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Project Title: Public Perceptions of Smoke: Contrasting Tolerance amongst WUI and Urban Communities in the Interior West and the South-central United States

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Summary

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. 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, this study focused on the lack of understanding related to 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. Thus, this study aimed to answer the research question: How do cognitive factors and personal characteristics influence public tolerance of smoke and support for prescribed fire management activities? Part I was written in two sections; the first section 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 section explore how overall tolerance of smoke and prescribed fire management support differ as a function of these variables. Part II builds off of Part I and describes the conjoint analysis 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. Part III of the project was focused on improving communication of smoke perceptions to land managers and the public. To achieve this we developed a series of youtube videos and a new photo guide focused on visual impacts of smoke concentrations.

Background and Purpose

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 part was written as a framework in two sections, 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 section 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 sections are integrated in the single chapter, which serves as the final report on this project.

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.

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

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).

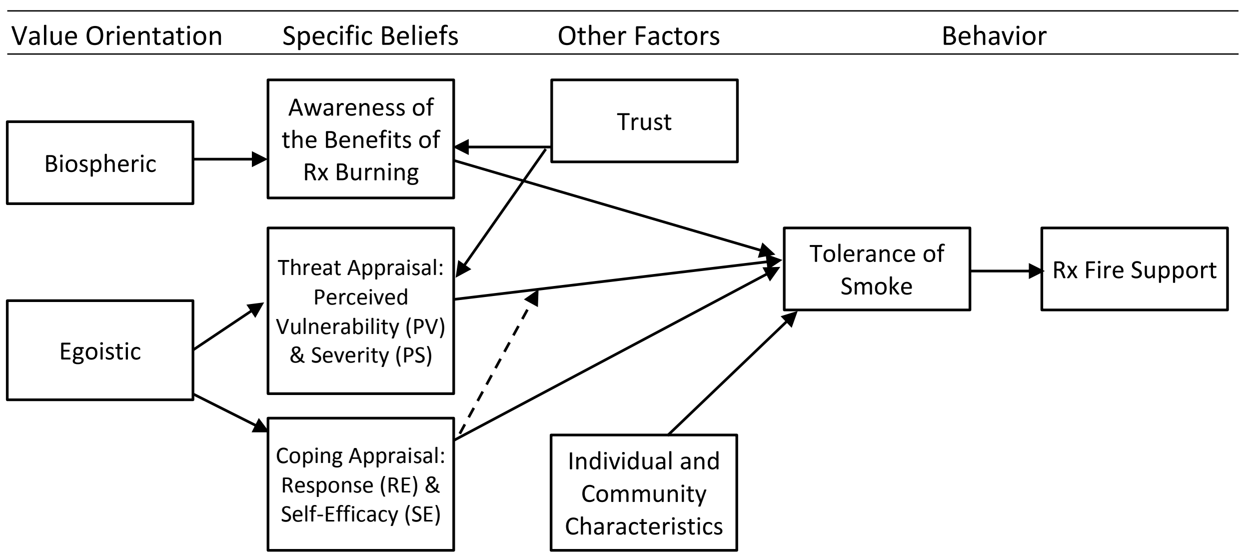

Figure 1. Conceptual framework of respondent tolerance of smoke and support for Rx fire. The dashed line indicates a moderating effect.

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 tolerance of smoke?	*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. *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.

Part I. Study Description and Location

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.

Part I. Key Findings

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	**NORO** (n=1488)		Yes No	19 81

related to forests	**SOUTH** (n=345)	Yes No	15 85
Education level	**NORO** (n=1493)	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.)	2 11 22 11 31 23
	SOUTH (n=352)	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.)	4 16 25 9 24 21
Household income	**NORO** (n=1386)	Less than $20,000 per year $20,001 to $40,000 $40,001 to $60,000 $60,001 to $80,000 $80,001 to $100,000 $100,001 to $120,000 more than $120,000	10 22 23 16 11 7 10
	SOUTH (n=319)	Less than $20,000 per year $20,001 to $40,000 $40,001 to $60,000 $60,001 to $80,000 $80,001 to $100,000 $100,001 to $120,000 more than $120,000	8 24 18 14 12 11 13
Ethnicity	**NORO** (n=1538)	White/Caucasian Black/African-American Hispanic, Latino, or Spanish Origin American Indian or Alaska Native Asian Native Hawaiian or Other Pacific Islander Other or Unknown	94 <1 <1 2 1 <1 1
	SOUTH (n=375)	White/Caucasian Black/African-American Hispanic, Latino, or Spanish Origin American Indian or Alaska Native Asian Native Hawaiian or Other Pacific Islander Other or Unknown	81 6 2 3 1 <1 2
Political orientation	**NORO** (n=1469)	Liberal (0-2) Neither (3) Conservative (4-6)	29 24 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.

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 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	
		% Importance						% Importance						*t*
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

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			
				Urb	MP	LP				Urb	MP	LP	*t*
	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

Item	NORO						SOUTH						REGION
	Total	Urban	Rural	Preparedness			Total	Urban	Rural	Preparedness			
				Urb	MP	LP				Urb	MP	LP	*t*
	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	*t*
Item	mean (SE .04-.07)						mean (SE .09-.18)						
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

Item	NORO						SOUTH						REGION
	Total	Urban	Rural	Preparedness			Total	Urban	Rural	Preparedness			
				Urb	MP	LP				Urb	MP	LP	*t*
	mean (SE .01-.20)						mean (SE .01-.20)						
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.

	NORO						SOUTH						REGION
	Total	Urban	Rural	Preparedness			Total	Urban	Rural	Preparedness			
				Urb	MP	LP				Urb	MP	LP	*t*
Item	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***
Item	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

	NORO						SOUTH						REGION
	Total	Urban	Rural	Preparedness			Total	Urban	Rural	Preparedness			
				Urb	MP	LP				Urb	MP	LP	*t*
Item	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.**

	NORO		SOUTH	
	Factor Loadings (pattern matrix)			
Item	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**

	NORO	SOUTH
Item	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**

Item	NORO		SOUTH
	Factor Loadings (pattern matrix)		
	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**

Item	NORO	SOUTH
	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.**

Item	NORO	SOUTH
	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

FACTOR	NORO						SOUTH						REGION
	Total	Urban	Rural	Preparedness			Total	Urban	Rural	Preparedness			
				Urb	MP	LP				Urb	MP	LP	*t*
	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 H 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 H). 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.

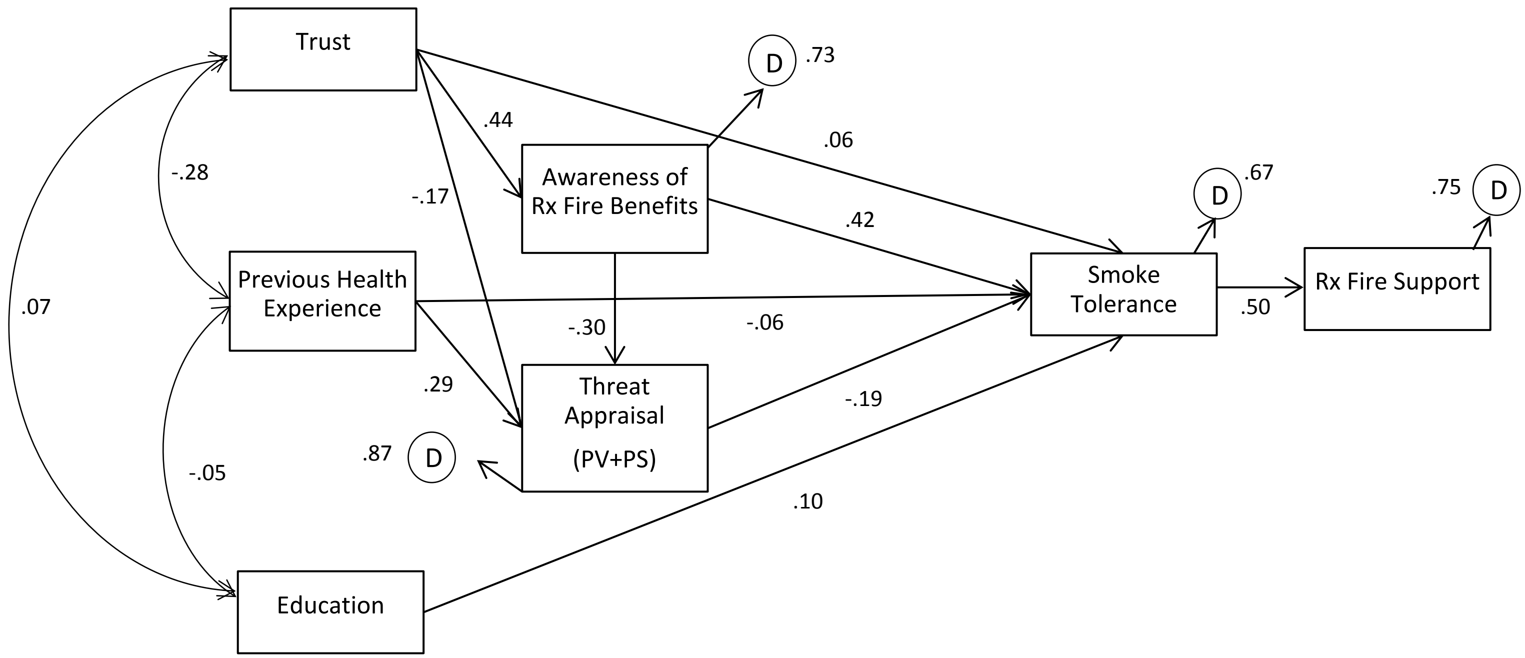

Figure 3. Combined regions final path measurement model. Numbers associated with single-headed arrows are standardized path coefficients. Numbers associated with curved double-headed arrows are correlations. The numbers next to the disturbance circles are the residuals associated with a dependent variable.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

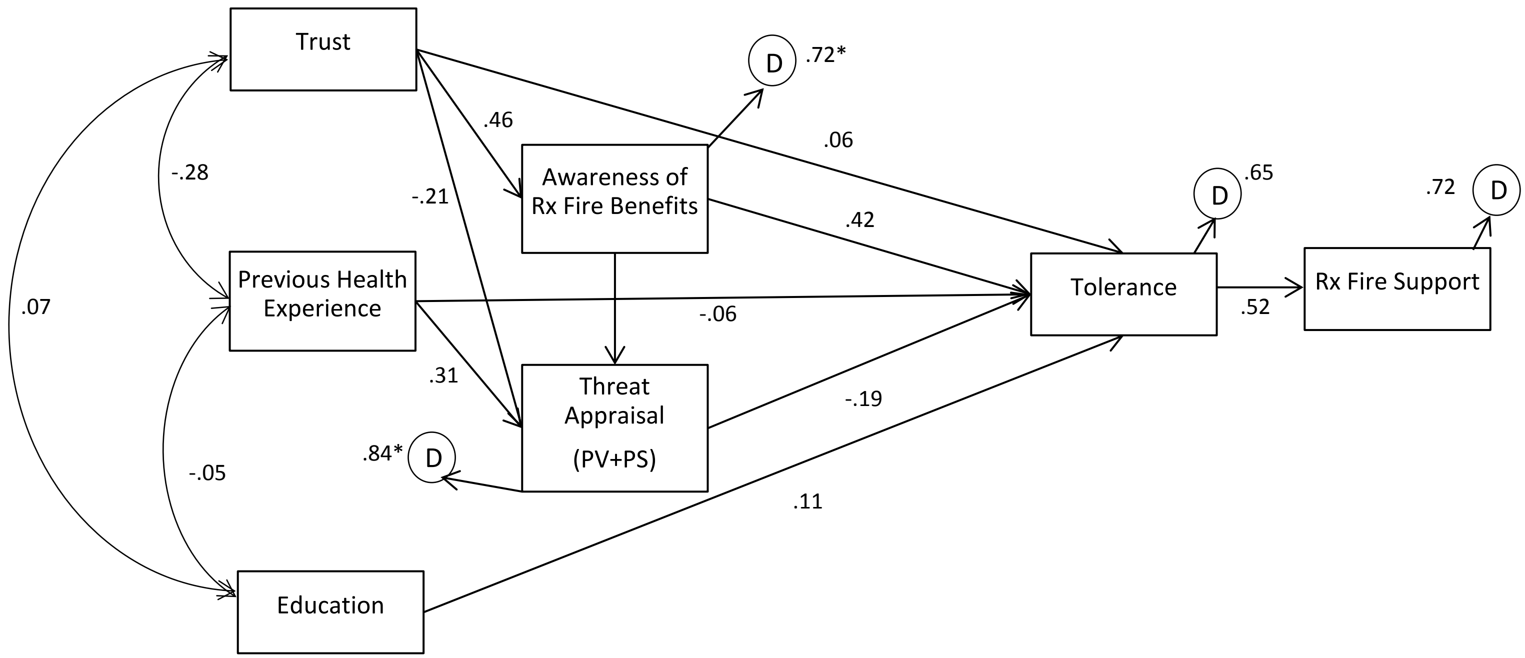

Figure 4. NORO final path measurement model. Numbers associated with single-headed arrows are standardized path coefficients. Numbers associated with curved double-headed arrows are correlations. Numbers within circles are the residuals associated with a dependent variable. All path coefficients are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

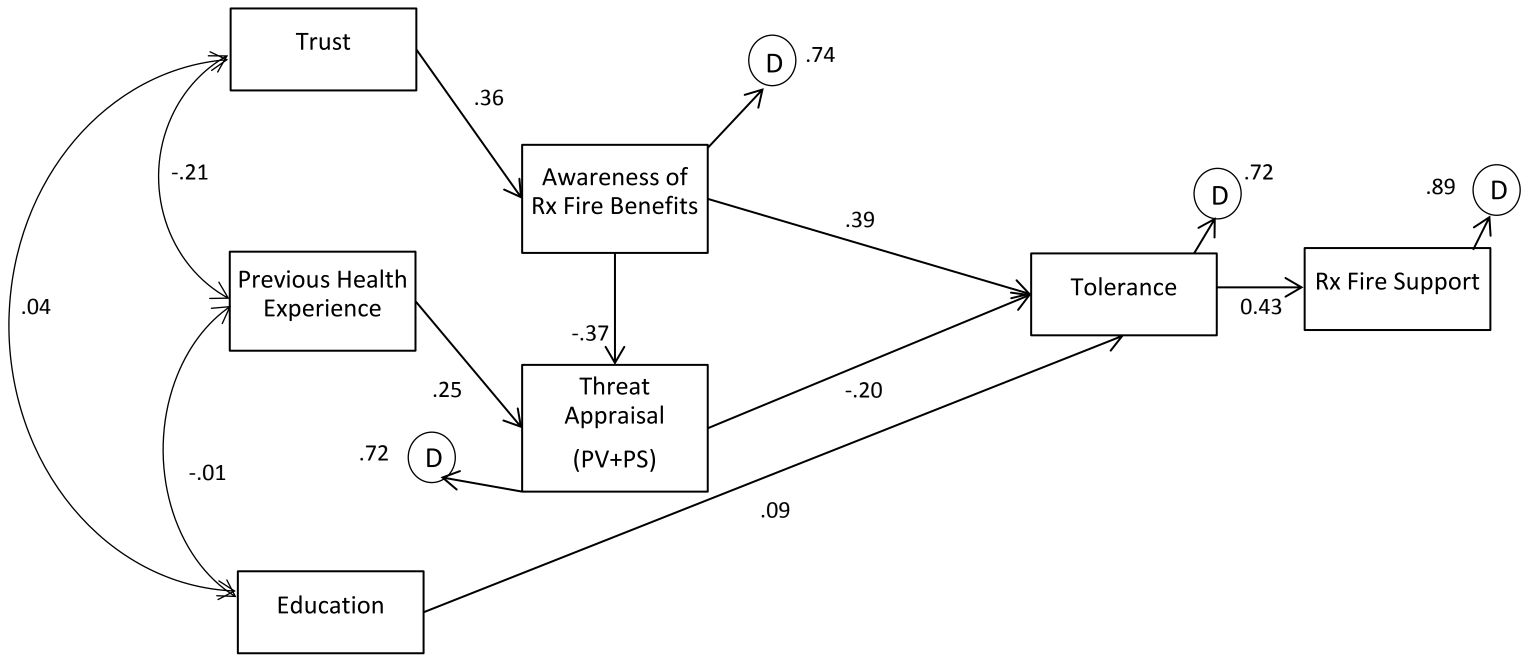

Figure 5. SOUTH final path measurement model. Numbers associated with single-headed arrows are standardized path coefficients. Numbers associated with curved double-headed arrows are correlations. Numbers within circles are the residuals associated with a dependent variable. All path coefficients are 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 I. 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.

Part I. Management Implications and Relationship to Other Research

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 and Future Work Needed

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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Part II. DECONSTRUCTING PUBLIC PREFERENCES AND TRADEOFFS ABOUT SMOKE FROM WILDLAND AND PRESCRIBED FIRES USING CONJOINT ANALYSIS

Background and Purpose

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.

Part II. Study Description and Location

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:

Minimum number of scenarios = Total number of levels across all factors − 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).

Part II. Key Findings, Management Implications, and Relationship to Other Research

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 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).

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.

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-	WUIMP	WUILP	Urban	Rural	Men	Women	Health	Health

		WUI							– Y	– 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

Part II. Conclusions and Future Work Needed

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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Deliverables Crosswalk

Deliverable Type	Description	Delivery Dates
Website	Emissions and Air Quality portal hosted by FRAMES: https://www.frames.gov/partner-sites/emissions-and-smoke/smoke-portal-home/	Fall 2011
Non-refereed Publication	Development of Online Smoke Photo Series	Spring 2014
Referred Publication **[Not listed in proposal]**	Hyde, Joshua C.; Blades, Jarod; Hall, Troy; Ottmar, Roger D; Smith, Alistair. 2015. Smoke management photographic guide – A visual aid for communicating smoke impacts. Gen. Tech. Rep. PNW-GTR-XXX. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 59 p	Spring 2015
Conference Presentations/Posters	Blades, J., & Hall, T. E. (2013). Engaging Students and Managers through Video Modules: Development of a Short Course about Public Perceptions of Smoke. International Smoke Symposium. Washington D.C.	2013
	Blades, J., & Hall, T. E. (2013). Public Tolerance of Smoke from Wildland Fire: Comparative Results from Surveys in Nine US States. International Smoke Symposium. Washington D.C.	2013
	Blades, J., & Hall, T. E. (2012). Enhancing Public Communication by Comparing Tolerance of Smoke from Wildland Fires in the Northern Rockies and South-Central U.S. Paper presented at the International Symposium on Society and Resource Management, Edmonton, Canada.	2012
	Blades, J., Hall, T. E., & Shook, S. (2012). Deconstructing public preferences and tradeoffs about smoke from wildland fires in the Northern Rockies using conjoint analysis. Paper presented at the 3rd Human Dimensions of Wildland Fire Conference, Seattle, Washington.	2012
	Blades, J., & Hall, T. E. (2012). The future is smoky: Toward explaining public tolerance of smoke from wildland fire and fuels management. Paper presented at the 3rd Human Dimensions of Wildland Fire Conference, Seattle, Washington.	2012
Refereed Publications	Blades, J., Hall, T. E., & Shook, S. (Accepted, in revision). Deconstructing public preferences and tradeoffs about smoke from wildland fires in the U.S. Northern Rocky Mountains and South-central U.S. using conjoint analysis. *Canadian Journal of Forest Research*	Summer 2014

	Two other publications are in preparation that address the comparison of highly and less prepared WUI communities and the path analytic model	In Prep
[Not listed in proposal]	Joshua C. Hyde, Kara M. Yedinak, Peter Lahm, Mark Fitch, Wade T. Tinkham, and Alistair M.S. Smith, A review of United States federal air quality policy and management responses addressing smoke from wildland fires, *Journal of the Air & Waste Management Association*	In review
Training Sessions	Classroom training: PhD student Blades provided a 20-minute training session session for the University of Idaho course FOR 454, Prescribed Fire Lab (Fall, 2013).	2013
	Webinar: Advances in Fire Practice. 60-minute webinar conducted by Advances in Fire Practice (September 20, 2012). The webinar was titled "Current Research on Public Perceptions of Smoke from Wildland and Prescribed Fire to Inform Communication and Outreach." Approximately 150 wildland and prescribed fire practitioners and researchers attended the webinar. The webinar can be viewed at http://www.youtube.com/watch?v=4pV21itPhME and is also available on our project website.	2012
	Webinar: Public perceptions and messaging about smoke and wildland fire (2011). NWCG Smoke Committee (SmoC) hosted a webinar in collaboration with the NWCG Communication, Education, and Prevention Committee, USFS Smoke FARM Team, and NIFC External Affairs. Webinar can be found at the project website on FRAMES.	2011
Training Module Videos	This is a four part video series, intended for Rx-410 and university courses, which addresses public beliefs and tolerance of smoke, individual and community characteristics, and public trust and advanced warnings. These training resources were developed and offered by the University of Idaho as part of an effort to enhance understanding and communications between fire practitioners and the public. These can be viewed and downloaded from the project website on FRAMES.	2013, 2014
Module 1	Why Public Perceptions Matter: https://www.youtube.com/watch?v=NwYwqXnV1_8&feature=youtu.be	2013
Module 2	Values, Beliefs, Attitudes, and Tolerance:	2013

	https://www.youtube.com/watch?v=I7FjEPoslec&feature=youtu.be	
Module 3	Individual and Community Characteristics: https://www.youtube.com/watch?v=tQlJuHlBMcU&feature=youtu.be	2014
Module 4	Public Trust and Advanced Warning: https://www.youtube.com/watch?v=ZVqxOS89o-w&feature=youtu.be	2014
Conference Special Session	Special Session (2013): Smoke and People: Bringing Clarity to Beliefs, Attitudes, and Influencing Factors. Moderator: Christine Olsen. International Smoke Symposium. Washington D.C.	2013
Ph.D. Dissertation	Blades Dissertation Defended at the University of Idaho. Bridging natural resource communication boundaries: Public perceptions of smoke from wildland fires and forest managers' perspectives of climate change science.	2013

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

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 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

Smoke Scenario 2

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

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 Public Service Announcement about anticipated smoke
- The smoke is from a prescribed fire
- The smoke would be very unhealthy for everyone (see picture 3)
- 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 4

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

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 personal phone call about anticipated smoke
- The smoke is from a prescribed fire
- There would be moderate health effects from smoke (see picture 1)
- 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

Smoke Scenario 6

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

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 <u>no advanced warning</u> about anticipated smoke
- The smoke is from a <u>wildfire</u> (lightning or unintentional)
- There would be <u>moderate health effects</u> from smoke (see picture 1)
- 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 8

- You receive a <u>personal phone call</u> about anticipated smoke
- The smoke is from a <u>prescribed-natural fire</u>
- The smoke would be <u>unhealthy for sensitive groups</u> (see picture 2)
- 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 9

- 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>unhealthy for sensitive groups</u> (see picture 2)
- 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

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

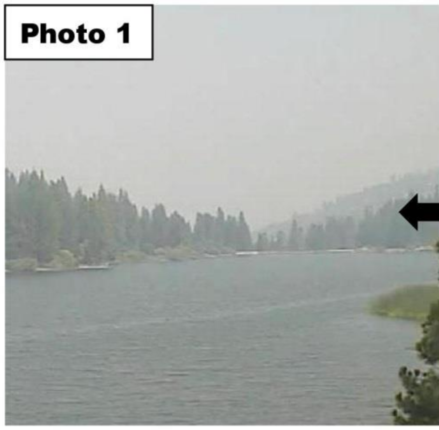
Joint Fire Science Program

Appendix F.

Supplemental Photos for Conjoint Scenarios – Public Perceptions of Smoke

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

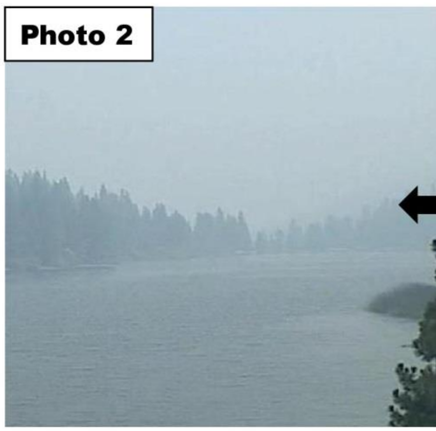
Photo 1



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.

Bivariate Correlations for Part I

Correlation matrix (*Pearson's r*) for factors and variables included in the path analytic model

	Factors and Variables	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.
1.	Tolerance	1																					
2.	Rx Fire Management Support	.516**	1																				
3.	Trust	.365**	.413**	1																			
4.	Awareness of Rx Benefits	.526**	.663**	.507**	1																		
5.	Biospheric Value Orientations	-.013	-.031	.205**	.068**	1																	
6.	Egoistic Value Orientations	.004	-.070**	-.004	-.006	-.196**	1																
7.	Threat Appraisal - All	-.421**	-.464**	-.260**	-.379**	.158**	-.011	1															
8.	Coping Appraisal - Stay	.009	-.045	.199**	.071**	.175**	.017	.205**	1														
9.	Coping Appraisal - Leave	-.011	-.017	.060**	.016	.122**	-.074**	.214**	.356**	1													
10.	Knowledge	.059*	.178**	-.056*	.100**	-.057*	.019	-.042	-.072**	-.063**	1												
11.	Experienced personal health effects from smoke	-.290**	-.259**	-.269**	-.223**	-.001	.010	.332**	.034	.053*	.089**	1											
12.	Family has experienced health effects from smoke	-.193**	-.181**	-.232**	-.168**	-.044	-.015	.270**	.026	.018	.123**	.468**	1										
13.	Urban or Rural	-.031	-.022	-.014	.002	-.035	.066**	-.017	.116**	.075**	-.083**	-.012	.010	1									
14.	Preparedness Stratification	-.131**	-.069**	-.158**	-.076**	-.060*	.031	.105**	.018	-.010	.067**	.151**	.207**	.515**	1								
15.	Age	-.069**	-.107**	-.055*	-.019	.015	.152**	.071**	-.022	-.077**	.131**	.049*	.014	-.054*	.084**	1							
16.	Education	.168**	.238**	.064**	.119**	-.015	-.226**	-.123**	-.090**	.040	.143**	-.051*	.002	-.117**	-.125**	-.067**	1						
17.	Permanent (year round) or part- time resident in community	-.014	-.035	-.040	-.043	-.009	.008	.022	.010	.034	-.019	.027	-.019	.006	-.006	.028	.032	1					
18.	Years lived in community	-.057*	-.035	-.067**	-.042	.008	.064**	.011	-.052*	-.102**	.097**	.056*	.057*	-.020	.016	.160**	-.037	-.001	1				
19.	Employment or any source of income related to forests	-.056*	-.085**	.012	-.069**	.056*	-.132**	.055*	.091**	.050*	-.113**	.020	-.004	-.023	-.079**	.058*	.062**	.049*	-.042	1			
20.	Gender	-.059*	-.085**	.095**	-.074**	.169**	-.112**	.206**	.194**	.043	-.102**	.076**	.050*	-.025	.016	-.062**	-.063**	.026	-.060*	.151**	1		
21.	Current household income before taxes	.146**	.208**	.042	.095**	-.034	-.147**	-.191**	-.044	.034	.072**	-.101**	-.052*	-.004	-.130**	-.230**	.449**	.049*	.023	.011	-.211**	1	
22.	Political Orientation	-.008	-.065**	-.115**	-.038	-.317**	.380**	-.033	.032	-.061**	-.053*	-.030	-.015	.131**	.022	.102**	-.173**	.001	-.018	-.003	-.167**	-.012	1
	N	1902	1899	1848	1866	1845	1843	1861	1858	1855	1872	1917	1917	1914	1914	1838	1845	1848	1843	1833	1827	1705	1815
	Mean	0.9	1.2	1.2	1.5	1.6	0.6	-0.2	1.2	-0.3	0.9	0.3	0.4	1.3	2.1	62.2	4.2	1.0	2.9	1.8	1.3	3.6	4.5
	SE	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.05	0.06	0.00	0.01	0.01	0.01	0.02	0.31	0.03	0.00	0.01	0.01	0.01	0.04	0.04

** $p< 0.01$, * $p < .05$

Appendix I.

Hypothesis Testing for Part I

Summary of research questions and supporting hypotheses

Overarching Research Question: How do cognitive factors and personal characteristics influence tolerance of smoke?					
Supporting RQs	**Hypotheses**	**TEST**	**OVERALL (combined regions)**	**NORO**	**SOUTH**
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.	**AC-BEN correlation with BIOSPHERIC** **Path BIO →AC-BEN**	**Not Supported** Weak correlation .068 NS relationship in path analysis (*p*=.19)	**Not Supported** Weak correlation .09 NS relationship in path analysis (*p*=.19)	**Not Supported** Weak correlation -.04 NS relationship in path analysis (*p*=.12)
	H2: A stronger egoistic value orientation will lead to increased awareness of the adverse consequences of smoke.	**EGOISTIC correlation with Risk Perceptions** **Path EGO → Risk Perceptions**	**Not Supported** Very weak correlation .01 NS relationship in path analysis (*p*=.19)	**Not Supported** Very weak correlation .014 NS relationship in path analysis (*p*=.70)	**Not Supported** Very weak correlation -.08 NS relationship in path analysis (*p*=.50)
RQ2. How do specific beliefs about the consequences of smoke and agency trust relate to tolerance of smoke?	*H3*: Increased perceptions of the benefits of using prescribed fire to improve forest health will increase tolerance of smoke.	**AC-BEN correlation Tolerance** **Path AC-BEN→TOL**	**Supported** Moderate correlation .53 Sig relationship in path analysis (β=.41, *p*<.01)	**Supported** Moderate correlation .54 Sig relationship in path analysis (β=.41, *p*<.01)	**Supported** Moderate correlation .45 Sig relationship in path analysis (β=.40, *p*<.01)
	H4: Increased threat appraisal of smoke impacts will decrease tolerance for smoke.	**Threat Appraisal correlation Tolerance** **Path Analysis: Threat Appraisal → Tolerance**	**Supported** Moderate neg correlation -.42 Sig relationship in path analysis (β=-.21, *p*<.01)	**Supported** Moderate neg correlation -.41 Sig relationship in path analysis (β=-.20, *p*<.01)	**Supported** Moderate neg correlation -.45 Sig relationship in path analysis (β=-.21, *p*<.01)
	H5: Increased coping appraisal will increase tolerance for smoke.	**RE Stay corr TOL** **Path RE Stay → TOL**	**Not Supported** Weak correlation .10 NS relationship in path analysis (*p*=.06)	**Not Supported**	**Not Supported**
		RE Leave corr TOL **Path RE Leave → TOL**	**Not Supported** Weak correlation .08 NS relationship in path analysis (*p*=.11)	**Not Supported**	**Not Supported**
		SE Stay corr TOL **Path RE Stay → TOL**	**Not Supported** Weak correlation -.06 NS relationship in path analysis (*p*=.08)	**Not Supported**	**Not Supported**
		RE Leave corr TOL **Path RE Leave → TOL**	**Not Supported** Weak correlation -.09 NS relationship in path analysis (*p*=.40)	**Not Supported**	**Not Supported**
	H6: Coping appraisal will moderate the effect of perceived vulnerability and perceived severity on tolerance.	**Interaction term for threat appraisal and coping appraisal to test effect on TOL**	Interaction term added to path model and was moderator was not significant. Model x2 and all fit indices became worse.		
	H7: Higher levels of agency trust will be associated with a higher awareness of the	**Trust corr AC-BEN**	**Supported**	**Supported**	**Supported**

	positive consequences associated with fire and smoke.	**Path Trust → AC-BEN**	Moderate correlation .51 Sig relationship in path analysis (β=.50, p<.01)	Moderate correlation .51 Sig relationship in path analysis (β=.50, p<.01)	Moderate correlation .51 Sig relationship in path analysis (β=.50, p<.01)
	H8: Higher levels of agency trust will be associated with lower threat appraisal of smoke impacts.	**Trust corr Risk Per** **Path Trust → RP**	**Supported** Correlation -.26 Sig relationship in path analysis (β=-.25, p<.01)	**Supported** Correlation -.30 Sig relationship in path analysis (β=-.29, p<.01)	**Not Supported** Weak correlation -.08 Non- Sig relationship in path analysis (β=.50, p>.05)
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.	**T-test TOL and Urb/Rural**	**Not Supported** – Inverse (may be rural sample size?) Mean Tolerance Urban (n=1393): .96 (.04) Mean Tolerance Rural (506): .85 (.07) (t=1.34, p=.01) Urban Tolerant of Smoke: 74% Rural Tolerant of Smoke: 71% Non-significant path coefficient	**Not Supported** – Inverse (may be rural sample size?) Mean Tolerance Urban (n=1233): .95 (.04) Mean Tolerance Rural (n=296): .69 (.10) (F=19.35, t=2.66, p<.01) Urban Tolerant of Smoke: 71% Rural Tolerant of Smoke: 61% Non-significant path coefficient	**Not Supported – no sig diff** Mean Tolerance Urban (n=160): 1.02 (.12) Mean Tolerance Rural (n=210): 1.37 (.09) (F=1.63, t=-.425, p=.67) Urban Tolerant of Smoke: 73% Rural Tolerant of Smoke: 77% Non-significant path coefficient
	H10: Rural residents will be more aware of the relationship between smoke and forest health.	**T-test AC-Ben and Urb/Rural (also tested item ACBEN_6)**	**Not supported** **No sig diffs**	**Not supported**	**Not supported**
	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.	**T-test Health effect (y/n) by TOL** **T-test ANY experience (y/n) by TOL**	**Supported** t=9.96, p<.01 Path coefficient Health → TOL significant	**Supported for Health, partially for any exp.** t=7.821, p<.01 Path coefficient Health → TOL significant t=3.56, p<.01 (Any experience) Path coefficient Any Exp → TOL non-significant	**Supported for Health, not for any exp.** t=5.9, p<.01 Path coefficient Health → TOL significant t=1.36, p=.17 (Any exp) Path coefficient Any Exp → TOL non-significant
	H12: Residents in WUI communities that are more prepared for fire will be more tolerant of smoke and (*H13*) fuels management than those that are not prepared.	**One-way ANOVA TOL by preparedness** **One-way ANOVA Rx Mngt support by prep**	**Supported** Tolerance Urban (n=584): 1.16 (.05) WUI More Prepared (n=620): .98 (.06) WUI Less Prepared (n=695): .68(.06)* $F_{2,1896}$= 16.9, p<.01	**Supported** Tolerance Urban: 1.16 (.05) WUI More Prepared: .98 (.06) WUI Less Prepared: .68(.06)* $F_{2,1526}$= 21.2, p<.01	**Partially Supported (management yes)** Tolerance Urban: 1.05 (.13) WUI More Prepared: 1.06 (.14) WUI Less Prepared: 1.06 (.12) $F_{2,367}$= .002, p=.99
			Management $F_{2,1893}$= 5.01, $p<.01$ Less prepared less supportive	Management $F_{2,1524}$= 11.23, p<.01 Less prepared less supportive	Management $F_{2,366}$= 3.39, p=.04 Urban more supportive than rural less prep

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Smoke Management Photographic Guide – A Visual Aid for Communicating Smoke Impacts

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Abstract

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When communicating emissions impacts with to the public, it can sometimes be difficult to quantitatively convey smoke concentrations. Regulators and land managers often refer to particulate matter concentrations in micrograms per cubic meter, but this may not be intuitive or meaningful to members of the public. The primary purpose of this guide is to serve as a tool for communicating potential particulate matter ($PM_{2.5}$) levels during wildfire events using visual representation. Examples of visibility impairment under various smoke concentrations and humidities have been modeled using the WinHaze program.

Keywords: air quality, regional haze, smoke management

Cooperators

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Introduction

When describing the impacts of emissions from wildland fire on air quality it is difficult to quantitatively assess smoke concentrations. Smoke is composed of a variety of chemical compounds, but regulators and land managers often focus on particulate matter (PM) owing to its effects on human health and visibility degradation. Particles in smoke generally range in size from 0.1 to 100 micrometers (μm) in diameter (Hardy et al. 2001). Particulate matter less than or equal to 10 μm in diameter (PM_{10}) and less than or equal to 2.5 μm in diameter ($PM_{2.5}$) are the most common size classes used in air quality measurement and monitoring. Particulate matter concentration is measured in units of micrograms per cubic meter ($\mu g \cdot m^{-3}$), but this may not be intuitive or meaningful to members of the public. The primary purpose of this guide is to serve as a tool for communicating the level of $PM_{2.5}$ by using visual representation.

Visibility is impacted by several factors, including the composition and concentration of wildland fire smoke. Particulate matter emitted from fire can contain ammonium nitrate (NH_4NO_3), ammonium sulfate ($(NH_4)_2SO_4$), and light absorbing carbon (LAC; Malm et al. 1994). The effect these compounds have on visibility can be magnified by relative humidity (RH), as water vapor binds to these particles and alters the way they absorb and reflect light (Malm et al. 2003). In addition, background levels of visibility vary geographically (Malm et al. 1994, Hand et al.

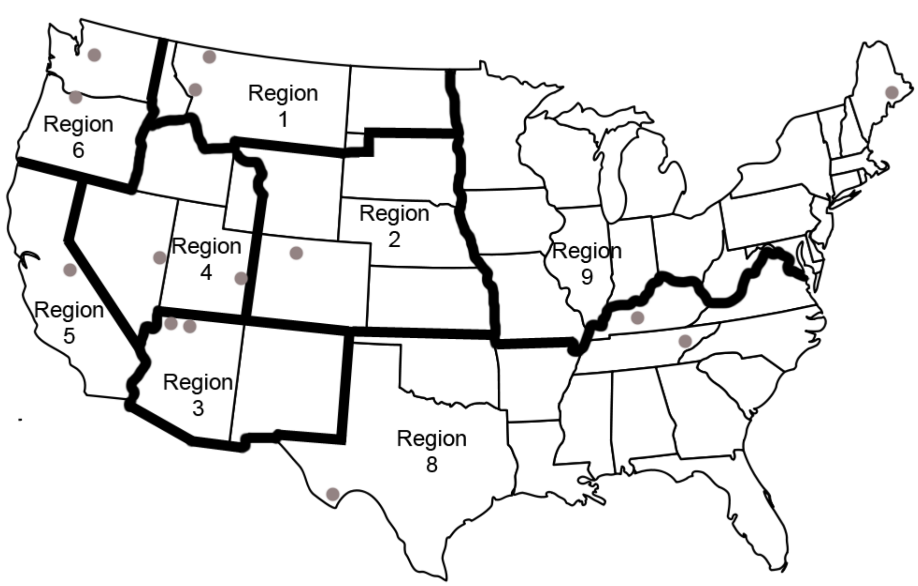

Figure 7—Map showing the location of U.S. Forest Service, Regions and photo site locations (grey dots). The images and data in this guide are intended to represent typical conditions in these regions.

R1: Selway-Bitterroot Wilderness (south), Glacier NP (north)
R2: Rocky Mountain NP
R3: Grand Canyon NP (both)
R4: Canyonlands NP (east), Great Basin NP (west)
R5: Yosemite NP
R6: Columbia River Gorge (south), Snoqualmie Pass (north)
R8: Great Smoky Mountains NP (east), Mammoth Cave NP (center), Big Bend NP (west)
R9: Acadia NP

This guide will help air quality regulators and land managers communicate $PM_{2.5}$ concentrations during wildland fires.

2014). This guide is intended to illustrate the effects of wildland fire smoke on visibility in U.S. Forest Service Regions 1-6, 8, and 9 (fig. 1). Due to the complex relationship between contrasts perceived by the naked eye, its relationship to visual range, and the subsequent particle concentration associated with those conditions, observed visual range approximations should be used as general indicators, not precise measurements.

This guide was developed with images from locations on National Park Service and U.S. Forest Service lands to assess visibility impairment associated with wildland fires. Images presented in this guide were generated by using WinHaze (Air Resource Specialists, Inc. 2013), a software tool developed to visualize the impacts of air pollutants on visibility.

Methods

To represent visual impacts from smoke in numerous locations across the United States this reference guide was generated using WinHaze imaging software version 2.9.9.1. (Air Resource Specialists, Inc. 2013). WinHaze incorporates several years of particulate monitoring data and images from National Parks and Wilderness Areas and simulates visibility based on those data and an equation to determine the reduction of visibility referred to as beta extinction (Hand and Malm 2006). The beta extinction equation and particulate monitoring data are products of the Interagency Monitoring of Protected Visual Environments (IMPROVE) program. Through the IMRPOVE program, stationary cameras and air quality monitoring equipment are stationed at several National Parks throughout the U.S. For full details on the IMPROVE monitoring network, methods equation for representing visibility impairment, please refer to the IMPROVE website (http://vista.cira.colostate.edu/improve/Default.htm).

The use of WinHaze allows for consistent visual representation of air quality under varying humidity, background pollutant, and $PM_{2.5}$ concentrations levels. Each example location in this guide contains a simulated baseline image to represent visual range under average particulate matter concentrations as found in the IMPROVE data contained in WinHaze. Also included are several images of simulated visual impairment from smoky conditions. Visual impairment from smoke was simulated first by establishing constant values for the constituents of PM 2.5 that are unlikely to change as the result of smoke from fires;

ammonium sulfate, ammonium nitrate, and fine soil were determined by using values recorded for the 20% worst visibility days. Organic carbon and black carbon were then increased to reflect increasing concentrations of smoke, as this carbon comprises nearly 75% of the emissions from forest fires (Andreae and Merlet 2001). The ratio of organic carbon to black carbon is represented by a 15.4:1 ratio based on estimates for wildland fire in non-tropical forests (Andreae and Merlet 2001). The coarse particulate inputs used to simulate each image were chosen based on the greater of two values: either the average value of the 20% worst monitored days, or 10% of the $PM_{2.5}$ concentration based on Ward and Hardy (1991). Based on the relationship between $PM_{2.5}$ and PM_{10} (Ward and Hardy 1991), elevated coarse particulates were represented to be 10% of the total $PM_{2.5}$ value (ammonium sulfate, ammonium nitrate, fine soil, organic carbon and black carbon).

The version of WinHaze used for this work includes the first version of the IMPROVE beta extinction equation, as described in Hand and Malm (2006). To improve the accuracy of the simulations presented here, a correction factor was applied to the organic carbon values prior to generating each image and visual range determination. The organic carbon correction factor accounts for hygroscopicity (based on Malm et al. 2005), such that the light scattering (total beta extinction) of organic carbon increased linearly by a factor of 1.2 at 80% RH relative to zero RH. Each photograph includes prominent landmarks with which to judge visual range. The distance between the camera locations and various landmarks was measured with Google Earth and verified by using location information from Air Resource Specialists, Inc.

Because RH impacts visibility and changes throughout the day and seasonally, a range of values were chosen to represent morning and afternoon monthly averages most likely to be present during the wildland fire season (May to September) in all locations in National Parks (EPA 2014). Because these data were unavailable for the chosen locations in Forest Service Region 6, meteorological station data were chosen from a location as geographically close to the available site as possible (NOAA 2014).

The $PM_{2.5}$ levels that were chosen for display in this guide, are those that are deemed as Good ($<38\ \mu g \cdot m^{-3}$), Unhealthy for Sensitive Groups (89-138 $\mu g \cdot m^{-3}$), and Unhealthy (139-351 $\mu g \cdot m^{-3}$) for short periods of time

Public health officials may recomment different actions based on the concentration of smoke in the area.

(1-3 hours) based on the levels outlined in *Wildfire smoke: a guide for public health officials* (table 1; Lipsett et al. 2012). The mid-point of each range was chosen to represent each heath level: 19 $\mu g \cdot m^{-3}$ for Good, 114 $\mu g \cdot m^{-3}$ for Unhealthy for Sensitive Groups and 245 $\mu g \cdot m^{-3}$ for Unhealthy. These levels correspond to actions that need to be taken by public health officials, where Good requires no action, Unhealthy for Sensitive Groups merits warnings or alerts to those with heart or lung conditions, or other pertinent health issues, and Unhealthy requires that all people should be notified, regardless of health status (Lipsett et al. 2012). The specific values were chosen because they are sufficiently different as to be easily discernable to the naked eye.

Table 1—Photographs and visual range estimates representing the PM concentration mid-points of the Good (19 $\mu g \cdot m^{-3}$), Unhealthy for Sensitive Groups (114 $\mu g \cdot m^{-3}$), and Unhealthy (245 $\mu g \cdot m^{-3}$) categories. Adapted from Lipsett et al. (2012) and EPA (2013)

Air Quality	PM_{10} or $PM_{2.5}$ Concentration[a]	Actions to protect one's health from PM_{10} or $PM_{2.5}$ pollution
	$\mu g \cdot m^{-3}$	
Good	0-38	- None
Moderate	39-88	- Unusually sensitive people should consider reducing prolonged or heavy exertion
Unhealthy for Sensitive Groups	89-138	- People with heart or lung disease, children, and older adults should reduce prolonged or heavy outdoor exertion - Everyone else should limit prolonged or heavy exertion
Unhealthy	139-351	- People with heart or lung disease, children, and older adults should avoid all physical activity outdoors - Everyone else should avoid prolonged or heavy exertion
Very Unhealthy	>351	- People with heart or lung disease, children, and older adults should remain indoors and keep activity levels low - Everyone else should avoid all physical activity outdoors

[a]Particulate Matter concentrations are 1- to 3-hr averages

Using This Guide

Each set of photographs in this guide is preceded by a description of the air quality data for the site depicted. This includes the date range and number of sampling days of particulate matter data used by WinHaze, the source for the RH data, a table listing the constituents of smoke (both $PM_{2.5}$ and PM_{10}) represented in the images, and a table listing all of the visible range distances for each $PM_{2.5}$ concentration and RH level.

To use this guide to represent $PM_{2.5}$ concentration, select the Region and location that best matches the terrain and RH conditions of the location you are assessing and compare your line of sight with landmarks that are located at distances that are similar to those shown in the photographs. For each location, images are included that represent baseline (smoke free), Good (19 $\mu g \cdot m^{-3}$), Unhealthy for Sensitive Groups (114 $\mu g \cdot m^{-3}$), and Unhealthy (245 $\mu g \cdot m^{-3}$) conditions, except in cases where no distinction could be made between photographs, which sometimes occurs at the higher $PM_{2.5}$ concentration levels.

Tables documenting the constituents of particulate matter (PM) at different concentration levels, and visual range at different PM concentration and relative humidity levels are included for each set of photo-graphs.

Limitations

Visual range is simulated based on scientific analysis of air quality data and the constituents of wildland fire smoke. Images included in this guide were generated independently of sun angle, which does affect visibility. Those seeking more information on the influence of sun angle on visibility can refer to: Malm and Schitchtel (2013) and Middleton (1968). It should also be noted that the $PM_{2.5}$ concentration levels for Good, Unhealthy for Sensitive Groups, and Unhealthy conditions shown in the photographs are based on average $PM_{2.5}$ levels over a 1-3 hour period, not the instantaneous $PM_{2.5}$ concentration, and that visual range can change relatively rapidly.

English Equivalents

When you know:	Multiply by:	To find:
Microns (µm)	0.039	Mil
Kilometers (km)	0.62	Miles

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U.S. Forest Service, Region 1 –Glacier National Park & Selway-Bitterroot Wilderness, MT

Particulate data from 1,037 days of sampling (March 1988 to May 1999) at Glacier National Park were chosen to represent baseline and elevated regional air quality concentrations (table 2). The baseline image represents an area free of smoke-impaired visibility (<5 $\mu g \cdot m^{-3}$ fine and coarse particulates). Visual range at different levels of $PM_{2.5}$ concentration (19, 114, and 245 $\mu g \cdot m^{-3}$) and RH are noted (table 3) and illustrated for the Selway-Bitterroot Wilderness and Glacier National Park on the following pages. Data used for estimating the effect of RH on visual range during the May-September fire season are from Glacier National Park (≥40% RH; EPA 2014) and Missoula, MT (<40% RH; NOAA 2014).

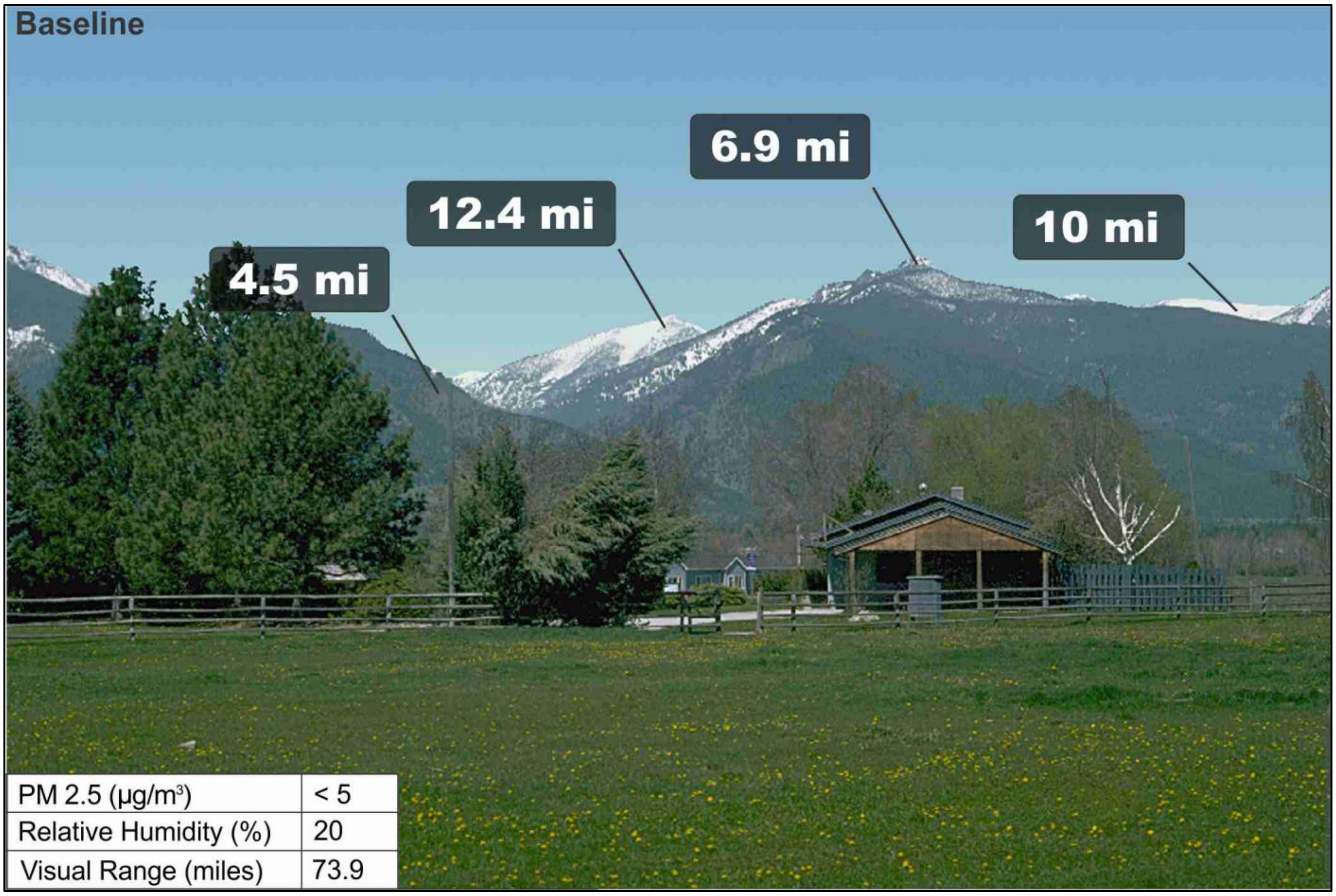
Table 2—Constituents of particulate matter ($PM_{2.5}$ and PM_{10}) at baseline and elevated levels in the Selway-Bitterroot Wilderness and Glacier National Park, MT

Particulate Matter	Particulate Matter Concentration			
Constituents	**Baseline**	**19**	**114**	**245**
	$\mu g \cdot m^{-3}$			
Ammonium sulfate	0.96	1.29	1.29	1.29
Ammonium nitrate	0.30	0.61	0.61	0.61
Organic carbon	2.67	14.95	104.14	227.13
LAC/Black carbon	0.43	0.97	6.78	14.79
Fine soil	0.58	1.19	1.19	1.19
Coarse mass	6.12	10.21	11.40	24.50

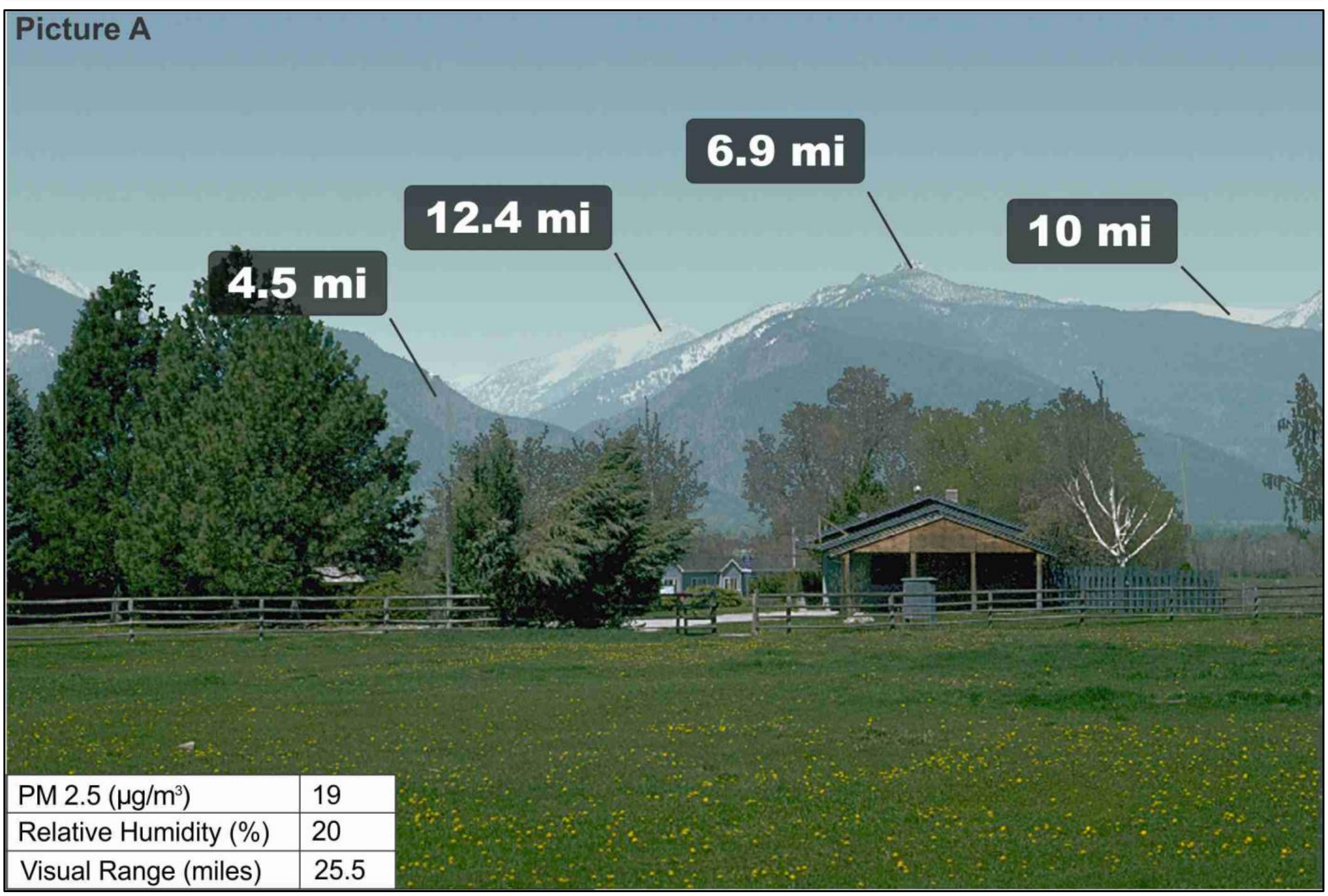
Table 3—Visual range as a function of $PM_{2.5}$ concentration and relative humidity in the Selway-Bitterroot Wilderness (SBW) and Glacier National Park (GNP), MT

$PM_{2.5}$ Concentration	Relative Humidity	Visual Range	
$\mu g \cdot m^{-3}$	*percent*	*miles*	*km*
<5 (baseline, SBW)	20	73.9	119.0
(baseline, GNP)	40	72.7	117.0
19 (picture A, SBW)	20	25.5	41.0
	30	25.1	40.4
(picture A, GNP)	40	24.6	39.6
	60	23.1	37.2
	80	21.3	34.3
	90	19.9	32.1
114 (picture B, SBW)	20	4.6	7.4
	30	4.5	7.3
(picture B, GNP)	40	4.4	7.1
	60	4.2	6.8
	80	4.0	6.5
	90	3.9	6.3
245 (picture C, SBW)	20-30	2.1	3.4
(picture C, GNP)	40	2.1	3.3
	50-60	2.0	3.2
	70-90	1.9	3.1

SELWAY-BITTERROOT WILDERNESS, MT

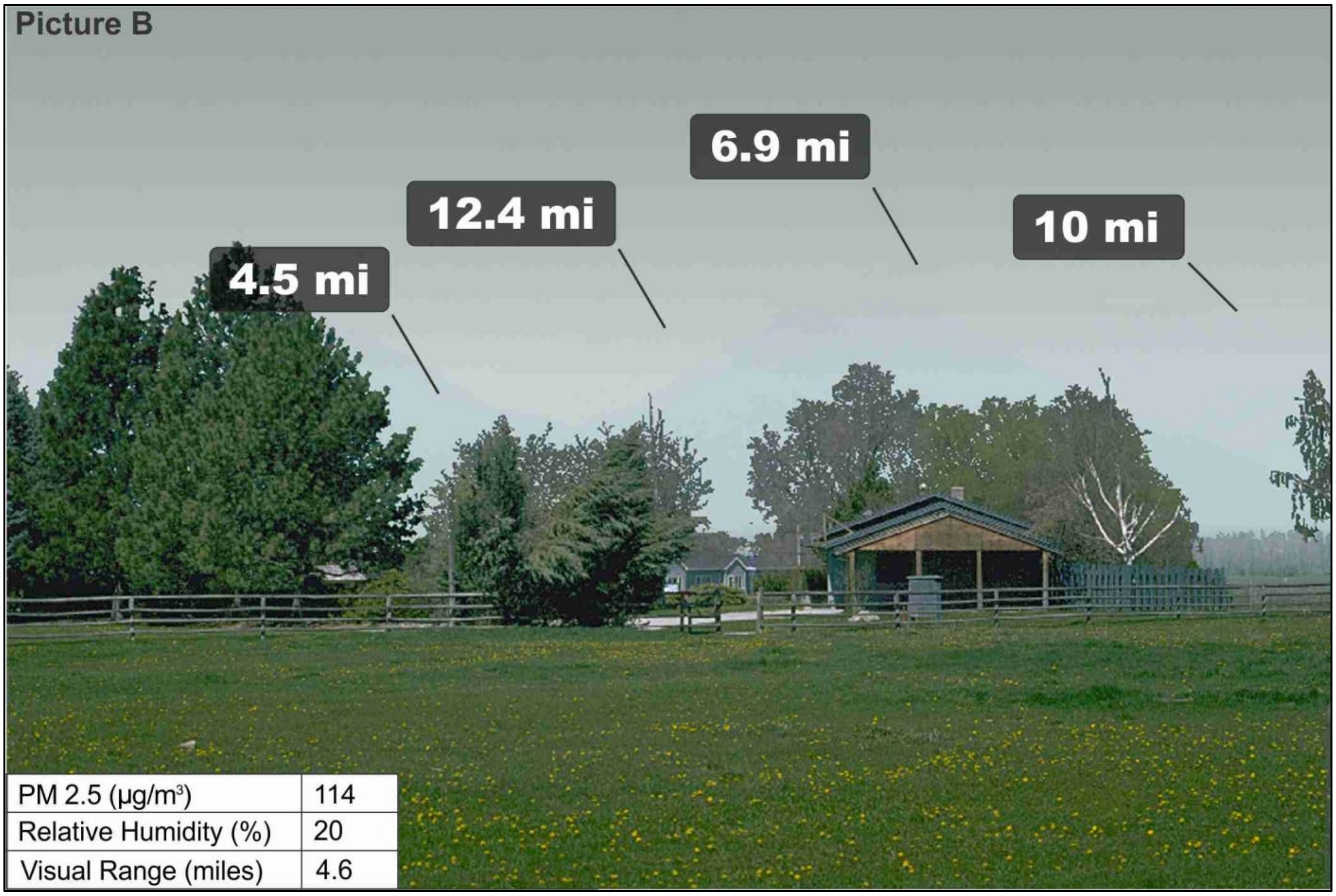


PM 2.5 (µg/m³)	< 5
Relative Humidity (%)	20
Visual Range (miles)	73.9



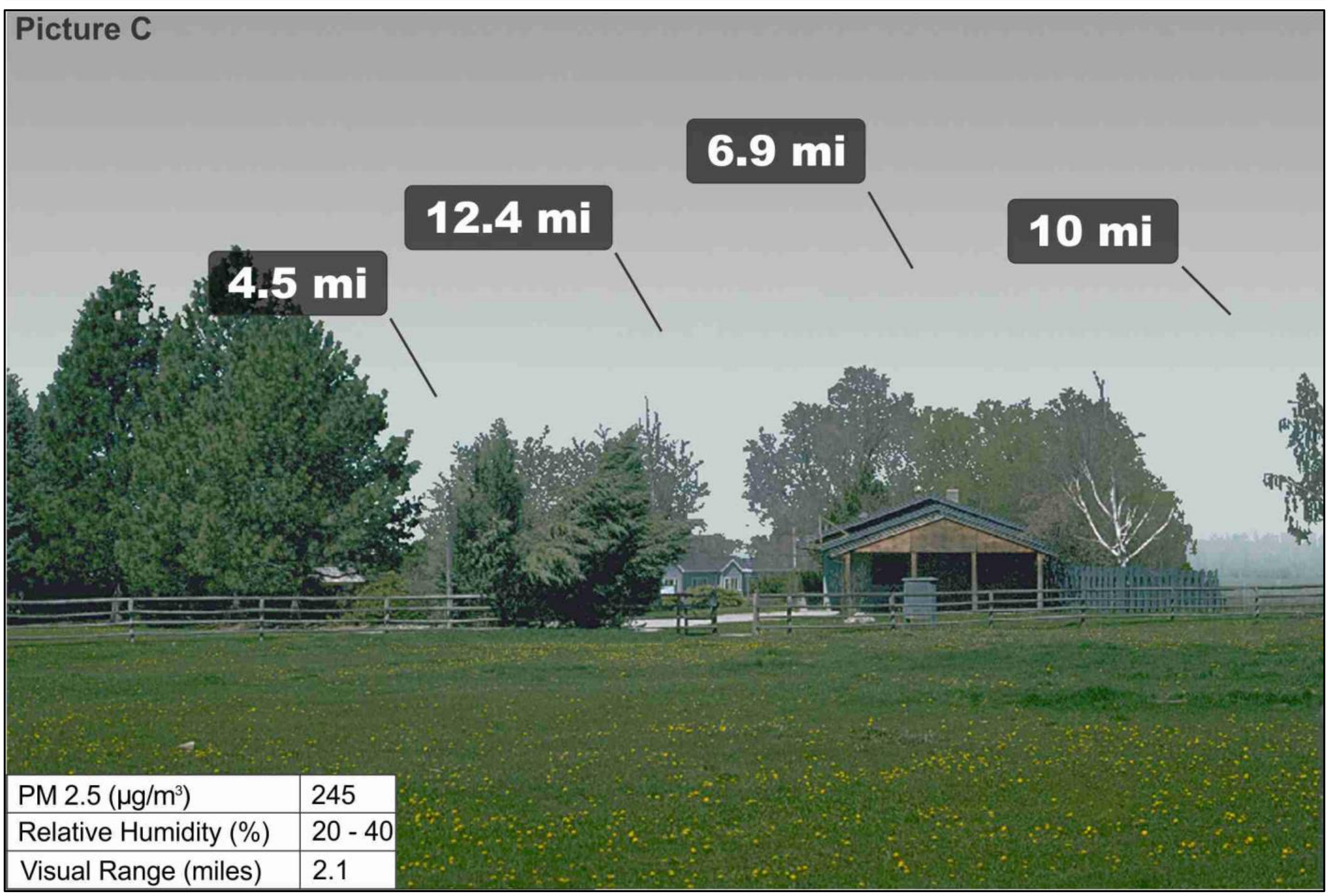
PM 2.5 (µg/m³)	19
Relative Humidity (%)	20
Visual Range (miles)	25.5

Picture B



PM 2.5 (µg/m³)	114
Relative Humidity (%)	20
Visual Range (miles)	4.6

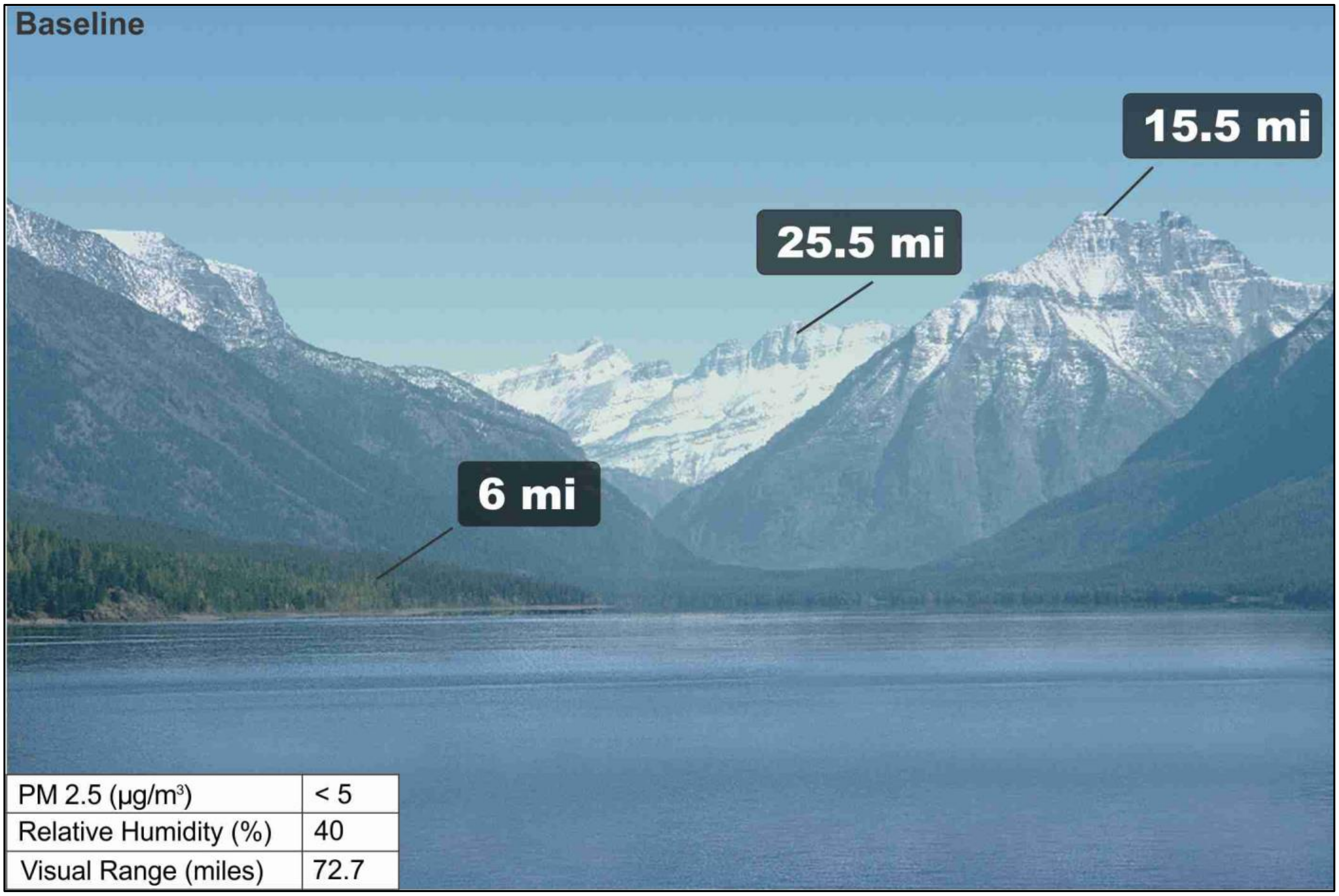
Picture C



PM 2.5 (µg/m³)	245
Relative Humidity (%)	20 - 40
Visual Range (miles)	2.1

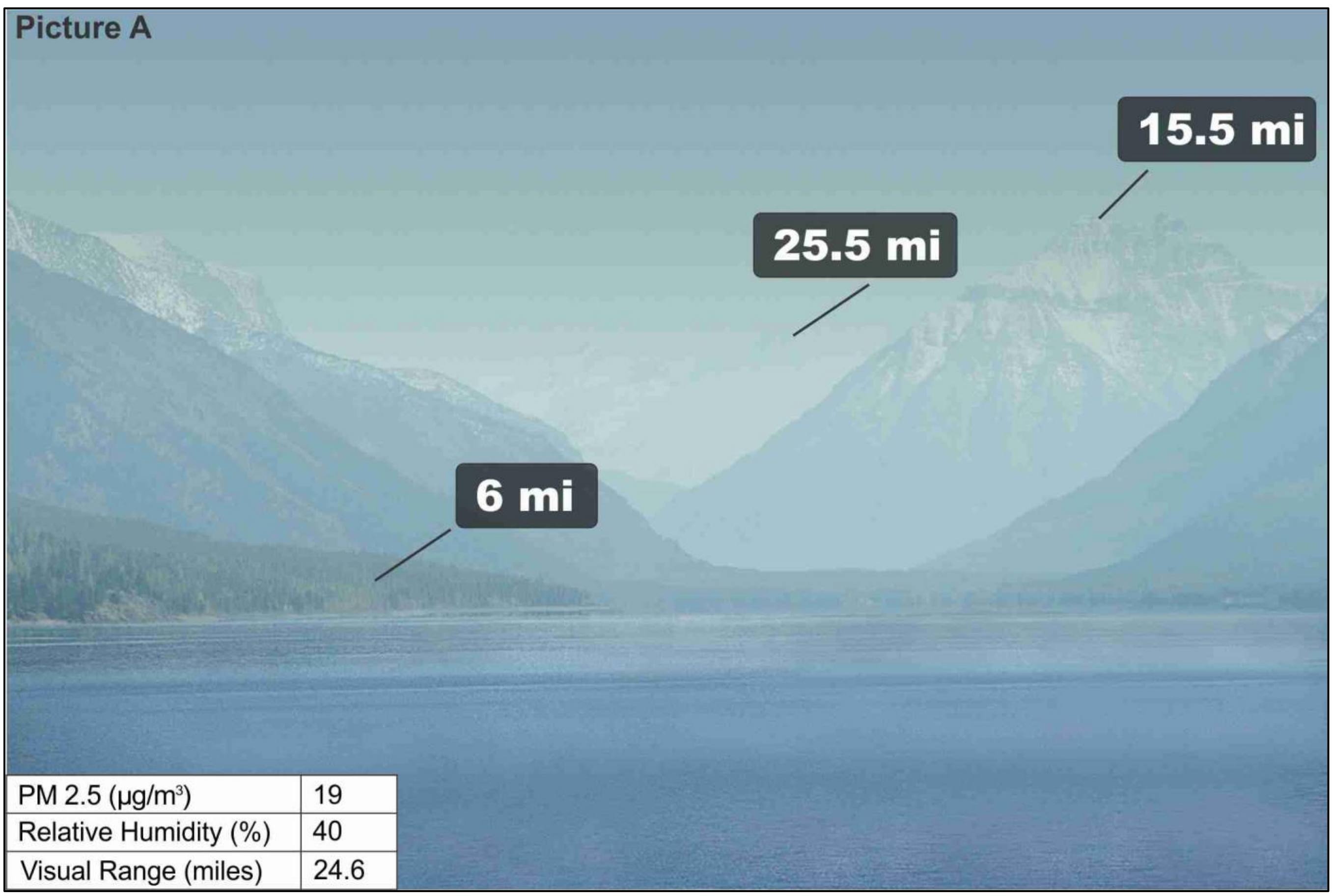
GLACIER NATIONAL PARK, MT

Baseline

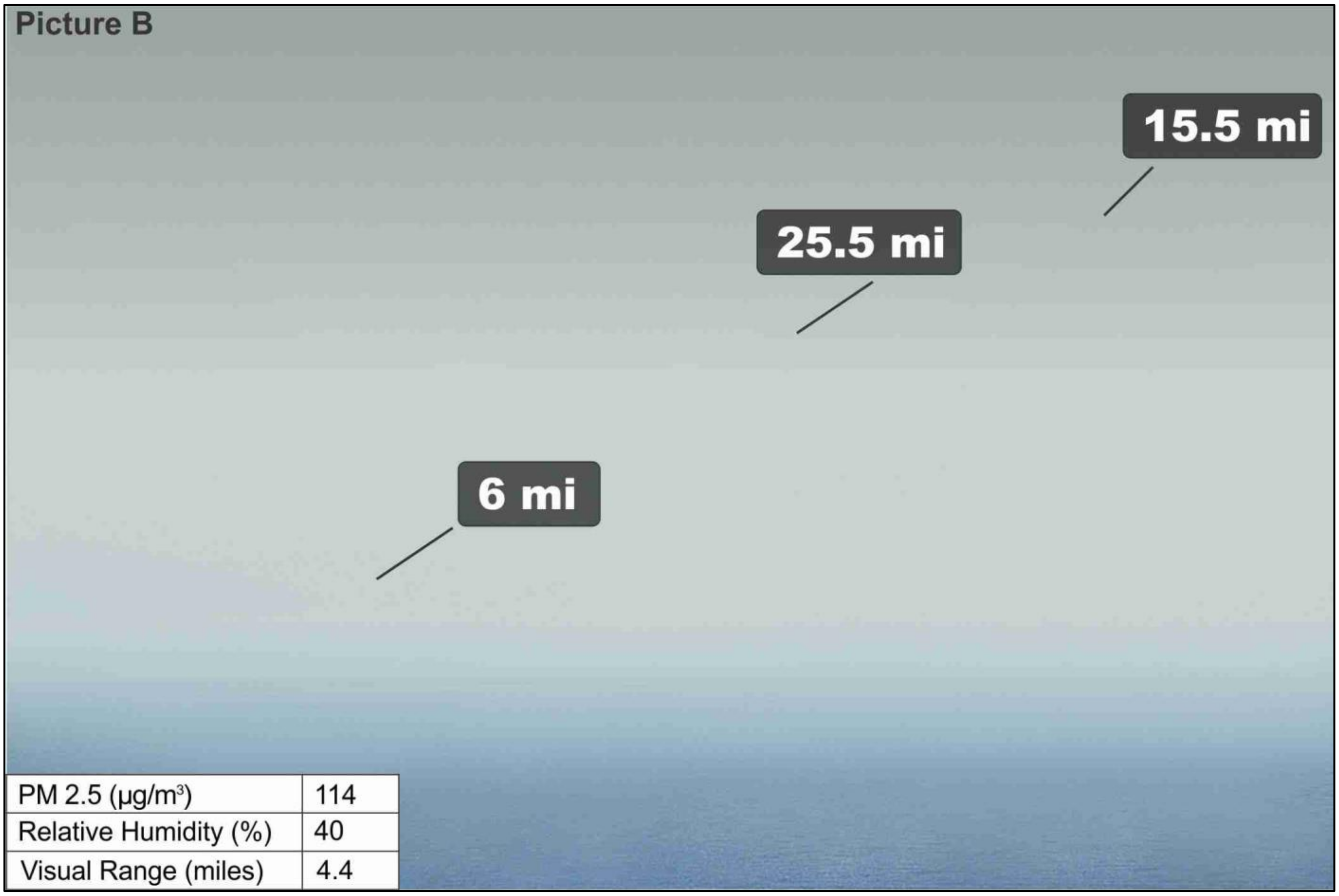


PM 2.5 (μg/m³)	< 5
Relative Humidity (%)	40
Visual Range (miles)	72.7

Picture A



PM 2.5 (μg/m³)	19
Relative Humidity (%)	40
Visual Range (miles)	24.6


Picture B
15.5 mi
25.5 mi
6 mi
PM 2.5 (µg/m³) 114
Relative Humidity (%) 40
Visual Range (miles) 4.4

U.S. Forest Service, Region 2 – Rocky Mountain National Park, CO

Particulate data from 794 days of sampling (September 1990 to May 1999) at Rocky Mountain National Park were chosen to represent baseline and elevated regional air quality concentrations (table 4). The baseline image represents an area free of smoke-impaired visibility (<5 $\mu g \cdot m^{-3}$ fine and coarse particulates). Visual range at different levels of $PM_{2.5}$ concentration (19, 114, and 245 $\mu g \cdot m^{-3}$) and RH are noted (table 5) and illustrated for Rocky Mountain National Park on the following pages. Data used for estimating the effect of RH on visual range during the May-September fire season are from Rocky Mountain National Park (EPA 2014).

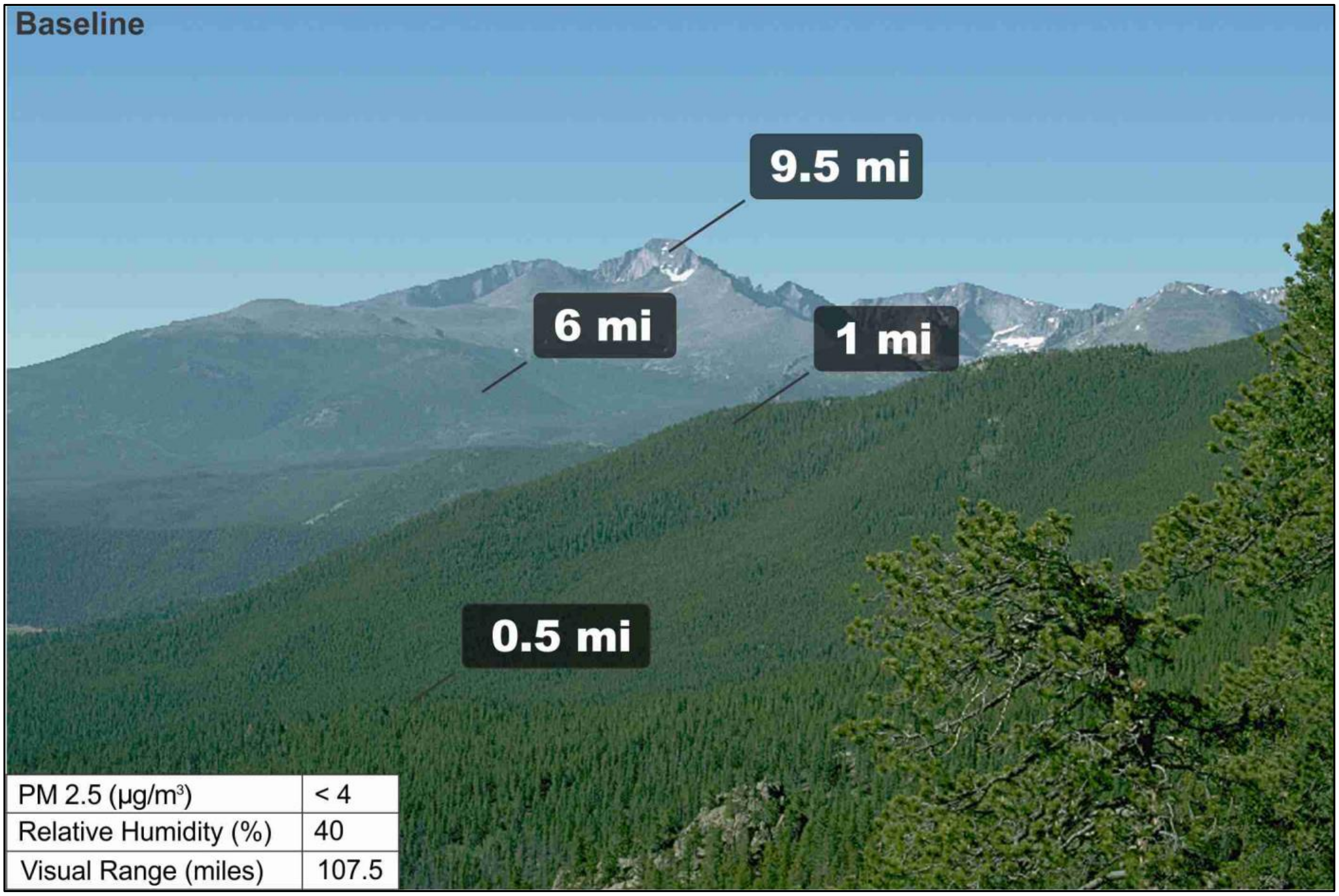
Table 4—Constituents of particulate matter ($PM_{2.5}$ and PM_{10}) at baseline and elevated levels in Rocky Mountain National Park, CO

Particulate Matter Constituents	**Particulate Matter Concentration** Baseline	**19**	**114**	**245**
	----------------	$\mu g \cdot m^{-3}$	----------------	
Ammonium sulfate	0.93	1.49	1.49	1.49
Ammonium nitrate	0.29	0.50	0.50	0.50
Organic carbon	1.00	14.77	103.96	226.95
LAC/Black carbon	0.17	0.96	6.77	14.78
Fine soil	0.63	1.28	1.28	1.28
Coarse mass	3.96	5.88	11.40	24.50

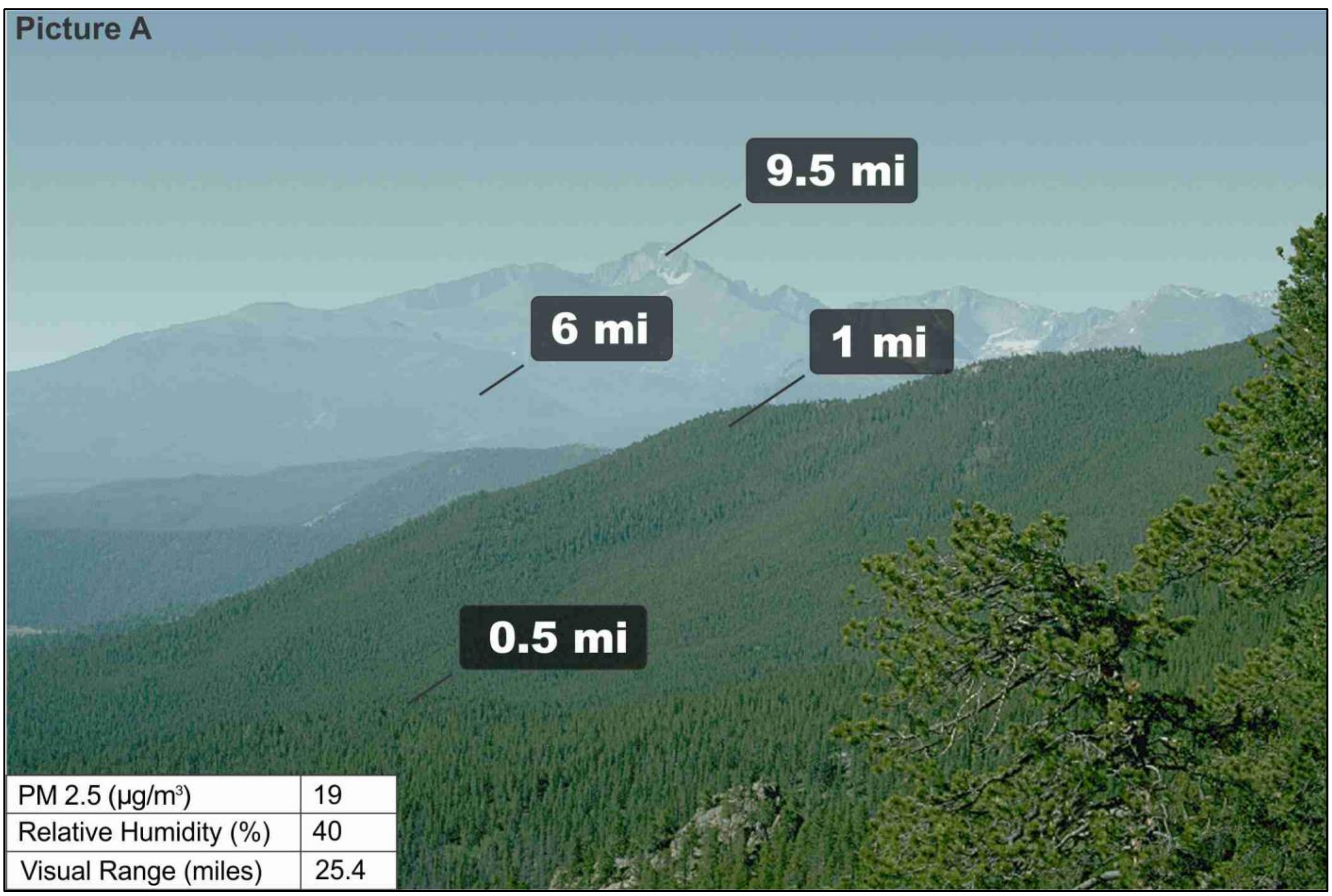
Table 5—Visual range as a function of $PM_{2.5}$ concentration and relative humidity in Rocky Mountain National Park, CO

$PM_{2.5}$ Concentration	**Relative Humidity**	**Visual Range**	
$\mu g \cdot m^{-3}$	*percent*	*miles*	*km*
<5 (baseline)	40	107.5	173.0
19 (picture A)	40	25.4	40.9
	50	24.6	39.6
	60	23.8	38.3
114 (picture B)	40	4.4	7.1
	50	4.3	7.0
	60	4.2	6.8
245 (picture C)	40	2.1	3.3
	50-60	2.0	3.2

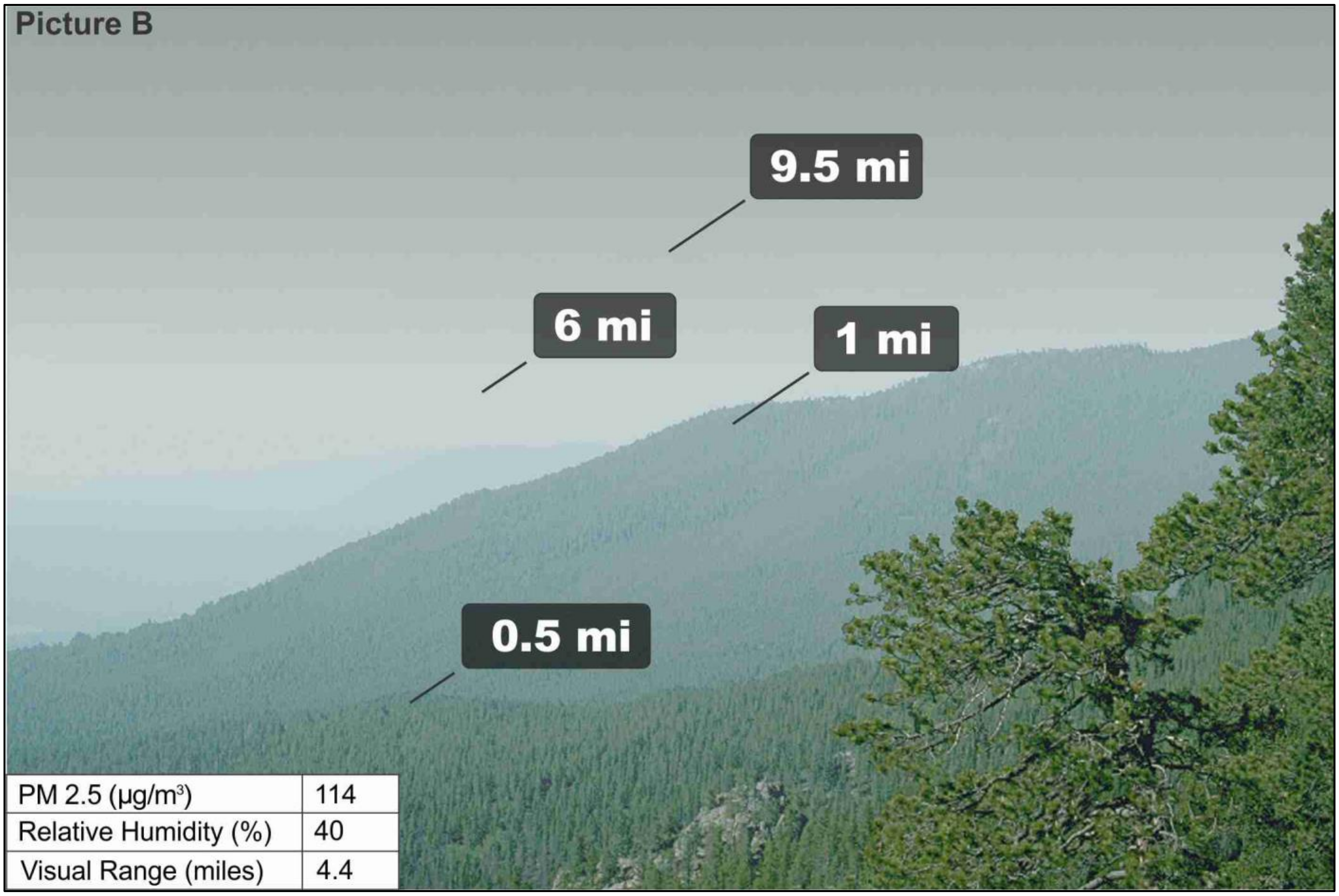
ROCKY MOUNTAIN NATIONAL PARK, CO



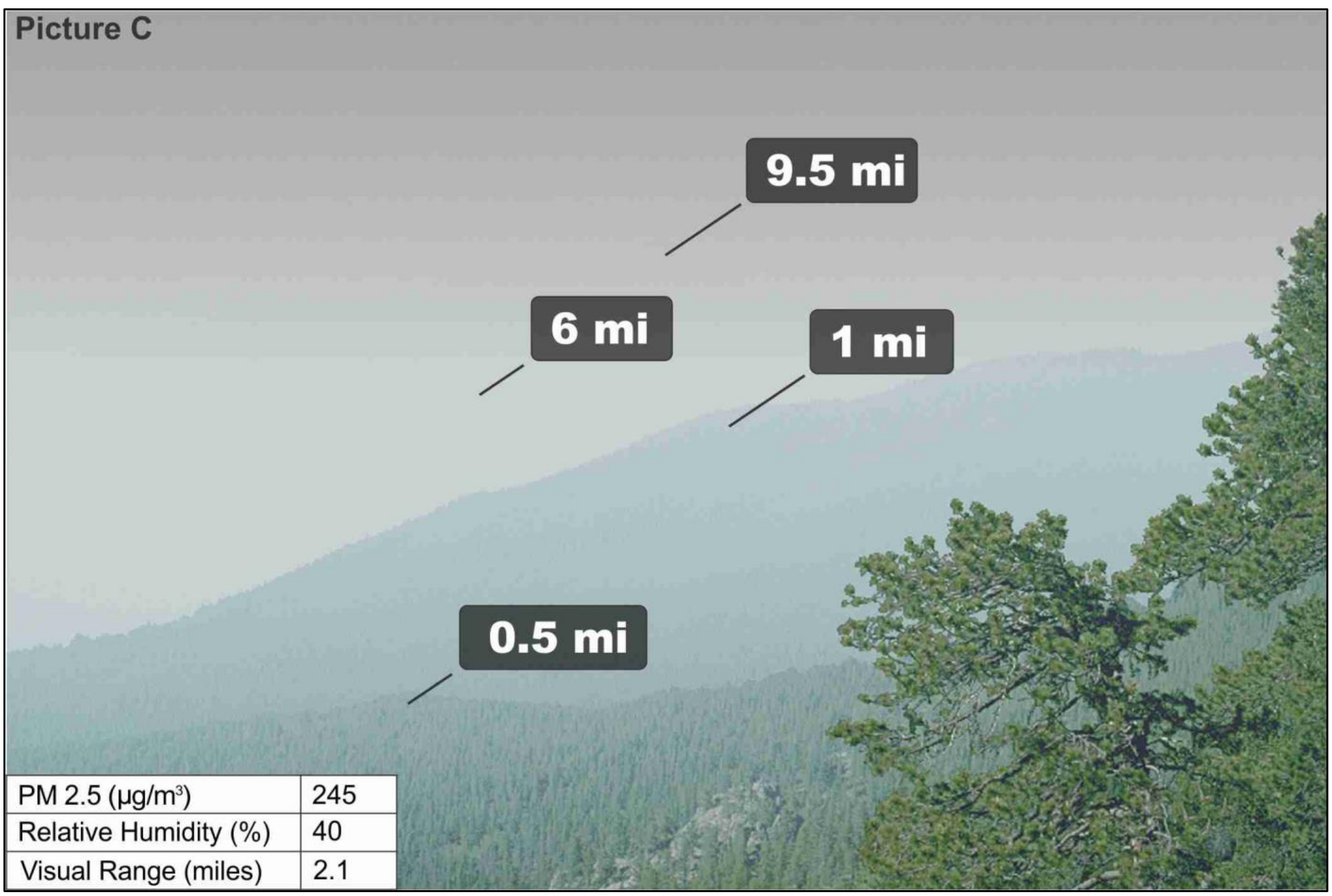
PM 2.5 (µg/m³)	< 4
Relative Humidity (%)	40
Visual Range (miles)	107.5



PM 2.5 (µg/m³)	19
Relative Humidity (%)	40
Visual Range (miles)	25.4



PM 2.5 (µg/m³)	114
Relative Humidity (%)	40
Visual Range (miles)	4.4



PM 2.5 (µg/m³)	245
Relative Humidity (%)	40
Visual Range (miles)	2.1

U.S. Forest Service, Region 3 – Grand Canyon National Park, AZ

Particulate matter data from 857 days (March 1988 to August 1998) at Grand Canyon National Park were chosen to represent baseline and elevated regional air quality concentrations (table 6). The baseline image represents an area free of smoke-impaired visibility (<5 $\mu g \cdot m^{-3}$ fine and coarse particulates). Visual range at different levels of $PM_{2.5}$ concentration (19, 114, and 245 $\mu g \cdot m^{-3}$) and RH are noted (table 7) and illustrated for Grand Canyon National Park on the following pages. Data used for estimating the effect of RH on visual range during the May-September fire season are from Grand Canyon National Park (EPA 2014).

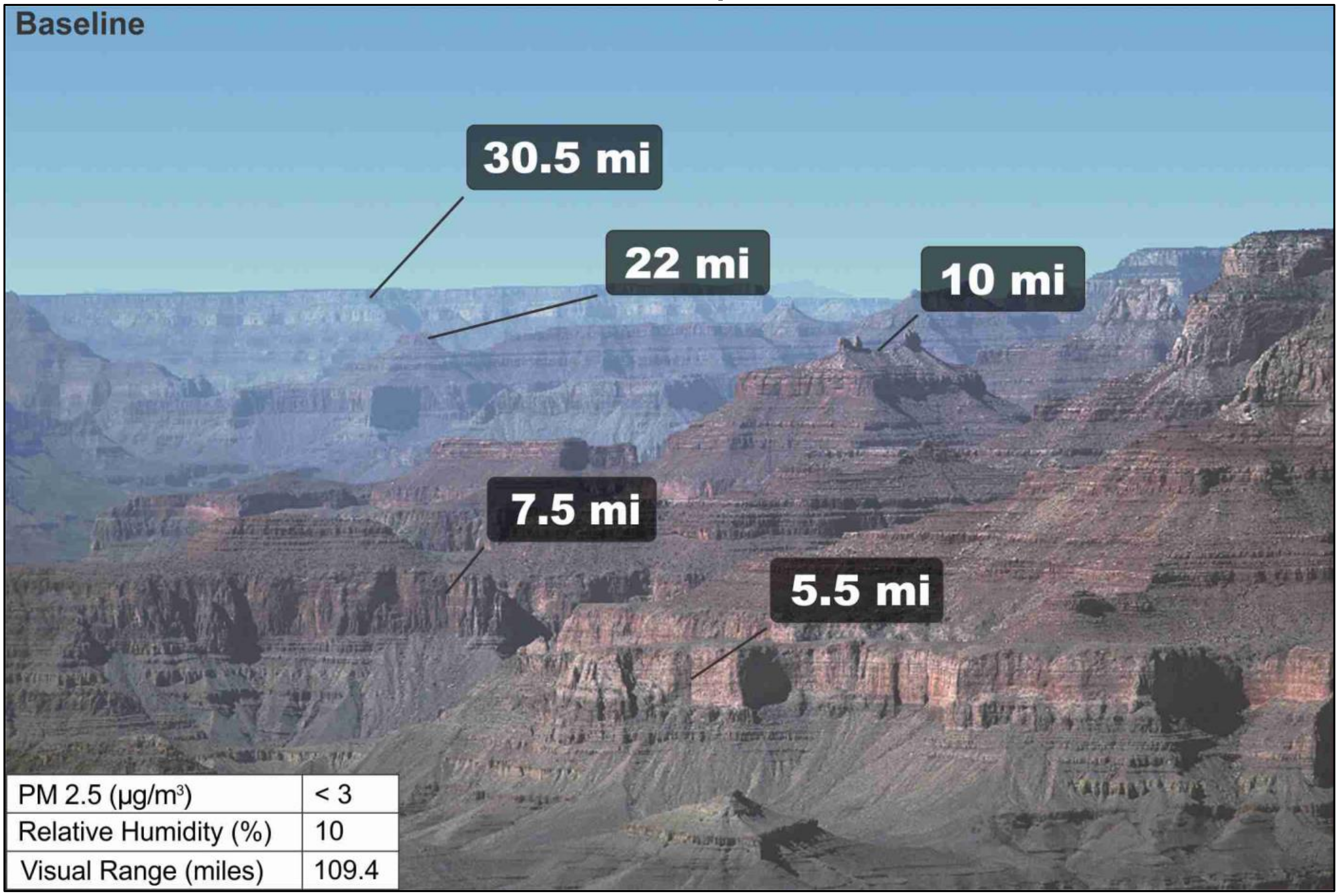
Table 6—Constituents of particulate matter ($PM_{2.5}$ and PM_{10}) at baseline and elevated levels in Grand Canyon National Park, AZ

Particulate Matter	Particulate Matter Concentration			
Constituents	**Baseline**	**19**	**114**	**245**
	----------------------------- *$\mu g \cdot m^{-3}$* -----------------------------			
Ammonium sulfate	1.01	1.59	1.59	1.59
Ammonium nitrate	0.20	0.31	0.31	0.31
Organic carbon	0.80	14.90	104.09	227.08
LAC/Black carbon	0.18	0.97	6.78	14.79
Fine soil	0.61	1.23	1.23	1.23
Coarse mass	4.99	7.16	11.40	24.50

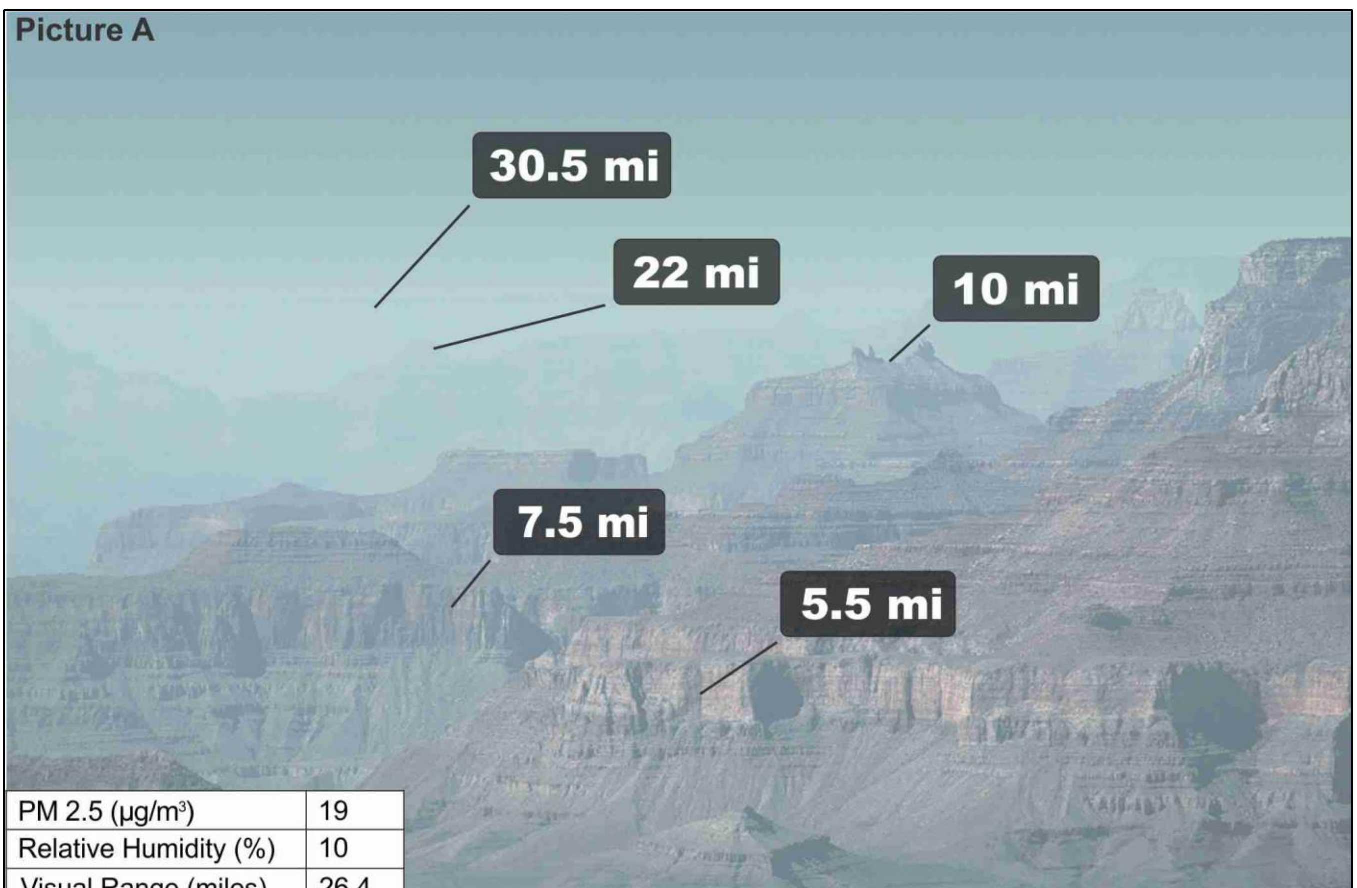
Table 7—Visual range as a function of $PM_{2.5}$ concentration and relative humidity in Grand Canyon National Park, AZ

$PM_{2.5}$ Concentration	Relative Humidity	Visual Range	
$\mu g \cdot m^{-3}$	*percent*	*miles*	*km*
<5 (baseline)	10	109.4	176.0
19 (picture A)	10	26.4	42.5
	20	26.0	41.8
	30	25.6	41.2
	40	25.1	40.4
	50	24.4	39.2
	60	23.5	37.9
114 (picture B)	10	4.7	7.6
	20	4.6	7.4
	30	4.5	7.3
	40	4.4	7.1
	50	4.3	7.0
	60	4.2	6.8
245 (picture C)	10	2.2	3.5
	20-40	2.1	3.4
	50	2.0	3.2
	60	1.9	3.1

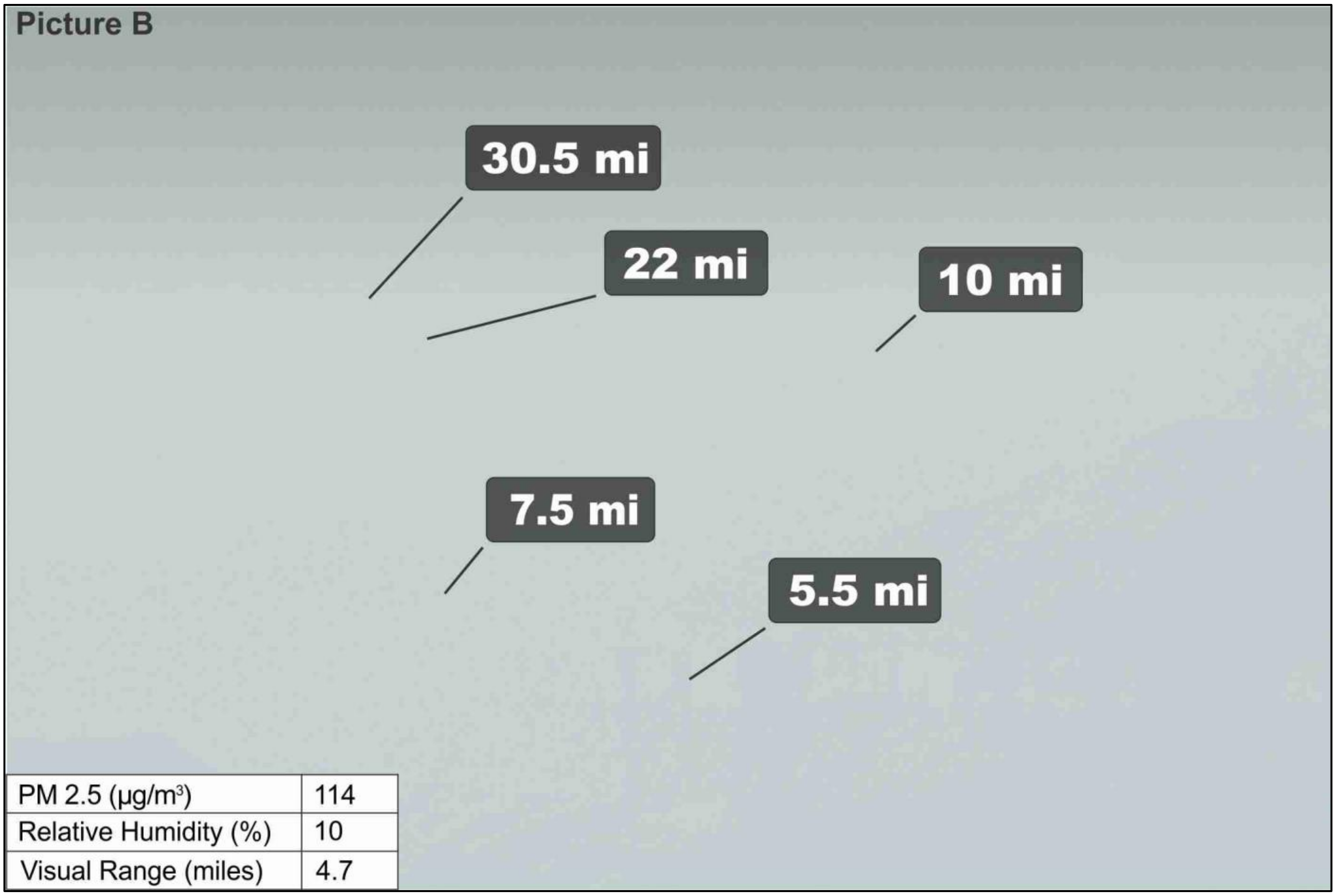
GRAND CANYON NATIONAL PARK, AZ – Example 1



PM 2.5 (μg/m³)	< 3
Relative Humidity (%)	10
Visual Range (miles)	109.4

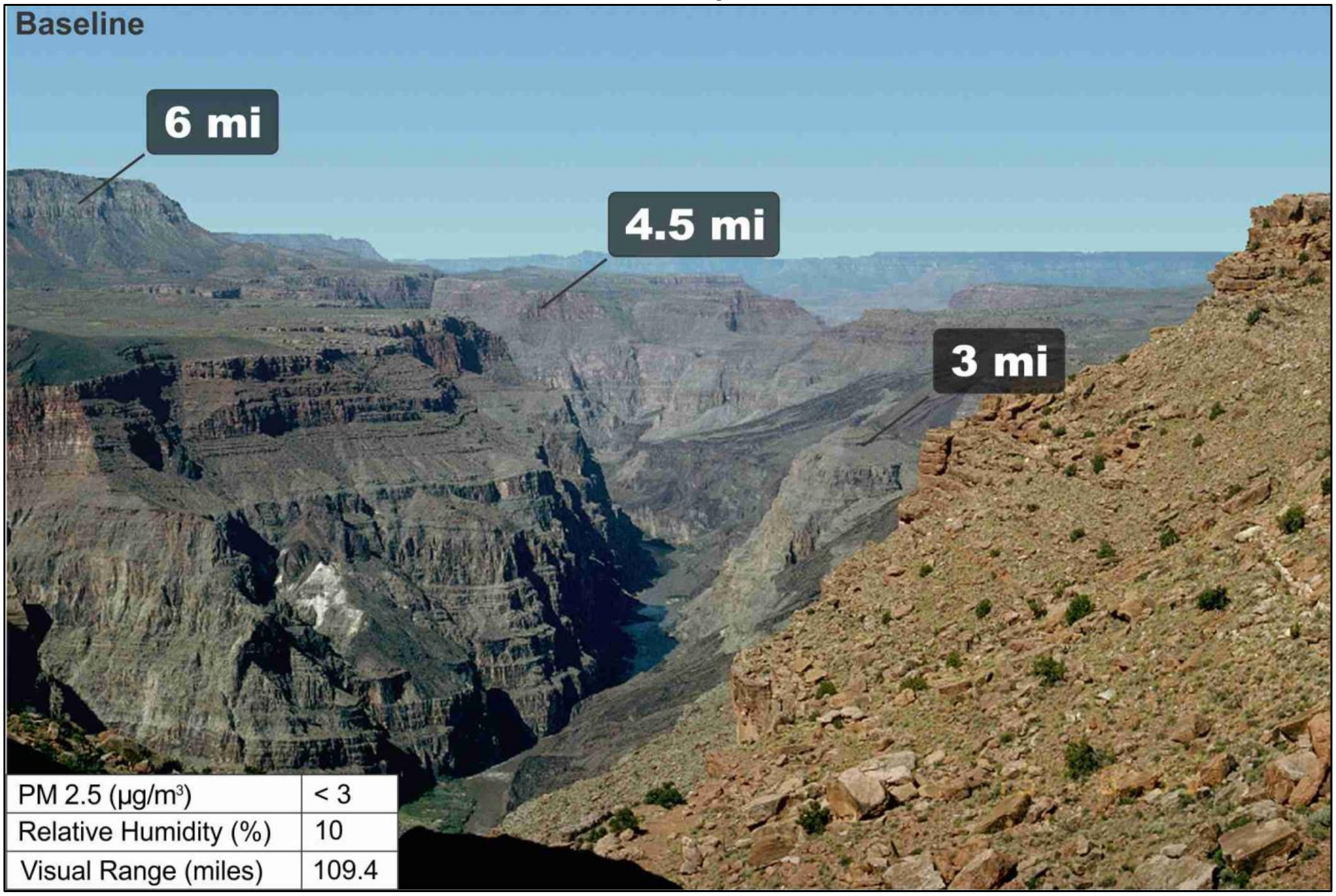


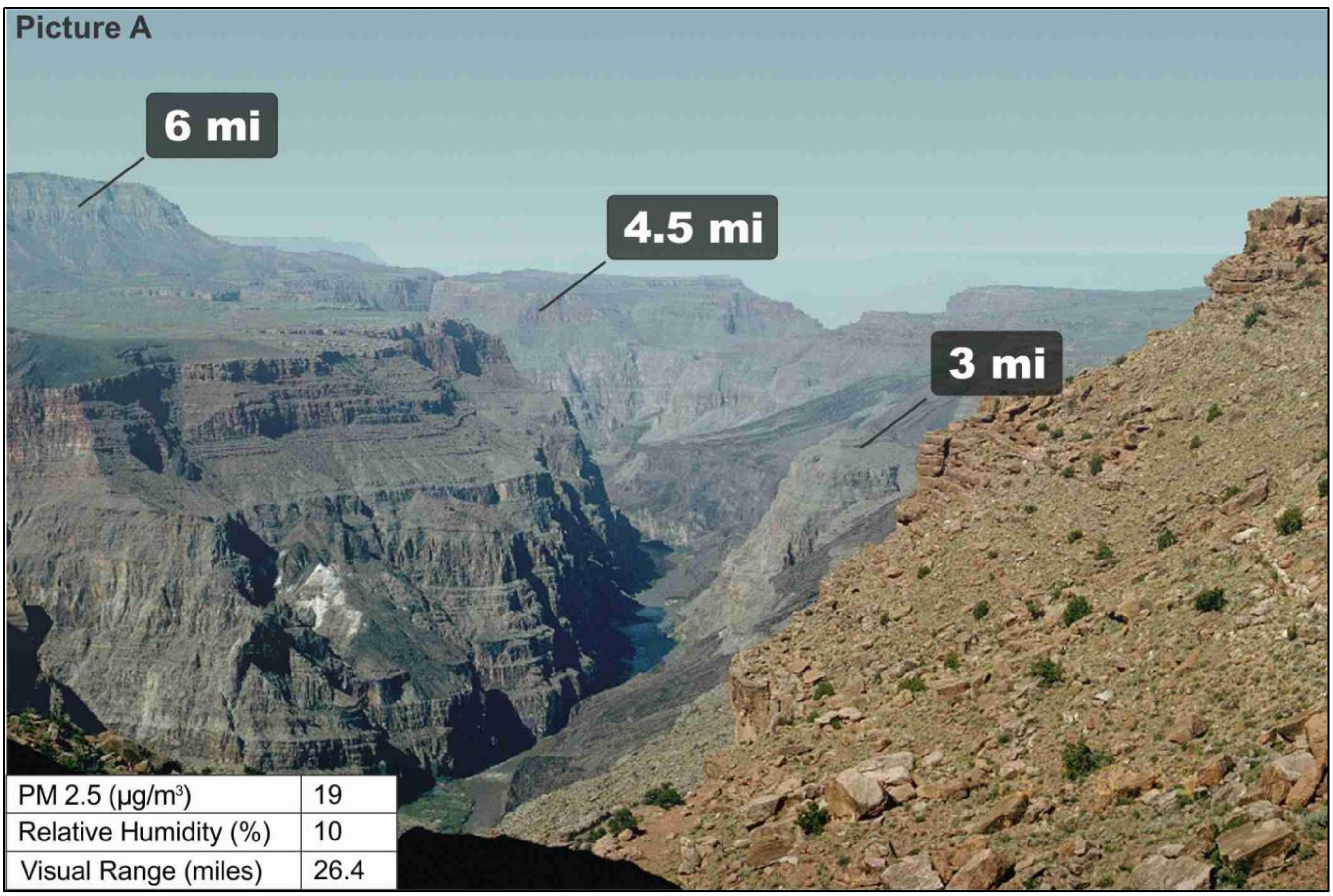
PM 2.5 (μg/m³)	19
Relative Humidity (%)	10
Visual Range (miles)	26.4



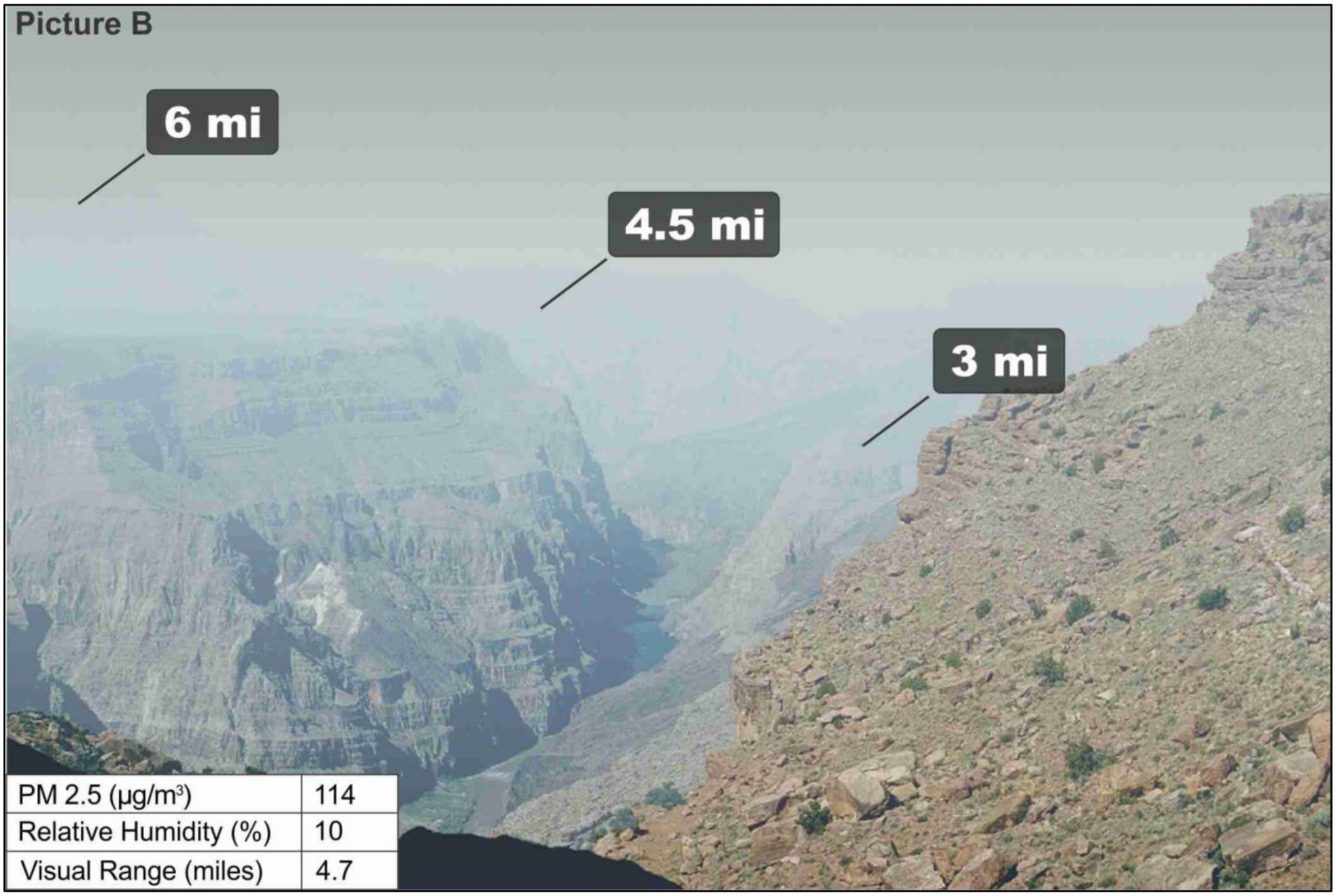
PM 2.5 (µg/m³)	114
Relative Humidity (%)	10
Visual Range (miles)	4.7

GRAND CANYON NATIONAL PARK, AZ – Example 2



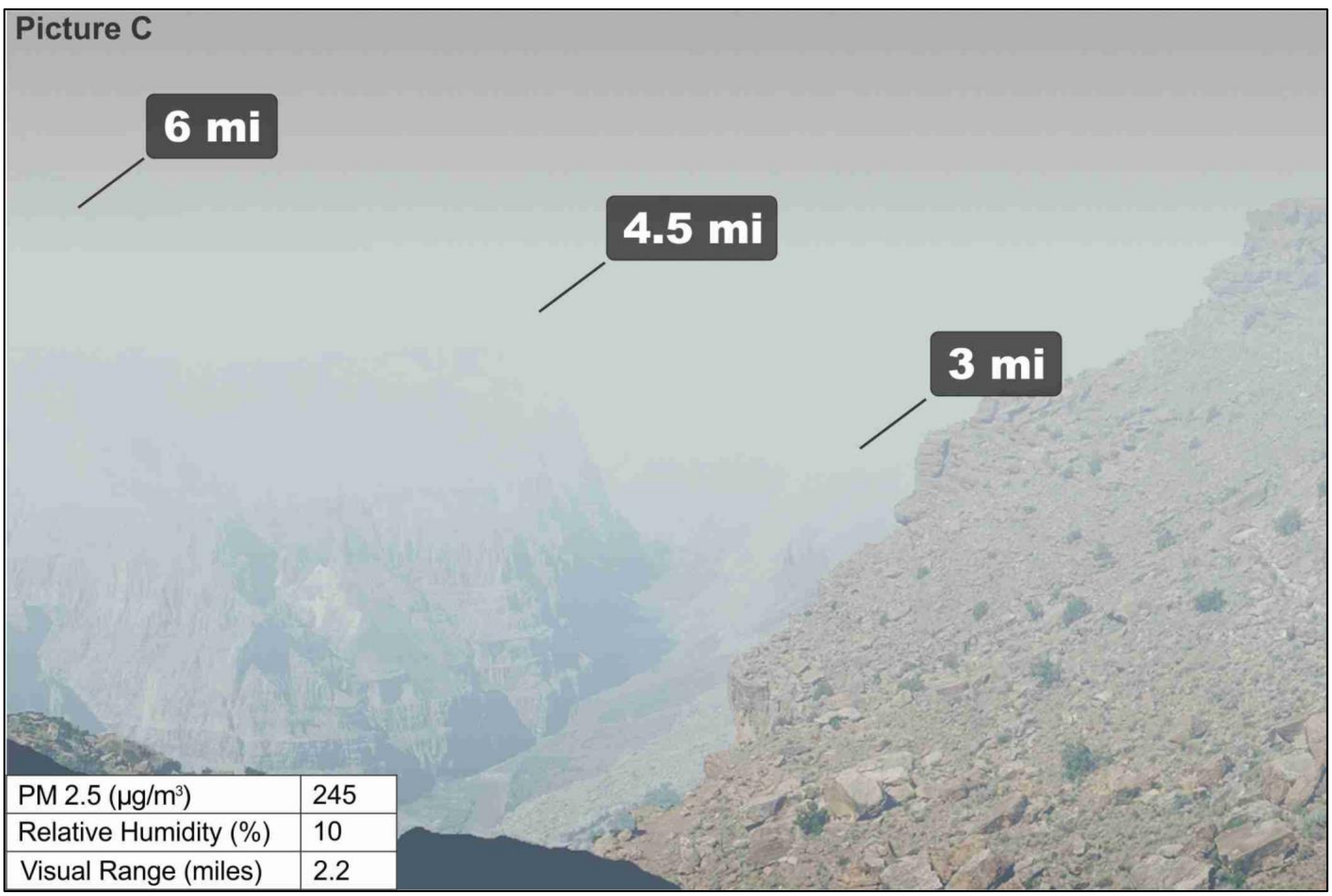


Picture B



PM 2.5 (µg/m³)	114
Relative Humidity (%)	10
Visual Range (miles)	4.7

Picture C



PM 2.5 (µg/m³)	245
Relative Humidity (%)	10
Visual Range (miles)	2.2

U.S. Forest Service, Region 4 – Canyonlands National Park, UT

Particulate data from 964 days (March 1988 to May 1999) at Canyonlands National Park were chosen to represent baseline and elevated regional air quality concentrations (table 8). The baseline image represents an area free of smoke-impaired visibility (<5 µg · m^{-3} fine and coarse particulates). Visual range at different levels of $PM_{2.5}$ concentration (19, 114, and 245 µg · m^{-3}) and RH are noted (table 9) and illustrated for Canyonlands National Park on the following pages. Data used for estimating the effect of RH on visual range during the May-September fire season are from Canyonlands National Park (EPA 2014).

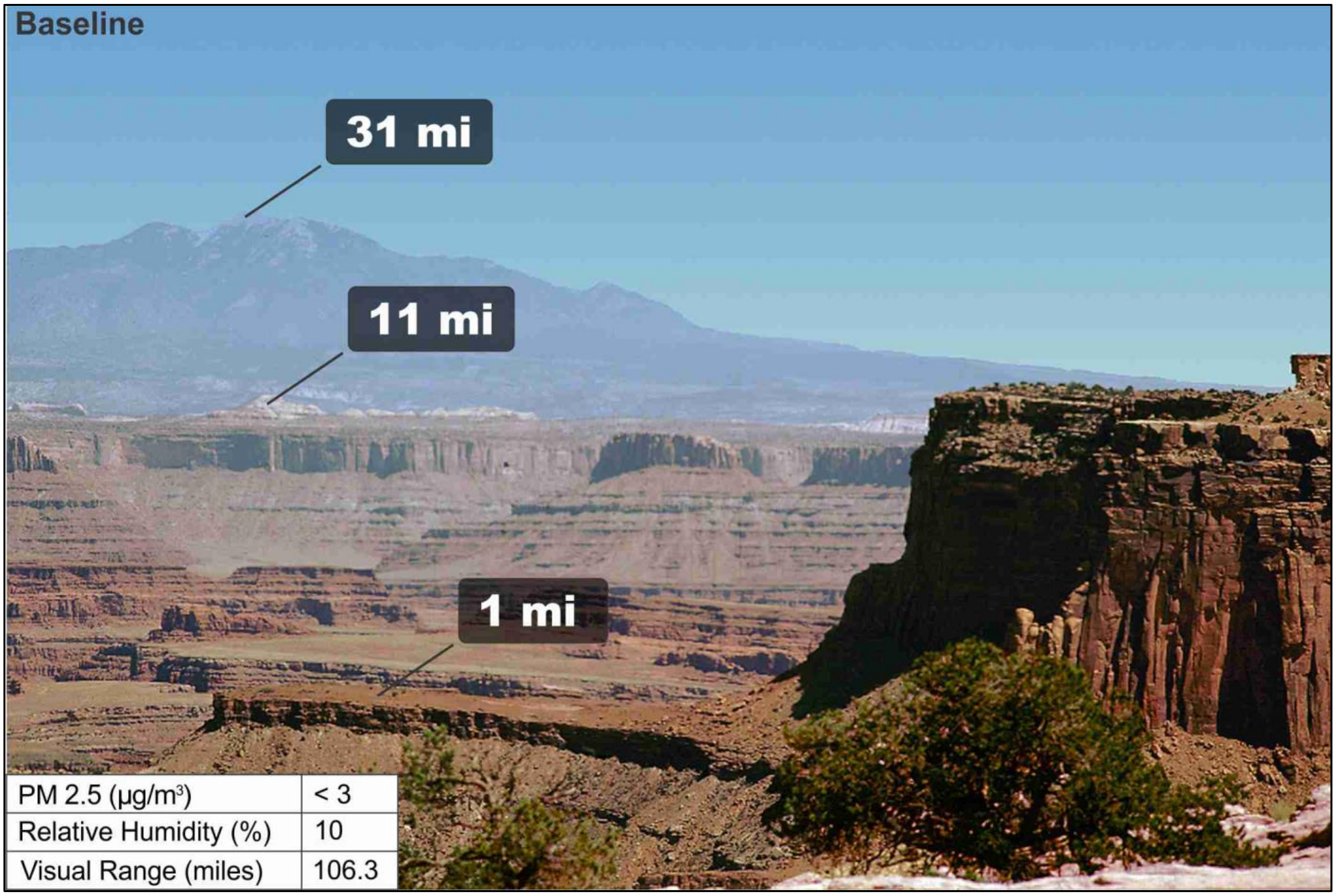
Table 8—Constituents of particulate matter ($PM_{2.5}$ and PM_{10}) at baseline and elevated levels in Canyonlands National Park, UT

Particulate Matter Constituents	Particulate Matter Concentration: Baseline	19	114	245
	------------------------------ *µg · m⁻³* ------------------------------			
Ammonium sulfate	1.08	1.54	1.54	1.54
Ammonium nitrate	0.23	0.37	0.37	0.37
Organic carbon	0.82	14.77	103.96	226.95
LAC/Black carbon	0.16	0.96	6.77	14.78
Fine soil	0.69	1.36	1.36	1.36
Coarse mass	5.60	8.43	11.40	24.50

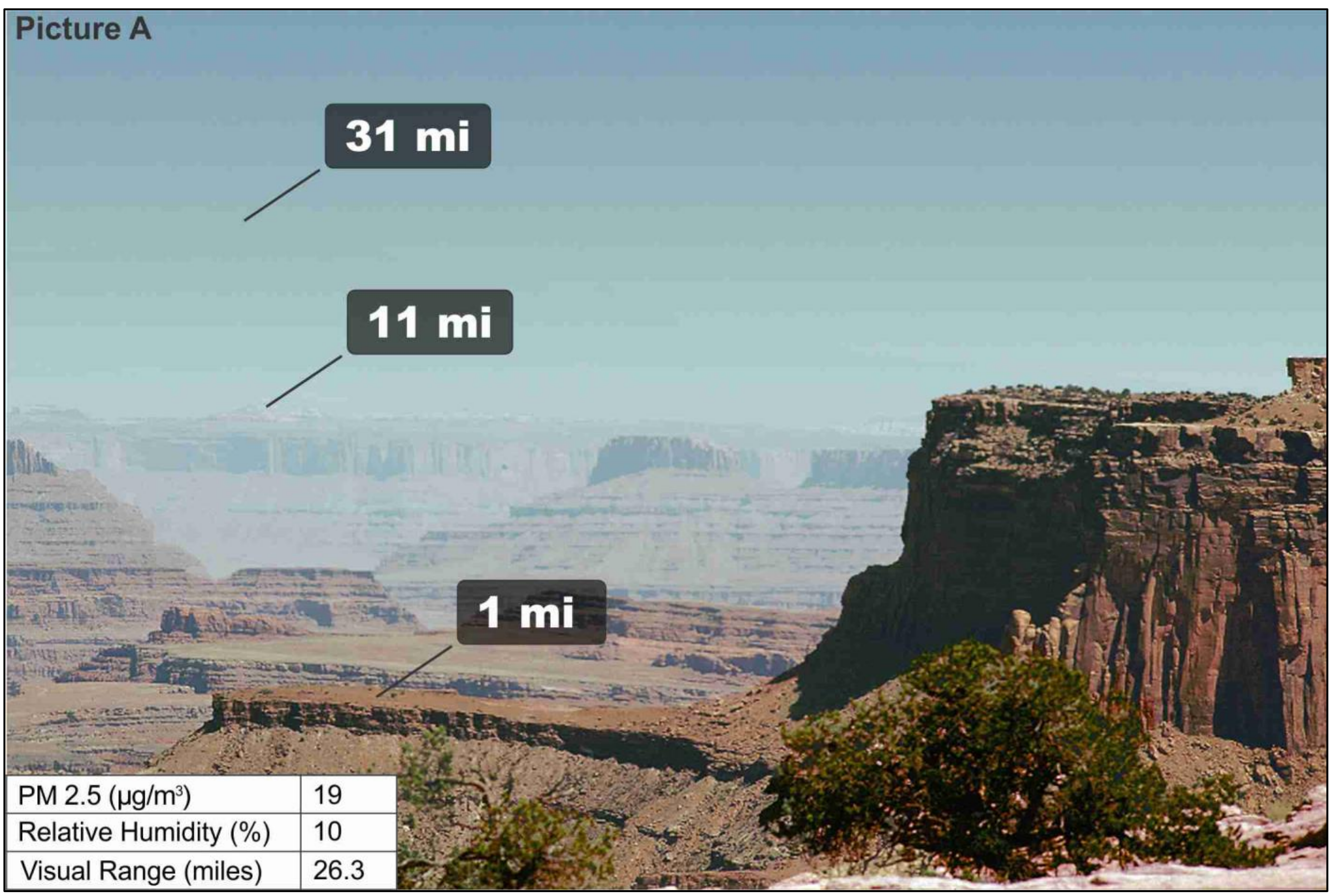
Table 9—Visual range as a function of $PM_{2.5}$ concentration and relative humidity in Canyonlands National Park, UT

$PM_{2.5}$ Concentration	Relative Humidity	Visual Range	
µg · m^{-3}	*percent*	*miles*	*km*
<5 (baseline)	10	106.3	171.0
19 (picture A)	10	26.3	42.4
	20	26.0	41.8
	30	25.5	41.1
	40	25.0	40.3
114 (picture B)	10	4.7	7.6
	20	4.6	7.4
	30	4.5	7.3
	40	4.4	7.1
245 (picture C)	10	2.2	3.5
	20-40	2.1	3.4

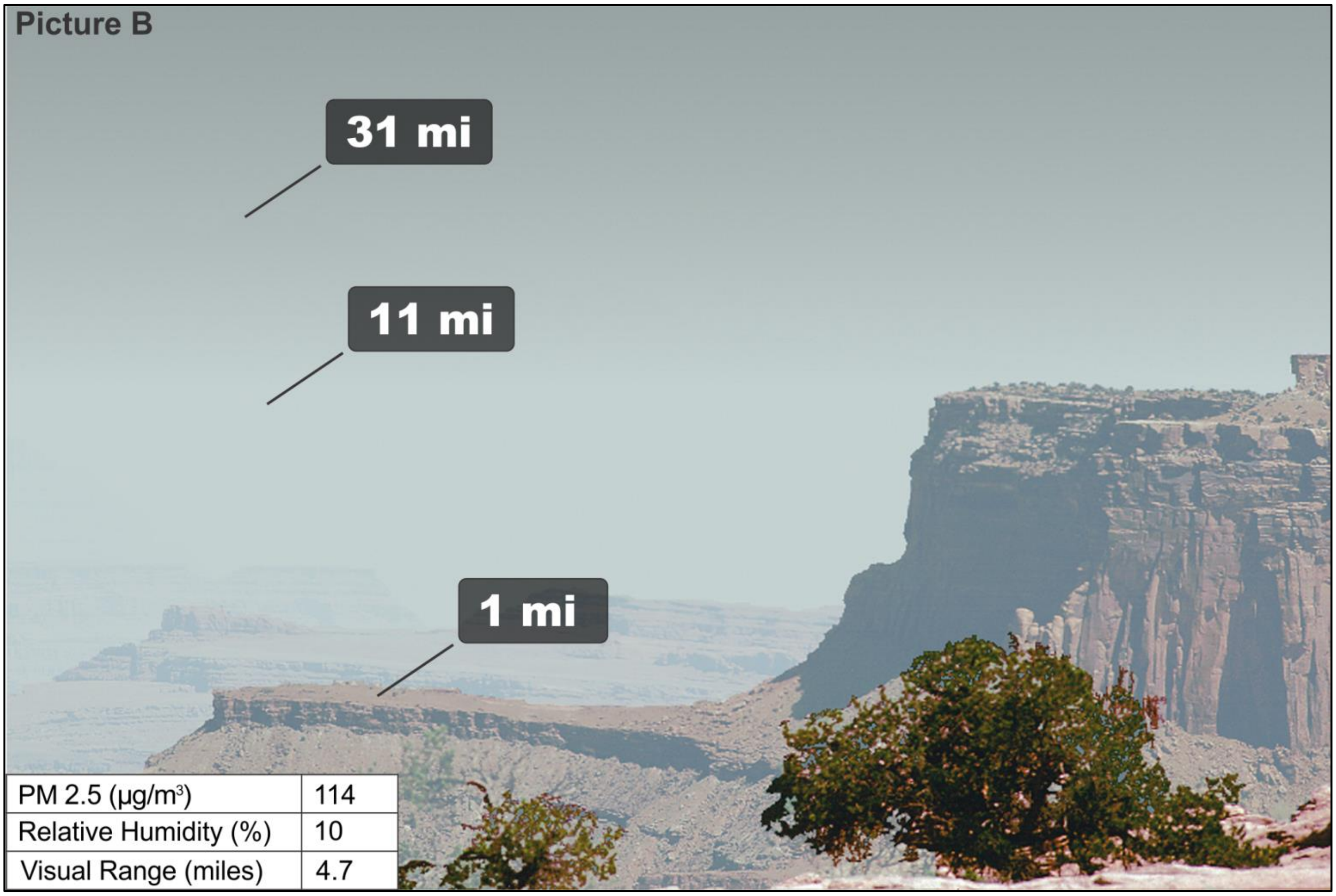
CANYONLANDS NATIONAL PARK, UT



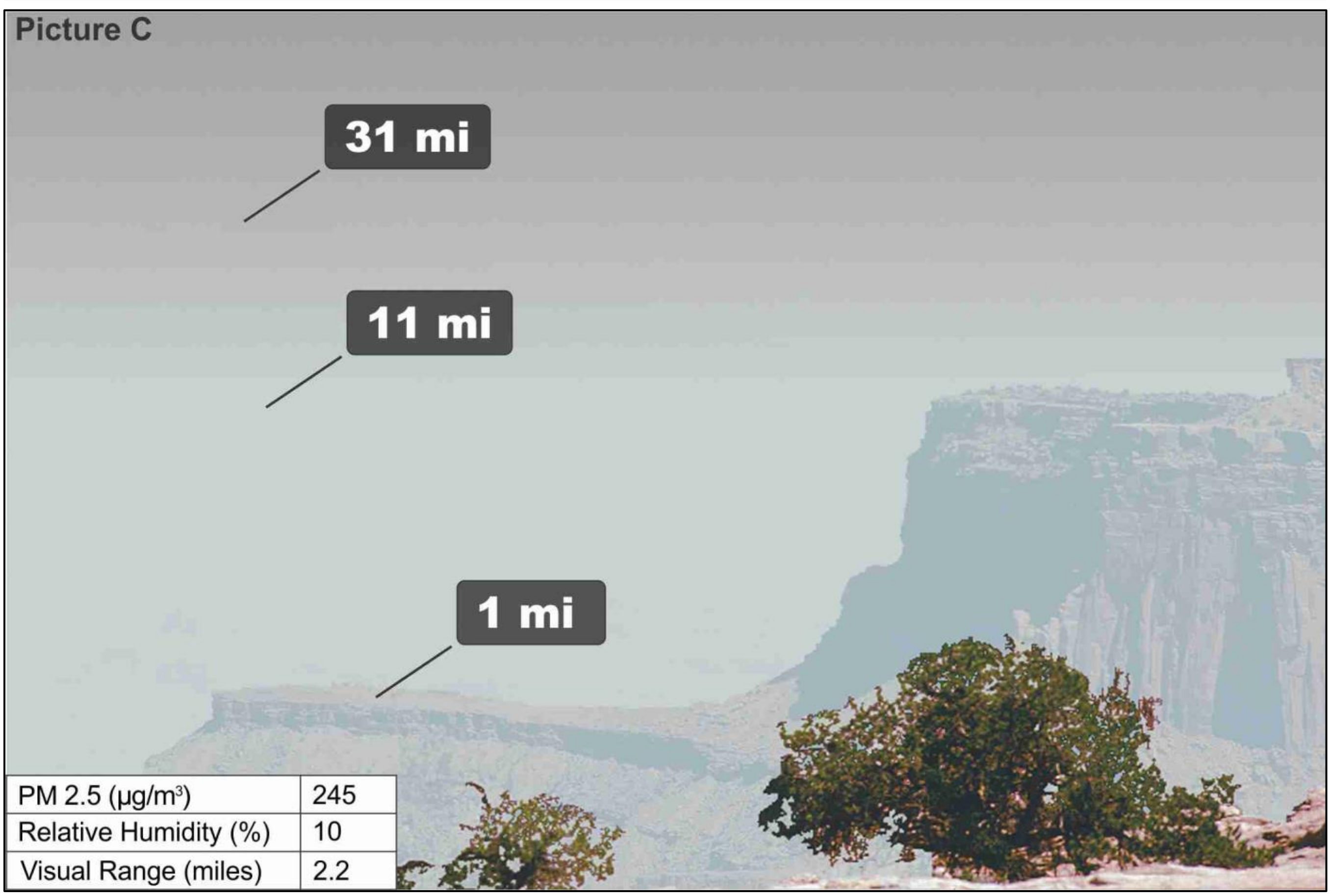
PM 2.5 (µg/m³)	< 3
Relative Humidity (%)	10
Visual Range (miles)	106.3



PM 2.5 (µg/m³)	19
Relative Humidity (%)	10
Visual Range (miles)	26.3



PM 2.5 (µg/m³)	114
Relative Humidity (%)	10
Visual Range (miles)	4.7



PM 2.5 (µg/m³)	245
Relative Humidity (%)	10
Visual Range (miles)	2.2

U.S. Forest Service, Region 4 – Great Basin National Park, NV

Particulate data from 681 days of sampling (May 1992 to May 1999) at Great Basin National Park were chosen to represent baseline and elevated regional air quality concentrations (table 10). The baseline image represents an area free of smoke-impaired visibility (<5 $\mu g \cdot m^{-3}$ fine and coarse particulates). Visual range at different levels of $PM_{2.5}$ concentration (19, 114, and 245 $\mu g \cdot m^{-3}$) and RH are noted (table 11) and illustrated for Great Basin National Park on the following pages. Data used for estimating the effect of RH on visual range during the May-September fire season are from Great Basin National Park (EPA 2014).

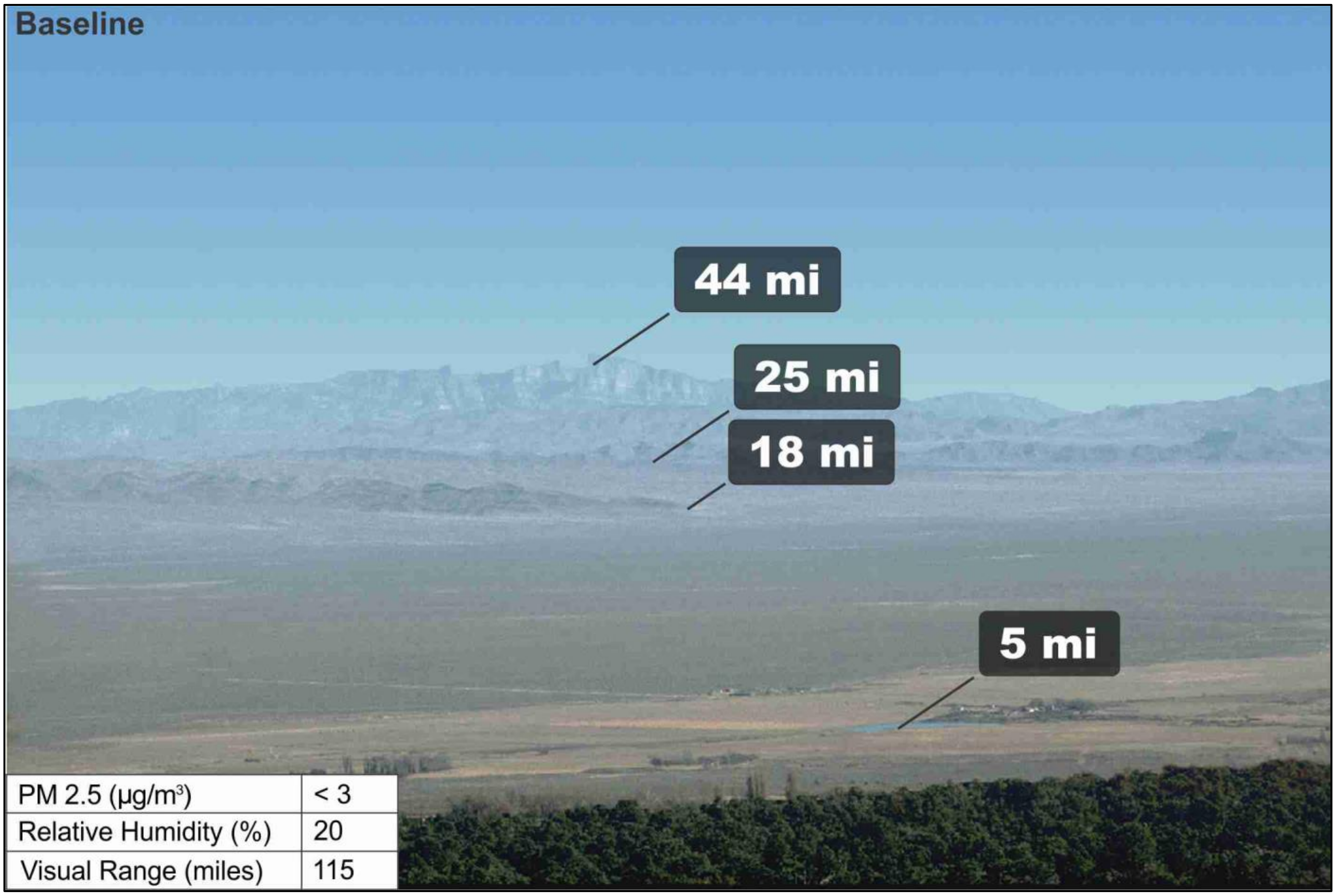
Table 10—Constituents of particulate matter ($PM_{2.5}$ and PM_{10}) at baseline and elevated levels in Great Basin National Park, NV

Particulate Matter Constituents	Particulate Matter Concentration Baseline	19	114	245
	---------- $\mu g \cdot m^{-3}$ ----------			
Ammonium sulfate	0.68	1.13	1.13	1.13
Ammonium nitrate	0.16	0.31	0.31	0.31
Organic carbon	0.98	15.18	104.37	227.37
LAC/Black carbon	0.19	0.99	6.80	14.81
Fine soil	0.60	1.39	1.39	1.39
Coarse mass	3.73	5.50	11.40	24.50

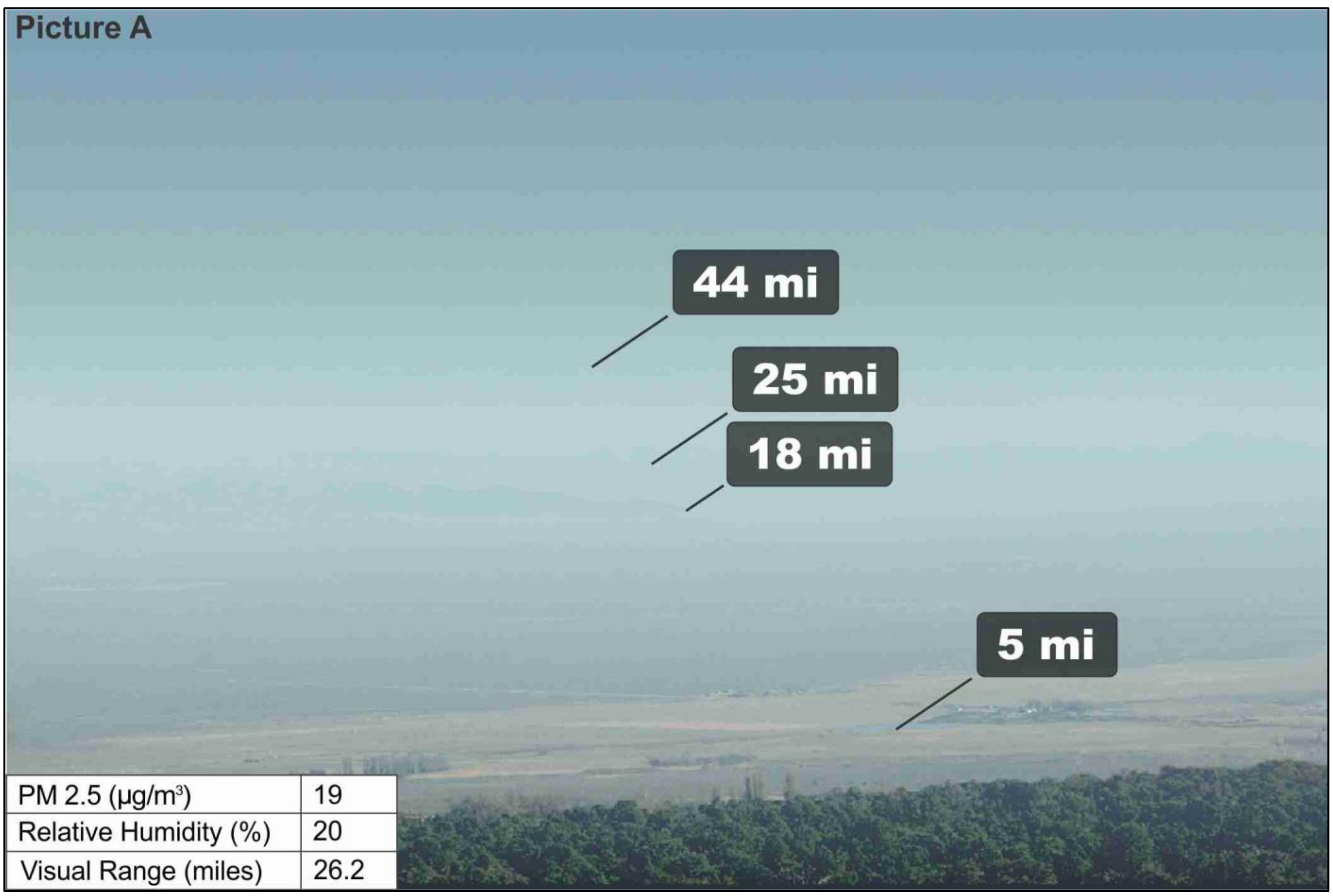
Table 11—Visual range as a function of $PM_{2.5}$ concentration and relative humidity in Great Basin National Park, NV

$PM_{2.5}$ Concentration	Relative Humidity	Visual Range	
$\mu g \cdot m^{-3}$	*percent*	*miles*	*km*
<5 (baseline)	20	115.0	185.0
19 (picture A)	20	26.2	42.2
	30	25.8	41.6
	40	25.4	40.8
	50	24.7	39.7
114 (picture B)	20	4.6	7.4
	30	4.5	7.3
	40	4.4	7.1
	50	4.3	7.0
245 (picture C)	20-40	2.1	3.4
	50	2.0	3.3

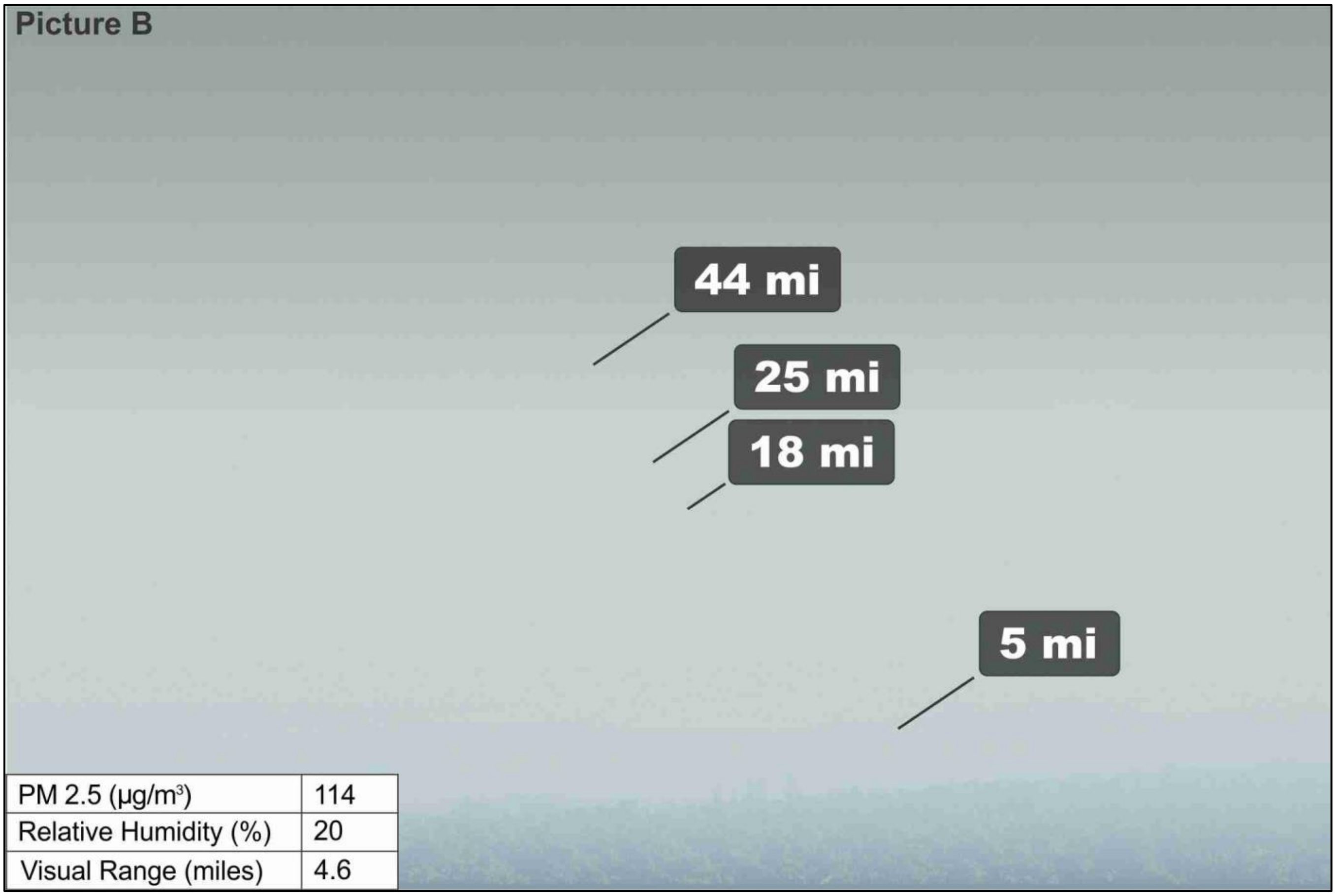
GREAT BASIN NATIONAL PARK, NV



PM 2.5 (µg/m³)	< 3
Relative Humidity (%)	20
Visual Range (miles)	115



PM 2.5 (µg/m³)	19
Relative Humidity (%)	20
Visual Range (miles)	26.2



PM 2.5 (µg/m³)	114
Relative Humidity (%)	20
Visual Range (miles)	4.6

U.S. Forest Service, Region 5 – Yosemite National Park, CA

Particulate data from 951 days (March 1988 to May 1999) at Yosemite National Park were chosen to represent baseline and elevated regional air quality concentrations (table 12). The baseline image represents an area free of smoke-impaired visibility (<5 µg · m^{-3} fine and coarse particulates). Visual range at different levels of $PM_{2.5}$ concentration (19, 114, and 245 µg · m^{-3}) and RH are noted (table 13) and illustrated for Yosemite National Park on the following pages. Data used for estimating the effect of RH on visual range during the May-September fire season are from Yosemite National Park (EPA 2014).

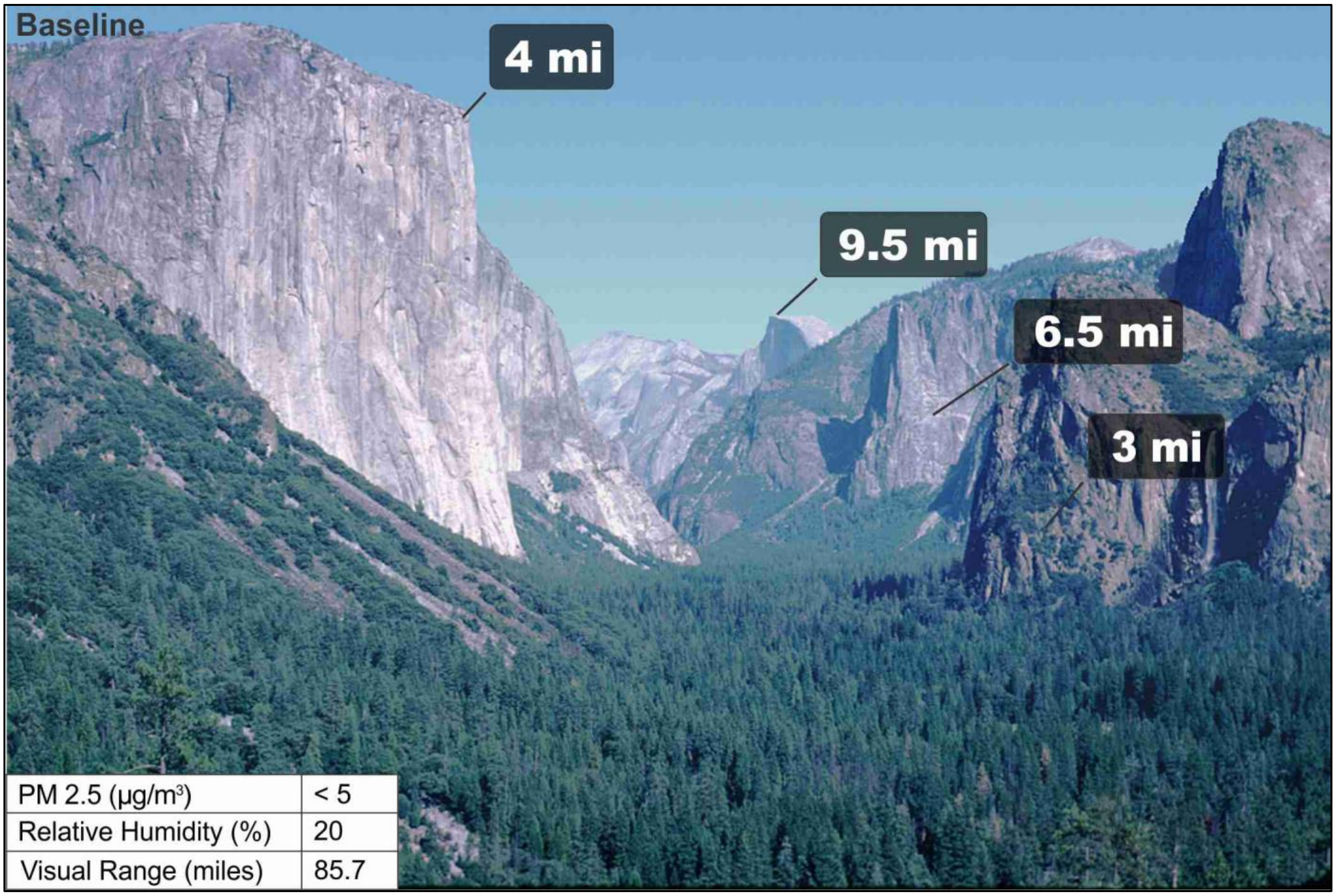
Table 12—Constituents of particulate matter ($PM_{2.5}$ and PM_{10}) at baseline and elevated levels in Yosemite National Park

Particulate Matter Constituents	Particulate Matter Concentration Baseline	19	114	245
	------------------------------ *µg · m^{-3}*	------------------------------		
Ammonium sulfate	0.99	1.90	1.90	1.90
Ammonium nitrate	0.47	0.94	0.94	0.94
Organic carbon	1.94	14.20	103.39	226.38
LAC/Black carbon	0.27	0.92	6.73	14.74
Fine soil	0.56	1.04	1.04	1.04
Coarse mass	4.78	7.64	11.40	24.50

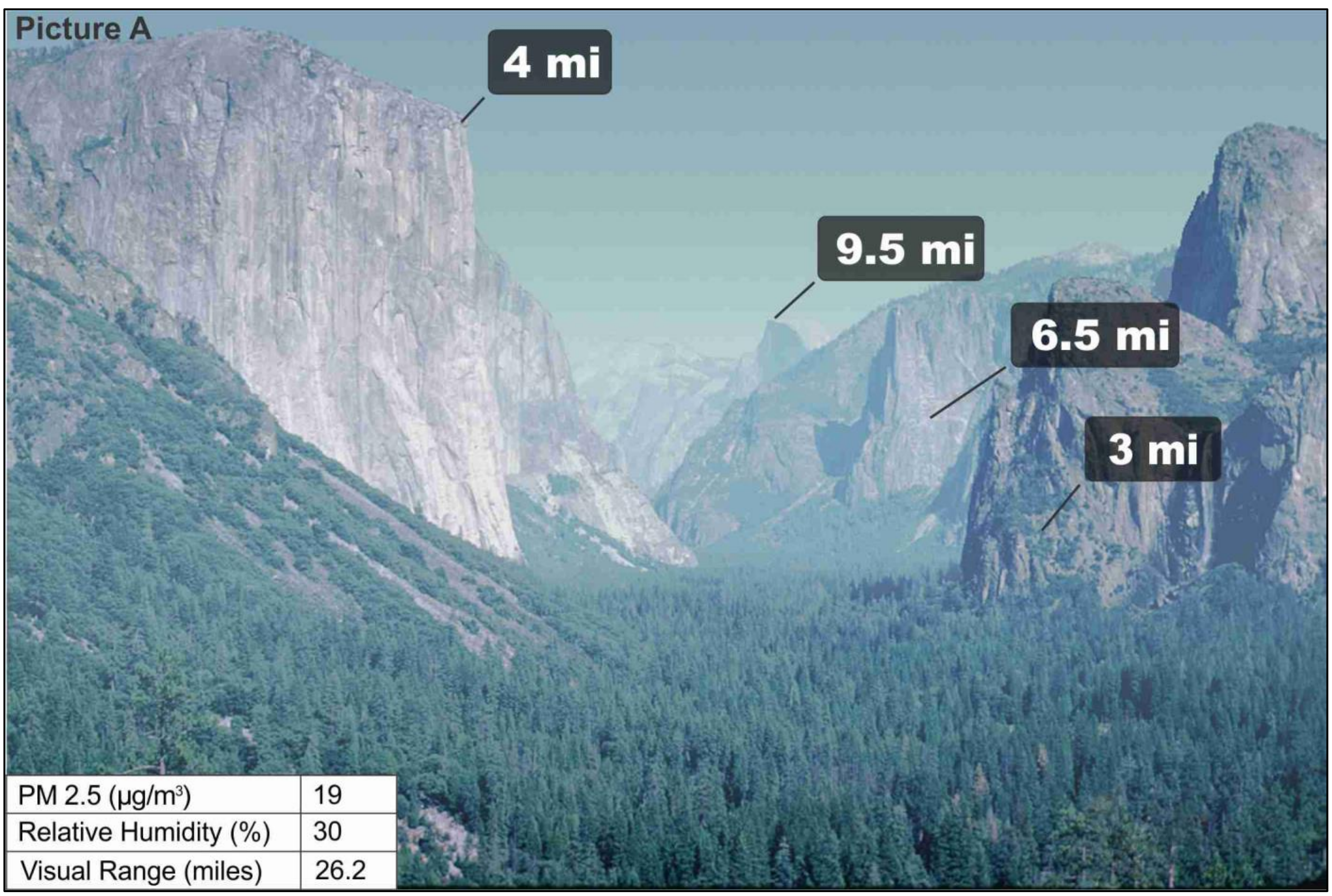
Table 13—Visual range as a function of $PM_{2.5}$ concentration and relative humidity in Yosemite National Park

$PM_{2.5}$ Concentration	Relative Humidity	Visual Range	
µg · m^{-3}	*percent*	*miles*	*km*
<5 (baseline)	20	85.7	138.0
19 (picture A)	20	26.2	42.1
	30	25.8	41.5
	40	25.2	40.6
	50	24.4	39.2
114 (picture B)	20	4.6	7.4
	30	4.5	7.3
	40	4.4	7.1
	50	4.3	7.0
245 (picture C)	20-40	2.1	3.4
	50	2.0	3.2

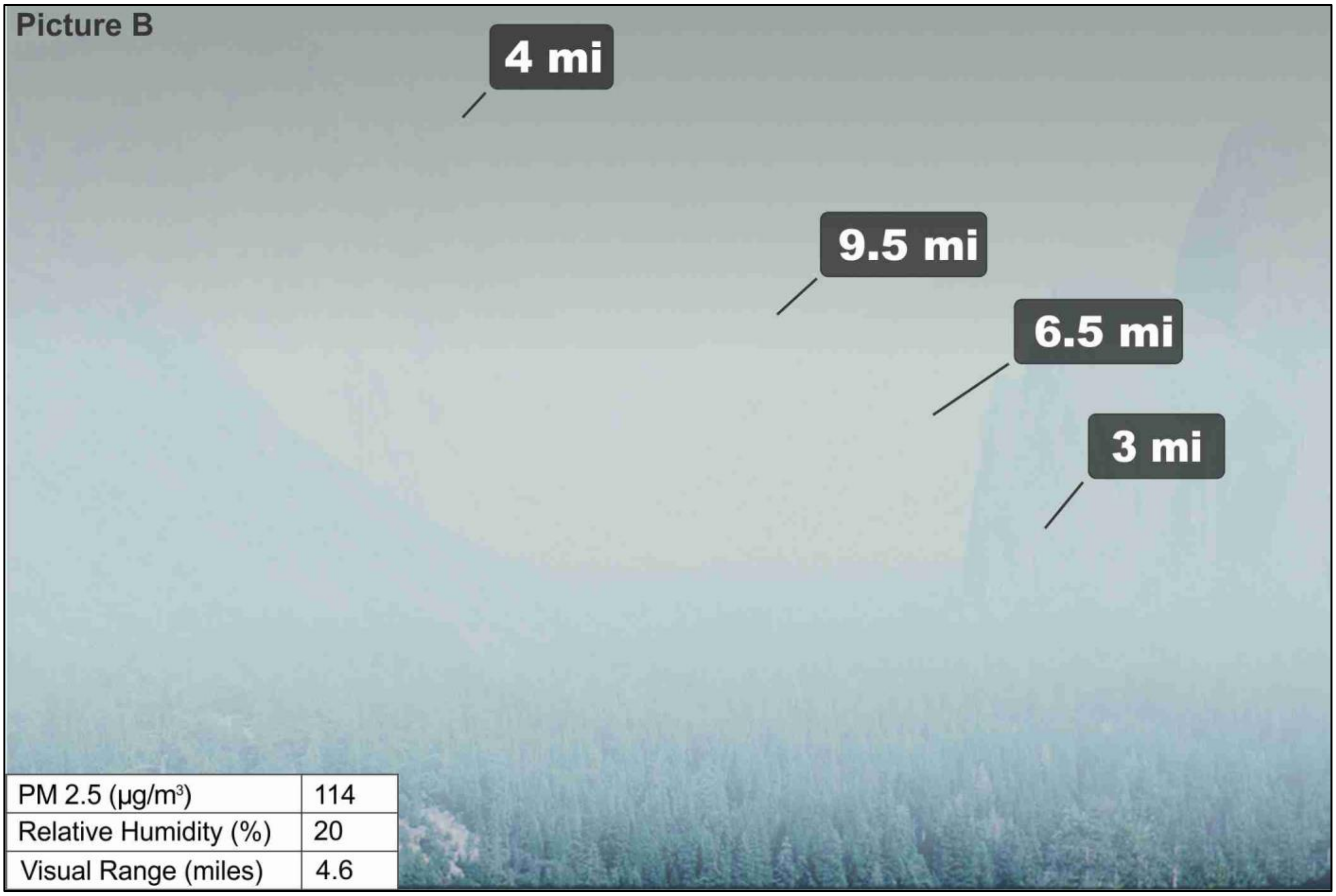
YOSEMITE NATIONAL PARK, CA



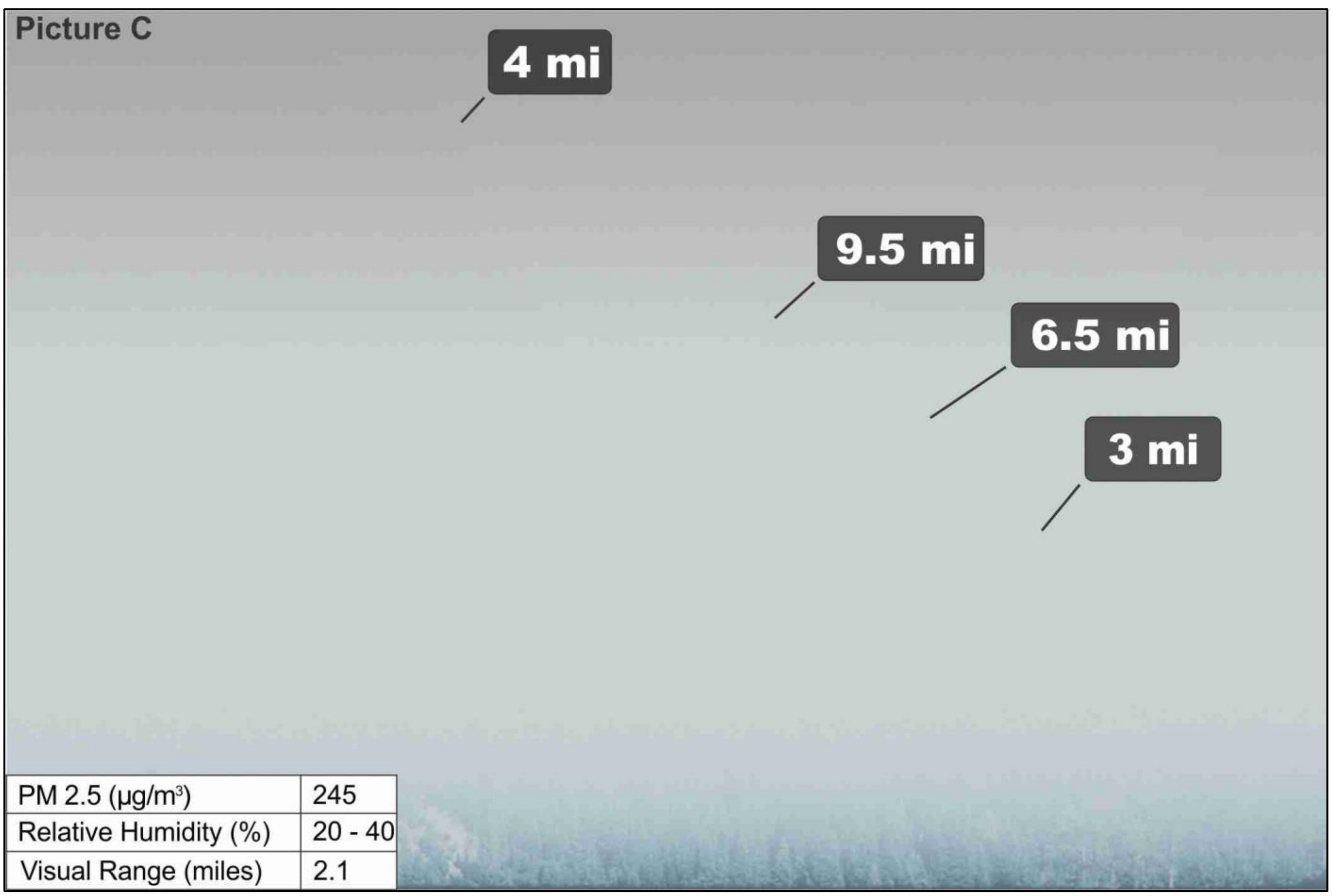
PM 2.5 (µg/m³)	< 5
Relative Humidity (%)	20
Visual Range (miles)	85.7



PM 2.5 (µg/m³)	19
Relative Humidity (%)	30
Visual Range (miles)	26.2



PM 2.5 (µg/m³)	114
Relative Humidity (%)	20
Visual Range (miles)	4.6



PM 2.5 (µg/m³)	245
Relative Humidity (%)	20 - 40
Visual Range (miles)	2.1

U.S. Forest Service, Region 6 – Columbia River Gorge, OR

Particulate data from 551 days of sampling (July 1993 to May 1999) in the Columbia River Gorge were chosen to represent baseline and elevated regional air quality concentrations (table 14). The baseline image represents an area free of smoke-impaired visibility (<5 $\mu g \cdot m^{-3}$ fine and coarse particulates). Visual range at different levels of $PM_{2.5}$ concentration (19, 114, and 245 $\mu g \cdot m^{-3}$) and RH are noted (table 15) and illustrated for the Columbia River Gorge on the following pages. Data used for estimating the effect of RH on visual range during the May-September fire season are from Portland, OR (NOAA 2014).

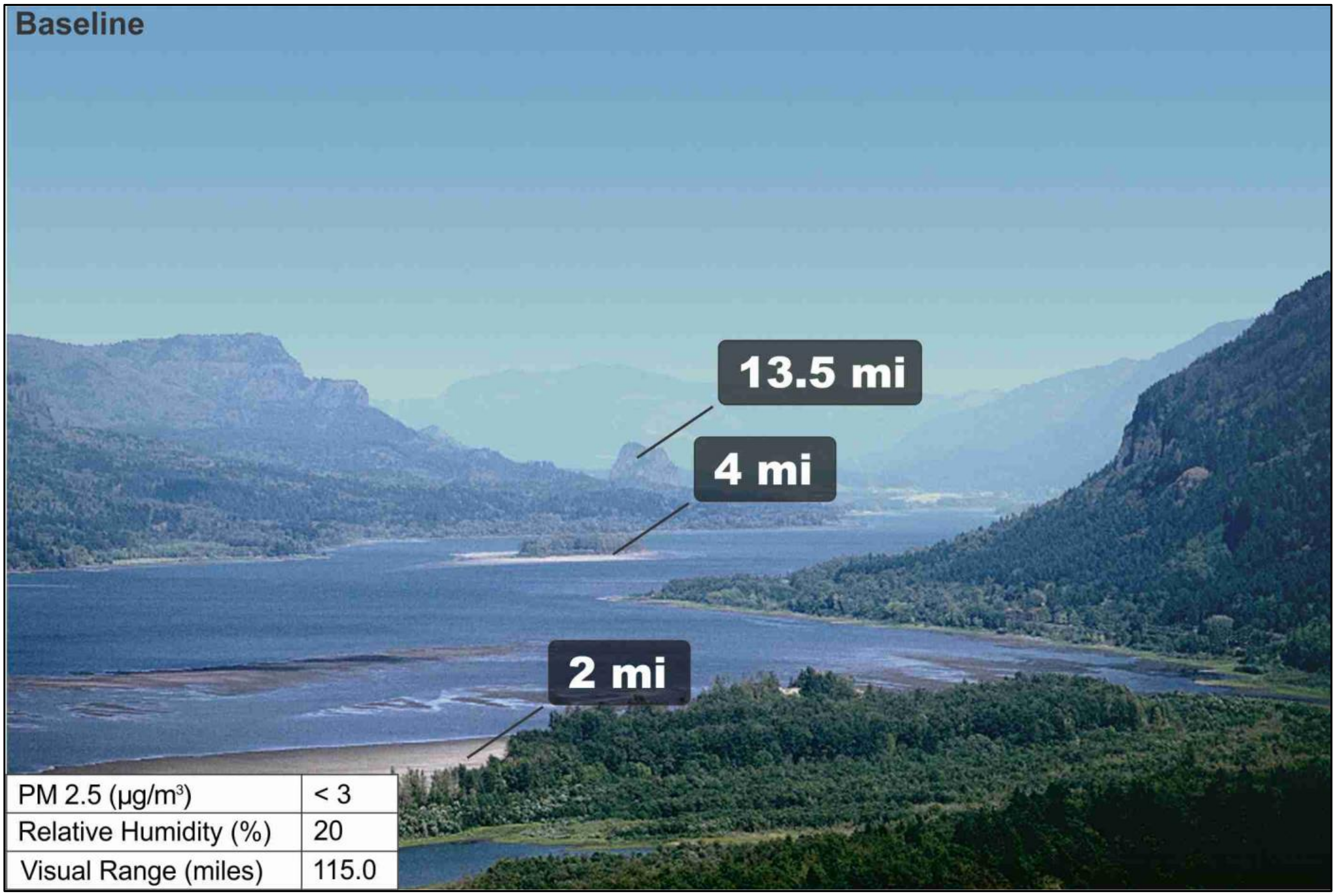
Table 14—Constituents of particulate matter ($PM_{2.5}$ and PM_{10}) at baseline and elevated levels in the Columbia River Gorge, OR

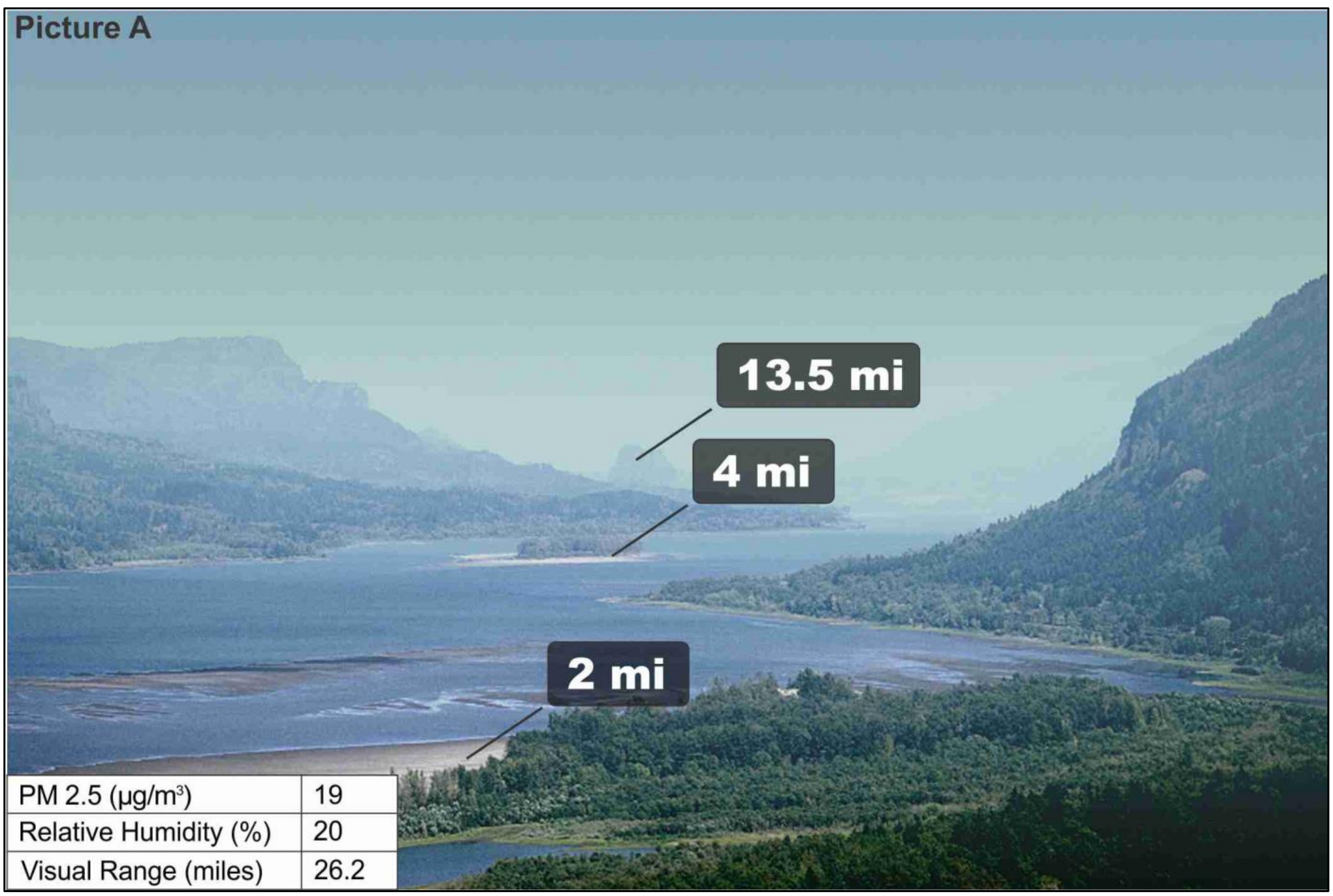
Particulate Matter Constituents	**Particulate Matter Concentration** Baseline	**19**	**114**	**245**
	------ *$\mu g \cdot m^{-3}$* ------			
Ammonium sulfate	1.48	2.56	2.56	2.56
Ammonium nitrate	0.77	1.78	1.78	1.78
Organic carbon	2.32	12.56	101.75	224.75
LAC/Black carbon	0.47	0.82	6.63	14.63
Fine soil	0.66	1.28	1.28	1.28
Coarse mass	7.90	11.88	11.88	24.50

Table 15—Visual range as a function of $PM_{2.5}$ concentration and relative humidity in the Columbia River Gorge, OR

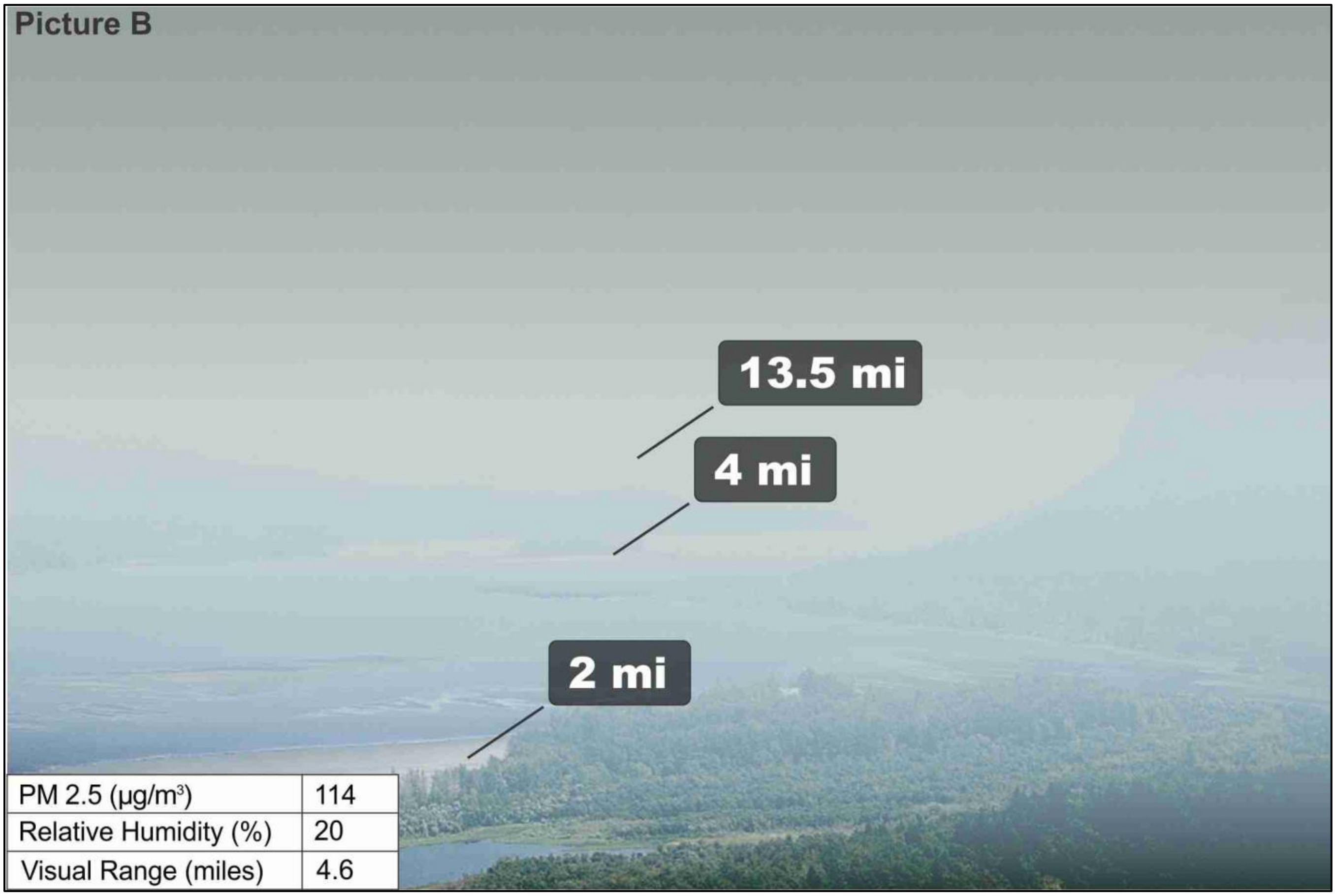
$PM_{2.5}$ Concentration	**Relative Humidity**	**Visual Range**	
$\mu g \cdot m^{-3}$	*percent*	*miles*	*km*
<5 (baseline)	40	66.5	107.0
19 (picture A)	40	25.4	40.8
	50	24.2	39.0
	60	22.9	36.9
	70	21.5	34.6
	80	19.9	32.0
114 (picture B)	40	4.4	7.2
	50	4.3	7.0
	60	4.2	6.8
	70	4.1	6.6
	80	4.0	6.4
245 (picture C)	40	2.1	3.3
	50-60	2.0	3.2
	70-80	1.9	3.1

COLUMBIA RIVER GORGE, OR



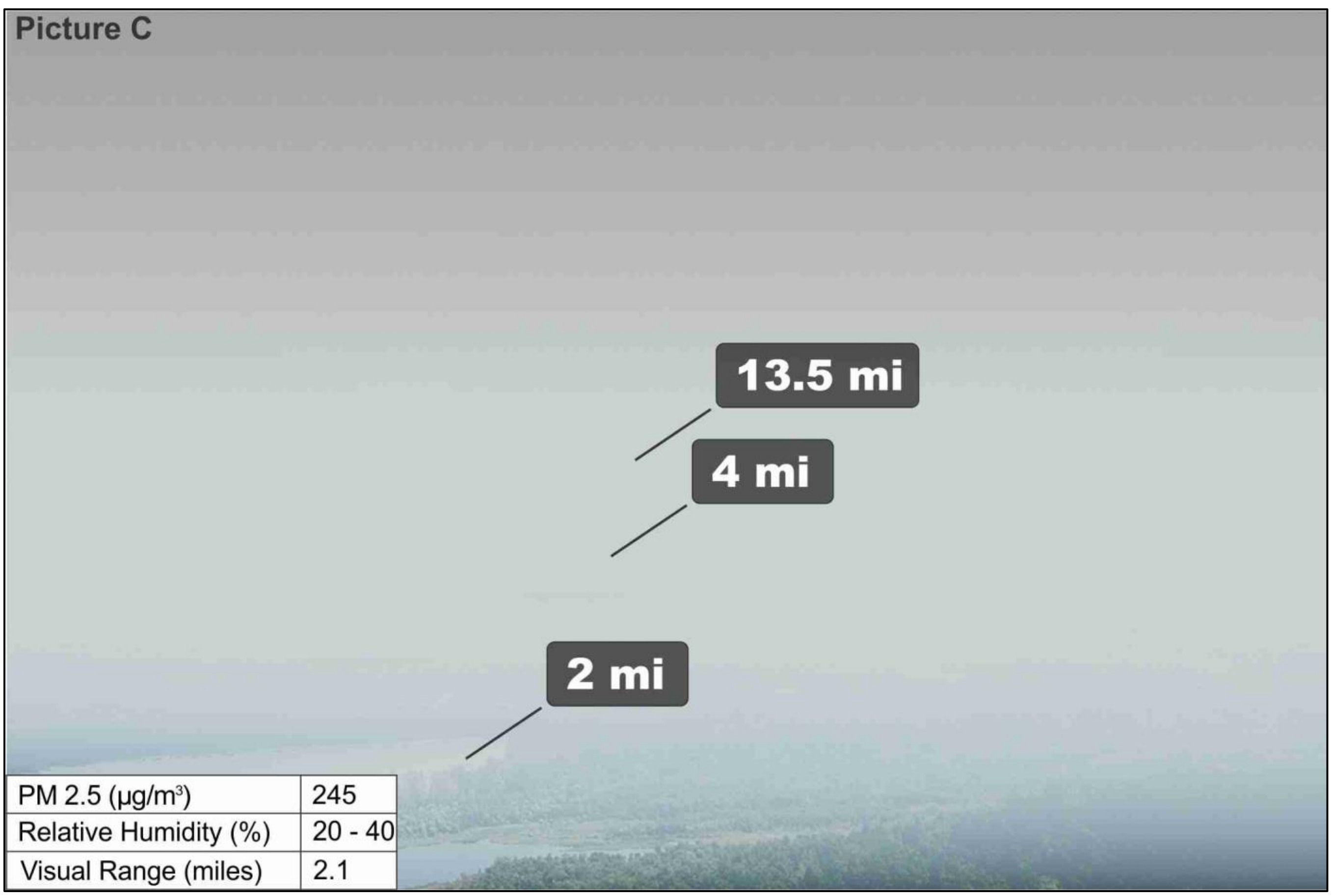


Picture B



PM 2.5 (µg/m³)	114
Relative Humidity (%)	20
Visual Range (miles)	4.6

Picture C



PM 2.5 (µg/m³)	245
Relative Humidity (%)	20 - 40
Visual Range (miles)	2.1

U.S. Forest Service, Region 6 – Snoqualmie Pass, WA

Particulate data from 353 days of sampling (December 1993 to May 1999) at Snoqualmie Pass were chosen to represent baseline and elevated regional air quality concentrations (table 16). The baseline image represents an area free of smoke-impaired visibility (<5 $\mu g \cdot m^{-3}$ fine and coarse particulates). Visual range at different levels of $PM_{2.5}$ concentration (19, 114, and 245 $\mu g \cdot m^{-3}$) and RH are noted (table 17) and illustrated for the Snoqualmie Pass on the following pages. Data used for estimating the effect of RH on visual range during the May-September fire season are from Seattle-Tacoma International Airport, WA (NOAA 2014).

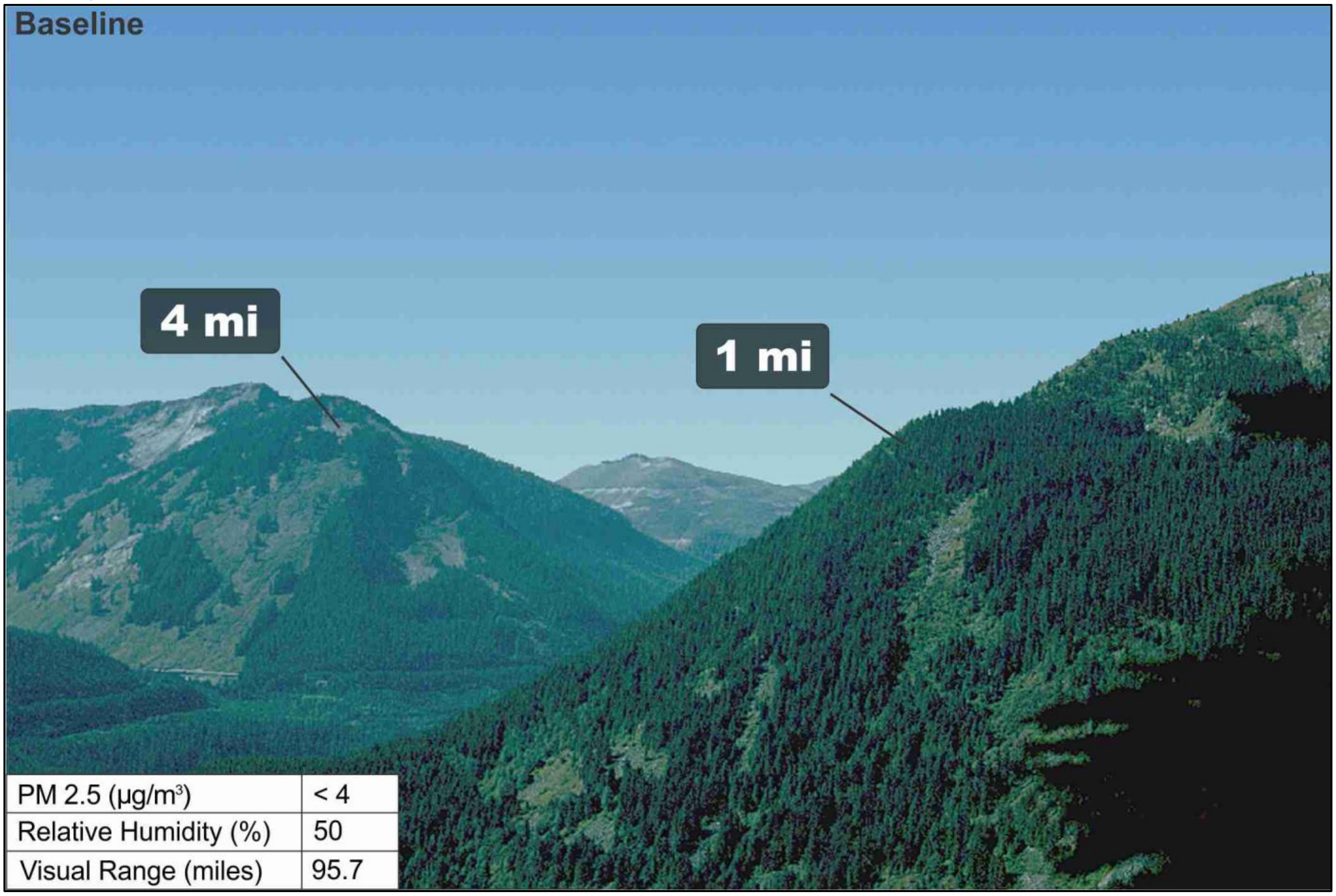
Table 16—Constituents of particulate matter ($PM_{2.5}$ and PM_{10}) at baseline and elevated levels at Snoqualmie Pass, WA

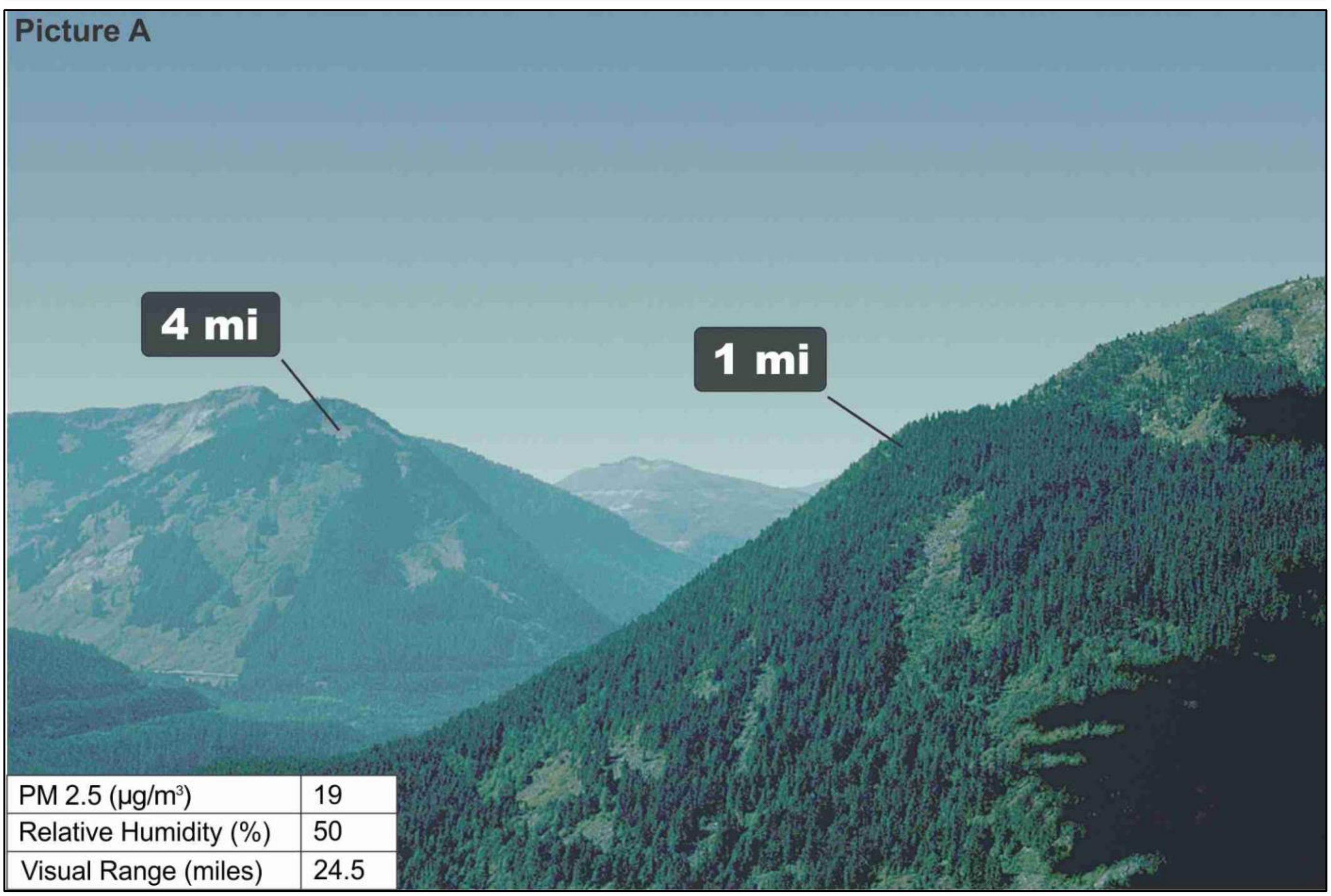
Particulate Matter Constituents	Particulate Matter Concentration			
	Baseline	19	114	245
	------------------------------ $\mu g \cdot m^{-3}$ ------------------------------			
Ammonium sulfate	0.98	1.84	1.84	1.84
Ammonium nitrate	0.35	0.59	0.59	0.59
Organic carbon	1.28	14.80	103.99	226.98
LAC/Black carbon	0.31	0.96	6.77	14.78
Fine soil	0.29	0.81	0.81	0.81
Coarse mass	2.94	3.82	11.40	24.50

Table 17—Visual range as a function of $PM_{2.5}$ concentration and relative humidity at Snoqualmie Pass, WA

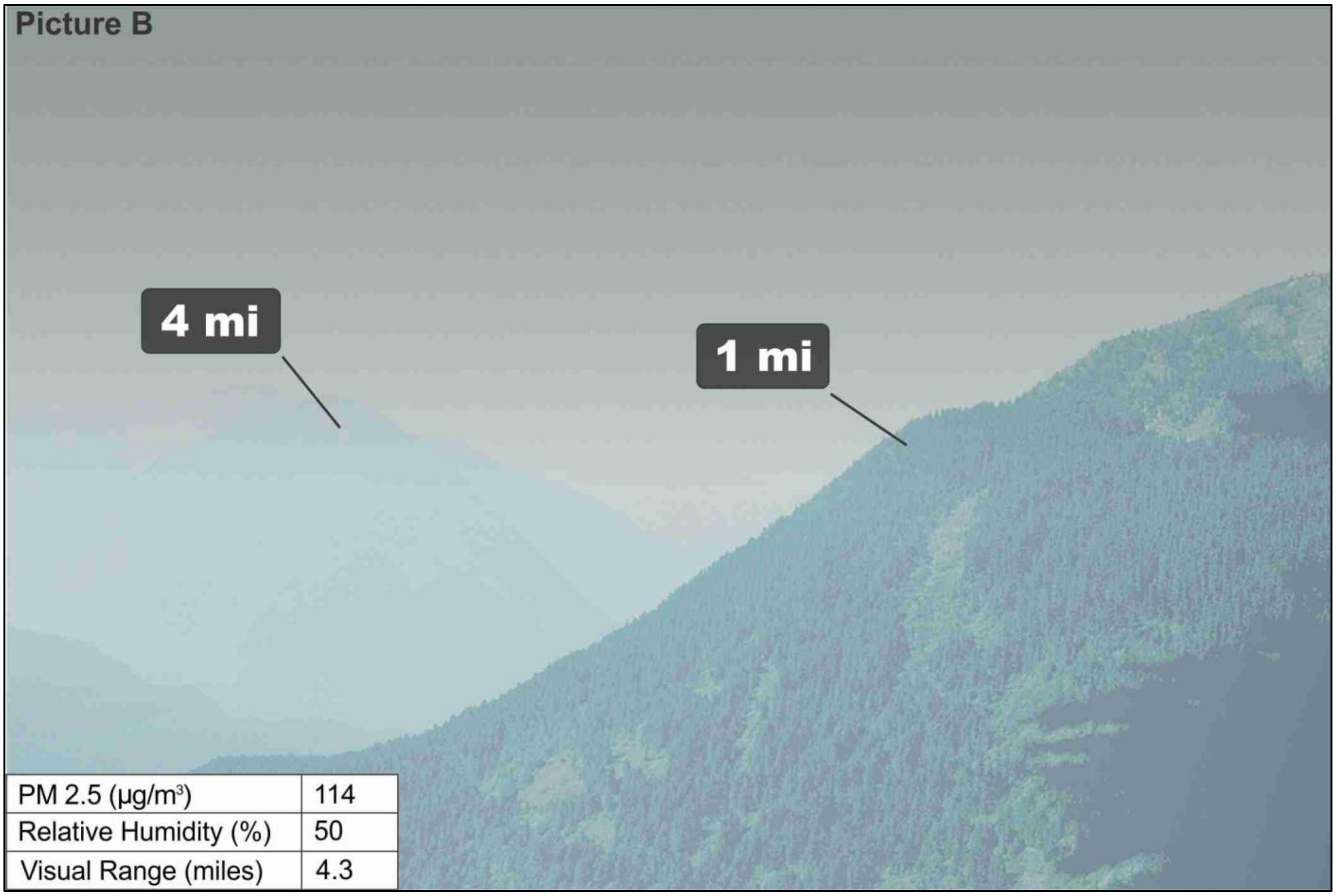
$PM_{2.5}$ Concentration	Relative Humidity	Visual Range	
$\mu g \cdot m^{-3}$	*percent*	*miles*	*km*
<5 (baseline)	50	95.7	154.0
19 (picture A)	50	24.5	39.5
	60	23.6	38.0
	70	22.6	36.3
	80	21.4	34.4
	90	19.7	31.7
114 (picture B)	50	4.3	7.0
	60	4.2	6.8
	70	4.1	6.6
	80	4.0	6.5
	90	3.9	6.3
245 (picture C)	50	2.0	3.2
	60	2.0	3.2
	70-90	1.9	3.1

SNOQUALMIE PASS, WA



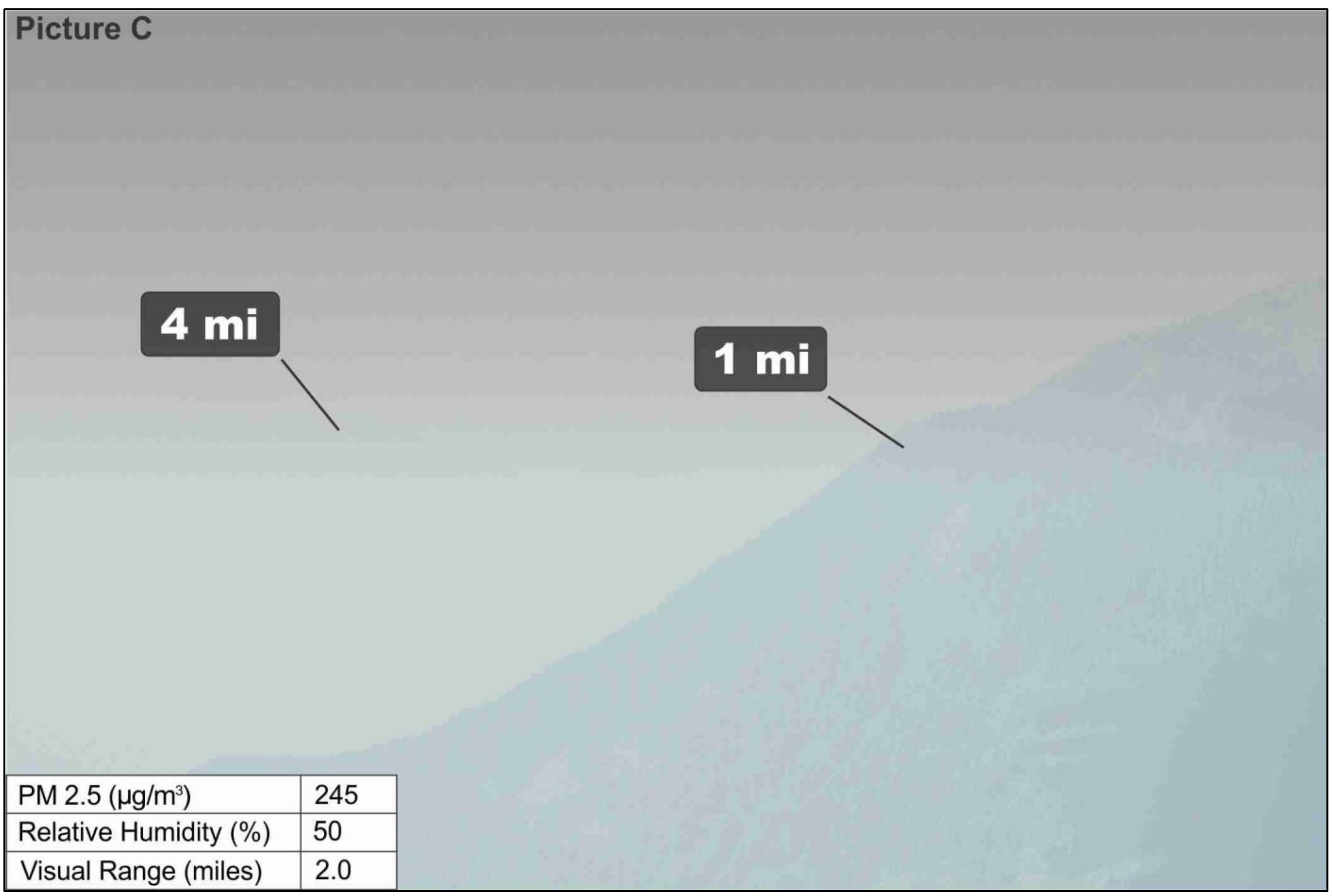


Picture B



PM 2.5 (µg/m³)	114
Relative Humidity (%)	50
Visual Range (miles)	4.3

Picture C



PM 2.5 (µg/m³)	245
Relative Humidity (%)	50
Visual Range (miles)	2.0

U.S. Forest Service, Region 8 – Great Smoky Mountains National Park, TN

Particulate data from 935 days (March 1988 to May 1999) at Great Smoky Mountains National Park were chosen to represent baseline and elevated regional air quality concentrations (table 18). The baseline image represents an area free of smoke-impaired visibility (<5 $\mu g \cdot m^{-3}$ fine and coarse particulates). Visual range at different levels of $PM_{2.5}$ concentration (19, 114, and 245 $\mu g \cdot m^{-3}$) and RH are noted (table 19) and illustrated for Great Smoky Mountains Park on the following pages. Data used for estimating the effect of RH on visual range during the May-September fire season are from Great Smoky Mountains National Park (EPA 2014).

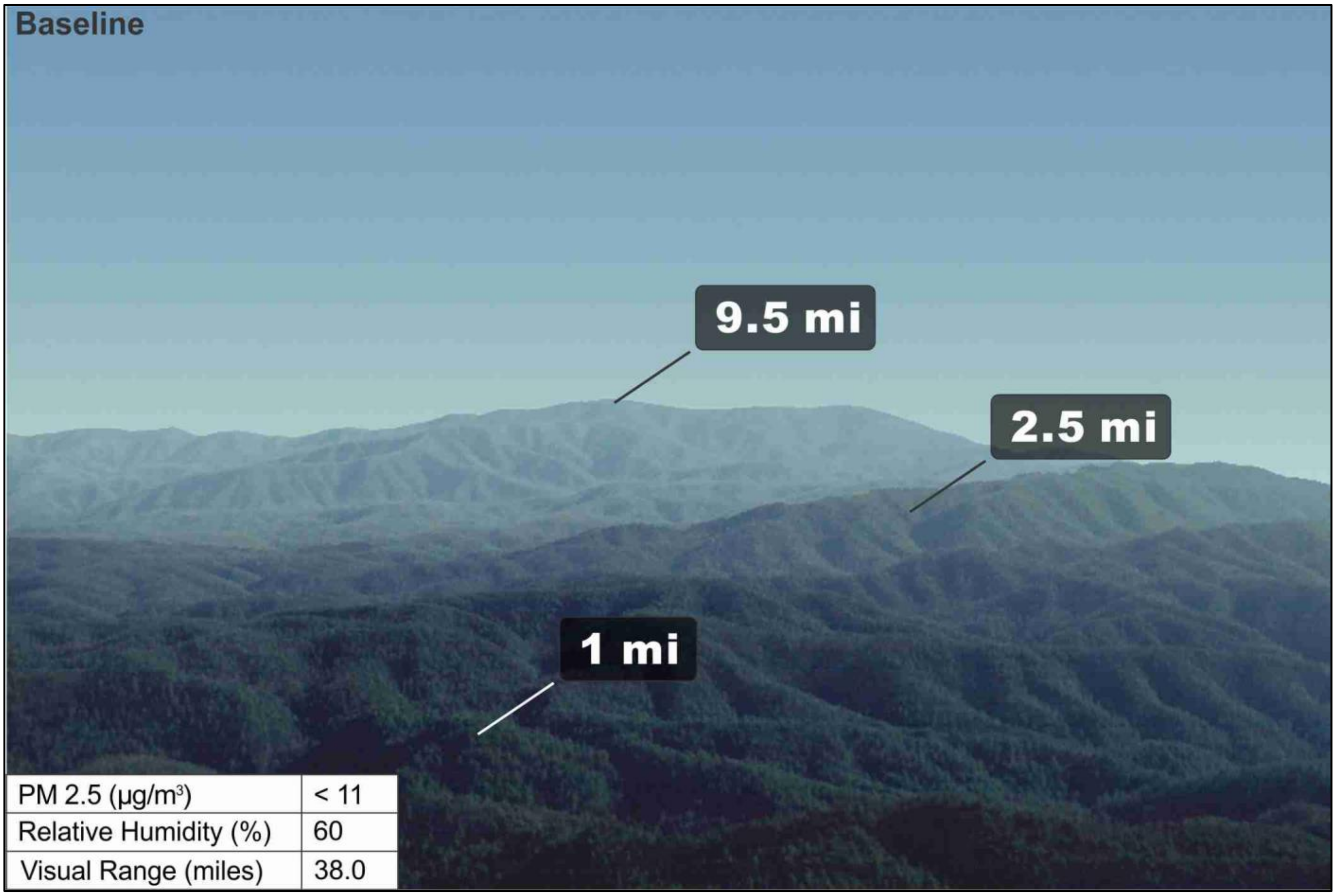
Table 18—Constituents of particulate matter ($PM_{2.5}$ and PM_{10}) at baseline and elevated levels in Great Smoky Mountains National Park, TN

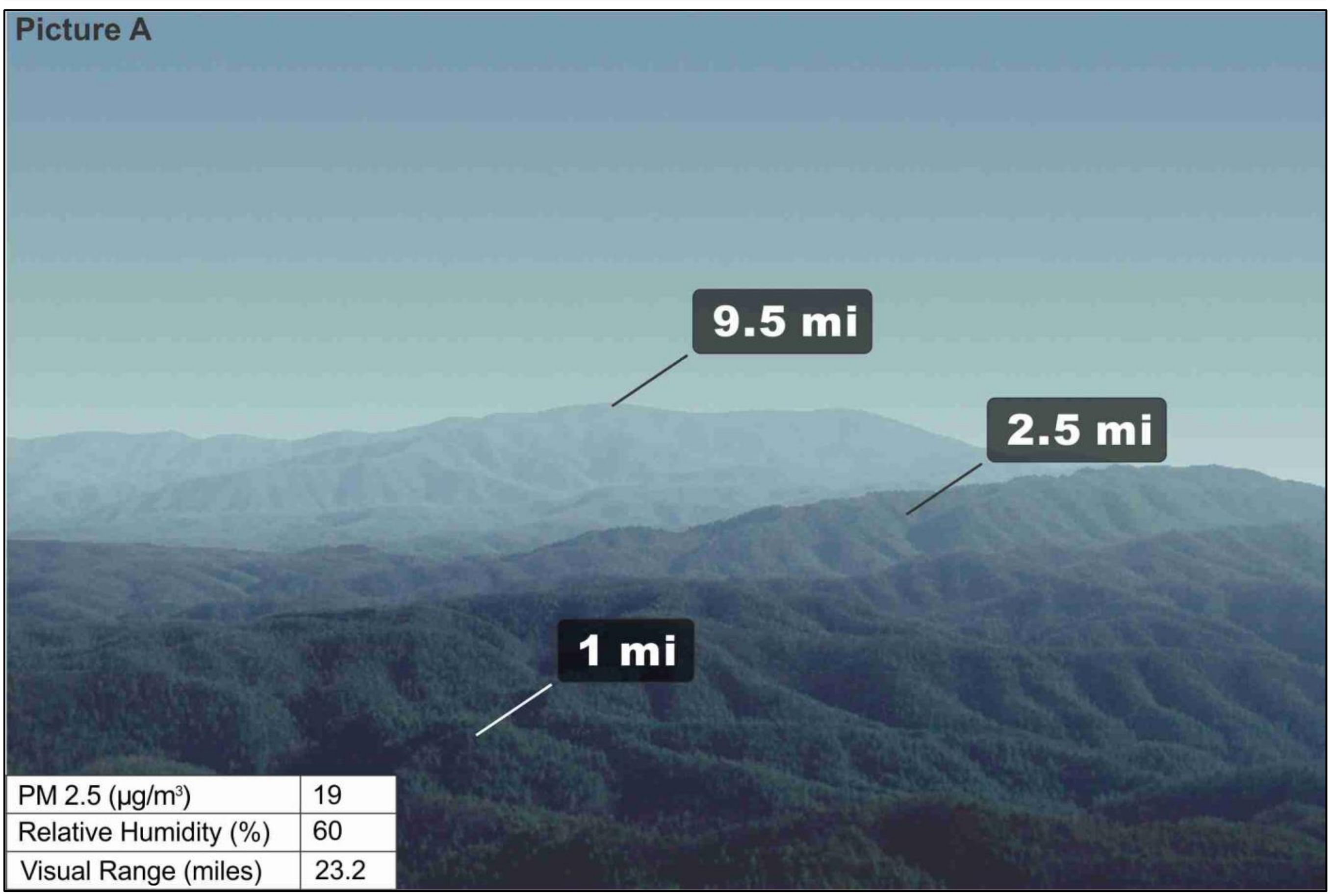
Particulate Matter Constituents	Particulate Matter Concentration Baseline	19	114	245
	------ *$\mu g \cdot m^{-3}$* ------			
Ammonium sulfate	6.42	13.97	13.97	13.97
Ammonium nitrate	0.43	0.31	0.31	0.31
Organic carbon	2.78	3.46	92.66	215.65
LAC/Black carbon	0.47	0.23	6.03	14.04
Fine soil	0.55	1.03	1.03	1.03
Coarse mass	5.74	7.23	11.40	24.50

Table 19—Visual range as a function of $PM_{2.5}$ concentration and relative humidity in Great Smoky Mountains National Park, TN

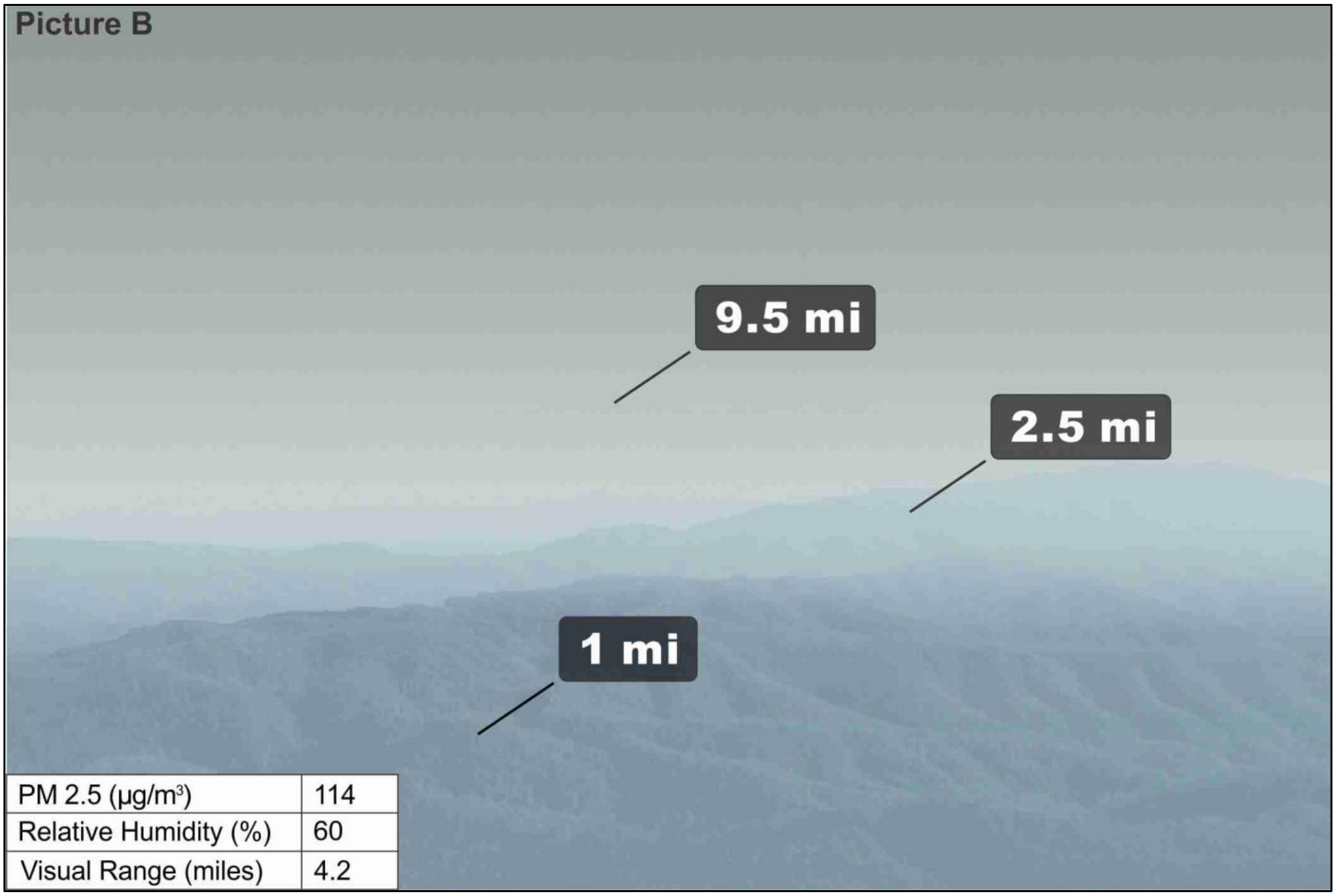
$PM_{2.5}$ Concentration	Relative Humidity	Visual Range	
$\mu g \cdot m^{-3}$	*percent*	*miles*	*km*
<5 (baseline)	60	38.0	61.2
19 (picture A)	60	23.2	37.4
	70	19.6	31.5
	80	16.2	26.0
114 (picture B)	60	4.2	6.8
	70	4.0	6.5
	80	3.8	6.1
245 (picture C)	60	2.0	3.2
	70	1.9	3.1
	80	1.8	2.9

GREAT SMOKY MOUNTAINS NATIONAL PARK, TN



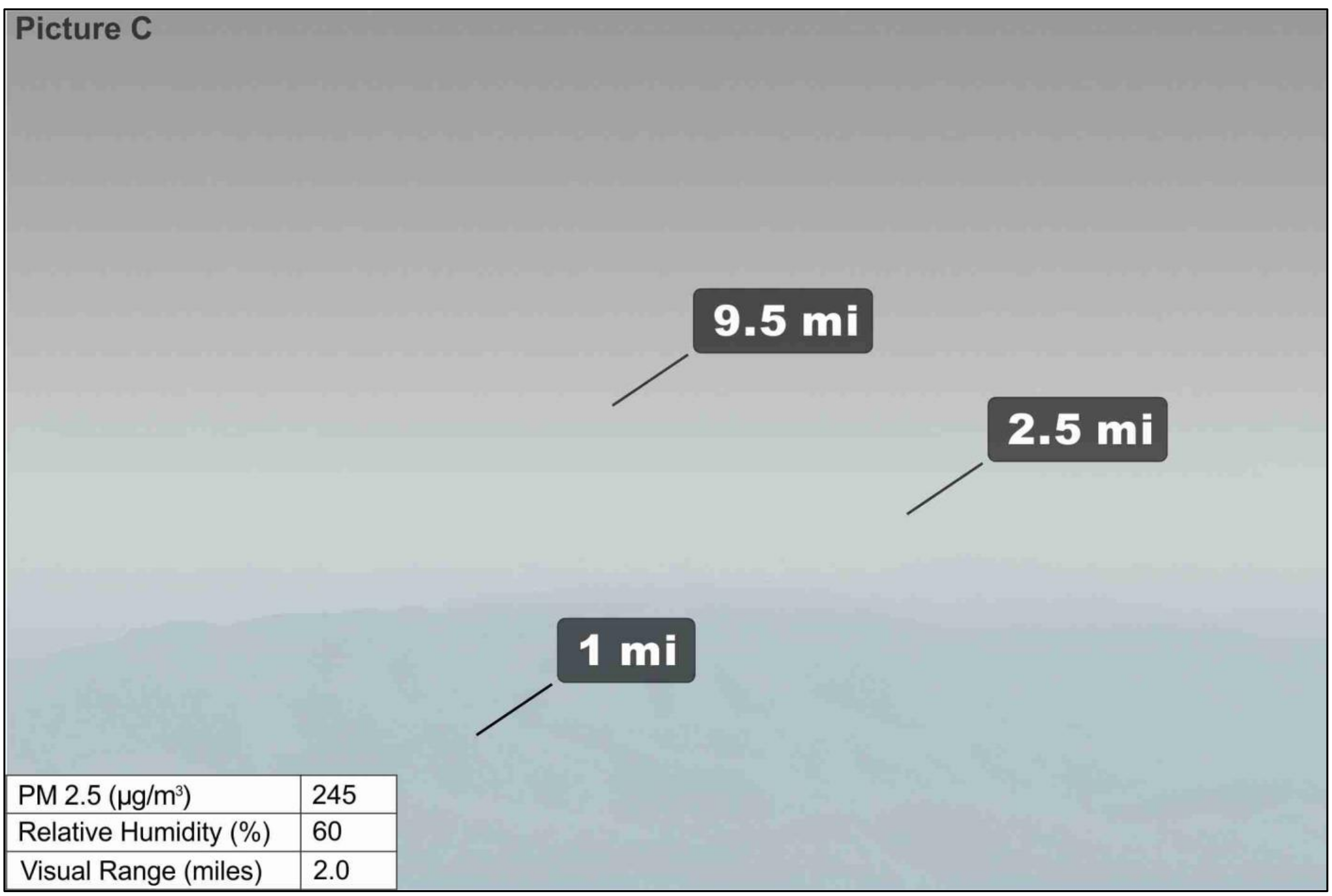


Picture B



PM 2.5 (µg/m³)	114
Relative Humidity (%)	60
Visual Range (miles)	4.2

Picture C



PM 2.5 (µg/m³)	245
Relative Humidity (%)	60
Visual Range (miles)	2.0

U.S. Forest Service, Region 8 – Mammoth Cave National Park, KY

Particulate data from 1,067 days of sampling (October 1991 to August 2003) at Mammoth Cave National Park were chosen to represent baseline and elevated regional air quality concentrations (table 20). The baseline image represents an area free of smoke-impaired visibility (<5 $\mu g \cdot m^{-3}$ fine and coarse particulates). Visual range at different levels of $PM_{2.5}$ concentration (19, 114, and 245 $\mu g \cdot m^{-3}$) and RH are noted (table 21) and illustrated for Mammoth Cave National Park on the following pages. Data used for estimating the effect of RH on visual range during the May-September fire season are from Mammoth Cave National Park (EPA 2014).

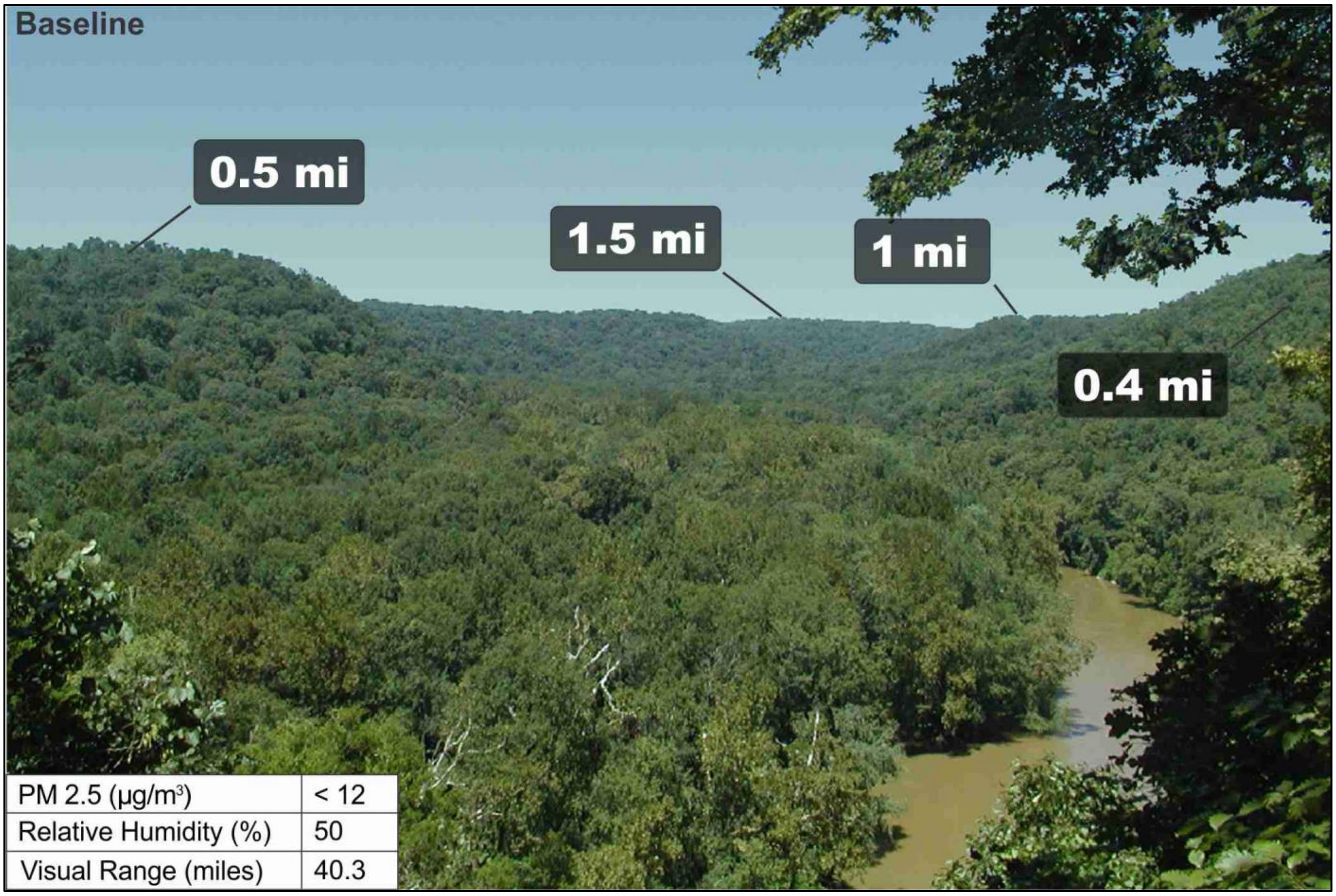
Table 20—Constituents of particulate matter ($PM_{2.5}$ and PM_{10}) at baseline and elevated levels in Mammoth Cave National Park, KY

Particulate Matter Constituents	Particulate Matter Concentration Baseline	19	114	245
	------------ $\mu g \cdot m^{-3}$ ------------			
Ammonium sulfate	6.94	13.99	13.99	13.99
Ammonium nitrate	0.90	0.65	0.65	0.65
Organic carbon	2.82	3.03	92.22	215.22
LAC/Black carbon	0.48	0.20	6.01	14.01
Fine soil	0.58	1.13	1.13	1.13
Coarse mass	4.43	6.26	11.40	24.50

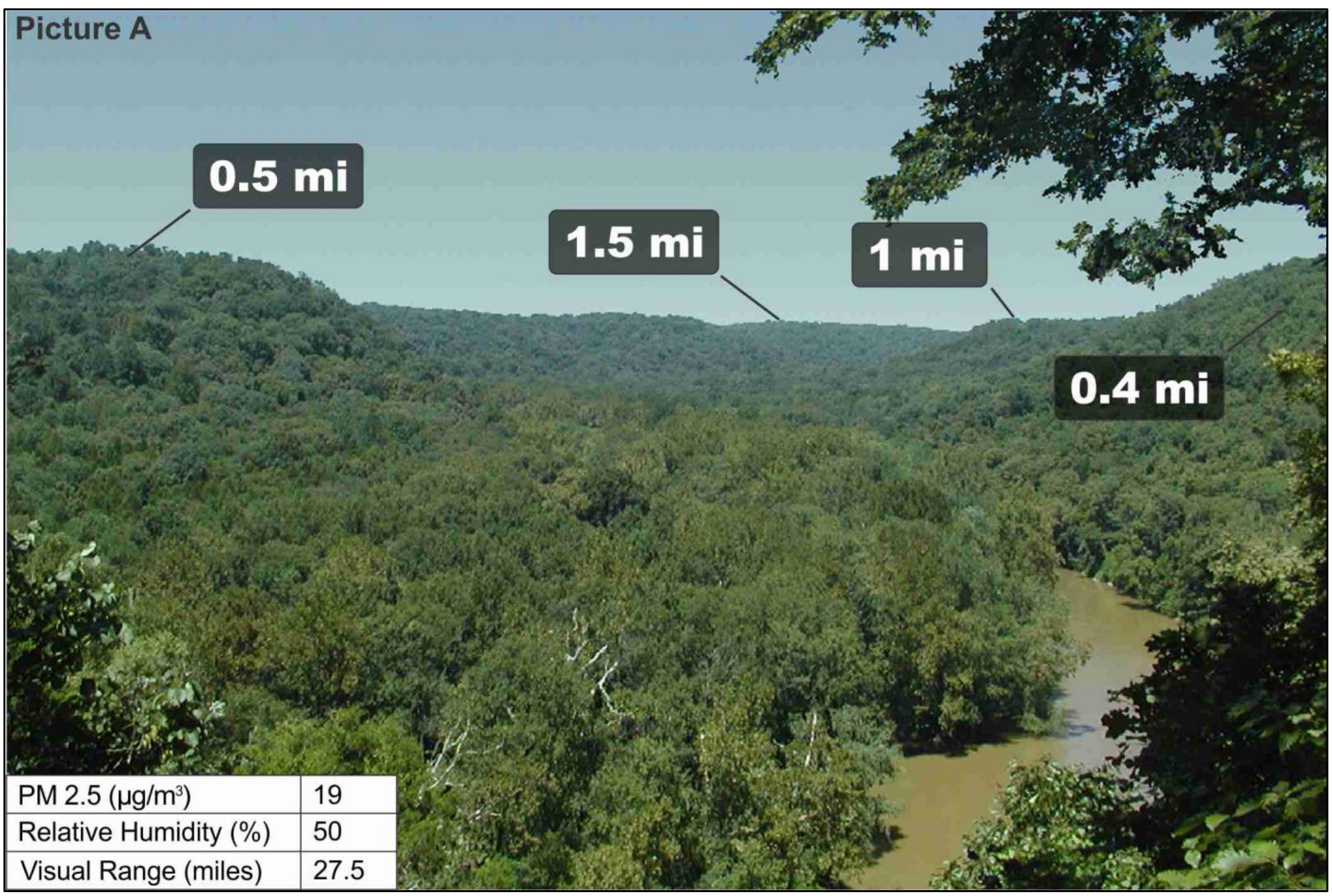
Table 21—Visual range as a function of $PM_{2.5}$ concentration and relative humidity in Mammoth Cave National Park, KY

$PM_{2.5}$ Concentration	Relative Humidity	Visual Range	
$\mu g \cdot m^{-3}$	*percent*	*miles*	*km*
<5 (baseline)	50	40.3	64.8
19 (picture A)	50	27.5	44.2
	60	23.4	37.7
	70	19.6	31.6
	80	16.2	26.0
114 (picture B)	50	4.4	7.1
	60	4.2	6.8
	70	4.0	6.5
	80	3.8	6.1
245 (picture C)	50	2.0	3.3
	60	2.0	3.2
	70	1.9	3.1
	80	1.8	2.9

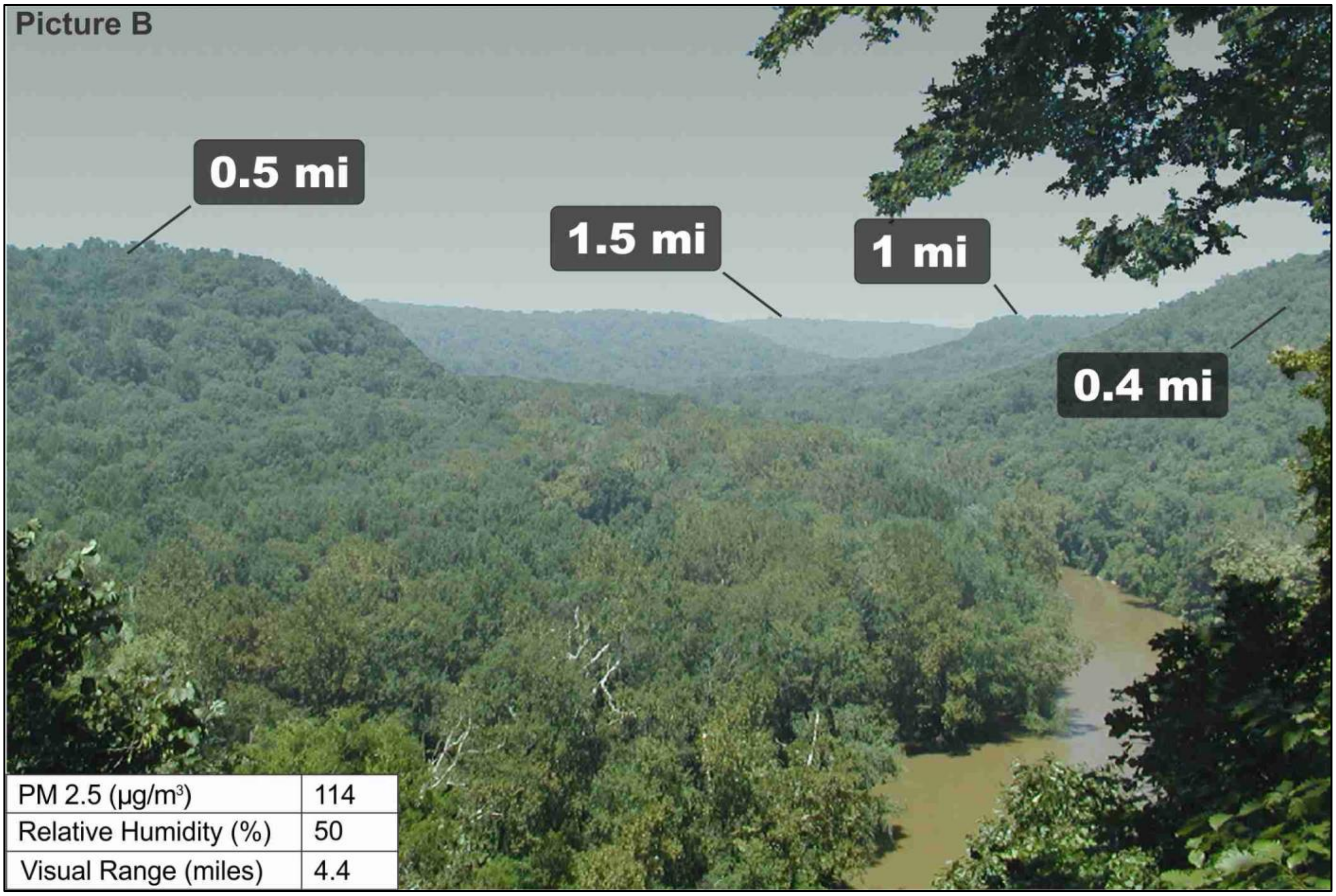
MAMMOTH CAVE NATIONAL PARK, KY

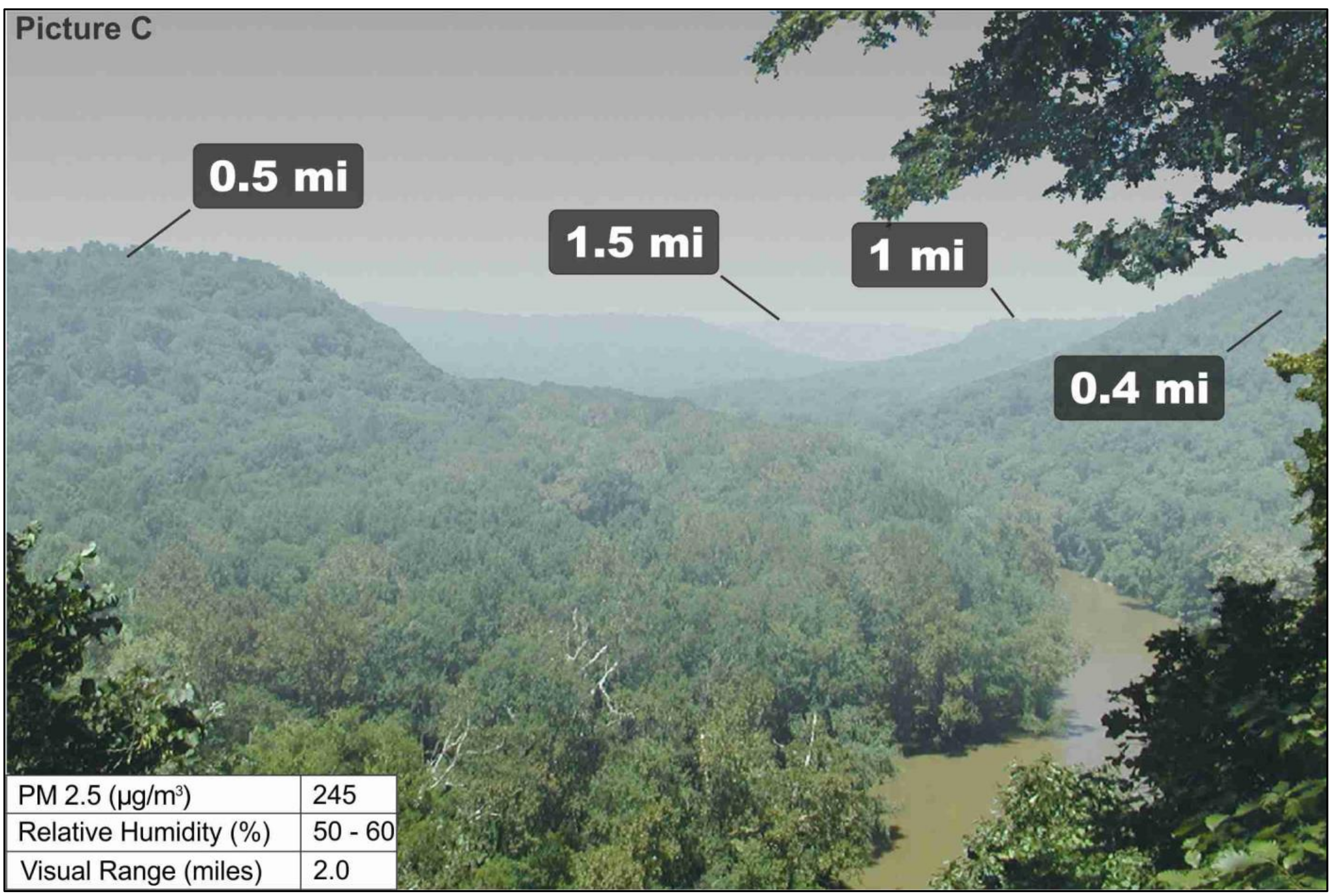


PM 2.5 (µg/m³)	< 12
Relative Humidity (%)	50
Visual Range (miles)	40.3



PM 2.5 (µg/m³)	19
Relative Humidity (%)	50
Visual Range (miles)	27.5


Picture B
0.5 mi
1.5 mi
1 mi
0.4 mi
PM 2.5 (µg/m³) 114
Relative Humidity (%) 50
Visual Range (miles) 4.4


Picture C
0.5 mi
1.5 mi
1 mi
0.4 mi
PM 2.5 (µg/m³) 245
Relative Humidity (%) 50 - 60
Visual Range (miles) 2.0

U.S. Forest Service, Region 8 – Big Bend National Park, TX

Particulate data from 973 days of sampling (March 1988 to May 1999) at Big Bend National Park were chosen to represent baseline and elevated regional air quality concentrations (table 22). The baseline image represents an area free of smoke-impaired visibility (<5 $\mu g \cdot m^{-3}$ fine and coarse particulates). Visual range at different levels of $PM_{2.5}$ concentration (19, 114, and 245 $\mu g \cdot m^{-3}$) and RH are noted (table 23) and illustrated for Big Bend National Park on the following pages. Data used for estimating the effect of RH on visual range during the May-September fire season are from Big Bend National Park (EPA 2014).

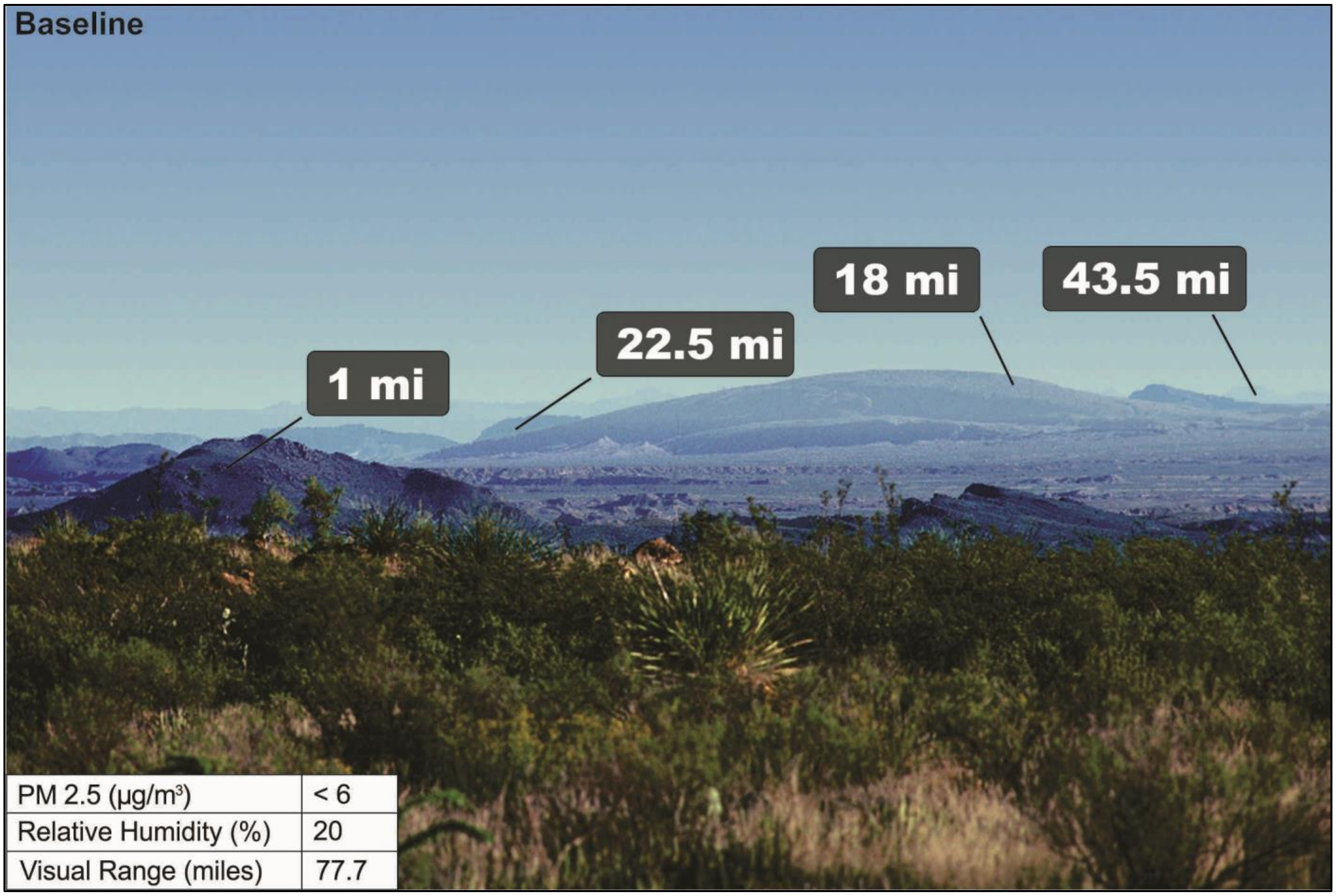
Table 22—Constituents of particulate matter ($PM_{2.5}$ and PM_{10}) at baseline and elevated levels in Big Bend National Park, TX

Particulate Matter Constituents	Particulate Matter Concentration Baseline	19	114	245
	------------------------------ $\mu g \cdot m^{-3}$	------------------------------		
Ammonium sulfate	2.47	4.31	4.31	4.31
Ammonium nitrate	0.24	0.42	0.42	0.42
Organic carbon	1.3	10.89	100.08	223.07
LAC/Black carbon	0.21	0.71	6.52	14.53
Fine soil	1.2	2.67	2.67	2.67
Coarse mass	7.69	11.82	11.82	24.50

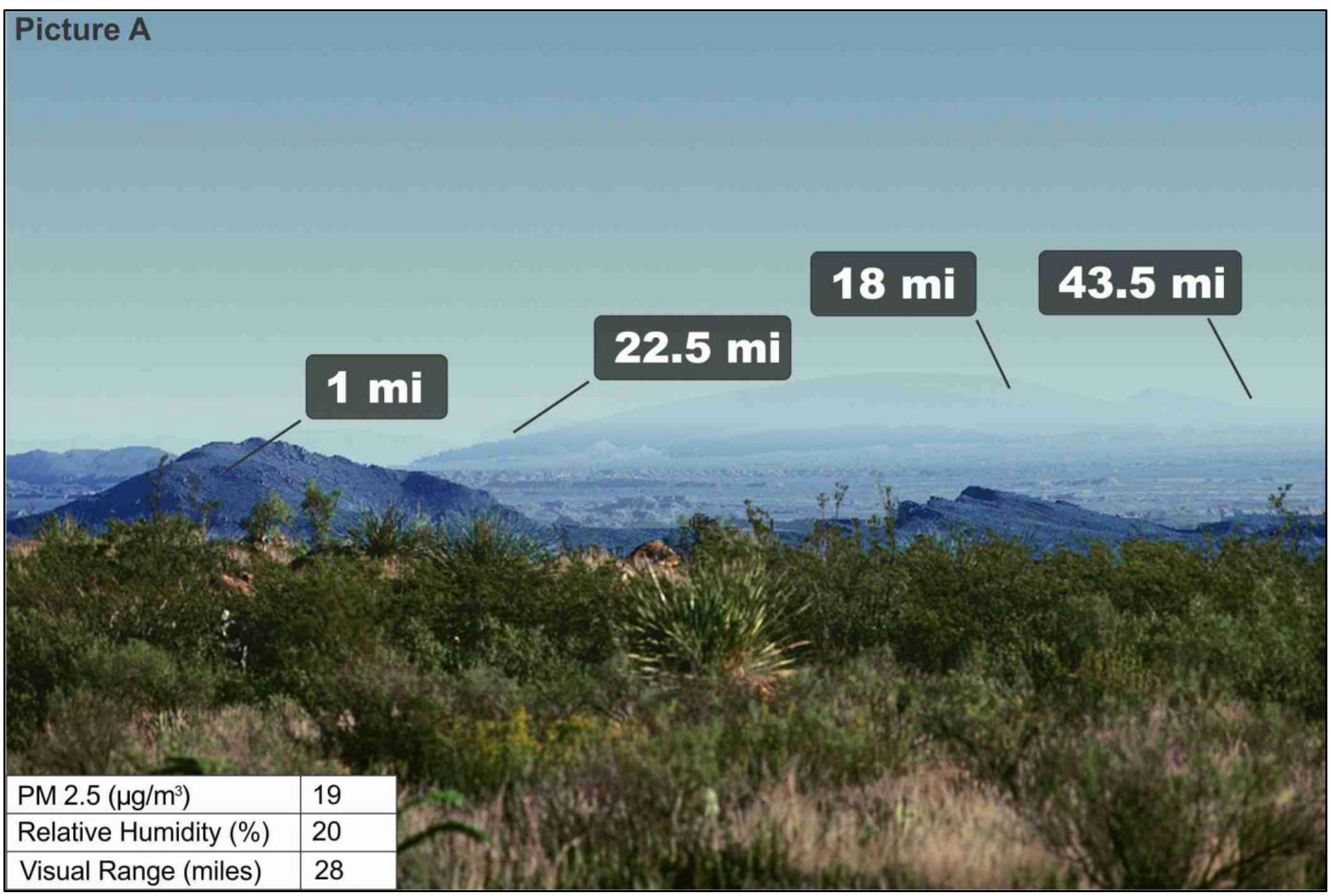
Table 23—Visual range as a function of $PM_{2.5}$ concentration and relative humidity in Big Bend National Park, TX

$PM_{2.5}$ Concentration	Relative Humidity	Visual Range	
$\mu g \cdot m^{-3}$	*percent*	*miles*	*km*
<5 (baseline)	20	77.7	125.0
19 (picture A)	20	28.0	45.1
	30	27.7	44.5
	40	27.0	43.5
	50	25.7	41.3
	60	24.2	38.9
	70	22.5	36.2
114 (picture B)	20	4.7	7.5
	30	4.6	7.4
	40	4.5	7.2
	50	4.4	7.1
	60	4.3	6.9
	70	4.2	6.7
245 (picture C)	20	2.2	3.5
	30-40	2.1	3.4
	50-60	2.0	3.2
	70	1.9	3.1

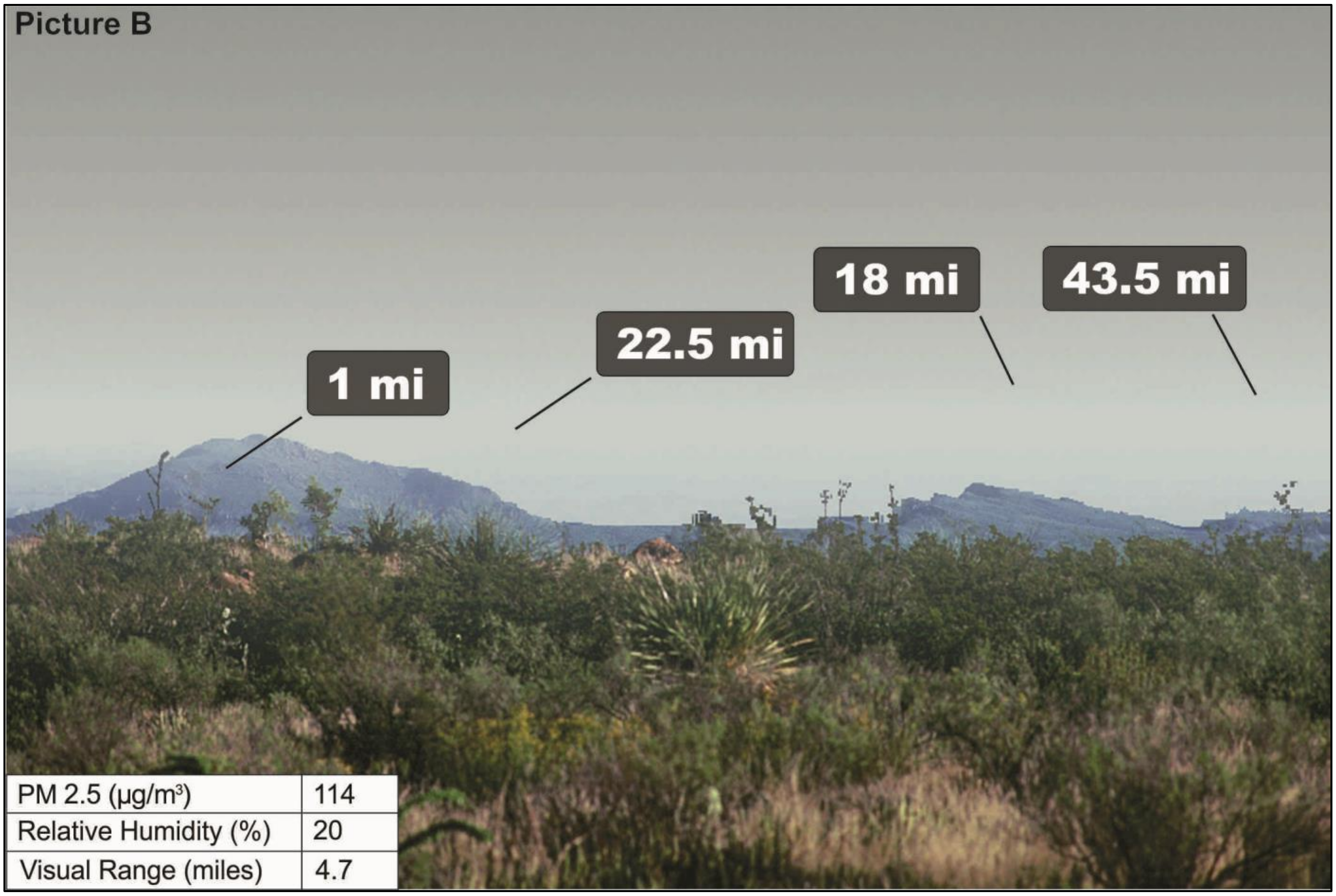
BIG BEND NATIONAL PARK, TX

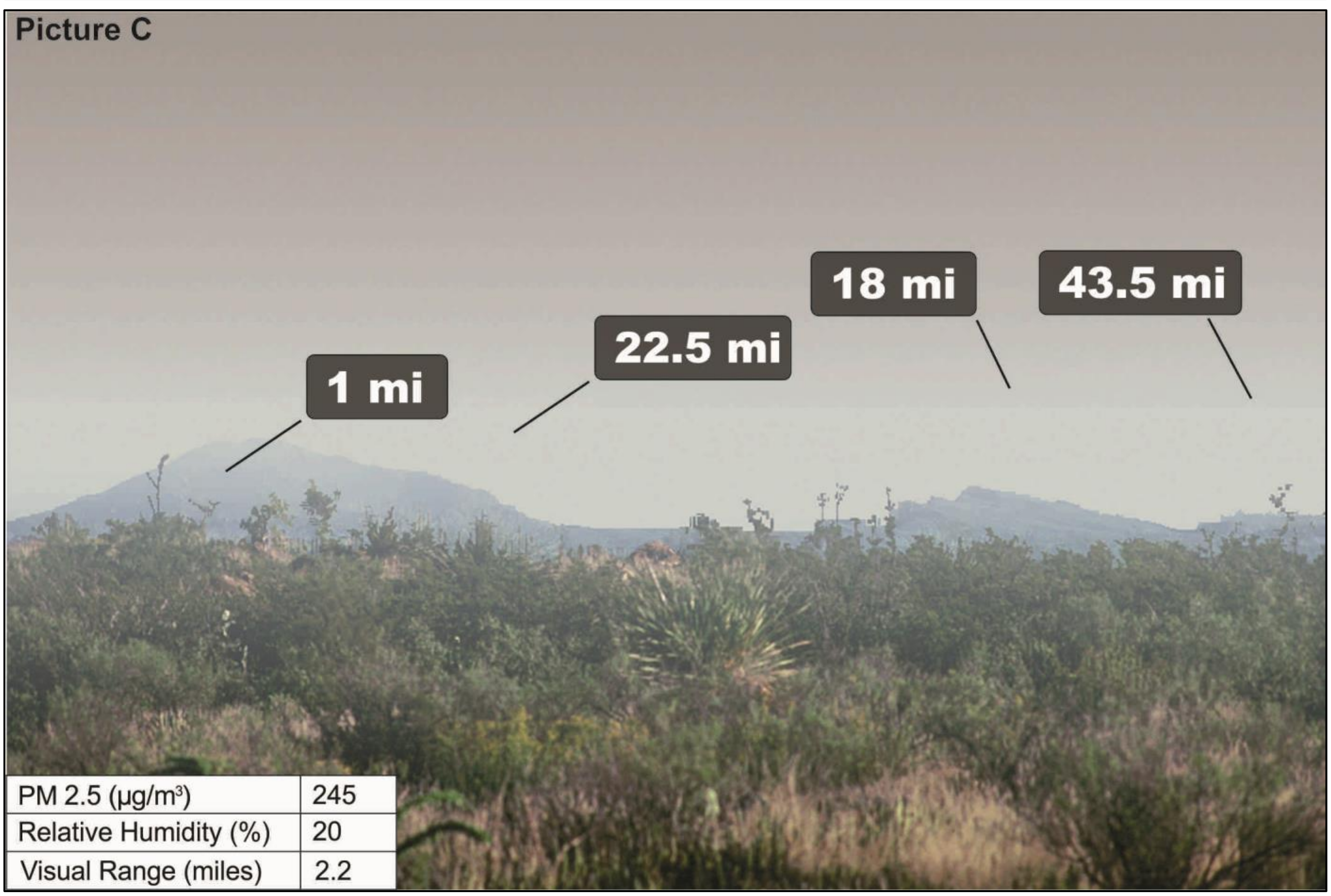


PM 2.5 (µg/m³)	< 6
Relative Humidity (%)	20
Visual Range (miles)	77.7



PM 2.5 (µg/m³)	19
Relative Humidity (%)	20
Visual Range (miles)	28


Picture B
18 mi
43.5 mi
22.5 mi
1 mi
PM 2.5 (µg/m³) 114
Relative Humidity (%) 20
Visual Range (miles) 4.7


Picture C
18 mi
43.5 mi
22.5 mi
1 mi
PM 2.5 (µg/m³) 245
Relative Humidity (%) 20
Visual Range (miles) 2.2

U.S. Forest Service, Region 9 – Acadia National Park, ME

Particulate data from 986 days of sampling (March 1988 to May 1999) at Acadia National Park were chosen to represent baseline and elevated regional air quality concentrations (table 24). The baseline image represents an area free of smoke-impaired visibility (<5 $\mu g \cdot m^{-3}$ fine and coarse particulates). Visual range at different levels of $PM_{2.5}$ concentration (19, 114, and 245 $\mu g \cdot m^{-3}$) and RH are noted (table 25) and illustrated for Acadia National Park on the following pages. Data used for estimating the effect of RH on visual range during the May-September fire season are from Acadia National Park (EPA 2014).

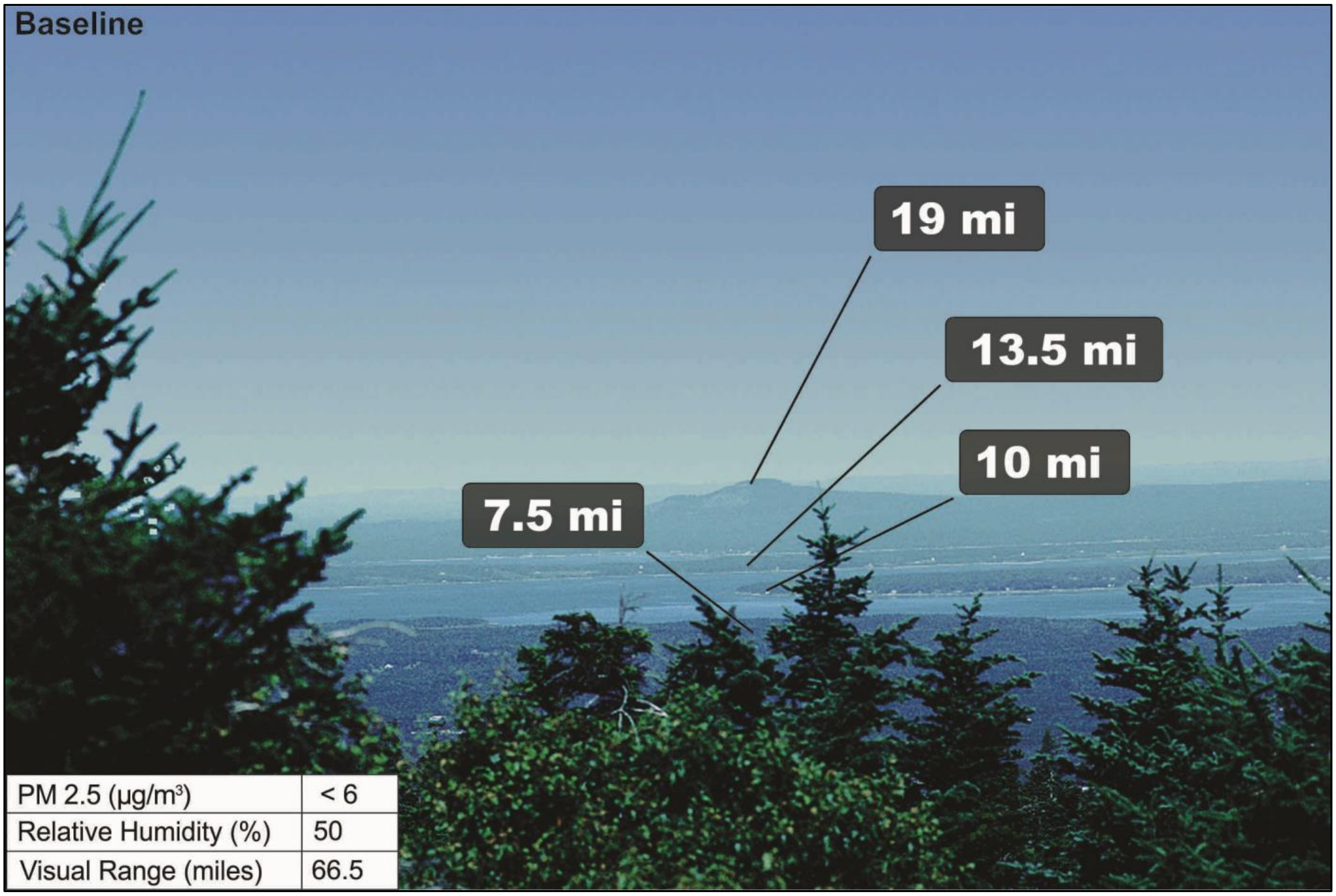
Table 24—Constituents of particulate matter ($PM_{2.5}$ and PM_{10}) at baseline and elevated levels in Acadia National Park, ME

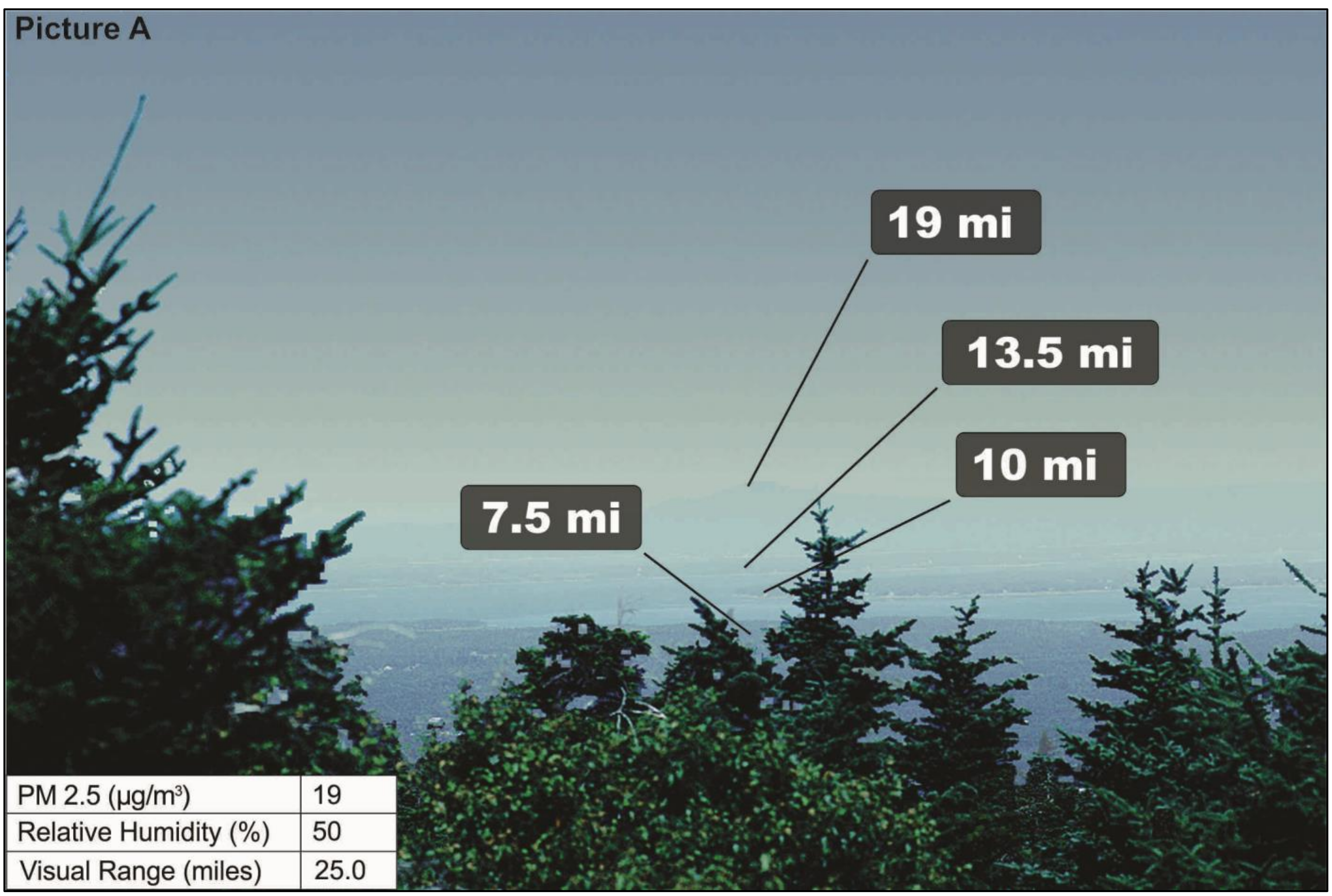
Particulate Matter Constituents	**Particulate Matter Concentration**			
	Baseline	**19**	**114**	**245**
	------------	------------ $\mu g \cdot m^{-3}$	------------	------------
Ammonium sulfate	3.07	6.83	6.83	6.83
Ammonium nitrate	0.37	0.71	0.71	0.71
Organic carbon	1.59	10.42	99.61	222.60
LAC/Black carbon	0.34	0.68	6.49	14.50
Fine soil	0.22	0.36	0.36	0.36
Coarse mass	4.66	5.78	11.40	24.50

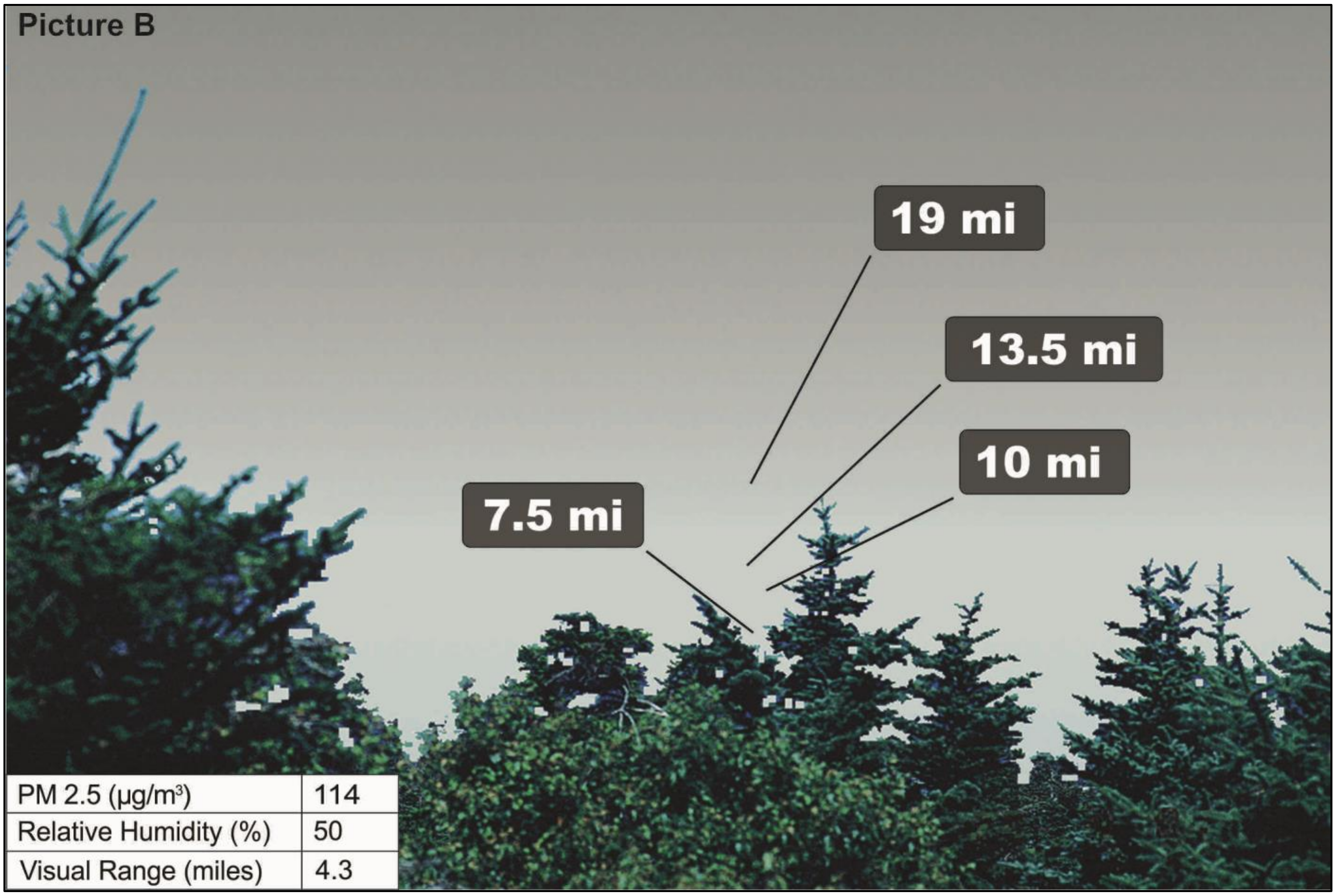
Table 25—Visual range as a function of $PM_{2.5}$ concentration and relative humidity in Acadia National Park, ME

$PM_{2.5}$ Concentration	**Relative Humidity**	**Visual Range**	
$\mu g \cdot m^{-3}$	*percent*	*miles*	*km*
<5 (baseline)	50	66.5	107.0
19 (picture A)	50	25.0	40.2
	60	22.9	36.9
	70	20.7	33.3
	80	18.4	29.6
114 (picture B)	50	4.3	7.0
	60	4.2	6.8
	70	4.1	6.5
	80	3.9	6.3
245	50-60	1.9	3.1
	70	1.8	2.9
	80	1.7	2.7

ACADIA NATIONAL PARK, ME






Picture B
19 mi
13.5 mi
10 mi
7.5 mi
PM 2.5 (µg/m³) 114
Relative Humidity (%) 50
Visual Range (miles) 4.3

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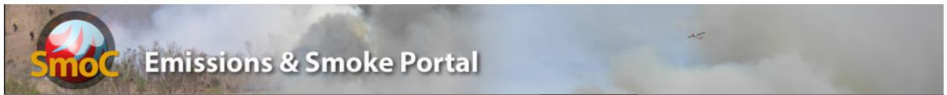

Public Perceptions and Tolerance of Smoke from Wildland Fires

Overview

Smoke production from fires is a serious land management consideration because it can affect public and firefighter health, impair visibility for road and air traffic, damage property, become a "nuisance," and contribute to air pollution in populated areas that are regulated by EPA air quality standards. However, a very limited amount of research has been conducted specific to public perceptions and tolerance of smoke from wildland fires. Recently the fire management community has called for research to improve the scientific understanding of what factors influence public tolerance of smoke from wildland fires, how people value their personal health and the health of their surrounding ecosystems, especially in circumstances where fire, climate change and increasing populations are interconnecting. This page is dedicated to providing information about current Joint Fire Science Program research specific to public perceptions and tolerance of smoke from wildland fires.

Current Literature and Updates

-**Public Perceptions and Tolerance of Smoke From Wildland Fire** – Draft Chapter for the Second Edition of the Smoke Management Guide for Prescribed and Wildland Fire. 2013. Authors: Jarod Blades, Troy Hall, Sarah McCaffrey. (PDF)

-**Traversing Through the Haze, Exploring the Human Perspective of Smoke From Fire**. Northwest Fire Science Consortium Research Brief 1. Spring 2013. Authors: Stacey Sargent Frederick, Dr. Christine Olsen, and Dr. Eric Toman. (PDF)

-**Eight Questions Answered: Social Science and Wildfire**. In Press. McCaffrey, S., and Olson, C. (PDF) Readers of this work are urged to consult the full reference by the same authors: **Research Perspectives on the Public and Fire Management: A Synthesis of Current Social Science on Eight Essential Questions**. (PDF)

-**Best practices in risk and crisis communication: Implications for natural hazards management**. 2013. Article in Natural Hazards, 65(1) pgs 683-705. Authors: Steelman, T., and McCaffrey, S. (PDF)

-**Public perceptions and tolerance of smoke from prescribed and wildland fire. Working literature synthesis**.2011. A working document which synthesizes recent research on smoke perceptions and tolerance. Authors: Blades, J., and Hall, T. (PDF).

Communicating Smoke Impacts

Photographic Guides for Communicating Smoke Impacts – A series of modeled visibility impacts at differing particulate matter concentrations and relative humidity.

Webinars & Videos

Smoke Perception Modules

(*Above*) Smoke Perceptions Module 1, available on YouTube. This is one of a four part series which addresses public beliefs and tolerance of smoke, individual and community characteristics, and public trust and advanced warnings. These training resources are offered by researchers at the University of Idaho as part of an effort to enhance understanding and communications between fire practitioners and the public.

Smoke Perceptions Module 1 – Why Public Perception Matters

Smoke Perceptions Module 2 – Values, Beliefs, Attitudes, and Tolerance

Smoke Perceptions Module 3 – Individual and Community Characteristics

Smoke Perceptions Module 4 – Public Trust and Advanced Warning

Public Perceptions of Smoke in Oregon and California

Appendix L.

New Public Perceptions Chapter – Smoke Management Guide

Public Perceptions and Tolerance of Smoke from Wildland Fire

Jarod Blades

Troy Hall

Sarah McCaffrey

Introduction

Land managers and officials need to understand the diverse public opinions toward smoke from wildland fires; however, a very limited amount of research has been conducted on this topic. Hence, land and fire managers are largely uncertain about society's willingness to tolerate smoke in the short-term for long-term benefits, and they need effective ways to describe the likely smoke outcomes of alternative fire management programs (e.g., prescribed burning treatments vs. suppression) and why these programs serve the public interest (Potter et al. 2007). Information about values, attitudes, and beliefs can be used to inform land management decisions and tailor public communication strategies that better align with local and regional perspectives. Additionally, there has been a recent call from the fire management community to improve the scientific understanding of how people value personal health and ecosystem health, notably where fire, climate change and increasing populations are interconnecting (Riebau and Fox 2010). This chapter provides a brief overview of the research that has been conducted to date on public perceptions of smoke.

It is difficult to disentangle public perceptions and tolerance of smoke from tolerance of wildland fire – the source of the smoke. This chapter reviews the limited literature exploring the complex factors that influence public tolerance of smoke (figure 1); many of the cited sources come from studies focused primarily on wildland fire, where smoke was a smaller and secondary focus. This review will address the following: 1) public knowledge, beliefs, and attitudes about smoke from wildland fires; 2) agency trust and advanced warning; and 3) selected individual and community characteristics (e.g., past experience with smoke, preparedness, and sociodemographic characteristics).

Public Knowledge, Beliefs, and Attitudes about Smoke from Wildland Fire

Different levels of knowledge, beliefs, and understanding of current fire and smoke issues can influence public smoke tolerance and support for fire management. Higher tolerance has been found to be associated with knowledge about the necessity of the action involving smoke, the positive effects of wildland fire (e.g., improving forest health, reducing wildfire risk, and improving wildlife habitat), and steps agencies have taken to minimize smoke impacts on communities (Blades and Hall, 2012; Jacobson et al. 2001; Ryan and Wamsley 2008; Shindler and Toman 2003; Winter et al. 2004, 2006). However, greater knowledge does not always lead to higher tolerance because other factors may be more important, as explored below.

Concerns about Personal Health and Property

KEY POINT: A small percentage of the U.S. population considers smoke from wildland fires to be a serious issue. However, these individuals often have an existing health condition and can be the most vocal about health concerns – which can affect current and future management activities.

Smoke from wildland fires can impact community residents in a variety of ways, through health effects, ash deposition (soiling of materials), public nuisance, impaired visibility, and economic impacts (see Chapter 3). For most people, smoke from wildland fires does not have a noticeable impact on health; however, certain segments of the population and people at greater risk of exposure to smoke (e.g., WUI residents, outdoor enthusiasts, firefighters) are more vulnerable to health risks (Fowler 2003). Individuals, households, and communities that have existing health problems are more aware of smoke health impacts and are typically less tolerant of smoke from wildland fires. Fears about human safety and apprehension about increased levels of smoke can be a primary concern surrounding wildland fire (Brunson and Shindler 2004; Kneeshaw et al. 2004); however, general population surveys show that the majority of residents do not consider smoke to be a serious issue (Blades and Hall 2012; Brunson and Evans 2005; Jacobson et al. 2001; Loomis et al. 2001; McCaffrey et al. 2008; McCaffrey and Olsen 2012; Ryan and Wamsley 2008). Nevertheless, smoke from wildland fires is highly salient for people with existing health issues (e.g., asthma), which has been shown to be approximately 30% of households (McCaffrey and Olsen 2012). These individuals are often more vocal about concerns, although some people with health issues have accepted smoke as a reality of where they live (Weisshaupt et al. 2005). Given rising asthma rates and an aging U.S. population, the issue of health impacts from wildland fire smoke will be an increasing concern.

Concerns about Recreation and Tourism

KEY POINT: Community concerns about the impacts of smoke on recreation, tourism, and outdoor activities can be greater than other concerns.

People travel to National Forests and protected areas to enjoy solitude and scenery – both of which can be impacted by fire and smoke. The wildfire season often coincides with the peak tourism and recreation season, increasing the likelihood of smoke impacts to outdoor-related businesses. Smoke is sometimes perceived as a negative impact to aesthetic quality and recreation, and can result in substantial revenue losses if visitation declines (Brunson and Shindler 2004; Ross 1988; Sandberg et al. 2002; Thapa et al. 2004; Winter et al. 2002). Recent research in the U.S. northern Rocky Mountains has found that the public perceives the likelihood of smoke impacts on outdoor recreation, scenery, and school recess to be greater than the likelihood of impacts to personal health and people from rural areas are more concerned about such impacts than people from urban areas (Blades and Hall 2012). Given that many rural communities, notably in the western U.S., are shifting from commodity to amenity based-economies (Winkler et al. 2007), impacts to recreation, tourism, or other amenity-based lifestyles are an increasing concern.

Ecosystem Health and the Role of Fire

KEY POINT: The public is more tolerant of smoke when there is an accurate understanding of the positive effects of wildland fire, such as improving forest health and wildlife habitat.

Many people value natural landscapes and agree that ecosystem health is important. However, there are divergent opinions about what defines a healthy ecosystem, the appropriate role of fire, and whether smoke is an inevitable natural consequence of living near wildlands.

For some people, concerns about prescribed fire impacts on fish and wildlife are higher than concerns about health effects of smoke or the cost of conducting the treatment (Bowker et al. 2008; Jacobson et al. 2001). Reinforcing and improving public understanding about the role of fire in improving ecosystem health and reducing community wildfire risk should be a focal point of public communication aimed at increasing public tolerance of smoke.

Public Trust in Land Management Agencies

Trust has long been established as an important component of public land management. In any aspect of life, trust is difficult to establish, easy to lose, and very hard to regain. Expectations for land managers are higher now than in the past because fire and smoke management have more direct impacts on citizens living in rural WUI communities, largely due to population growth and greater opportunities for people to experience wildland fire effects.

Public acceptance of fuel treatments that involve smoke is often related to the degree to which people trust the implementing agencies (Vogt et al. 2003). Several dimensions of trust related to land management and fire have emerged as being most salient to the public, notably competence, credibility, care, and shared values (Absher et al. 2009; Winter et al. 2004, 2006). Care and credibility are established by agency efforts to communicate with the public about current and future agency actions, especially regarding the risks associated with wildland fire and smoke. Providing the public with advanced warning about smoke provides an opportunity for citizens to ask questions early, conduct personal and community preparations, and maintain relationships with fire management professionals (see section 11.2, Local Situational Analysis). Advanced warning was identified in one regional study as the most important aspect of public tolerance of smoke from wildland fire (Blades et al. 2012). Further, a personal phone call from an agency representative that provided advanced warning about potential smoke impacts was considered much more preferable to a radio, television, or newspaper public service announcement. Credibility and competency increase public trust and acceptance of forest treatment activities, resulting in a belief that the agency is able to manage the burn safely (Winter et al., 2002). Social trust is enhanced when people perceive that they share similar goals, thoughts, values, and opinions with the agency (Absher et al. 2009; Winter et al. 2004). Feelings of involvement, ownership, and shared responsibility have also been found to be key components of trust (Blanchard and Ryan 2007).

The Controllability of Fire and Escaped Fires

As stated at the beginning of this chapter, it is often difficult to separate perceptions of smoke from perceptions of fire – where beliefs about wildland fire are intertwined with beliefs about the resulting smoke. Public support for wildland fire and smoke management is often dependent on whether people believe that the fire and smoke can be effectively controlled – either during a fire event or when using fuels treatments to modify future fire behavior. Does the public believe that prescribed burning will reduce the likelihood of an extreme wildfire (very unhealthy, dense smoke) and reduce future risks to ecosystems and/or human health and property? People from various parts of the U.S. have been found willing to trade-off the negative aspects of smoke from prescribed fires conducted now for the future benefits of less smoke and reduced threat of extreme wildfires (Blades and Hall 2012; Weisshaupt et al. 2005; Winter et al. 2006). Overall, people are more tolerant of smoke from prescribed fires if they believe that it ensures greater control over present or future fires, benefits the ecosystem, and reduces the risks to personal health and property.

On the other hand, sometimes the threat of an escaped fire and widespread smoke is perceived as being greater than the potential benefits of burning. Stated another way, the cure is perceived to be worse than the disease. People who have concerns about the possibility of a prescribed fire escaping have a lower tolerance for its use (Absher et al. 2009; Blanchard and Ryan 2007; Brunson and Evans 2005; Fried et al. 2006; Weisshaupt et al. 2005).

KEY POINTS: Trust has long been established as an important factor of effective land and fire management, and the same holds true for smoke management. Advanced warning about potential smoke impacts is one of the most important aspects of public tolerance of smoke from wildland fires.

People are often willing to trade-off the negative short-term consequences of smoke from prescribed fires if they **believe that it could reduce the threat of extreme wildfire and smoke events in the future, and trust that the likelihood of an escaped fire is low.**

To address public concerns, it is important to communicate all the trade-offs associated with fuel treatments clearly because vague or incomplete discussion of smoke risks could jeopardize public trust and support. Face-to-face personal contact helps to promote trust. Shindler (2004) recommends that communications should clearly reflect land managers' understanding of public concerns and reflect a public-management relationship commitment over the long-term. Building and maintaining trust between land managers and public stakeholders is not a new concept; however, a stronger focus on advanced warning and personal communications about potential smoke impacts and smoke mitigation strategies could enhance public trust surrounding smoke management.

Other Individual and Community Characteristics Related to Tolerance of Wildland Fire Smoke

Past Experience with Fire and Smoke

The past experiences of an individual, community, and region with wildland fire and smoke have been suggested as driving differences in support for prescribed fire practices (Loomis et al. 2001), and the same is likely true for tolerance of smoke. Individuals or communities with more wildland fire experience and those individuals who have worked in natural resource-related fields are more accepting of fuel treatments (Blanchard and Ryan 2007; Winter et al. 2006). Moreover, people who have experienced recent and severe wildfire smoke may believe that prescribed burning is an effective technique for reducing wildfire and smoke risks (Weisshaupt et al. 2005). On the other hand, less personal experience with wildland fire and smoke has been linked to beliefs about negative outcomes of prescribed fire, such as escaped fires, and lower support for forest treatments (Winter et al. 2006). This is an important consideration because the lack of wildland fire could actually increase the risk of severe wildfire and smoke in the future, as well as the need for treatment. Therefore, understanding the type of individual and community past experiences with wildland fire and smoke (e.g., good or bad experience, short- or long-term impacts) is important to understanding public tolerance of smoke and support for management actions involving smoke.

Community Type and Proximity to Wildlands

How does the location of a person's home (e.g., urban, suburban, exurban, or rural) and proximity to wildlands influence perception and tolerance of smoke from wildland fires? A public preference for lower-risk treatments (i.e., mechanical thinning) near developed areas and perceived higher-risk treatments (i.e., prescribed fire) in remote rural areas has been documented in some instances (Bright and Newman 2006; Weisshaupt et al. 2005). Recent research in the northern U.S. Rocky Mountains found that residents of both rural and urban communities understood the benefits of prescribed fire, trusted management agencies, were somewhat tolerant of smoke from wildland fires, and supported prescribed fire management activities; however, rural communities were significantly lower in all of these categories than urban communities (Blades and Hall 2012). It is not surprising to find a difference between urban and rural residents, but it is encouraging that their beliefs and attitudes generally trend in the same direction, and that a consistent communication strategy could be effective regardless of location and proximity to wildlands.

Community Preparedness for Fire and Smoke

KEY POINT: The amount and type of past experience with fire and smoke can influence beliefs and attitudes about fire management and smoke.

There are important relationships among space, community, and culture that define a WUI community and its level of preparedness for wildland fire and smoke (Bowker et al. 2008; Jakes et al. 1998, 2007; Lee 1991; Paveglio et al. 2009). Does a community's level of preparedness for fire (e.g., completed and following through with a Community Wildfire Protection Plan, coordination between structural and wildland firefighters, or formation of a WUI committee) result in differing levels of tolerance for smoke from wildland fires? Recent research (Blades & Hall, 2012) has shown that communities that are more prepared for wildland fire are significantly more tolerant of smoke than less-prepared communities, and more supportive of fuels management involving smoke (i.e., prescribed fire and wildfire use). This is likely related to the positive association, discussed earlier, between knowledge levels and support for prescribed fire.

Sociodemographic Characteristics

Demographic characteristics have rarely been documented as having a strong relationship to the public level of support for fire management activities or policies (Absher et al. 2009; Blades and Hall 2012; Fried et al. 2006; McCaffrey and Olsen 2012; Shindler and Toman 2003). This is not altogether surprising in that issues of smoke and fire are often complex and impacted by geographic, social, and other contextual factors, as this chapter has established. Nevertheless, some studies have indicated that women (notably African-American and Hispanic) are more concerned than men about the environment in general, and certainly more concerned about the potential adverse effects of prescribed fire and smoke (Bowker et al. 2008; Lim et al. 2009; Ryan and Wamsley 2008).

Summary and Conclusions

This chapter has focused on the complex factors that influence public perceptions and tolerance of smoke from wildland fires. The studies reviewed here suggest that public perceptions and tolerance of smoke may be similar at regional levels for some aspects (e.g., support for the use of prescribed fire, awareness of prescribed fire benefits, general tolerance of smoke from wildland fires, moderate trust of public land and fire managers), but also vary significantly among different types of communities and individuals. Often public communication materials are developed for a homogenous audience, yet these studies are a useful reminder of the variability that exists within communities and regions, and that locally tailored messages may be more effective for achieving stronger public tolerance or acceptance of smoke from wildland fire management. In summary, wildland fire smoke management programs and plans should take into account some key points about public perceptions and tolerance of smoke:

1. Public beliefs and attitudes about the benefits or detriments of wildland fire directly influence tolerance of smoke — The strength of different beliefs and attitudes about the consequences of fire and smoke influence tolerance of smoke and support for management strategies that produce smoke. Public concern about health impacts appears to be the main issue for wildland fire smoke. However, where concerns are present thay can be substantial, to date this appears to be a concern for around one-third of households. Health issues related to smoke are anticipated to increase in the future, so an early and ongoing relationship with individuals who have existing health conditions is advisable in order to mitigate concerns and reduce management complications from a vocal public. Community concerns about the impacts of smoke on recreation, tourism, and outdoor activities can be greater than other concerns. The public is generally more tolerant of smoke when there is an accurate understanding of the positive effects of wildland fire, such as improving forest health and wildlife habitat.

2. Build and maintain trust, and validate concerns about controlling fire and smoke — The development of trust and maintaining a relationship with the public has always been an important aspect of effective land and fire management, and the same holds true for smoke management. Advanced warning about potential smoke impacts is one of the most important contributors to public tolerance of smoke from wildland fires and agency trust. People are often willing to trade-off the negative short-term consequences of smoke from prescribed fires if they believe that this will reduce the threat of extreme wildfire and smoke events in the future, and if they trust that the likelihood of an escaped fire is low. Managers should clearly communicate all trade-offs surrounding wildland fire smoke because vague, untimely, incomplete or glossed-over representations of smoke effects and exaggerated expectations of safety could jeopardize public trust and support (see section 11.1).

3. The devil's in the details, so understanding each audience is important — Of course, this is not a new suggestion, but individual and community characteristics such as past experience, community preparedness, and individual characteristics influence perceptions and tolerance of smoke in complex ways. Because there is a mosaic of varying interests and lifestyles that are intermixed, often without clearly delineated boundaries, it is important to dive into the details of each community in an attempt to understand contextual and spatial differences that could influence perceptions and tolerance of smoke.

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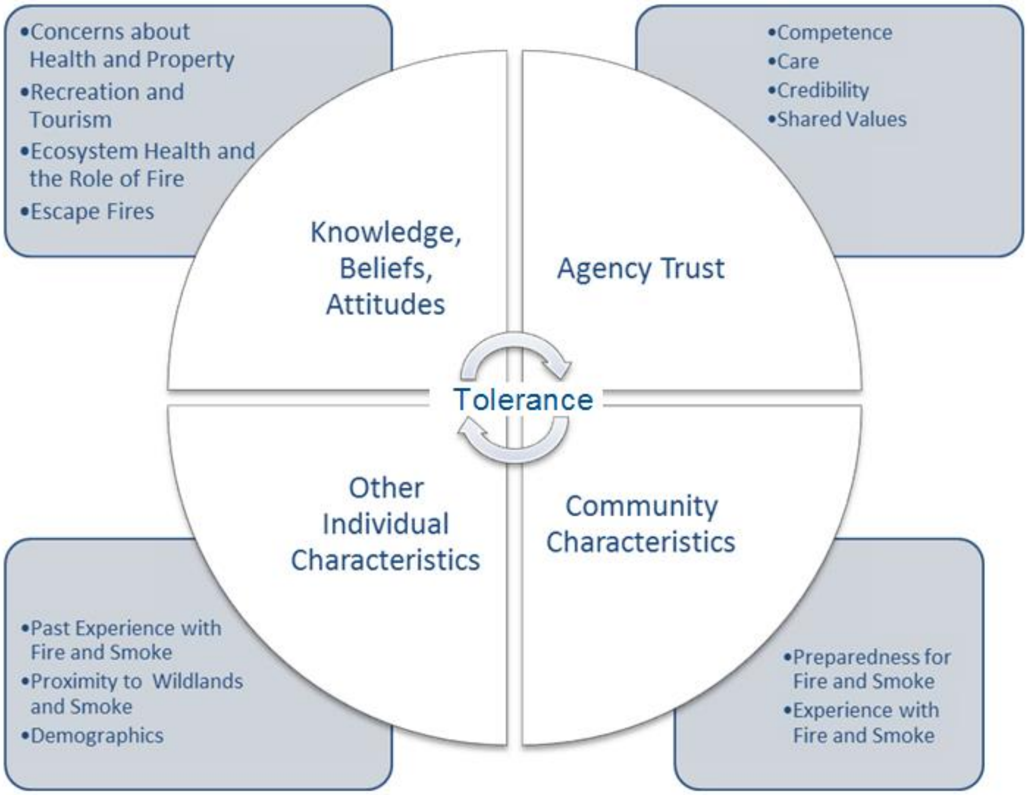

Figure 8. A framework for public tolerance of smoke from wildland fires.

JOINT FIRE SCIENCE PROGRAM