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Characterizing Public Tolerance of Smoke from Wildland Fires in Communities across the United States

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Little is known about public tolerance of smoke from wildland fires. By combining data from two household surveys, we sought to determine whether tolerance of smoke from wildland fires varies with its origin or managerial rationale, to describe geographical variation in tolerance of smoke, and to describe the relationship between personal smoke-related health experience and tolerance of smoke. Tolerance tended to be moderate and higher in cases when managers were attempting to suppress wildfires. Negligible differences existed across states or between rural and urban areas. However, individuals who had experienced health impacts from smoke in the recent past were significantly less tolerant of smoke. Our studies highlight the importance of communicating the ecological benefits of different types of wildland fire, as well as the public health risks of smoke and ways to mitigate them.

Keywords: communication, public tolerance of smoke, wildfires, forest management, public health

To improve the ecological health of our nation's forests and to ameliorate the potential for extreme fire events, land management agencies need to use prescribed fire and allow some natural ignitions to burn (we refer to these as managed wildfire) to meet management objectives (Ryan et al. 2013). North et al. (2012, p. 399) called for

> a fundamental change in the scale and objectives of fuel treatments…to emphasize treating entire firesheds and restoring ecosystem processes.

This would involve more prescribed burning and managed wildfire to promote ecological restoration, because current levels of burning are unlikely to significantly advance restoration efforts (North et al. 2015).

There are significant hurdles to promoting natural fire regimes. For instance, North et al. (2012) identified the risk of escaped fires, a culture of suppression within the US Department of Agriculture [USDA] Forest Service, and costs as factors influencing fire-friendly management. Williamson (2008) found that among USDA Forest Service district rangers fire danger and resource availability were among the primary barriers in decisions about managed wildfire. That study and others (e.g., Steelman and McCaffrey 2011) also acknowledged that perceived or real public opposition can be an impediment to managed wildfire. Last, new nonattainment areas have been created as a result of the tightening of National Air Quality Standards, constraining the use of prescribed fires and managed wildfire due to an increase in air quality violations (Riebau and Fox 2010, Environmental Protection Agency 2013). Land managers face significant challenges to simultaneously manage for forest health and air quality objectives.

Although many studies have investigated citizens' attitudes toward forest management actions, including prescribed fire, relatively little is known about tolerance of smoke from wildland fire, because such issues are rarely the focus of surveys. The limited findings suggest that many people accept that smoke (especially from wildfires) is inevitable (Shindler and Toman 2003, McCaffrey and Olsen 2012). However, there is variation in tolerance within populations. For instance, Piatek and McGill (2010) found that 26% of private forest owners in West Virginia would not tolerate smoke from prescribed fire at all, whereas 20% would tolerate such smoke more than twice per year. Similarly, 40% of community residents near forests in Victoria, Australia, deemed smoke from prescribed fire not to be

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a problem, whereas approximately one-quarter of those surveyed said it was a problem (Bell and Oliveras 2006). In another study, Thapa et al. (2008) found that 9% of tourists to fire-prone parts of Florida said they would cancel their trip, and 38% said they would change their destination, if smoke from fire was present in the area. Such findings suggest that concern over smoke may be substantial among some segments of the population, although each study's focus on a narrowly defined geographic area limits the generalizability of this conclusion.

It is important for land managers to understand the variables that influence attitudes toward smoke as they develop smoke management plans and communication campaigns. In particular, it is useful to know whether public perceptions toward smoke depend on the cause of the fire or whether managers intend to use the fire to achieve resource benefits. Managed fire has forest health benefits and may reduce the severity of future wildfires (Prichard et al. 2010, Ryan et al. 2013). In addition, smaller controlled burns are a lesser threat to public health than large uncontrolled wildfires, which burn with greater intensity and duration, thereby producing greater amounts and higher densities of smoke (Goldammer et al. 2008, North et al. 2012, Williamson et al. 2013). If people are unaware of these tradeoffs, educational campaigns targeting such awareness could be fruitful in garnering acceptance (Olsen et al. 2014).

Beyond communicating about forest and fire management programs, understanding public reaction to smoke is important, because the incidence of exposure and documented health effects are growing. An increase in more frequent and longer fires (Westerling et al. 2006) coupled with population growth in wildland-urban interface (WUI) areas (Radeloff et al. 2005) puts more people at risk of exposure to high concentrations of particulates and other pollutants. In a recent study, researchers found that exposure to smoke from a 2011 wildfire near Albuquerque led to an increased risk for emergency room visits, and they concluded that the public did not know how to prevent exposure to smoke or did not take preventative actions (Resnick et al. 2015). A comprehensive review concluded that biomass smoke has led to increased respiratory symptoms and illnesses, hospital admissions, and emergency room visits (Naeher et al. 2007). As just one example, Le et al. (2014) documented a substantial increase in hospital admissions among seniors in 11 New England and mid-Atlantic states due to smoke from fires burning in Quebec. It is a possibility that if people are tolerant of and ignorant about the potential health impacts of dangerous levels of smoke, they might not participate in mitigation strategies to reduce its health impacts, such as the use of high-efficiency particulate air filters and breathing masks or vouchers for hotel services (Mott et al. 2002). If this is the case, educational campaigns might need to focus on the health consequences of smoke and protective measures that can be taken to mitigate the significant costs to public health.

To better understand variables that influence tolerance of smoke emissions and management, we combined data from two studies conducted in several regions of the United States. Both studies focused on tolerance of smoke, but they had slightly different goals. Thus, several identical or quite similar survey questions allowed exploration of variation in tolerance of smoke from wildfires. Capitalizing on these commonalities, our goals in this article are the following: to determine whether tolerance of smoke from wildland fires varies with its origin or managerial rationale, to describe variation in tolerance of smoke across states and between rural and urban residents, and to describe the relationship between personal smoke-related health experience and tolerance of smoke from wildland fires.

Potential Dimensions of Difference in Tolerance of Smoke from Wildland Fires

Previous research suggests that the tolerance of prescribed fire may vary based on its context and its stated purpose. Specifically, there is some evidence that local peoples' awareness of ecological systems and the ecological benefits of prescribed fire may increase support of fire management strategies (Shindler and Toman 2003, McCaffrey and Olsen 2012, Diaz et al. 2016). Presumably, this extends to smoke tolerance, although few researchers have explicitly investigated this. A frequently cited source for this conclusion is Weisshaupt et al. (2006), who used focus groups in eastern Washington and western Montana to determine how different stakeholders reacted to smoke from agricultural burning, prescribed forest fires, or wildfires. Their key finding was that smoke from prescribed fires was more tolerated if the rationale for the fire and its methods were understood. Similarly, Blanchard and Ryan (2004) suggested that residents of Long Island, New York, who had knowledge about the practice and benefits of prescribed burning were less likely to be concerned about smoke.

One of our goals was to provide a more nuanced understanding of tolerance of smoke from wildland fires with various types of origins and managerial purposes across communities in the United States because this understanding remains only conjecture at this point. Given this, our first research question was: Does tolerance of smoke vary with the origin or managerial rationale for the smoke? (RQ1). We hypothesized (H1) that tolerance will be higher for smoke when people believe it is associated with ecological benefits.

The Role of Geographical Variation in the Tolerance of Smoke

People's exposure to fires and smoke varies across the country, and therefore tolerance of smoke may vary across US

Management and Policy Implications

Understanding the factors that influence the public's level of tolerance of smoke from wildland fires may help forest managers increase public acceptance of fuels management. Although our results show negligible differences in levels of tolerance of smoke from wildland fires across regions of the United States or between urban and rural populations, the origins and management intent of smoke from wildland fires influence public tolerance. Given this, efforts to engage local residents regarding fire and fuel management efforts may be more effective if forest managers include specific information about the fire events, including whether fires are being used to achieve forest health objectives. As the population increases in areas prone to wildland fires, more people will be adversely affected by smoke because of increased exposure. Agency communication efforts can be improved by emphasizing the role of fires in maintaining economically and ecologically healthy forests, the connection between achieving these objectives and the resulting smoke emissions, and the health risks and mitigation strategies associated with smoke.

communities. Some differences might be expected due to the differences in fire frequency and extent. For example, prescribed fires are used extensively and frequently in fire-dependent ecosystems in the South, such as longleaf pine (*Pinus palustris*) forests (Mitchell et al. 2006, Kobziar et al. 2015). Familiarity might account for why 64% of Florida residents felt that forest managers should periodically use prescribed fires in pine forests (Loomis et al. 2001), and this might lead to greater tolerance of smoke in that region. In a multisite study, Toman et al. (2014) found large differences of opinion about the use of prescribed fire, with support being higher in western than in midwestern states. In addition, respondents from the West agreed more strongly that prescribed fire creates more smoke in the short term but reduces risk of severe wildfire and smoke impacts over the long term. Comparing populations in two western regions, Brunson and Shindler (2004) found that people living in central Oregon were more accepting of prescribed burns than those living near Salt Lake City. These studies suggest that tolerance of prescribed fire and therefore perhaps tolerance of smoke are higher where the practice is more common. A broad understanding of these regional differences could provide land management agencies an empirical foundation for more nuanced communication strategies across the United States.

Our second research question was: How much does tolerance of smoke from wildland fires vary among communities across the US? (RQ2). We hypothesized (H2) that tolerance of smoke from prescribed fires would be higher in the southern United States than in the western United States and that tolerance of smoke from wildfires would be higher in the western United States than in the southern United States. These expectations were based on the more common occurrence of prescribed fires in the South and large wildfires in the West.

Some researchers have argued that regional differences in attitudes toward fire and forest management are the result of communities having different experiences with land management (e.g., Damon et al. 2010). People in rural communities may have more knowledge of forest management and more experience with smoke than urban populations, leading them to be more tolerant of smoke emissions. Thus, we hypothesized (H3) that rural populations would express higher tolerance of smoke than urban populations.

The Role of Personal Health Histories of Smoke Impacts and Tolerance of Smoke from Wildland Fires

Our final focus was on how health status relates to tolerance. The health impacts from severe smoke events can be substantial, as seen in measurable increases in illness, hospital admissions, and deaths (Weinhold 2011, Moeltner et al. 2013, Johnston and Bowman 2014). Some have argued that the segments of the population who object to smoke are probably those with health concerns (McCaffrey and Olsen 2012), but this has not been directly investigated. Given this, our third research question was: How much does personal health history with smoke influence tolerance of smoke from wildland fires? (RQ3). We hypothesized (H4) that individuals who had experienced a previous negative health impact from smoke would be less tolerant of smoke, regardless of the source.

Methods

Study Populations

In the first survey (hereafter, study 1), sites were selected to reflect geographic and sociodemographic diversity in areas where wildfires occur near four national forests: Fremont-Winema (Oregon), Kootenai (Montana), Francis Marion (South Carolina), and Shasta-Trinity (California). We sent 4,325 surveys to randomly selected households provided by a commercial provider (stratified by urban and rural areas). A modified Dillman process (Dillman et al. 2009) was used in which participants received a postcard alerting them about the study, followed by a packet including a cover letter with instructions for completing the survey online if desired, a paper copy of the questionnaire, and a stamped, addressed return envelope. A second full packet was mailed 3 weeks later, and a final packet was mailed 3 weeks after that.

In study 1, 992 surveys were returned completed. Response rates differed across sites: 30% in Montana, 25% in Oregon, 24% in California, and 13% in South Carolina. Nonresponse phone calls were made to a sample of nonrespondents in each location using a subset of survey questions (Vaske 2008). No significant differences were found in demographic characteristics and survey responses between survey participants and nonparticipants.

The second study (hereafter, study 2) focused on communities in northern and central Idaho, southwestern Montana, eastern Texas, and western Louisiana. The sites were chosen due to forecasted changes in forests and precipitation associated with climate change, increases in wildfire activity, and geographic, ecological, and demographic differences. Prescribed burning in national forests in eastern Texas and in western Louisiana forests has occurred annually to address fuel loads. In general, residents in this region have more experience with prescribed fire and associated smoke than those in northern and central Idaho and southwestern Montana. Conversely, Idaho and Montana residents have experience with long periods of smoke from extensive wildfires. Communities from each region were stratified into three different community types: WUI communities that were more prepared for fire (as determined by having completed and implemented a Community Wildfire Protection Plan), WUI communities that were less prepared for fire, and non-WUI urban areas that have a substantial likelihood to be affected by smoke (Blades 2013). A random sample was purchased from a commercial provider. A modified Dillman process (Dillman et al. 2009) was used, in which participants received a letter directing them to a website to complete the survey online. A reminder postcard was sent after 15 days, followed by a paper copy of the survey mailed 3 weeks later.

In study 2, we received 1,538 completed surveys from Idaho and Montana, for a response rate of 28%. From the Texas and Louisiana sites, we received 376 surveys, for a response rate of 6%. We contacted 100 randomly selected nonrespondents by phone to determine whether there were any systematic differences between study participants and nonparticipants (Vaske 2008). Based on a subset of questions from the survey related to tolerance of smoke, we found no significant differences between those who did and did not complete the questionnaire.

Survey Questions

The surveys provided a brief definition of forest fuels (living or dead vegetation that can burn) and prescribed fire (fire intentionally set to meet certain objectives). Both studies asked questions with 7-point Likert-type response scales to assess tolerance of

smoke from different sources (i.e., lightning versus prescribed fire) and from fires managed with full suppression or allowed to burn (prescribed fire and managed wildfire). There were slight differences in question wording in the two studies. First, study 1 asked about "acceptance of smoke," whereas study 2 asked about "tolerance." Second, the wording of some of the forest management and smoke options varied. For example, study 1 had an item asking about acceptance of smoke from "a prescribed fire that is ignited by land managers on public lands," whereas study 2 phrased this as tolerance of "a prescribed fire that is ignited by land managers to achieve forest health objectives." Because of these differences, data for each item are presented separately, and differences in results that are potentially associated with question wording are explored in the Discussion.

In study 1, responses were anchored with 1 (strongly disagree) and 7 (strongly agree) and included a "don't know" option (selected by <3.5% of respondents; excluded from analyses). For the purposes of this analysis, responses of 5, 6, and 7 were considered accepting of smoke. In study 2, responses were anchored with −3 (very intolerant) and +3 (very tolerant), without a "don't know" option. For the purposes of this analysis, responses of +3, +2, and +1 were considered tolerant of smoke in the particular scenarios. To facilitate comparison of results, data from study 1 were recoded to match the scale of study 2.

To explore geographical differences among population segments, we used the respondents' state of residence (H2), and to test H3 we classified people as either urban or rural residents (based on the US Census Bureau (2010) definition of rural communities having <2,500 residents). To test H4, both surveys asked whether participants had experienced personal health effects from smoke in the recent past (last 5 years in study 1; last 3 years in study 2). Finally, to characterize the samples, we collected information on education (eight categories, ranging from have completed some high school to holding an advanced graduate degree), age, gender, income, and race.

Results

The respondents in both studies represented a range of regional, demographic, and educational backgrounds. Most of the respondents, however, were male and substantially older than the mean age of US citizens (Table 1), which is 35.3 years (US Census Bureau 2010). In both studies, most respondents were white (90.5% in study 1 and 92.3% in study 2). The median education level across the studies was "some college" in five states and a "4-year degree" in three states. The median income was $40,000–60,000 in all but two states. In study 1, the majority of the participants lived in rural areas. However, in study 2 the majority of participants lived in urban areas, except for those from western Louisiana.

Table 1. Regional, demographic, and educational background of participants in studies 1 and 2.

State	No. urban	No. rural	Female (%)	Mean age (yr)	Median education	Median income ($)
Study 1						
California	98	154	39.5	63.1	Some college	40,001–60,000
Oregon	131	139	41.7	60.8	Some college	40,001–60,000
South Carolina	66	81	46.0	56.7	Some college	40,001–60,000
Montana	0	323	42.6	60.9	Some college	20,001–40,000
Study 2						
Idaho	640	117	27.3	61.4	4-year degree	40,001–60,000
Texas	136	95	29.6	59.6	4-year degree	60,001–80,000
Louisiana	28	116	29.5	59.4	Some college	40,001–60,000
Montana	603	179	26.1	64.2	4-year degree	40,001–60,000

Table 2. Mean tolerance/acceptance of smoke from different sources.

	Mean	SD
Study 1 [$F(2, 901) = 130.5$, $P < 0.0005$]		
Smoke from a prescribed fire that is ignited by land managers on public lands is acceptable	0.71[a]	1.87
Smoke from a naturally ignited fire started (such as lightning) on public lands that is allowed to burn is acceptable	0.50[b]	1.92
Smoke from a wildfire that managers are attempting to suppress is acceptable	1.45[c]	1.69
Study 2 [$F(3, 1863) = 58.5$, $P < 0.0005$]		
Smoke from slash pile burning after a forest fuel reduction project (thinning)	0.77[a]	1.72
Smoke from a prescribed fire that is ignited by land managers to achieve forest health objectives	0.87[b]	1.75
Smoke from a prescribed natural fire/wildland fire that is unintentionally started (e.g., lightning), but allowed to burn to achieve forest health objectives	0.88[b]	1.74
Smoke from a wildfire that was started by lightning	1.21[c]	1.73

Scale: −3 to + 3; means with different superscript letters differ at $\alpha = 0.05$.

To explore differences in tolerance of different sources of smoke (RQ1), we compared three items in study 1 and four items in study 2 (Table 2). Counter to our hypothesis, smoke from wildfires under active suppression was clearly the most tolerable. Interestingly, in both studies, smoke from management-ignited prescribed fires and smoke from natural ignitions allowed to burn (managed wildfires) were equally acceptable. There does appear to be some support for our hypothesis that the articulation of forest health objectives or purposes increases tolerance of smoke. Specifically, tolerance for prescribed fire was statistically higher when forest health objectives were mentioned (study 2) than otherwise (study 1; $t = 2.17$, $P = 0.03$). Likewise, smoke from a natural ignition allowed to burn was significantly more tolerable when forest health objectives were mentioned ($t = 5.20$, $P < 0.0005$). These differences do not simply reflect a higher overall level of smoke tolerance in study 2, as acceptance of smoke from wildfires under suppression was reversed, being higher in study 1 than in study 2 ($t = -3.47$, $P = 0.001$).

Geographical Variations in Tolerance of Smoke from Wildland Fires

There were no statistically significant differences in tolerance of smoke between states in study 1 (Table 3). Although up to three-quarters of respondents would accept smoke from a wildfire that managers were attempting to suppress, acceptance of smoke from other sources was not particularly high, especially compared with the results from study 2.

In study 2, tolerance of smoke was relatively high, with nearly two-thirds of respondents tolerating smoke from all four of the scenarios (Table 4). There were no statistically significant state-level differences in tolerance of smoke from a wildfire started by lightning or smoke from slash burning. However, unlike in study 1, smoke from for-

Table 3. Percentage of respondents agreeing that smoke is acceptable, by state (study 1).*

	State					
	CA (n = 237)	OR (n = 255)	SC (n = 139)	MT (n = 306)	χ^2	P
	(%)					
Smoke from a prescribed fire that is ignited by land managers on public lands is acceptable	54.4	55.3	60.4	56.9	1.44	0.30
Smoke from a naturally ignited fire started (such as lightning) on public lands that is allowed to burn is acceptable	51.9	50.6	52.9	49.5	0.56	0.91
Smoke from a wildfire that managers are attempting to suppress is acceptable	70.0	68.0	75.6	74.2	3.95	0.27

* Percentages are based on excluding "don't know" responses from the base N.

Table 4. Percentage of respondents agreeing that smoke is tolerable, by state (study 2).

	State					
	ID (n = 753)	TX (n = 228)	LA (n = 142)	MT (n = 776)	χ^2	P
	(%)					
Smoke from a prescribed fire that is ignited by land managers to achieve forest health objectives	71.0	76.3	74.5	63.9	18.68	0.0003
Smoke from a prescribed natural fire/wildland fire that is unintentionally started (e.g., lightning), but allowed to burn to achieve forest health objectives	71.4	74.4	66.9	64.6	12.19	0.007
Smoke from slash pile burning following a forest fuel reduction project (thinning)	66.4	71.8	66.9	62.7	7.04	0.07
Smoke from a wildfire that was started by lightning	76.4	70.7	69.1	71.3	7.01	0.07

Table 5. Percentage of respondents in urban and rural areas agreeing that smoke from a given source is acceptable or tolerable.

	Urban	Rural	χ^2	P
	(%)			
A wildfire that managers are attempting to suppress*	72.7	71.2	0.20	0.65
A prescribed fire that is ignited by land managers on public lands*	56.9	56.1	0.05	0.82
A naturally ignited fire started (such as lightning) on public lands that is allowed to burn*	52.9	50.1	0.63	0.43
A wildfire that was started by lightning†	74.6	68.9	6.07	0.01
A prescribed fire that is ignited by land managers to achieve forest health objectives†	69.4	67.9	0.40	0.54
A prescribed natural fire/wildland fire that is unintentionally started (e.g., lightning), but allowed to burn to achieve forest health objectives†	69.8	65.7	2.87	0.09
Slash pile burning after a forest fuel reduction project (thinning)†	65.6	65.3	0.01	0.91

* Study 1: n (urban) = 276; n (rural) = 663.
† Study 2: n (urban) = 1,395; n (rural) = 505.

est fires managed to achieve forest health objectives elicited different levels of tolerance in different regions, with Montana residents being significantly less likely to tolerate smoke than respondents from the other three states. Montanans included in study 1 were generally less tolerant of smoke than Montanans included in study 2, and this difference will be explored in the Discussion.

A majority of both urban and rural respondents were tolerant of smoke, regardless of the source (Table 5). More than two-thirds accepted smoke started by lightning and fires that are allowed to burn to achieve forest health outcomes or reduce fuel loadings (i.e., fires managed for resource benefit). The differences between urban and rural residents were mostly minimal, with the only statistically significant difference being <6% (for smoke from a wildfire started by lightning, study 1).

Personal Health Histories of Smoke Impacts and Public Tolerance of Smoke

Respondents who said they had a previous health problem associated with smoke in the recent past comprised 28 and 25% of the samples in study 1 and 2, respectively. For all sources of smoke, people who had experienced personal health effects from smoke in the recent past were less tolerant of smoke than people without such experience (Table 6). Interestingly, for some smoke sources, a majority of people who had experienced smoke-related health impacts were nonetheless, as a group, relatively tolerant of smoke. This was especially true for naturally ignited fires. However, two scenarios in study 1 presented fires managed for resource benefit (intentional ignitions and natural ignitions allowed to burn), which would be tolerable sources of smoke for only approximately 40% of people who had experienced smoke-related health problems in the recent past.

Discussion

Origin and Managerial Rationale of Fire Influences Tolerance of Associated Smoke

The two studies reported here represent a broad effort to assess tolerance of smoke from different sources across communities in the United States. Addressing RQ1, our findings suggest that the source, type, and management intent of wildland fires may influence how much the public tolerates smoke. Overall, tolerance ranged from a low of 40% acceptance to a high of 75% acceptance, depending on the origin and outcomes of the smoke. Contrary to our hypothesis (H1 in Table 7), tolerance of smoke from wildfires being suppressed was highest in both studies. This may reflect public rec-

Table 6. Tolerance of smoke among respondents who had (yes) and did not have (no) previous health effects related to smoke.

	Previous health effects related to smoke			
	Yes (% agreeing smoke is tolerable/acceptable)	No	χ^2	P
A prescribed fire that is ignited by land managers on public lands*	41.9	62.3	31.47	<0.0005
A naturally ignited fire started (such as lightning) on public lands that is allowed to burn*	40.5	54.8	15.08	<0.0005
A wildfire that managers are attempting to suppress*	63.9	74.8	10.80	0.001
A prescribed fire that is ignited by land managers to achieve forest health objectives†	52.1	74.8	86.44	<0.0005
A prescribed natural fire/wildland fire that is unintentionally started (e.g., lightning), but allowed to burn to achieve forest health objectives†	52.6	74.2	77.33	<0.0005
Slash pile burning following a forest fuel reduction project (thinning)†	51.7	70.4	55.01	<0.0005
A wildfire that was started by lightning†	60.0	77.7	59.15	<0.0005

* Study 1: n (yes) = 259; n (no) = 665.
† Study 2: n (yes) = 489; n (no) = 1,403.

Table 7. Results of hypothesis testing.

Hypothesis no.	Hypothesis content	Support
H1	Tolerance will be higher for smoke when people believe it is associated with ecological benefits.	Partially supported
H2	Tolerance of smoke from prescribed fires would be higher in the southern United States than in the western United States and tolerance of smoke from wildfires would be higher in the western United States than the southern United States.	Not supported
H3	Rural populations will express higher tolerance of smoke than urban populations.	Not supported
H4	Individuals who had experienced a previous negative health impact from smoke would be less tolerant of smoke, regardless of the source.	Supported

ognition that managers are doing all they can do and that smoke inevitably accompanies fire.

Nevertheless, there is some support for H1, because where ecological rationales were provided (study 2), tolerance was significantly higher for both prescribed fire and managed wildfire. Given the differences in the two study populations, this tentative conclusion deserves further investigation, and it is not known to what extent the public understands the ecological role of managed fires or if they hold the assumption that unmanaged fires simply destroy the forest. However, it would be prudent for communications to emphasize the long-term ecological benefits associated with smoke-producing fires.

Geographical Variation May Not Be a Critical Factor in Tolerance of Smoke

Contrary to our hypothesis that tolerance of smoke would vary by region, we found little evidence of geographical difference. There were no state-level differences in tolerance of smoke from five of the seven wildland fire scenarios (H2 in Table 7). For the two cases (study 2) for which differences were observed, more than two-thirds of respondents from every state expressed tolerance of smoke, suggesting that smoke may not be of great concern to the majority of citizens. In testing H3, the only statistically significant difference was opposite to our hypothesis, with urban residents being more tolerant of smoke than rural residents.

The findings from Montana may indicate that using state or urban/rural distinction as the scale to examine regional variation may be too coarse to detect local differences. The Montana sample from study 1 was taken from a rural area near the Kootenai National Forest, and these respondents were less tolerant of smoke from prescribed fire or managed wildfire than Montanans in study 2. One area sampled within study 1 was an air quality nonattainment area (i.e., an area with air quality worse than the National Ambient Air Quality Standards) at the time while data were being collected. This area was situated in a valley prone to inversions and the settling of smoke. Because of the nonattainment status, residents were unable to use woodstoves, and some business activities were restricted. These unique circumstances may provide one possible explanation for the lower tolerance of smoke than that of Montanans in study 2. Further, the Montana population sampled in study 2 included both the city and outskirts of Missoula, an urban enclave with an active WUI organization that coordinates fire activities between rural, volunteer, state agency, and USDA Forest Service fire personnel (Blades 2013). Respondents from this area may have higher tolerance of smoke from managed fires than residents in other parts of the state. These findings reinforce the point made by Gordon et al. (2012) that differences within a community "type" may be larger than average differences across community types. McCaffrey (2009) also pointed out that unique situations, such as negative experiences with escaped prescribed fires, can alter views at the community level. Thus, aggregating data at the state level may obscure important differences among specific communities.

Personal Health Histories of Smoke Impacts Influence Public Tolerance of Smoke

Consistent with our hypothesis related to RQ3, previous negative health impacts from smoke were related to lower levels of tolerance (H4 in Table 7). Across every scenario presented to participants, those who had experienced negative health effects from smoke were less tolerant of smoke from wildland fires than those who had not, with absolute differences ranging from 11 to 22%. This provides evidence in support of McCaffrey and Olsen's (2012) assertion that perceived health effects of smoke affect public tolerance.

Recent studies have documented the impact of smoke on hospital admissions (Moeltner et al. 2013), emergency room visits (Rappold et al. 2012), and use of medications (Caamano-Isorna et al. 2011). This information leads to a potentially significant implication of our studies: because smoke tolerance was relatively high among those

without a previous negative health experience related to smoke, more targeted outreach may be needed to ensure that people engage in mitigation actions to protect their health. However, the relationship between levels of smoke tolerance and engagement in risk mitigation strategies is not known and further research is needed to explore it.

Implications for Forest Managers

Our findings have several implications for communication regarding fire and smoke management. First, tolerance of smoke is moderately high, particularly when it is clear that managers are attempting to suppress a fire. Differences in tolerance across the scenarios depicted in the surveys suggest that it may be important to communicate the link between smoke, fire origin, and forest health, as scenarios that explicitly linked smoke to achievement of forest health objectives elicited higher levels of tolerance. Olsen et al. (2014) remarked on the particular challenges land managers experience in communicating about smoke from prescribed fire when different entities provide conflicting messages to the public and when the public does not understand why an agency is actively creating smoke.

We did not find many geographical differences in tolerance of smoke. For instance, residents of the South, where prescribed fire is frequent and adjacent to populated areas, and the west, where wildfires are more common, had similar levels of tolerance. However, differences between the Montana communities reinforce the need to understand whether people residing in particular locales might find smoke more objectionable (McCaffrey and Olsen 2012). The lower levels of tolerance among Montana residents observed in study 1, whether due to a particular history with forest, fire, and smoke management, nonattainment of air quality status, or some other factor, serve as a reminder of the need to understand local conditions and concerns.

Our findings have useful implications for public health and the responsibility of land managers to facilitate education and outreach with the public generally and vulnerable communities in particular. Research is increasingly demonstrating the adverse health impacts of even limited smoke exposure (Naeher et al. 2007, Weinhold 2011). At least 10% and up to 37% of respondents in our surveys marked the highest level of tolerance for each of the smoke scenarios. If these individuals discount the health impacts from smoke exposure, they may be putting themselves at risk. As one example, Sugerman et al. (2012) found that 88% of residents in an urban California community affected by extended smoke events recalled hearing certain public service announcements about protecting themselves from air pollution, but only 59% complied with recommendations to stay indoors and only 76% kept windows and doors closed. Further, less than 5% recalled hearing messages about proper use of air conditioners, air filters, or respirators. More troubling, vulnerable populations, such as elderly individuals, minorities, and those with less income and education, had lower compliance than other groups. According to the authors, people in these groups trust information more if it comes from their social networks, rather than from sources outside their community. More effective and persuasive means may be needed to reach groups who are exposed to smoke but are either unaware of its potential health effects or untrusting of official sources. Managers may need to reach out to broader audiences and through expanded channels, perhaps developing partnerships with urban and rural health providers to reach vulnerable populations.

Limitations and Future Research

Although there are strengths in merging two independent data sets to enhance our ability to draw conclusions across a broad range of respondents, several limitations are evident. The two studies did not include common measures of other potentially relevant variables. For example, although Diaz et al. (2016) suggest that high levels of ecological knowledge increased locals' support for fire management strategies, we did not explore the relationship between knowledge about forest and fire ecology and tolerance of smoke from wildland fires. Further, we did not evaluate the fear of impacts to life and property from wildland fire to help discriminate between smoke and fire risks or other questions that could help explain tolerance of smoke across and within communities in the United States.

We did not conduct representative statewide surveys; instead we sought to capture a range of communities near areas with federal forests. Although this approach is useful for exploring smoke-impacted areas, we must be careful not to assume that the specific findings represent other parts of the country where fire is rare.

In addition, the use of commercially available contact information and relatively low response rates led to a sample that was older and more dominated by men than the populations of the states sampled. Nevertheless, a phone survey of nonrespondents suggested that nonrespondents to the mail/Internet survey did not differ on key variables from respondents.

The relationship between levels of tolerance of smoke from wildfires and levels of engagement in health mitigation strategies is not known. Future research to determine the nature of this relationship is needed to provide a more nuanced understanding of variables that influence risk mitigation behavior. Further, an understanding of people's levels of tolerance along the entire gradient of rurality and urbanity should be explored to better understand differences between urban areas with high and low population numbers and differences among the diverse communities that fall within the US Census (2010) definition of rural. Last, a constraint of our study and an opportunity for future research is that participants did not provide specificity on type or degree of personal health impacts related to smoke, which could have provided greater nuance on the ranges of levels of tolerances among those whose health had been previously affected by smoke from wildfires.

Conclusion

Before now, research on tolerance of smoke from wildland fires has been predominately limited to a few questions asked mostly in single locations. There has been no comprehensive effort to explore smoke tolerance across communities in the United States. We sampled a wide range of communities in seven states and asked several questions about different dimensions of smoke. Our study supported the assertion that tolerance of smoke from wildland fires varies with its origin or managerial rationale, although it was surprising to see no differences in tolerance of smoke from prescribed fire or managed wildfire. We also explored the relationships between tolerance of smoke from wildland fires and three variables: region of residence (i.e., what state a person resides in), whether or not a person lives in an urban or rural area, and personal health history related to smoke from wildland fires. Negligible differences existed in levels of tolerance among people living in different regions of the United States and be-

tween rural and urban residents, but health status was a relatively strong predictor of tolerance. Our studies highlight the importance of communicating the ecological benefits of different types of wildland fire, as well as the public health risks of smoke and ways to mitigate them. Such efforts may promote the broader fireshed management that North et al. (2012) argued is needed to significantly advance ecological restoration efforts in the United States.

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