were derived, where possible, from studies used in previous comparable projects. This is also referred to as content validity, which was established by using scales that had been previously tested for validity and reliability in related research. Internal consistency or concurrent validity, the degree of consistency of multiple items or elements within an assessment instrument being used to form a composite measure, was typically evaluated with factor analysis and Cronbach's alpha (Field, 2005; Raykov & Marcoulides, 2011).

Another aspect of ensuring credibility was developing a familiarity with the study regions and participants so that they felt comfortable providing honest and candid answers. We used informed consent and assured confidentiality, allowing the participants to decline or stop participation at any time. Another credibility tactic, triangulation of our data, was possible for the CCWs (Chapter IV) by comparing responses from different groups (location and disciplines), but also by comparing the quantitative and qualitative data. Perhaps the most important credibility consideration was member checking during interviews, where the participants were asked, "is this what you mean by that?" to verify accuracy of the interpretation. Dependability refers to reliability, or the replicability of the study and methods employed. To that effect, the proposed research design, implementation, and operational details of data collection and measures have been described richly, so at minimum the methods and approach can be reliably replicated.

Transferability and external validity refer the extent to which our findings could be applied to other situations (Guba, 1981; Morse & Richards, 2002; Raykov & Marcoulides, 2011; Shenton, 2004). For the smoke study, the representativeness of our sampling approach and large sample size helped to promote external validity. We also conducted a robust examination of non-response bias to ensure that responders and non-responders were not significantly different. With regard to the CCWs, some qualitative researchers believe that, because many studies are specific to a small number of particular environments and individuals, they are not ever applicable to other situations. Others believe that all studies represent some larger group, or at a minimum can generalize to the same sample at a later time (see Shenton, 2004 for examples). For the CCW study, we evaluated how participants and contextual aspects related to other locations and settings, and determined that transferability was possible to other forests and agency settings that were addressing similar climate change impacts and adaptation. This research also strived for what is referred to as "analytic generalizations," that are applied to wider theory on the basis of how selected cases align with previously validated constructs (Curtis, Gesler, Smith, & Washburn, 2000; Onwuegbuzie & Leech, 2010). For example, the significant increase in credibility and salience was consistent with other boundary work findings (e.g., Cutts, White, & Kinzig, 2011) and could likely be generalized to other locations and methodological approaches.

Future Research Considerations

Each manuscript in this work has provided specific recommendations for future research directions that could be pursued based on our findings. However, from a more cumulative perspective, considering this work as a whole, some other more general observations that arise for future research opportunities.

In general, the biggest opportunities are related to applying or testing these findings in realistic management and/or public engagement situations. For example, our findings confirm that the general public is quite tolerant of smoke, trusting of fire managers, not overly concerned about the risks of smoke impacts, and is willing to trade-off short-term smoke impacts from Rx fire for long-term improvements in forest health and community protection. I think these findings will be somewhat surprising to both the management community and public. There is a real opportunity to create a positive messaging campaign aimed at reinforcing and increasing public support for Rx management practices. A quasi-experimental study could investigate different messaging approaches, such as heuristic or systematic formats (Chaiken, 1980), on public focus groups from different community types to determine which messaging is more effective at strengthening Rx management support.

Similarly, future research should focus on achieving a better understanding of public attitudes and preferences for advanced warnings related to smoke from wildland fires, which would be consistent with recent calls from the natural hazards and fire management community (Gladwin, Willoughby, Lazo, Morrow, & Peacock, 2009; Joint Fire Science Program, 2013). A similar design as described above could be applied with a focus on the projected timing and locations of smoke impacts, and the potential health impacts that could result from the smoke concentrations. This line of work could also focus on information sources for advanced warning, community dissemination channels, and the structure, format, and timing of warnings.

The conjoint approach used in Chapter III was embedded within our larger survey effort and was designed to be a starting point for exploring public tolerance of smoke as it relates to four primary attributes (fire origin, advanced warning, health impacts, and smoke duration), with only three levels for each attribute. An appropriate follow-up study could use conjoint analysis to explore public preferences for specific messaging types that focus on health and advanced warning using different communication types (e.g., ArcGIS maps, simplified drawings, written messages, new media, 3-D simulations, etc.). The public has identified the importance of advanced warning, and now it seems timely to explore different ways of delivering those messages.

The obvious future research opportunity related to the CCWs would be to conduct more workshops over time, in the same locations, to evaluate the stability of the measures of boundary objects and organizations in a longitudinal approach. This effort could be expanded to other regions, where the content of the CCWs would be tailored to those specific ecosystems, but the format of the workshops would be maintained (i.e., scale of presentations, small working groups, pre-post measurements). As climate change science becomes increasingly more accurate and precise over time, future research should track perceptions of credibility, salience, and legitimacy of climate change boundary objects at different spatial and temporal scales. To understand the impact of CCWs on actual forest management practices, future research should focus on the longitudinal effect of climate change boundary objects on actual subsequent forest management decisions. Lastly, a major need expressed by land managers was to take our CCW approach to a public audience. The possibilities for exploring climate change communication techniques in a public setting are sizeable, and this could be coupled with the land manager CCWs to understand effective science communication between academics and both of these audiences.

Hopefully, the studies presented in this dissertation have contributed to understanding public perceptions and tolerance of smoke from wildland and Rx fires, and provided a better understanding of how boundary organizations and objects can be used to communicate climate change science information. Further, I hope these studies have demonstrated for future students and natural resource practitioners how multiple theoretical and methodological frameworks can be applied to research questions and produce actionable outcomes.

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Appendix A.

University of Idaho Institutional Review Board Approval Forms

University of Idaho

Office of Research Assurances
Institutional Review Board
PO Box 443010
Moscow ID 83844-3010

Phone: 208-885-6162
Fax: 208-885-5752
irb@uidaho.edu

To:	Troy Hall
Cc:	Jarod Blades
From:	Traci Craig, PhD Chair, University of Idaho Institutional Review Board University Research Office Moscow, ID 83844-3010
IRB No.:	IRB00000843
FWA:	FWA00005639
Date:	August 18, 2011
Title:	'Public Perceptions of Smoke: Contrasting Tolerance amongst WUI and Urban Communities in the Interior West and the Southern United States
Project:	11-015
Approved:	08/15/11
Expires:	08/14/12

On behalf of the Institutional Review Board at the University of Idaho, I am pleased to inform you that the protocol for the above-named research project is approved as offering no significant risk to human subjects.

This approval is valid for one year from the date of this memo. Should there be significant changes in the protocol for this project, it will be necessary for you to resubmit the protocol for review by the Committee.

Traci Craig

Traci Craig

University of Idaho

Office of Research Assurances
Institutional Review Board
PO Box 443010
Moscow ID 83844-3010

Phone: 208-885-6162
Fax: 208-885-5752
irb@uidaho.edu

October 3, 2012

To: Hall, Troy
Cc: Blades, Jarod

From: Traci Craig, PhD
Chair, University of Idaho Institutional Review Board
University Research Office
Moscow, ID 83844-3010

Title: 'Multi-scale Climate Change Information for Forests of the Northern Rockies'

Project: 12-303
Approved: 10/02/12
Expires: 10/01/13

On behalf of the Institutional Review Board at the University of Idaho, I am pleased to inform you that the protocol for the above-named research project is approved as offering no significant risk to human subjects.

This approval is valid for one year from the date of this memo. Should there be significant changes in the protocol for this project, it will be necessary for you to resubmit the protocol for review by the Committee.

Traci Craig

Traci Craig

Appendix B.

Initial Survey Cover Letter – Public Perceptions of Smoke

University of Idaho
College of Natural Resources

P.O. Box 441139
Moscow, Idaho 83844-1139 U.S.A.
Phone: 208-885-7911
Fax: 208-885-6226
E-mail: jblades@uidaho.edu
www.cnrhome.uidaho.edu/css

UNIQUE ID: UNIQUE ID

First Name Last Name
Address
City State ZIP-ZIP4

Dear First Name Last Name,

I am a graduate student in the College of Natural Resources conducting a study about public opinions of smoke from forest fires. I would like to invite you to participate in this study. Participation will automatically enter your name into a lottery to receive one of six $250 cash gift cards!

Your answers will provide fire managers and community leaders with important information about public opinions of smoke from forest fires, and how to best incorporate your values and beliefs into fire and smoke management. Your answers will also help improve firefighter and fire manager training programs, and student courses at the University of Idaho.

The survey should take about 20 minutes to complete. Your participation is voluntary, and you are free to end the survey at any time. Your answers will be strictly confidential. Your name will not be connected to any of your responses. To take the survey, please enter the following link into the address line of your web browser: **www.uidaho.edu/smoke**

Please make sure to enter your **UNIQUE ID** (located at the top of this letter) into the first questions of the survey. I know your time is valuable, and we genuinely appreciate your assistance with this porject, but please complete the questionnaire by Friday, March 2nd, 2012. Please contact me or Dr. Troy Hall if you have any questions about this project or survey. Thank you for your time and participation.

Sincerely,

Jarod Blades
University of Idaho
Dept. of Conservation Social Sciences
Moscow, ID 83844-1139
Ph. 208-885-7164
Email: jblades@uidaho.edu

Dr. Troy Hall
University of Idaho
Dept. of Conservation Social Sciences
Ph. 208-885-7911

P.S. Please know that the information you provide is extremely important for the future management of forests and fires. Please call or email me at any time if you have questions.

Appendix C.

First Postcard Reminder – Public Perceptions of Smoke

Dear FirstName LastName,

About two weeks ago we contacted you to participate in an online survey about public perceptions of smoke from wildfire and prescribed fire. If you are one of the many people who have already responded, please accept our thanks.

If you have not yet had the opportunity to complete this survey, please do so. Remember that when you complete the survey your name will be entered into a lottery for one of six $250 gift certificates!

Please enter the website located below into your web browser address bar, and enter the Unique ID into the first question. Please complete the questionnaire by March 2nd, 2012. Feel free to contact us if you have any questions. Thank you for your time and participation!

Take the survey now:

www.uidaho.edu/smoke

UNIQUE ID: **Unique ID**

Jarod J. Blades

Dr. Troy Hall

Appendix D.

Paper Survey Letter – Public Perceptions of Smoke

University of Idaho
College of Natural Resources

P.O. Box 441139
Moscow, Idaho 83844-1139 U.S.A.
Phone: 208-885-7911
Fax: 208-885-6226
E-mail: jblades@uidaho.edu
www.cnrhome.uidaho.edu/css

*********AUTO**5-DIGIT 59802 1/1

Dear ,

In the previous month I've sent you invitations to participate in my graduate student research project and complete the survey: "Opinions about Smoke from Forest Fires and Associated Management."

If you have already completed the questionnaire on the internet, I thank you very much. If you have not had time to complete the questionnaire, please do so as soon as possible. You can either go to the website at www.uidaho.edu/smoke and enter your Unique ID: **NR4612**; OR there is a paper copy of the survey enclosed in this package for your convenience. If completing the paper copy works best for you, please fold and insert your completed questionnaire into the pre-paid return envelope and mail it back to me.

I would like to reiterate that your answers will provide fire managers and community leaders with important information about public opinions of smoke from forest fires, and help improve professional firefighter and fire manager training programs, and courses at the University of Idaho. And remember that participation enters your name into a lottery to receive one of six $250 cash gift cards!

The survey should take about 20 minutes to complete. Your participation is completely voluntary, and your answers will be strictly confidential. Your name will not be connected to any of your responses. I know your time is valuable, and we genuinely appreciate your assistance with this project, but please complete the survey by Friday, December 2nd. Please contact me or Dr. Troy Hall if you have any questions about this project or survey.

Sincerely,

Jarod Blades
Ph.D. Student
University of Idaho
College of Natural Resources
Moscow, ID 83844-1139
Ph. 208-885-7164
Email: jblades@uidaho.edu

Dr. Troy Hall
University of Idaho
College of Natural Resources
Moscow, ID 83844-1139
Ph. 208-885-7911

P.S. Please know that the information you provide is extremely important. Please call or email me at any time if you have questions.

Appendix E.

Mailed Paper Questionnaire – Public Perceptions of Smoke

Opinions about Smoke from Forest Fires and Associated Management

Conducted by Jarod Blades and Dr. Troy Hall

University of Idaho
College of Natural Resources

DEFINITIONS

Here are definitions for some terms you will see in the survey:

Forest Fuels - Forest fuels are any living and dead vegetation that can be ignited and burned.

Wildland Fire (wildfire) - Any nonstructural fire that occurs in forests, rangelands, grasslands, or other wildland setting (other than prescribed fire). When we refer to wildfires in this survey, we specifically mean fires in forests.

Prescribed Fire - Any fire ignited by land managers to meet specific forest resource management objectives.

Prescribed-Natural Fire - Any fire that is naturally ignited (e.g., lightning) that is managed to meet specific forest resource management objectives***Slash Pile Burning*** - The burning of branches, tops, and other woody material that are piled up after a logging activity or forest fuel reduction project.

Definitions and picture from the U.S. Forest Service Fire Effects Information Glossary

Question 1. Please answer each of the questions below about your knowledge of smoke and forest fire management.

Have you heard or read about the use of prescribed fire?	Yes	No
Have you heard or read about the potential impacts of smoke from forest fires?	Yes	No
Have you heard or read about managing or using wildfire to improve forest health?	Yes	No
Have you heard or read about the need to reduce forest fuels near your community?	Yes	No

Question 2. Please indicate your level of agreement with the following forest management statements:

	Strongly Disagree			Neutral			Strongly Agree
The use of prescribed fire is appropriate, so long as smoke health impacts are minimal in my community.	-3	-2	-1	0	1	2	3
Prescribed fire should not be used because of the potential health problems from smoke in my community.	-3	-2	-1	0	1	2	3
Prescribed fire is too dangerous to be used in forests near my community.	-3	-2	-1	0	1	2	3
All fires near my community, regardless of origin, should be put out as soon as possible.	-3	-2	-1	0	1	2	3
Forest managers should periodically burn underbrush and debris in forests near my community, even though it results in periodic smoke.	-3	-2	-1	0	1	2	3

Question 3. Please indicate your level of previous experience with smoke from forest fire (ONLY IN THE LAST 3 YEARS). You can check more than one response for each item.

	From Prescribed Fire	From Wildfire	Didn't Know the Source	No
Have you suffered personal health effects from smoke?	☐	☐	☐	☐
Have you experienced discomfort from smoke?	☐	☐	☐	☐
Have you suffered personal property damage due to smoke?	☐	☐	☐	☐
Have you experienced a road closure or delay due to smoke?	☐	☐	☐	☐
Have your friends, family, or neighbors suffered property damage from smoke?	☐	☐	☐	☐
Have your friends, family, or neighbors suffered personal health effects from smoke?	☐	☐	☐	☐
Have you evacuated your home or office due to smoke?	☐	☐	☐	☐
A forest fire has occurred near my home in the past 3 years.	☐	☐	☐	☐

In the next series of questions you will be presented with 9 forest fire smoke scenarios. Each of the scenarios differs on four things that could happen during a forest fire smoke event (listed below). Carefully read each item below, and then evaluate how tolerant you are of each smoke scenario on the following pages (tolerance is the same as acceptability).

To help you evaluate each scenario, we have provided a **separate page of representative photos** that illustrates what each scenario might look like based on the smoke concentrations associated with the health effect category. The separate sheet of photos is included in this mailing.

Keep in mind that we are only asking your opinion based on the four attributes below:

1) **Advanced warning** about potential smoke effects

- Personal Phone Call (agency personnel give you a call)
- Public Service Announcement (A message is broadcasted on the local radio or TV news, or in the local newspaper)
- None (No advanced warning)

2) The **origin of the fire** (see page 2 for definitions)

- Prescribed Fire
- Prescribed-natural Fire
- Wildfire

3) The **health effects from smoke**

- Moderate (Extremely sensitive individuals may experience respiratory symptoms)
- Unhealthy for Sensitive Groups (Increasing likelihood of respiratory symptoms and breathing discomfort in sensitive groups)
- Very Unhealthy for Everyone (Substantial risk of respiratory effects in the general population)

4) The **length of time that the smoke is present in your community**

- Up to 6 hours
- Up to 2 days
- More than 2 days

Smoke Scenario 1

- There is <u>no advanced warning</u> about anticipated smoke
- The smoke is from a <u>prescribed-natural fire</u>
- The smoke would be <u>very unhealthy for everyone</u> (see picture 3 on separate included page)
- The smoke will be <u>present for up to 2 days</u>

How tolerant (accepting) are you of the above scenario?

Very Intolerant			Neutral			Very Tolerant
-3	-2	-1	0	1	2	3

Smoke Scenario 2

- There is a <u>Public Service Announcement</u> about anticipated smoke
- The smoke is from a <u>prescribed-natural fire</u>
- There would be <u>moderate health effects</u> from smoke (see picture 1)
- The smoke will be present for <u>more than 2 days</u>

How tolerant (accepting) are you of the above scenario?

Very Intolerant			Neutral			Very Tolerant
-3	-2	-1	0	1	2	3

Smoke Scenario 3

- There is a <u>Public Service Announcement</u> about anticipated smoke
- The smoke is from a <u>prescribed fire</u>
- The smoke would be <u>very unhealthy for everyone</u> (see picture 3)
- The smoke will be present for <u>up to 6 hours</u>

How tolerant (accepting) are you of the above scenario?

Very Intolerant			Neutral			Very Tolerant
-3	-2	-1	0	1	2	3

Smoke Scenario 4

- There is <u>no advanced warning</u> about anticipated smoke
- The smoke is from a <u>prescribed fire</u>
- The smoke would be <u>unhealthy for sensitive groups</u> (see picture 2)
- The smoke will be present for <u>more than 2 days</u>

How tolerant (accepting) are you of the above scenario?

Very Intolerant			Neutral			Very Tolerant
-3	-2	-1	0	1	2	3

Smoke Scenario 5

- You receive a <u>personal phone call</u> about anticipated smoke
- The smoke is from a <u>prescribed fire</u>
- There would be <u>moderate health effects from smoke</u> (see picture 1)
- The smoke will be present for <u>up to 2 days</u>

How tolerant (accepting) are you of the above scenario?

Very Intolerant			Neutral			Very Tolerant
-3	-2	-1	0	1	2	3

Smoke Scenario 6

- There is a <u>Public Service Announcement</u> about anticipated smoke
- The smoke is from a <u>wildfire</u> (lightning or unintentional)
- The smoke would be <u>very unhealthy for everyone</u> (see picture 3)
- The smoke will be present <u>more than 2 days</u>

How tolerant (accepting) are you of the above scenario?

Very Intolerant			Neutral			Very Tolerant
-3	-2	-1	0	1	2	3

Smoke Scenario 7

- There is no advanced warning about anticipated smoke
- The smoke is from a wildfire (lightning or unintentional)
- There would be moderate health effects from smoke (see picture 1)
- The smoke will be present for up to 6 hours

How tolerant (accepting) are you of the above scenario?

Very Intolerant			Neutral			Very Tolerant
-3	-2	-1	0	1	2	3

Smoke Scenario 8

- You receive a personal phone call about anticipated smoke
- The smoke is from a prescribed-natural fire
- The smoke would be unhealthy for sensitive groups (see picture 2)
- The smoke will be present for up to 6 hours

How tolerant (accepting) are you of the above scenario?

Very Intolerant			Neutral			Very Tolerant
-3	-2	-1	0	1	2	3

Smoke Scenario 9

- There is a Public Service Announcement about anticipated smoke
- The smoke is from a wildfire (lightning or unintentional)
- The smoke would be unhealthy for sensitive groups (see picture 2)
- The smoke will be present for up to 2 days

How tolerant (accepting) are you of the above scenario?

Very Intolerant			Neutral			Very Tolerant
-3	-2	-1	0	1	2	3

Question 4.
Consider how important each of the attributes were in the previous smoke scenarios. Please allocate a total of 100 percentage points (don't exceed 100% total) showing the relative importance of each attribute.

_______ Health Impact

_______ Smoke Duration

_______ Advanced Warning

_______ Visibility Impact (how far you can see)

_______ Smoke Origin

100% = Total

Question 5. If you experience smoke in your community from the following forest fire sources, how tolerant or intolerant would you be of the smoke? Only consider the fire source.

	Very Intolerant			Neutral			Very Tolerant
Smoke from a prescribed fire that is ignited by land managers to achieve forest health objectives.	-3	-2	-1	0	1	2	3
Smoke from a prescribed-natural fire / wildland fire that is unintentionally started (e.g., lightning) but allowed to burn to achieve forest health objectives.	-3	-2	-1	0	1	2	3
Smoke from slash pile burning following a forest fuel reduction project (thinning).	-3	-2	-1	0	1	2	3
Smoke from a wildfire that was started by lightning.	-3	-2	-1	0	1	2	3

Question 6. How prepared for wildfire is your community as a whole?

☐ Not Prepared at All ☐ Unprepared ☐ Somewhat Unprepared ☐ Somewhat Prepared ☐ Prepared ☐ Very Prepared ☐ Don't Know

Question 7. Does your community or county have a Wildfire Protection Plan?

☐ Yes ☐ No ☐ Don't Know

Question 8. This section asks for your views about the potential outcomes of prescribed fire and wildfire. Please indicate your level of agreement for each statement below

	Strongly Disagree			Neutral			Strongly Agree
Prescribed fire reduces the amount of excess fuels in the forest.	-3	-2	-1	0	1	2	3
Prescribed fire restores the forest to a more natural condition.	-3	-2	-1	0	1	2	3
Prescribed fire improves wildlife habitat.	-3	-2	-1	0	1	2	3
Prescribed fire near my community reduces the risk of large wildfires in the future and associated hazardous smoke impacts.	-3	-2	-1	0	1	2	3
Forest health will improve if we use more prescribed fire.	-3	-2	-1	0	1	2	3
The negative consequences of smoke from prescribed fire are an unavoidable outcome of improving forest health.	-3	-2	-1	0	1	2	3

Question 9. For this question think about the outcomes of fire in general (not specific to prescribed fire or wildfire). Please consider risks that may be associated with smoke from a forest fire near your community. For each item please indicate both how LIKELY and how SEVERE the impact from smoke would be.

Forest fire smoke in my community would result in........

	How LIKELY is this impact?							If there is smoke, how SEVERE will the impact be?						
	Very Unlikely			Neutral			Very Likely	No Impact			Moderate			Very Severe
Loss of recreation and tourism opportunities	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Negative impact to my health	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Injury or death of wildlife in the area	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Property damage from smoke	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Water contamination due to ash	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Negative scenery impacts	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Negative impact to my family's health	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Negative impact to my occupation	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Negative impact to my travel - road closures and/or car accidents	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Negative impact to school recess and outdoor sports	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3

Question 10. For this question think about different ways of potentially coping with forest fire smoke. For each suggested action please consider whether you think the suggestion would be effective for coping with smoke, AND how likely is it that you would take this action. Please provide two answers per row.

	Would this be effective for coping with smoke?							Would you do this?						
	Very Ineffective			Neutral			Very Effective	Very Unlikely			Undecided			Very Likely
Run your furnace or air conditioner to filter the air in your home.	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Leave town until the smoke clears.	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Remain indoors as much as possible.	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Keep your furnace fresh air intake closed.	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Go to a someone else's house or different location in town.	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Purchase and use an indoor air purifier.	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Leave town and stay at a hotel paid by the agency conducting the prescribed fire.	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3
Keep your windows and doors closed.	-3	-2	-1	0	1	2	3	-3	-2	-1	0	1	2	3

Question 11. The following questions ask for your opinion about forest fire managers. Please indicate your level of agreement or disagreement with each of the following statements.

I trust that forest fire managers know how to:

	Strongly Disagree			Neither Agree nor Disagree			Strongly Agree
Effectively manage smoke	-3	-2	-1	0	1	2	3
Protect private property when conducting a prescribed fire	-3	-2	-1	0	1	2	3
Use prescribed fire effectively	-3	-2	-1	0	1	2	3
Manage and control wildfires effectively	-3	-2	-1	0	1	2	3
Protect private property during a wildfire	-3	-2	-1	0	1	2	3

I trust forest fire managers to provide:

	Strongly Disagree			Neither Agree nor Disagree			Strongly Agree
The best available information on smoke issues	-3	-2	-1	0	1	2	3
Enough smoke information to decide what actions I should take	-3	-2	-1	0	1	2	3
The best available information about prescribed fire	-3	-2	-1	0	1	2	3
Timely information regarding smoke	-3	-2	-1	0	1	2	3
Information about safety related to wildfire	-3	-2	-1	0	1	2	3

Question 12. Understanding your values allows land managers to incorporate your values into forest management. Please rate how important or unimportant each of the values below are to you in your personal life.

	Not Important at All			Neither Important nor Unimportant			Extremely Important
The environment should be protected and nature should be preserved.	-3	-2	-1	0	1	2	3
The primary role of forests today is to provide places to play and recreate.	-3	-2	-1	0	1	2	3
We should have unity with nature and fit into forest processes.	-3	-2	-1	0	1	2	3
The primary role of forests today is to provide timber and wood products, grazing lands, and minerals for people.	-3	-2	-1	0	1	2	3
I have an obligation to respect the earth and be at harmony with other species.	-3	-2	-1	0	1	2	3
My personal health comes first (not being sick physically or mentally).	-3	-2	-1	0	1	2	3
Pollution should be prevented to protect nature.	-3	-2	-1	0	1	2	3
The primary role of forests today is to produce jobs and income.	-3	-2	-1	0	1	2	3

Question 13. We would like your opinion about policies related to smoke and air quality. Do you think that smoke from prescribed fires should be included in the Environmental Protection Agency's air quality limits for your state?

☐ Yes ☐ No ☐ No Opinion

Question 14. Would you support prescribed fire smoke being exempt from the State Smoke Management requirements and guidelines?

☐ Yes ☐ No ☐ No Opinion

To understand more about your community, we have a few questions about you.

15. What year were you born (YYYY)?

____

16. Please indicate the *highest level of education* that you have completed (*check one).*

- ☐ Less than a high school degree
- ☐ High school degree or GED
- ☐ Some college or post high school training
- ☐ Two year technical or associate degree
- ☐ Four year college degree (BA/BS)
- ☐ Advanced degree (MS, JD, MD, Ph.D.)

17. Are you a permanent (year round) or part-time resident in your community?

- ☐ Permanent
- ☐ Part-time or seasonal

18. How many years have you lived in this community?

- ☐ Less than 1 year
- ☐ 1-5 years
- ☐ More than 5 years

19. Is your employment or any source of income related to forests?

- ☐ Yes
- ☐ No

20. Please indicate your race/ethnicity below (you may select more than one).

- ☐ Black / African-American
- ☐ White / Caucasian
- ☐ Hispanic, Latino, or Spanish Origin
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ Other or Unknown

21. Are you ☐ Male or ☐ Female?

22. Please indicate the level of your current *household* income before taxes (*check one*).

- ☐ Less than $20,000 per year
- ☐ $20,001 to $40,000 per year
- ☐ $40,001 to $60,000 per year
- ☐ $60,001 to $80,000 per year
- ☐ $80,001 to $100,000 per year
- ☐ $100,001 to $120,000 per year
- ☐ more than $120,000 per year

23. Please check the box that most accurately describes your *political orientation* on the following scale:

Very Liberal			Neither			Very Conservative
☐	☐	☐	☐	☐	☐	☐

Question 24. Your opinions about forest fires, smoke, and related management are very important to us. In addition to this questionnaire, our study includes other components. Would you be willing to participate in any other aspects of our study?

YES / MAYBE ______ If so, what is the best phone number or email where you can be reached?

____

NO______, I do not wish to participate in any other aspects of your study.

Please use the space below to provide any additional concerns or comments regarding your opinions about smoke from forest fires, or comments related to any part of this survey. Or feel free to attach a separate sheet with more comments

Thank you for your help!! Please feel free to contact either Jarod Blades or Dr. Hall if you have any concerns or additional comments regarding this survey.

Jarod Blades and Dr. Troy Hall
University of Idaho
P.O. Box 441139
Moscow, ID 83844-1139
Phone: 208-885-7164
Email: jblades@uidaho.edu

University of Idaho
College of Natural Resources

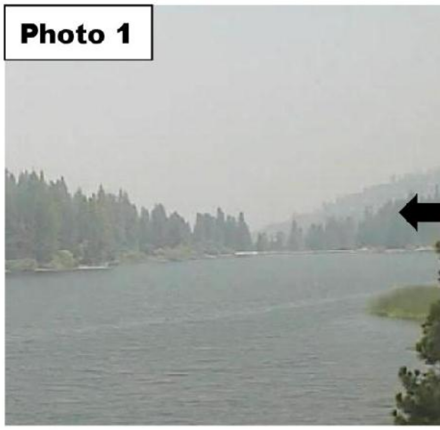
Joint Fire Science Program

Appendix F.

Supplemental Photos for Conjoint Scenarios – Public Perceptions of Smoke

SMOKE SCENARIO PHOTOS – Use with survey <u>Pages 5-7</u>

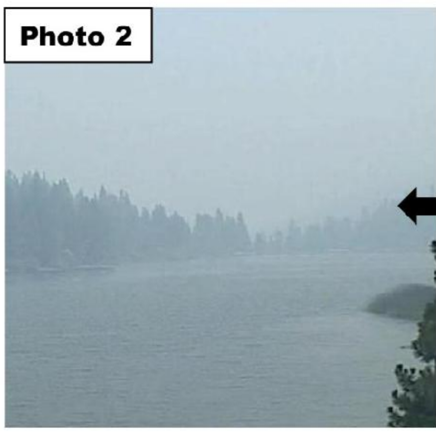
Photo 1



Moderate

- The health effects from smoke would be considered Moderate.
- Extremely sensitive individuals may experience respiratory symptoms.

Photo 2



Unhealthy for Sensitive Groups

- The health effects from smoke would be considered unhealthy for sensitive groups.
- Increasing likelihood of respiratory symptoms and breathing discomfort in sensitive groups.

Photo 3

Very Unhealthy for Everyone

- The health effects from smoke would be considered very unhealthy for everyone.
- There would be a substantial risk of respiratory effects in the general population.

Appendix G.

Final Postcard Reminder – Public Perceptions of Smoke

THANK YOU EAST TEXAS AND WESTERN LOUISIANA !

Dear Antonio Kusic,

In the past month I've been asking you to complete a survey about your opinions of smoke from forest fires. I wanted to take the time and thank you for participating! It means a great deal to my graduate student research, and is also very important for enhancing forest fire and smoke management in your area.

If you have not yet had the opportunity to complete this survey, the completion deadline has been extended until April 16, 2012. Remember that you will be eligible to win one of six $250 gift certificates, and you will be doing your community a great service!

Please enter the website located below into your web browser address bar, or fill out the paper version I mailed you. Thanks again for your time and participation!

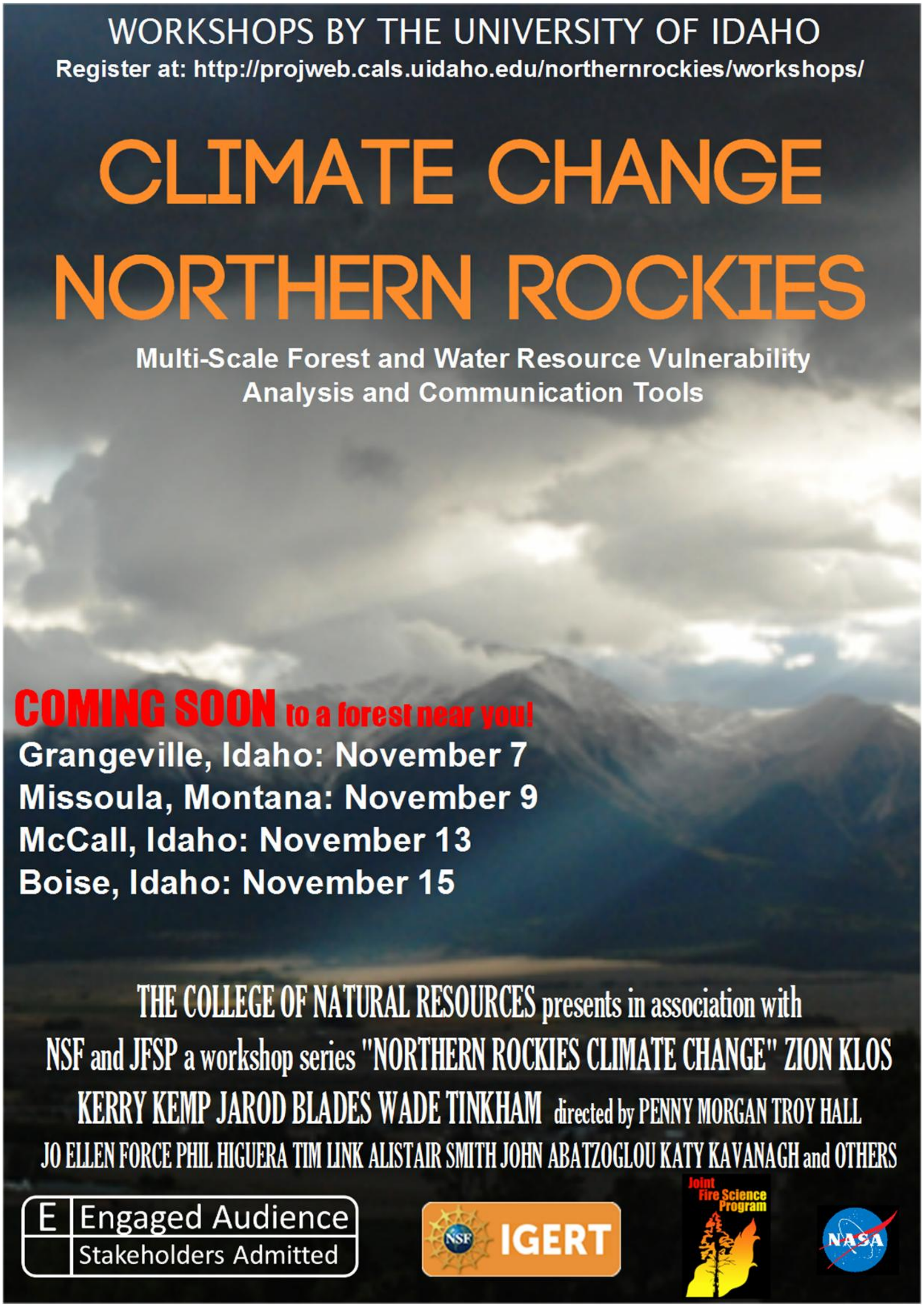
Take the survey now:
www.uidaho.edu/smoke
UNIQUE ID: **NR0001**

Jarod J. Blades   Dr. Troy Hall

Photo: Longleaf pine forest after a prescribed fire

Appendix H.

Workshop Poster – CCWs


WORKSHOPS BY THE UNIVERSITY OF IDAHO
Register at: http://projweb.cals.uidaho.edu/northernrockies/workshops/
CLIMATE CHANGE
NORTHERN ROCKIES
Multi-Scale Forest and Water Resource Vulnerability
Analysis and Communication Tools
COMING SOON to a forest near you!
Grangeville, Idaho: November 7
Missoula, Montana: November 9
McCall, Idaho: November 13
Boise, Idaho: November 15
THE COLLEGE OF NATURAL RESOURCES presents in association with
NSF and JFSP a workshop series "NORTHERN ROCKIES CLIMATE CHANGE" ZION KLOS
KERRY KEMP JAROD BLADES WADE TINKHAM directed by PENNY MORGAN TROY HALL
JO ELLEN FORCE PHIL HIGUERA TIM LINK ALISTAIR SMITH JOHN ABATZOGLOU KATY KAVANAGH and OTHERS
E Engaged Audience
Stakeholders Admitted
NSF IGERT
Joint Fire Science Program
NASA

Appendix I.

Workshop Invitation Email – CCWs

Subject: Invitation: Northern Rockies climate change workshop in Boise, ID
Attachments: Northern Rockies Workshops 2012 v2.pdf

Importance: High

HiXXX,

I want to invite you to an exciting workshop in Boise, November 15, 2012. Please check out our website and **REGISTER** (http://projweb.cals.uidaho.edu/northernrockies/workshops/).

I am the team leader for a group of faculty and PhD students from the University of Idaho that are committed to understanding and effectively communicating the effects of climate change on forests of the Northern Rockies. Our goal is to provide new research information on forest and water resources at multiple spatial and temporal scales. The workshop will be an interactive setting that addresses uncertainty and aims to understand how current climate change research is useful at planning and implementation levels. The workshop will provide for information exchange between scientists, resource specialists, land managers, and interested publics. As a representative of the West Central Highlands RC&D and member of the Boise Forest Coalition, your participation and perspective is particularly important! This workshop is designed to help you and your staff achieve the goals of the USFS climate change performance scorecard.

WHAT: Interactive Climate Change Workshops – main focus is forest ecology and water resources in the Northern Rockies (ID and western MT).

WHEN: November 15, 2012. 9:30 am – 3:30 pm

WHERE: The Foothills Learning Center, 3188 N Sunset Peak Rd, Boise, ID 83702

WHO: The workshop in Boise is designed for a USFS, BLM, state agencies, and collaborative group(s) audience. We are actively recruiting participants from a variety of interests. Please forward this email to individuals you think would be interested!

WHY: 1) Learn about current tools that are available to measure and visualize possible climate change impacts in your forest. 2) Deliberate with other specialists, managers, scientists, and engaged stakeholders about climate change and why (or why not) the information is useful for management and planning decisions.

You still may be asking, what is in it for me? Most importantly, by participating you will be enhancing science-management-public partnerships and forest management in our region. Additionally, we will be providing free high quality coffee, snacks, and a decent lunch (e.g., Leku Ona, Bittercreek, or Zeppole). The workshops are **FREE**, and we are also offering a **$50 cash card to the first 30 people that register to participate.**

Feel free to contact me or the workshop coordinator (Jarod Blades, jblades@uidaho.edu, 208-885-7164) if you have any questions or comments about the workshops. Attached please find a one-page summary sheet of our research. Again, it would be fantastic if you pass along this info to others that should attend (our website has a list of people who have already registered). I truly hope you will join us!

Kind regards,

Appendix J.

Workshop Agenda – CCWs

Northern Rockies Climate Change Workshops

Workshop Goals:

What we hope to provide:

- A greater understanding of climate change science
- Information specific to your location at regional and local scales

What we need from you:

- Are these types and scales of information useful to you? Why or why not?
- How could future climate change research be focused to increase its usefulness in management; what types of information would better serve your needs?

AGENDA

Workshop Opening

9:30 – 9:40 Penny Morgan introduction
9:40 – 9:50 Opening remarks and what to expect
9:50 – 10:00 Q&A about the day

Global and Regional Considerations

10:00 – 10:15 Global climate considerations
10:15 – 10:20 Q&A about global considerations
10:20 – 10:30 Break
10:30 – 11:00 Regional climate and water resource information
11:00 – 11:05 Q&A
11:05 – 11:25 Regional forest composition and wildland fire information
11:25 – 11:30 Q&A
11:30 – 11:45 Watershed views of regional considerations
11:45 – 11:50 Q&A
11:50 – 12:20 Small group breakout sessions to discuss the credibility and usefulness of global and regional information

12:20 – 1:30 Lunch

Local-scale Forest Simulations

1:30 – 2:00 Forest vegetation simulations at various elevations with various management options
2:00 – 2:10 Q&A
2:10 – 2:40 Small group breakout sessions to discuss the credibility and usefulness local-scale vegetation simulations
2:40 – 2:50 Break

Management Implications and Research Gaps

2:50 – 3:15 Small groups: Prioritizing gaps and opportunities
3:15 – 3:30 Concluding remarks and next steps

Appendix K.

Workshop Pre-test Survey – CCWs

Opinions about Climate Change Science, Impacts, and Forest Management

Conducted by the Northern Rockies Interdisciplinary Research Team

University of Idaho
College of Natural Resources

Please be assured that all answers provided are confidential. This research has been reviewed and approved by the University of Idaho Institutional Review Board.

To maintain your confidentiality, but allow us to match your pre-workshop survey and post-workshop survey with a unique ID, please enter the **last two letters of your first name, the year of your birth, and the workshop location you are attending**.

Last 2 letters of your first name:__________

Year of your birth (YYYY):_________

Workshop location you are attending:___________

Section A: Credibility and Usefulness of Climate Change Science
We are interested in your opinions about the credibility (accuracy/validity) and usefulness of climate change science in land use planning and management projects. For each of the following questions, please select the answer that most closely reflects your opinions.

Question 1. Please indicate your level of agreement with the following statements:

	Strongly Disagree			Neutral			Strongly Agree	Don't Know
Climate change science is useful in my work.	-3	-2	-1	0	1	2	3	x
Using climate change science in land management is consistent with the mission and objectives of my organization/agency.	-3	-2	-1	0	1	2	3	x
Using climate change science is within my job description and responsibilities.	-3	-2	-1	0	1	2	3	x
Other people in my organization/agency are currently using climate change science.	-3	-2	-1	0	1	2	3	x
Climate change science is useful in long-term land use planning.	-3	-2	-1	0	1	2	3	x
Climate change science is useful for specific management projects.	-3	-2	-1	0	1	2	3	x
Funding is a constraint for addressing climate change in my work.	-3	-2	-1	0	1	2	3	x
Time is a constraint for addressing climate change in my work.	-3	-2	-1	0	1	2	3	x
The politics of climate change are a constraint for using the science in my work.	-3	-2	-1	0	1	2	3	x
I plan to use climate change science in future work that I do.	-3	-2	-1	0	1	2	3	x

Question 2. For this question we are interested in how credible (valid/accurate) you think climate change science is. Please indicate your level of agreement with the following statements:

	Strongly Disagree			Neutral			Strongly Agree	Don't Know
Global and regional climate change science is credible.	-3	-2	-1	0	1	2	3	x
Local (forest stand-level) climate change science is credible.	-3	-2	-1	0	1	2	3	x
Historical data and calculations used in climate change science are credible.	-3	-2	-1	0	1	2	3	x
Projected/modeled future data and calculations used in climate change science are credible.	-3	-2	-1	0	1	2	3	x
I consider science about climate change impacts to be defensible when a decision is challenged or appealed.	-3	-2	-1	0	1	2	3	x
Models that simulate future vegetation scenarios are useful in land management.	-3	-2	-1	0	1	2	3	x
Models that simulate future precipitation patterns are useful in land management.	-3	-2	-1	0	1	2	3	x

Section B: Vulnerability and adaption to climate change impacts

We are interested in your opinions about the likelihood and severity of climate change impacts, and the effectiveness of potential adaptation actions.

Question 3. For this question, think about the impacts of climate change in Idaho and western Montana. For each item please indicate both how LIKELY (column A) you think the climate change impact is, **and** how SEVERE (column B) you think the impact will be.

In the next 20 years, climate change could have these impacts in the Northern Rockies........

	A) How LIKELY is this impact?						B) How SEVERE will the impact be?					
	Very Unlikely		Neither		Very Likely	Don't Know	No Impact		Mod		Very Severe	Don't Know
Increase in mean annual temperatures	-2	-1	0	1	2	x	0	1	2	3	4	x
Changes in seasonal amounts of precipitation	-2	-1	0	1	2	x	0	1	2	3	4	x
Increase in the intensity of precipitation	-2	-1	0	1	2	x	0	1	2	3	4	x

Question 3. Continued….	A) How LIKELY is the impact?						B) How SEVERE will it be?					
	Very Unlikely		Neither		Very Likely	Don't Know	No Impact		Mod		Very Severe	Don't Know
More rain and less snow in winter months	-2	-1	0	1	2	x	0	1	2	3	4	x
Earlier peak streamflow	-2	-1	0	1	2	x	0	1	2	3	4	x
Decrease in total annual streamflow	-2	-1	0	1	2	x	0	1	2	3	4	x
Increase in stream temperatures	-2	-1	0	1	2	x	0	1	2	3	4	x
Changes in where plant species occur on the landscape	-2	-1	0	1	2	x	0	1	2	3	4	x
More wildfire each year	-2	-1	0	1	2	x	0	1	2	3	4	x
Increase in the amount of area burned by wildfire	-2	-1	0	1	2	x	0	1	2	3	4	x
More severe fires	-2	-1	0	1	2	x	0	1	2	3	4	x
More disease and insect outbreaks	-2	-1	0	1	2	x	0	1	2	3	4	x
Other:	-2	-1	0	1	2	x	0	1	2	3	4	x
Other:	-2	-1	0	1	2	x	0	1	2	3	4	x

Question 4. For this question, think about different ways to adapt and mitigate climate change impacts in Idaho and Western Montana. For each management action please consider whether you think the action would be EFFECTIVE (Column A) for adapting to climate change impacts, **and** how likely is it that the organization/agency you work for WILL TAKE ACTION (Column B) to reduce the potential impacts. Please provide two answers per row.

	A) Would this be EFFECTIVE for adapting to climate change impacts?						B) How LIKELY is your organization/ agency to do this and specifically address climate change impacts?					
	Very Ineffective		Neither		Very Effective	Don't Know	Not at all		Mod		Extremely Likely	Don't Know
Forest treatments to improve forest health	-2	-1	0	1	2	x	0	1	2	3	4	x
Forest treatments to reduce fire hazard	-2	-1	0	1	2	x	0	1	2	3	4	x

Question 4 Continued…..

	A) Would this be EFFECTIVE						B) How LIKELY is your organization/agency to do this?					
	Very Ineffective		Neither		Very Effective	Don't Know	Not at all		Mod		Extremely Likely	Don't Know
Forest treatments to increase water supply	-2	-1	0	1	2	x	0	1	2	3	4	x
Prescribed burning	-2	-1	0	1	2	x	0	1	2	3	4	x
Assisted species migration	-2	-1	0	1	2	x	0	1	2	3	4	x
Road and culvert modifications	-2	-1	0	1	2	x	0	1	2	3	4	x
Consideration of alternative species or plant varieties for restoration	-2	-1	0	1	2	x	0	1	2	3	4	x
Development of restoration objectives beyond the Historical Range of Variability (HRV)	-2	-1	0	1	2	x	0	1	2	3	4	x
Insect and disease control	-2	-1	0	1	2	x	0	1	2	3	4	x
Expanded tree planting to promote reestablishment	-2	-1	0	1	2	x	0	1	2	3	4	x
Other:	-2	-1	0	1	2	x	0	1	2	3	4	x
Other:	-2	-1	0	1	2	x	0	1	2	3	4	x
Other:	-2	-1	0	1	2	x	0	1	2	3	4	x

Section C: To understand more about our workshop participants, we have a few questions about you. All of your answers are confidential.

7. What is your area of expertise (e.g., position title)?

____

8. How many years have you worked in the Northern Rockies?

- ☐ Less than 5 years
- ☐ 5 – 15 years
- ☐ More than 15 years

9. Please indicate the *highest level of education* that you have completed (*check one).*

- ☐ Less than a high school degree
- ☐ High school degree or GED
- ☐ Some college or post high school training
- ☐ Two year technical or associate degree
- ☐ Four year college degree (BA/BS)
- ☐ Advanced degree (MS, JD, MD, Ph.D.)

10. Are you ☐ Male or ☐ Female?

11. Please check the box that most accurately describes your *political orientation* on the following scale:

Very Liberal			Neither			Very Conservative
☐	☐	☐	☐	☐	☐	☐

Please provide any additional comments here. If you need more space attach a separate piece of paper.

Thank you for helping to improve climate change science, communication, and its usefulness in land management. Please feel free to contact either Jarod Blades or Dr. Hall if you have any concerns or additional comments regarding this survey.

Jarod Blades and Dr. Troy Hall
University of Idaho
P.O. Box 441139
Moscow, ID 83844-1139
Phone: 208-885-7164
Email: jblades@uidaho.edu

University of Idaho
College of Natural Resources

JOINT FIRE SCIENCE PROGRAM NSF IGERT NASA

Appendix L.

Workshop Pre-interview Informed Consent – CCWs

Script for Obtaining Informed Consent for Interview (to be read to participants)

Hello, my name is Jarod Blades. I am a graduate student at the University of Idaho, and I am working with a team of faculty and graduate students that is conducting multi-scale climate change research. I was glad to see that you registered for the workshop in Boise, and I'm calling to see if you would be willing to answer a few questions specific to the workshop. Your expertise and work related to forest management would provide some great insights into our research about how potential climate change effects are understood, and whether this type of research is useful in forest management decisions.

I want to let you know that this study has been approved by the University of Idaho Institutional Review Board. The interview will include questions about your knowledge and opinions about climate change research, potential forest-related climate change effects, what actions can be taken, and your use of climate change research when making forest management decisions.

The interview should take about 15-30 minutes. Would you be willing to participate?

Just so you know, you are free to end the survey at any time. You may also choose not to answer any of the questions, and it is fine if you don't know answers to some of them.

All of the information you provide will be confidential and seen only by myself and members of the research team. Your name will not be connected to any of your responses.

If you have questions about the study or interview, feel free to ask me anytime during the interview, when the interview is complete, or at a time you feel is appropriate. I would also be happy to provide you with my contact information and Dr. Hall's.

Jarod Blades
University of Idaho
Dept. of Conservation Social Sciences
Moscow, ID 83844-1139
Ph. 208-885-7164

Dr. Troy Hall
University of Idaho
Dept. of Conservation Social Sci.
Moscow, ID 83844-1139
Ph. 208-885-7911

Participant Consent:

YES_____, if yes, begin survey
NO_____, say thank you for your time and consideration. Ask if there is a better time I could call back or if there is any particular reason to not participate.

I confirm that consent was given verbally by the participant.

Participant name: ___________________________________

Researcher Name ___________________________________

Appendix M.

Pre-test Interview Questions and Small Group Facilitation Questions – CCWs

Interview questions (main questions, followed by probes/prompts)

Okay, this is __________________, and I am interviewing ____________________.

Tell me what your role is in forest planning and implementation projects (e.g., restoration)?

How long have you been working in the northern Rockies?

I'm going to ask you a few questions about your personal understanding of how climate change could affect forests in our region. This kind of information will help us further refine the materials we present in the workshop and make it more useful for you and your organization.

Mental Model Questions

I want to ask you some questions about your general understanding of how climate change influences forests.

1. How do you think climate change influences forest fires? (what is your best understanding)
2. How do you think climate change influences forest structure and tree regeneration?
3. How do you think climate change influences the hydrologic cycle related to forest systems?

Have you noticed any changes in ____________ (precipitation? Tree regeneration? Stream flows? Snow packs? Fires?)

Salience/Management Intentions

1. Do you use climate change science in the work you do? How?
   a. Forest planning, implementation projects, how?

2. Other than personal use, is your organization currently using science about climate change impacts? How?

3. Tell me what you think about the usefulness of climate change science in the work you do. What makes it useful or impedes its usefulness?
   a. Are there organizational barriers that impede usefulness?
      i. *Mission of the USFS?*
      ii. *Job description*
      iii. *Funding*
      iv. *Time*
      v. *Political issues*

4. Is climate change research more usable by one discipline/specialty than others? How so?

Credibility

1. In your opinion, how good (credible) are the data and models used in climate change research?
    a. *Global, regional, local*
    b. *Trust who collected the data, which agency, type of data, age of the data*
    c. *Defensible?*
    d. *Models in general*

Perceived Vulnerability

1. How vulnerable do you feel the forest(s) you work in are to climate change impacts? If yes, do you think they are happening now or in the foreseeable future?

2. Which resources are more likely to be affected? (e.g., water, vegetation, wildlife, recreation, etc.)

Perceived Severity

1. How severe will the impacts be within your region or forest?

2. To fire occurrence and severity?
3. To forest vegetation?
4. To water resources?

Response-efficacy

1. Are you aware of forest management actions that could reduce climate change impacts?
    A) Specific on-the-ground actions

2. Are any of these actions being done now? Why or why not?

Collective-efficacy

3. How confident do you feel **in the ability** of your organization/agency to take actions to reduce the potential impacts of climate change? Will they do it?

That was the final question; do have anything else you would like to add about what we have discussed today?

Thanks so much for taking the time to talk with me. Will you be at the workshop on November _______? Great! I look forward to meeting you and talking more in person.

Facilitation Script for Small Groups

11:45 – 12:15 Global and Regional Considerations

Facilitator: Hello, my name is ______________, and I am a [graduate] student from the University of Idaho/Montana. As Jarod mentioned, we will be using the next half hour to discuss three questions about the global and regional information that was just presented. But first, let's quickly go around and introduce ourselves by saying your name, affiliation, and specialty (Note: this should only take 1-2 mins).

Okay, great. Now that we know a little about each other let's talk about the information that was just presented. Please refer to your printed materials, especially the summary slides.

1. Do you consider the information presented credible (accurate/valid)?

    - Do the findings presented (about snow/rain, tree species distribution, fire) resonate with other projections you've heard?
    - Historic versus future projected data
    - Global, Regional (water, vegetation, fire), Local (veg simulations)
    - Is the information defensible for use in a management document or litigation?

    - **Session 2:** what do you think about these types of modeling approaches in general for projecting forest conditions?
    - If you haven't used FVS (or aren't familiar with it), what would you want to know about it to be able to judge its credibility?

2. How do you think the information presented could be useful in your work?

    - Land use planning
    - Specific projects
        - Restoration (seed mixes, varietals)
        - Habitat management
        - Transportation/culverts
    - Apart from your own work, how do you think this type of information could help your agency or other land management agencies?

      Session 2:
        - how are project decisions (eg timber harvest, restoration) made now? Is climate change considered? if so, how?
        - even if you aren't sure that the specific numbers generated by Wade's models are "correct", would it be useful to be able to run these types of projections?

After this point just allow the conversation to flow in any direction that the participants take it. Feel free to ask probing questions, such as "what do you mean when you say ___________?" or "how could the climate change science presented today influence that?"

During lunch the participants will be encouraged to walk around and look at other groups answers to questions.

2:15 – 2:45 Local Scale Considerations

Welcome back. We've covered a lot of information up to this point. For this session I want you to think specifically about the information that was just presented in the animated flyover and the Forest Vegetation Simulations. (Repeat questions 1-4 from above.)

During the break participants will be encouraged to walk around and look at other groups the answers to questions.

2:55 – 3:20 Management Implications and Information Gaps

For our final group session, first we are going to think about all the information presented today and discuss what we consider to be the most important management implications, or how these could be used. We are also going to list what where we think crucial gaps exist related to the topics covered today and prioritize which gaps need to be addressed by future research. Please take 5 minutes and jot down your opinion of the most important management implications and information gaps. After that we are going to compile them on flip chart paper and then pick our top three from each category. Please keep in mind that all of the ideas will be recorded and considered, this is just a fast and simple way to bring ideas that people agree on to the surface.

Allow 5 minutes for individual brainstorming

After 5 minutes: Okay, let's start by going round robin about what we think are the most important management implications. (Record these on flip chart paper)

Next, let's discuss important research gaps that need to be addressed related to the topics we've covered today. (Repeat the round robin process).

Lastly, you have the opportunity to place a sticky dot next to the top three management implications and research gaps. This will allow us to identify the priorities for research and management moving forward.

Appendix N.

Workshop Post-test Survey Questions – CCWs

Post-Workshop Opinions about Climate Change Science, Impacts, and Forest Management

Conducted by the Northern Rockies Interdisciplinary Research Team

University of Idaho
College of Natural Resources

Please be assured that all answers provided are confidential. This research has been reviewed and approved by the University of Idaho Institutional Review Board.

To maintain your confidentiality, but allow us to match your pre-workshop survey and post-workshop survey with a unique ID, please enter the **last two letters of your first name, the year of your birth, and the workshop location you attended**.

Last 2 letters of your first name:__________ Year of your birth (YYYY):_________

Workshop location you attended:___________

Section A: Usefulness and Credibility of Climate Change Science
We are interested in your opinions about the usefulness and credibility (accuracy/validity) of climate change science in general, and specifically about the information presented during this workshop. For each of the following questions, please select the answer that most closely reflects your

Question 1. Please indicate your level of agreement with the following statements:

	Strongly Disagree			Neutral			Strongly Agree	Don't Know
Climate change science is useful in my work.	-3	-2	-1	0	1	2	3	x
Climate change science is useful in long-term land use planning.	-3	-2	-1	0	1	2	3	x
Climate change science is useful for specific management projects.	-3	-2	-1	0	1	2	3	x
I plan to use climate change science in future work that I do.	-3	-2	-1	0	1	2	3	x
The global climate change science information is useful for land management (modeling and emission scenario information).	-3	-2	-1	0	1	2	3	x
I plan to use global climate change science in future work that I do.	-3	-2	-1	0	1	2	3	x
The regional climate and water research is useful for land management.	-3	-2	-1	0	1	2	3	x
I plan to use the regional climate and precipitation research in future work that I do.	-3	-2	-1	0	1	2	3	x
The regional vegetation and fire research is useful for land management.	-3	-2	-1	0	1	2	3	x
I plan to use the regional vegetation and fire research in future work that I do.	-3	-2	-1	0	1	2	3	x
The local-scale forest vegetation and climate simulations are useful for land management.	-3	-2	-1	0	1	2	3	x
I plan to use the local-scale forest vegetation and climate simulations in future work that I do.	-3	-2	-1	0	1	2	3	x

Question 2. For this question we are interested in how credible (valid/accurate) you think the climate change science presented at the workshop is. Please indicate your level of agreement with the following statements:

	Strongly Disagree			Neutral			Strongly Agree	Don't Know
Global and regional climate change science is credible.	-3	-2	-1	0	1	2	3	x
Models that simulate future vegetation scenarios are useful in land management.	-3	-2	-1	0	1	2	3	x
Models that simulate future precipitation patterns are useful in land management.	-3	-2	-1	0	1	2	3	x
Historical data and calculations used in climate change science are credible.	-3	-2	-1	0	1	2	3	x
Projected/modeled future data and calculations used in climate change science are credible.	-3	-2	-1	0	1	2	3	x
I consider science presented in the workshops about climate change impacts to be defensible if a decision is challenged or appealed.	-3	-2	-1	0	1	2	3	x

Section B: Vulnerability and adaption to climate change impacts

Based on the information we presented at the workshop, please share your opinions about the likelihood and severity of climate change impacts, and the effectiveness of potential adaptation actions.

Question 3. For this question, think about the impacts of climate change in Idaho and western Montana. For each item please indicate both how LIKELY (column A) you think the climate change impact is, **and** how SEVERE (column B) you think the impact will be.

In the next 20 years, climate change could have these impacts in the Northern Rockies........

	A) How LIKELY is this impact?						B) How SEVERE will the impact be?					
	Very Unlikely		Neither		Very Likely	Don't Know	No Impact		Mod		Very Severe	Don't Know
Increase in mean annual temperatures	-2	-1	0	1	2	x	0	1	2	3	4	x
Changes in seasonal amounts of precipitation	-2	-1	0	1	2	x	0	1	2	3	4	x
Increase in the intensity of precipitation	-2	-1	0	1	2	x	0	1	2	3	4	x

Question 3. Continued….	A) How LIKELY is the impact?						B) How SEVERE will it be?					
	Very Unlikely		Neither		Very Likely	Don't Know	No Impact		Mod		Very Severe	Don't Know
More rain and less snow in winter months	-2	-1	0	1	2	x	0	1	2	3	4	x
Earlier peak streamflow	-2	-1	0	1	2	x	0	1	2	3	4	x
Decrease in total annual streamflow	-2	-1	0	1	2	x	0	1	2	3	4	x
Increase in stream temperatures	-2	-1	0	1	2	x	0	1	2	3	4	x
Changes in where plant species occur on the landscape	-2	-1	0	1	2	x	0	1	2	3	4	x
More wildfire each year	-2	-1	0	1	2	x	0	1	2	3	4	x
Increase in the amount of area burned by wildfire	-2	-1	0	1	2	x	0	1	2	3	4	x
More severe fires	-2	-1	0	1	2	x	0	1	2	3	4	x
More disease and insect outbreaks	-2	-1	0	1	2	x	0	1	2	3	4	x
Other:	-2	-1	0	1	2	x	0	1	2	3	4	x
Other:	-2	-1	0	1	2	x	0	1	2	3	4	x

Question 4. For this question, think about different ways to adapt and mitigate climate change impacts in Idaho and Western Montana. For each management action please consider whether you think the action would be EFFECTIVE (Column A) for adapting to climate change impacts, **and** how likely is it that the organization/agency you work for WILL TAKE ACTION (Column B) to reduce the potential impacts. Please provide two answers per row.

	A) Would this be EFFECTIVE for adapting to climate change impacts?						B) How LIKELY is your organization/ agency to do this and <u>specifically address climate change impacts</u>?					
	Very Ineffective		Neither		Very Effective	Don't Know	Not at all		Mod		Extremely Likely	Don't Know
Forest treatments to improve forest health	-2	-1	0	1	2	x	0	1	2	3	4	x
Forest treatments to reduce fire hazard	-2	-1	0	1	2	x	0	1	2	3	4	x

Question 4 Continued…..	**A) Would this be EFFECTIVE**						**B) How LIKELY is your organization/agency to do this?**					
	Very Ineffective		Neither		Very Effective	Don't Know	Not at all		Mod		Extremely Likely	Don't Know
Forest treatments to increase water supply	-2	-1	0	1	2	x	0	1	2	3	4	x
Prescribed burning	-2	-1	0	1	2	x	0	1	2	3	4	x
Assisted species migration	-2	-1	0	1	2	x	0	1	2	3	4	x
Road and culvert modifications	-2	-1	0	1	2	x	0	1	2	3	4	x
Consideration of alternative species or plant varieties for restoration	-2	-1	0	1	2	x	0	1	2	3	4	x
Development of restoration objectives beyond the Historical Range of Variability (HRV)	-2	-1	0	1	2	x	0	1	2	3	4	x
Insect and disease control	-2	-1	0	1	2	x	0	1	2	3	4	x
Expanded tree planting to promote reestablishment	-2	-1	0	1	2	x	0	1	2	3	4	x
Other:	-2	-1	0	1	2	x	0	1	2	3	4	x
Other:	-2	-1	0	1	2	x	0	1	2	3	4	x
Other:	-2	-1	0	1	2	x	0	1	2	3	4	x

Section C: Workshop Evaluation

We are interested in your opinions about how the climate change workshop was conducted in terms of the information presented, and workshop coordination, facilitation, and the processes.

Question 5. Please indicate your level of agreement with the following statements:

	Strongly Disagree			Neutral			Strongly Agree
Scientific information and results were translated for practical use.	-3	-2	-1	0	1	2	3
Information needs were connected with sources of information.	-3	-2	-1	0	1	2	3
The workshop created a forum for individuals who otherwise would not have occasion to work together on these topics.	-3	-2	-1	0	1	2	3

Question 5 continued…..	Strongly Disagree			Neutral			Strongly Agree
The workshop encouraged the use of models and tools for linking science and decision making.	-3	-2	-1	0	1	2	3
Active listening took place during the Q&A and small group sessions.	-3	-2	-1	0	1	2	3
The small group discussions helped me understanding the presented information.	-3	-2	-1	0	1	2	3
Diverse disciplines and interests were <u>not</u> represented at the workshop.	-3	-2	-1	0	1	2	3
The workshop promoted information exchange between scientists, agency and interested stakeholders.	-3	-2	-1	0	1	2	3
The workshop added value by combining data and information from multiple sources.	-3	-2	-1	0	1	2	3
The workshops helped identify the underlying assumptions of the information presented.	-3	-2	-1	0	1	2	3
The workshop helped to understand how research could be used in decisions being made.	-3	-2	-1	0	1	2	3
The workshop was accountable to both resource specialists and decision-maker needs and interests.	-3	-2	-1	0	1	2	3
There was a clear dissemination strategy for workshop information and outcomes.	-3	-2	-1	0	1	2	3
I am confident that information and outcomes from the workshop will be shared with the participants.	-3	-2	-1	0	1	2	3
<u>Learning Environment</u>	Strongly Disagree			Neutral			Strongly Agree
It was easy for participants to speak openly.	-3	-2	-1	0	1	2	3
I was comfortable talking about any concerns or disagreements.	-3	-2	-1	0	1	2	3
Different opinions were welcome.	-3	-2	-1	0	1	2	3
There was adequate time to reflect on new information.	-3	-2	-1	0	1	2	3
The workshop helped participants engage in productive debate.	-3	-2	-1	0	1	2	3

Please provide any additional comments here. If you need more space attach a separate piece of paper.

Thank you for helping to improve climate change science, communication, and its usefulness in land management. Please feel free to contact either Jarod Blades or Dr. Hall if you have any concerns or additional comments regarding this survey.

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University of Idaho
College of Natural Resources

JOINT FIRE SCIENCE PROGRAM

NSF IGERT

NASA

Appendix O.

Workshop Post-test Interview Questions – CCWs

Post-Workshop Interview questions

This is __________________, and I am interviewing ____________________.

Thanks again for participating in our climate change workshop! Today I want to talk a little about your understanding of climate change and impacts now that you have participated in our workshop. Some of the questions will sound very similar to the last time we spoke on the phone – but that is on purpose because this time I am curious if your understanding or opinions are the same or different based on the information that was discussed at the workshop.

Workshop Evaluation

1. How do you think the workshop went? What did you like about it? What did you dislike?
2. How did the presentations and discussions during the workshop influence your views about uncertainty?

Mental Model Questions

Zion/Kerry/Jarod: Review notes and/or listen to the pre-interview to identify the main things the person said. Prompt them for full coverage about the topics.

1. What has changed in your thinking about how climate change influences:

- forest fires?
- forest structure and tree regeneration?
- the hydrologic cycle?

2. Have you been thinking about or noticed any changes that you have personally observed on the landscape based on the information we presented? (precipitation? Tree distributions? Stream flows? Snow packs? Fires?)

Salience

4. How useful is the climate change science and tools we presented at the workshop for the work you do? What makes it useful or impedes its usefulness?
   a. Global, regional water, regional vegetation, regional fire, local scale climate-FVS

Credibility & Legitimacy

2. In your opinion, how good (credible) were the data used in the climate change science we presented?
    a. *Global, regional, local*
    b. *Trust who collected the data, which agency, type of data, age of the data*
    c. *Defensible?*
    d. *Models in general*

Response-efficacy

4. How was Climate-FVS useful for exploring management actions that could reduce climate change impacts? What made it useful or not useful?

Collective-efficacy

1. Based on the information presented at the workshops, how confident do you feel in the ability of your organization/agency to take actions to reduce the potential impacts of climate change? Will they do it?

That was the final question; do have anything else you would like to add about what we have discussed today?

Thanks so much for taking the time to talk with me. We will be in touch in the near future to let you know about available materials on the website and our findings.

Appendix P.

Interview Coding Guide – CCWs

Code Book – NORO Climate Change Workshop Interviews

- Unit of analysis is a meaning unit (coherent ideas that could span several sentences).
- Remember to code all of the text - both the question and the answer. Every sentence should receive a code.
- Each statement could receive a general code, a topic code, scale code, or NA code. No codes are exclusive of others.

Code	Sub-Code	Description
IMP (Impacts)		Any mention or inference about CC impact(s) to human or natural systems. Observed or hypothetical.
EXP (Experience)		**Observations of climate change impacts**. Personal or heard from others. Includes learning and reading about CC. Also refers to **familiarity** with CC science, models, or information.
CRED (Credibility)	CRED	Statement about the **credibility** of climate change science without elaboration.
	CRED- animation	Credibility of the animated flyovers
	CRED- models	Credibility of models in general. Also refers to **familiarity** with CC models.
	CRED- defensibility	Credibility statements about the **defensibility** of climate change science, including **litigation, appeals, challenges**. Statements about the credibility of where the science came from – who produced it or how it was collected/analyzed/reported
	CRED- UNC (uncertainty)	Statement that directly or indirectly suggests uncertainty or speculation of CC science. Also includes the inability to discern natural from anthropogenic CCs.
RE (Response Efficacy)		Statements about **whether a recommended action (response) would be effective** for adapting to climate change impacts? **Evaluation** of forest treatments or the potential to use CC info in work/decisions. If they mention the action is or has been taken it will **also be coded as BEH.**
CE (Collective Efficacy)		Statements about **how likely it is that a person's organization/agency would or could do this to specifically address climate change impacts.** This code will also

Code	Sub-Code	Description
		include statements about the likelihood of an individual to address climate change.
USEFUL (Usefulness)	USEFUL (not specific)	Statement about the **<u>usefulness</u>** of climate change science without specific elaboration on planning or projects. This could be a personal statement or statement about how others feel. May refer to management actions that overlap with RE.
	USEFUL- planning	Usefulness in long-term, regional, watershed, landscape planning.
	USEFUL- projects	Climate change science is useful for specific management projects (restoration, Rx fire)
BEH (Behavior)		Statement about **<u>whether or not actions are being taken to use CC science</u>** or not for planning, management, or passing along workshop information to others. This could also be abstract: "we try to write about it."
BI (Behavioral Intention)		Statement about the **<u>intention to use</u>** any of the climate change science in future work. This could be **<u>activity-specific</u>** (plan to do more Rx burning) or a general **<u>inclination</u>** (plan to share the info with others)
BAR (Barriers)		Statements about any **<u>organizational factors</u>** that influence the use of CC science. Time. Funding. Politics. Policy. Also any time there is disagreement or pressure from colleagues or other staff.
EVAL (evaluation)		Statement about how the workshop went (liked, disliked). Any type of feedback about workshop processes or interactions.
WORKSHOP		Any reference the workshop in any way: data, processes, etc.
CHANGE		Explicit statement of how their personal opinion changed based on the workshop OR strengthened existing perspectives.
NA (Not Applicable)		Statements that are not related to the interview topics or our variables. Off topic.
QUOTE		Statements that you think are "quote worthy."
TEMP		Statement about temperature
HYDRO		Statement about water (rain, snow, stream flow, culverts, sediment)
FIRE		Statement about fire
VEG		Statement about vegetation (science about vegetation change and veg management actions)
FVS		Statements specific to FVS, and will always be coded as

Code	Sub-Code	Description
		VEG too.
OTHER		Statement about climate change in general, fish & wildlife, pests/disease, etc. Includes global weather patterns. OR where you can't tell which resource they are talking about.
HIST		Statement about historic and current data, observations, impacts related to CC
FUTURE		Statement about future projections, data, impacts related to CC
GLOBAL		Statement referring to global CC topics

Appendix S.

Supplemental Tables for Chapter IV

Summary of paired interviews and surveys conducted with the CCWs

	McCall	Boise	Grangeville	Missoula	Totals
Paired Interviews					
Manager/Planner	1	2	3	3	**9**
Forest	4	4	4	4	**16**
Water	3	2	2	3	**10**
Totals	**8**	**8**	**9**	**10**	**35**
Paired Surveys					
Manager/Planner	1	4	2	3	**10**
Forest	5	9	6	7	**27**
Water	5	3	7	9	**24**
Totals	**11**	**16**	**15**	**19**	**61**

Usefulness, credibility, organizational barriers, and behavioral intention **stratified by participant discipline**.

		Pre-test			**Post-test**			**Paired T-test (*p*)**		
Const-ruct	**Items**	**MP** (n=19)	**FFE** (n=36)	**WR** (n=31)	**MP** (n=14)	**FF** (n=38)	**WR** (n=26)	**MP**	**FFE**	**WR**
Usefulness PRE-POST	Climate change science is useful in my work.	1.7	1.8	2.3	1.9	2.0	2.2	0.51	0.07	0.45
	Climate change science is useful in long-term land use planning.	2.0	2.2	2.4	2.2	2.5	2.5	0.45	0.14	0.72
	Climate change science is useful for specific management projects.	0.8	1.6	1.6	**1.0**[a]	**1.7**[ab]	**2.1**[b]	0.44	0.68	**0.04***
	Models that simulate future vegetation scenarios are useful in land management.	1.6	1.7	1.5	1.3	1.5	1.6	0.39	0.23	0.67
	Models that simulate future precipitation patterns are useful in land management.	1.0	1.7	1.5	1.8	1.6	1.8	0.07	0.71	0.54
Usefulness PRE Only	Using climate change science in land management is consistent with the mission and objectives of my organization/agency.	2.2	2.3	2.5						
	Using climate change science is within my job description and responsibilities.	1.8	1.7	1.4						
	Other people in my organization/agency are currently using climate change science.	0.9	1.5	1.6						
Usefulness POST Only	The global climate change information is useful for land management (modeling and emission scenario information).				1.1	1.6	1.1			
	The regional climate and water research is useful for land management.				2.0	2.3	2.3			
	The regional vegetation and fire research is useful for land management.				2.0	2.3	2.2			
	The local-scale forest vegetation and climate simulations are useful for land management.				**1.1**[a]	**1.8**[ab]	**2.3**[b]			
Credibility	Global and regional climate change science is credible.	1.9	1.8	2.2	2.0	2.0	2.3	0.80	0.12	0.61
	Local (forest stand-level) climate change science is credible.	0.5	1.0	0.9	0.7	1.2	1.4	0.74	0.33	0.14
	Historical data and calculations used in climate change science are credible.	1.7	**1.5**	**1.4**	2.1	**2.1**	**2.1**	0.17	**0.02***	**0.02***
	Projected/modeled future data and calculations used in climate change science are credible.	0.6	**1.1**	**1.0**	1.0	**1.6**	**1.8**	0.07	**0.02***	**0.01***

	I consider science about climate change impacts to be defensible when a decision is challenged or appealed.	0.8	1.1	0.9	0.9	1.7	1.5	0.76	0.08	0.23
Org Barriers	Funding is a constraint for addressing climate change in my work.	1.1	1.3	1.2						
	Time is a constraint for addressing climate change in my work.	1.4	1.5	1.6						
	The politics of climate change are a constraint for using the science in my work.	-0.4	0.4	0.9						
Behavioral Intention	I plan to use climate change science in future work that I do.	1.7	1.9	2.2	1.7	1.8	2.1			
	I plan to use *global* climate change science in future work that I do.				1.0	1.2	1.2			
	I plan to use the *regional climate and precipitation* research in future work that I do.				1.9	1.9	2.1			
	I plan to use the *regional vegetation and fire* research in future work that I do.				1.7	1.9	1.5			
	I plan to use the *local-scale forest vegetation and climate simulations* in future work that I do.				0.9	1.3	1.7			

* significant at the $p < .05$ level

Scale values: -3 strongly disagree to 3 strongly agree

MP: Manager/Planner, FFE: Forest and Fire Ecologists, WR: Water Resource Specialists

Usefulness, credibility, organizational barriers, and behavioral intention **stratified by workshop location**.

		Pre-test				Post-test				Paired T-test (*p*)			
Const-ruct	**Items**	**GV** (n=23)	**MC** (n=16)	**MI** (n=29)	**BO** (n=22)	**GV** (n=15)	**MC** (n=11)	**MI** (n=20)	**BO** (n=15)	**GV**	**MC**	**MI**	**BO**
Usefulness PRE-POST	Climate change science is useful in my work.	1.8	2.0	2.2	1.8	1.9	1.8	2.4	2.0	0.72	0.66	0.10	0.27
	Climate change science is useful in long-term land use planning.	2.0	2.0	2.4	2.5	2.3	2.3	2.7	2.3	0.17	0.80	0.11	0.55
	Climate change science is useful for specific management projects.	1.1	0.8	1.8	1.7	1.7	1.5	2.0	1.6	0.06	0.24	0.26	0.55
	Models that simulate future vegetation scenarios are useful in land management.	1.4	1.8	1.6	1.8	1.6	1.3	1.6	1.5	0.66	0.11	1.00	0.27
	Models that simulate future precipitation patterns are useful in land management.	1.2	1.5	1.5	1.9	1.8	1.7	1.7	1.5	0.08	0.34	0.60	0.29
Usefulness PRE Only	Using climate change science in land management is consistent with the mission and objectives of my organization/agency.	2.1	2.2	2.8	2.3								
	Using climate change science is within my job description and responsibilities.	1.4	1.2	2.0	1.5								
	Other people in my organization/agency are currently using climate change science.	1.4	1.0	2.1	0.9								
Usefulness POST Only	The global climate change information is useful for land management (modeling and emission scenario information).					1.1	1.3	1.6	1.4				
	The regional climate and water research is useful for land management.					2.1	2.2	2.4	2.2				
	The regional vegetation and fire research is useful for land management.					2.2	1.9	2.4	2.1				
	The local-scale forest vegetation and climate simulations are useful for land management.					2.3	1.9	1.8	1.5				

Credibility	Global and regional climate change science is credible.	**1.1**[a]	**1.9**[ab]	**2.2**[b]	**2.4**[b]	1.7	2.4	2.4	2.0	**0.03**	**0.02**	0.38	0.11
	Local (forest stand-level) climate change science is credible.	**0.1**[a]	**0.7**[ab]	**1.1**[ab]	**1.7**[b]	1.7	0.9	0.9	1.3	**0.00**	0.84	0.33	0.75
	Historical data and calculations used in climate change science are credible.	0.7	1.6	1.8	1.8	1.9	2.5	1.9	2.3	**0.01**	**0.00**	0.51	0.19
	Projected/modeled future data and calculations used in climate change science are credible.	0.1	1.1	1.3	1.2	1.4	1.7	1.8	1.3	**0.01**	0.08	0.02	0.26
	I consider science about climate change impacts to be defensible when a decision is challenged or appealed.	0.1	1.0	1.3	1.5	1.4	1.2	1.7	1.4	**0.00**	1.00	0.18	1.00
Org Barriers	Funding is a constraint for addressing climate change in my work.	0.7	0.8	1.6	1.5								
	Time is a constraint for addressing climate change in my work.	1.3	1.4	1.7	1.6								
	The politics of climate change are a constraint for using the science in my work.	0.3	0.2	0.5	0.8								
Behavioral Intention	I plan to use climate change science in future work that I do.	1.5	1.7	2.4	2.1	1.6	1.5	2.4	1.9	0.82	0.51	1.00	0.33
	I plan to use *global* climate change science in future work that I do.					0.5	0.8	1.6	1.5				
	I plan to use the *regional climate and precipitation* research in future work that I do.					1.7	1.7	2.4	2.0				
	I plan to use the *regional vegetation and fire* research in future work that I do.					**1.4**[ab]	**1.0**[a]	**2.2**[b]	**1.9**[ab]				
	I plan to use the *local-scale forest vegetation and climate simulations* in future work that I do.					1.5	1.3	1.5	1.1				

* significant at the *p*< .05 level, ** significant at the *p*< .01 level
Scale values: -3 strongly disagree to 3 strongly agree
GV: Grangeville, ID; MI: Missoula, MT; MC: McCall, ID; BO: Boise, ID