

Introduction

Prescribed fire is the intentional burning of wildland or rangeland as a means of ecosystem management (Hiers et al., 2020). Prescribed burns are a routine practice in the Flint Hills region of Kansas to manage the tallgrass prairie, however, the smoke emitted from this practice and its impacts are understudied (Starns et al., 2020). The tallgrass prairie that remains today is less than 4% of its original area globally, making it one of the rarest and most endangered ecosystems in the world, and the Flint Hills remains the largest unplowed region of tallgrass prairie (U.S. Department of the Interior, 2022). Ranchers in Kansas have a long tradition of fire management, both to control invasive weeds, trees, and brush, and to augment the nutritional value of native grasses for cattle, on which they rely for their economic livelihoods (Liu, 2014; Kansas Department of Health and Environment, 2010; Twidwell et al., 2021). Fire is inherently dangerous, so it is natural to expect ranchers who practice this tradition to be acutely aware of its risks to life and property. However, fire can also pose other risks to health. Prescribed range burns produce smoke with a wide range of chemical compounds, particulate matter (PM), volatile and semi-volatile organic compounds (VOCs and SVOCs), and inorganic gasses that adversely affect human health (Whitehill et al., 2019; Liu et al., 2015; O'Dell et al., 2021). Experts recommend rescheduling burns when the forecasted weather conditions for a given day are expected to lead to poor air quality and smoke dispersal (Liu, 2014). Burns are not always rescheduled, however, especially when there is a routine cultural expectation to burn each spring.

Risk perception is one area of scholarship that has the opportunity to build on the understanding of how ranching and downwind communities consider the different risks that come from prescribed burning. In the fire scholarship, risk perceptions have mainly been studied around wildfire. For example, scholars have gathered information about community risk perceptions around health impacts from wildfire smoke exposure, evacuation, the role of information sources, and preparedness behaviors, among other topics (Brenkert-Smith et al., 2013; Champ et al., 2013; Kinateder et al., 2015; Velez et al., 2017). Despite this growing understanding of wildfire risk perceptions, studies on risk perceptions for prescribed burns are scant (Dupéy & Smith, 2018). The purpose of this study is to gain a better understanding of community perceptions of prescribed burns and the associated risks across the Flint Hills region of Kansas.

Literature Review

Most research to date concerning rangeland fire has focused on the physical and ecological aspects of fire, such as its effects on vegetation, soil erosion, and atmospheric air pollution (McCaffrey et al., 2013). In recent years, however, there has been an increase in social science studies of communities' relationship with fire in the wildland-urban interface (e.g., McCaffrey & Olson, 2012; Toman et al., 2013; Dupéy & Smith, 2018). These studies have focused on human dimensions of fire, such as risk perception, perceptions of information sources and their communication strategies, homeowners' decision-making, public acceptance of fire, and community preparedness (McCaffrey & Olsen 2012; McCaffrey et al. 2013; Toman et al. 2013; Dupéy & Smith, 2018).

However, there are gaps in this area of research regarding prescribed burns. In their empirical review of 74 papers relating to prescribed fire and wildfire, Dupéy and Smith (2018)

found that over half of the studies addressed wildfire exclusively, whereas only 7% addressed prescribed burning exclusively. Wildfire is distinctively different from prescribed fire, since wildfires are unintentional in spread or ignition and prescribed burning is conducted strategically to manage the material being burned (McCaffrey & Olson, 2012). Most years, prescribed burns exceed wildfires in acreage in the United States, but prescribed burning has received less scientific attention (Hiers et al., 2020). Hiers et al. (2020) argues for a refined research agenda concerning prescribed burns, as it requires a fundamentally different disciplinary approach from both physical and social sciences. Due to the differences in fire intensity and risks to life and property, findings concerning wildfires are of limited use in understanding prescribed burns. It is therefore important to investigate prescribed burning specifically to better understand the fire management and protective action practices of affected communities, like the Flint Hills.

The seasonal burning of the tallgrass prairies in the Kansas Flint Hills have been primarily studied from a physical science standpoint, focusing on issues such as woody encroachment, noxious weed suppression, yearling beef cattle weight gains, and air quality impacts (Alexander et al., 2021; Duncan et al., 2021; Twidwell et al., 2021; Mohler & Goodin, 2012). Social science studies of communities near tallgrass prairies have primarily concerned other regions of the Great Plains, such as Oklahoma and Texas (e.g., Elmore et al., 2019; Hoffman et al., 2021; Coleman, 2019). The most recent study of the Flint Hills' social history is an annotated bibliography from 1991, detailing memoirs of life in the Flint Hills, county histories, the culture of farming and ranching, and other aspects of daily social life (Hoy, 1991). While intentional and pasture burning is mentioned in some of the annotated bibliography, those references also focus primarily on the physical components of fire and not on the social history of burns. This study helps to address this lack of research regarding Kansas Flint Hills community members and their cultural connections to burns.

Risk Perception

How risk is measured varies across methodological approaches and research objectives. For example, risk perception is more subjective, while risk assessment is more objective (Kinatader et al., 2015). Risk assessment has been traditionally thought of as an equation that provides a statistical estimate of a hazard, where $\text{Risk} = \text{Probability (of event)} \times \text{Magnitude (of consequences)}$. However, risk is not that simple (Renn, 2011). Variation in time, topography, population density, and other factors can alter risk assessment, especially for environmental hazards (Kinatader et al., 2015). Risk perception has been traditionally viewed outside of the socio-cultural context, even though it varies from individual to individual. Risk is embedded within social systems, so the perception of risk depends not only on the objective threat itself, but also on the experiences and interactions that take place between individuals, groups, and institutions (Masuda & Garvin, 2006). Therefore, to study the risk perceptions of a community, the community itself must also be studied. We use two theoretical frameworks in this study to describe the Flint Hills community's understanding of and reaction to prescribed burns and their associated risks: the social amplification of risk framework (SARF) and the protective action decision model (PADM).

Social Amplification of Risk Framework (SARF)

Kasperson et al. (1988) created the social amplification of risk framework (SARF) to align the technical assessment of risk with a fuller determination of risk, acknowledging the “psychological, sociological, and cultural perspectives of risk perception and risk-related behavior” (p. 177). When a risk event happens, there are individual and social stations that amplify or attenuate how a public responds to the risk (Kasperson et al., 1988). Amplification occurs when information regarding a risk is transmitted, as well as in the response mechanisms of a community after receiving the initial information (Kasperson et al., 1988). A social station is a socially mediated communication channel, either between formal information sources or informal networks. Scientists, the news media, cultural groups, and interpersonal networks are examples of social stations that can amplify risk perceptions (Kasperson et al., 1988). How a risk is communicated through these different channels affects the perception of that risk; when a risk is amplified, the resulting behavioral responses (e.g., taking a protective action or seeking additional information) produce ripple effects that have secondary impacts onto a community, its economy, and society at large (Renn, 2011; Masuda & Garvin, 2006). SARF provides a descriptive model of information transfer, which reveals the complex, interacting factors that inform a community’s risk perceptions. In the context of prescribed burns in the Flint Hills, SARF can reveal a deeper understanding of the competing interests among the various communities in the area.

Protective Action Decision Model (PADM)

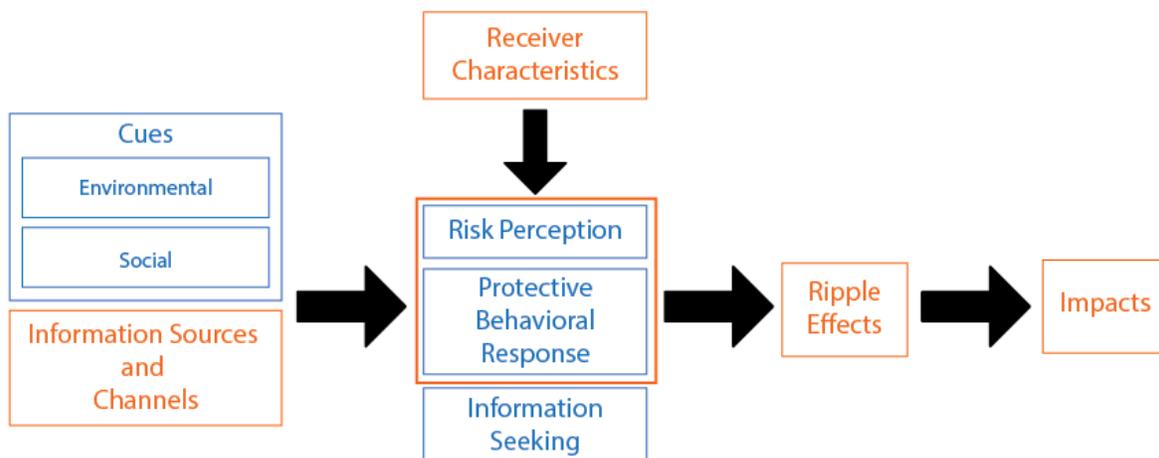
The Protective Action Decision Model (PADM) is a multistage, descriptive model of information flow and decision making for protective actions taken in response to a hazard or disaster (Kinatader et al., 2015; Kuligowski, 2013). PADM integrates information processing with the cognitive processes that lead individuals to take protective behaviors (Lindell & Perry, 2012). When a hazard becomes a threat, environmental cues and other information signal an impending risk, which gets transmitted by social sources to affected individuals via communication channels (Lindell & Perry, 2012). This transmission of information initiates pre-decision processes within individuals, prompting them to identify their personal risk, including their attention to the message and comprehension of the information (Lindell & Perry, 2012; Strahan & Watson, 2019). Once an individual has identified their risk, they begin to assess it, forming three core perceptions—threat perceptions (e.g., impression of the hazard or risk itself), protective action perceptions (e.g., impression of what one needs to do to be safer), and stakeholder perceptions (e.g., impression of who is talking about the risk). They then decide how to behaviorally respond to the hazard based on these perceptions (Lindell & Perry, 2012). Behavioral responses often include protective actions (e.g., planning burns to avoid high wind or staying indoors during poor air quality events) and seeking additional information. PADM affords this study not only another means of describing the social processes that influence information transmission during a hazard, but it incorporates decision making and behavioral responses into the understanding of risk perceptions among the communities of the Flint Hills.

Research Questions

Dupéy and Smith (2018) call for social science studies on wild and prescribed fire to use a more diverse set of theories beyond the Theory of Planned Behavior (TPB) and Protection Motivation Theory, as there are other psychosocial factors that can influence behavioral intentions. TPB in particular has been used in a majority of the studies on burns (Dupéy & Smith, 2018). Therefore, we use two different models to guide the findings concerning community perceptions of prescribed burning and any subsequent protective behavioral intentions. Using both SARF and PADM to examine the Flint Hills community provides a richer, more descriptive view of the risk perceptions around prescribed burns, as well as the effects these perceptions may have on protective actions and information seeking behaviors. Integrating SARF and PADM into one conceptual model, the proposed theoretical framework for this study is shown in Figure 1. From SARF, the model for this study includes how information flows from different sources (e.g., social stations) through communication channels, which can influence how different groups interpret and respond to a risk. This interpretation and response has ripple effects onto affected people and social groups at the community, industry, and societal levels that are seen in impacts such as a financial loss or imposition of regulations (for example) (Kasperson et al., 1988). Both SARF and PADM overlap in how they describe information flow from a risk event into people's interpretations and responses of that risk, like how risk perceptions of the event lead to a behavioral response. In the conceptual model of this study, this overlap is shown by the inclusion of both orange and blue outlines. From PADM, this study's conceptual model includes how receiver characteristics (such as their physical, social, or economic resources) of an individual and environmental and social cues about a risk may influence how they not only perceive their risk, but how they choose to protect themselves or seek further information (Lindell & Perry, 2012).

Figure 1

Integrated Conceptual Model of Social Amplification of Risk Framework (SARF) from Kasperson et al. (1988) (in orange) with the Protective Action Decision Model (PADM) from Lindell and Perry (2012) (in blue).



SARF and PADM have both been employed in risk communication research regarding fire and smoke, though not together (review in Kinateder et al., 2015). This study not only integrates the models with one another, but also describes the existing communication efforts surrounding prescribed burns in the Flint Hills area and any possible gaps therein. Risk communication is the exchange of information during a risk event, and successful risk communication produces safe behaviors during a threat without the negative effects that come from directly experiencing the threat (Kinateder et al., 2015). Ultimately, this study seeks to answer what risk perceptions surround prescribed burns in the Flint Hills community, and how these risks are attended to and attenuated by the community through protective actions. Additionally, the researchers are interested in how information around prescribed burns is communicated among the community and through which channels. The guiding research questions for this study include:

RQ1: How do different cues prompt risk perceptions and identified impacts of prescribed burning in the Flint Hills?

RQ2: To what extent do receiver characteristics and risk perceptions of Flint Hills community members influence protective actions during prescribed burning?

RQ3: How is information about prescribed burning communicated in the Flint Hills?

Methods

The researchers employed in-depth, semi-structured, qualitative interviews in order to elicit open-ended responses and more robustly capture the rural community and regional culture of the Flint Hills, Kansas region (Silverman, 2013; Wimmer & Dominick, 2014; Lindlof & Taylor, 2019). Open-ended questions allow participants more opportunities to elaborate on their responses and give researchers more flexibility to follow up and gather additional information (Wimmer & Dominick, 2014).

Researcher Reflexivity

This research was conducted as part of a NASA HAQAST (Health and Air Quality Applied Science Team, haqast.org) Tiger Team, which is a collaborative group of scientists and community stakeholders who work to address public health and air quality issues with NASA data and products. This Tiger Team in particular is focused on the extent and impacts of fire and smoke from prescribed fire in agricultural regions, with atmospheric scientists and epidemiologists leading the other studies from this collaboration. The leading authors on this paper have studied mass communication in different rural and urban communities, though this is their first formal study based in Kansas. The first author has expertise in atmospheric science and science communication, which enabled them to understand the nuances and intricacies of wind and smoke patterns frequently raised by participants. The second author has family who have resided in the Flint Hills since the late 1800s, and the author spent a significant amount of their youth around the land and community. This connection to the land enabled the first and second authors to better establish trust and open communication between themselves and the interview participants. Both authors discussed the methodological approach and findings from each interview together in order to limit any potential researcher bias. The other authors in this study were involved in reviewing the interview protocol, identifying interview participants, and

providing other support in the writing of this study such as the funding and design of the broader campaign on smoke in the Flint Hills.

Sampling

Sampling took a nonprobability approach and employed snowball sampling, a process in which researchers contact initial respondents and then ask those participants to recommend relatives, friends, or acquaintances who may also qualify to participate in the study (Wimmer & Dominick, 2014). Recruitment began by reaching out to interested stakeholders and air quality monitor hosts for a larger, related study. This sampling approach assisted in finding individuals that came from social organizations and groups who fit within the theoretical framework of the study. For example, groups of interest include members of different social stations from the Social Amplification of Risk Framework, such as scientists (e.g., USDA, university professors, USFS), news media outlets (e.g., local newspapers and radio), activist social organizations (e.g., Sierra Club), opinion leaders within social groups, personal networks of peer and reference groups (e.g., private ranchers), and other public agencies (Kasperson et al., 1988).

Participants were recruited by email. Eighteen individuals were initially contacted, and 16 additional people were recommended by participants. Ultimately 34 individuals were contacted to set up interviews, and 18 interviews were scheduled and completed. After 18 interviews, the authors determined that they had reached saturation in responses. Participants in these interviews represented each social station from SARF (five government employees, three university professors, two news media employees, three social activists, and five private ranchers). Interview participants were predominantly male ($n = 14$ males, $n = 4$ females). Of the 18 interviewed, 4 offered up their own personal health statuses as explanation for their views on burning. These conditions included being elderly, having compromised cardiovascular or respiratory systems (e.g., history of heart attacks or asthma), as well as having seasonal allergies. All participants either currently lived downwind from the Flint Hills, lived in the Flint Hills, owned property in the area, or had lived there for a large portion of their lives, if not their entire lives. On average, participants reported living in the Flint Hills or downwind counties for $M = 33.5$ years (max: 70 years; min: 8 years). Figure 2 depicts counties participants reside in and Table 1 contains participant characteristics and labels.

Figure 2

Kansas County Map of Interview Participants (Flint Hills overlay sourced from ksfire.org)

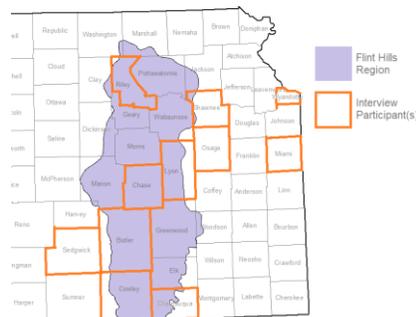


Table 1

Participant Characteristics

Participant Label	Gender	Social Station	Geographic Classification
Participant 1	Male	Government/Public Agency	Rural
Participant 2	Female	Social Activist	Urban
Participant 3	Female	Social Activist	Urban
Participant 4	Male	Private Rancher	Rural
Participant 5	Male	News Media	Urban
Participant 6	Male	Government/Public Agency	Rural
Participant 7	Male	Social Activist	Urban
Participant 8	Male	Private Rancher	Rural
Participant 9	Male	University	Urban
Participant 10	Male	Government/Public Agency	Rural
Participant 11	Male	University	Urban
Participant 12	Male	Government/Public Agency	Rural
Participant 13	Female	University	Urban
Participant 14	Male	Government/Public Agency	Rural
Participant 15	Male	News Media	Rural
Participant 16	Male	Private Rancher	Rural
Participant 17	Male	Private Rancher	Rural
Participant 18	Female	Private Rancher	Rural

Interview Procedures

Prior to the interview process, verbal consent forms were read to each participant in the study. Interviews were either conducted via phone and recorded with QuickTime Player (n = 2) or conducted via video call and recorded with Zoom (n = 16). The researchers followed a semi-structured interview protocol to learn about participants' experiences with prescribed fire, risk perceptions of annual burning, views on protective actions for their identified risks, and perspectives on how their community is impacted by the burning. Follow-up questions were

asked for clarification. All questions were approved by the Institutional Review Board prior to the interviews.

All interviews were conducted between April 4, 2022 and April 26, 2022, during the Flint Hills burning season. The first and second authors conducted 13 interviews together; three were conducted by the first author and the remaining two were conducted by the second author. All interview recordings were uploaded into a protected, shared drive. Interviews were scheduled to last one hour, including the time spent to consent participants and to wrap up logistics afterwards. Of the recorded content, interviews lasted on average $M = 28$ minutes and 39 seconds (max: 48 minutes and 31 seconds; min: 14 minutes and 36 seconds). After interviews were concluded, participants were compensated with \$50 electronic gift cards sent via email.

Coding Strategy

Interviews were transcribed using Otter.ai and transcripts were analyzed using MAXQDA. The analytic strategy for these interviews took a maximum variation approach for capturing exhaustive themes. The first author developed an initial coding schema from existing research that implemented the Social Amplification of Risk Framework (SARF) and the Protective Action Decision Model (PADM). Interviews were then analyzed using a deductive and inductive qualitative approach. While SARF and PADM guided the initial analysis, emergent themes that arose from the data were captured as well, following a quasi-grounded theory approach (Strauss & Corbin, 1998). The first and second authors reviewed emergent themes from the data; there was a stability of responses from both coders, signaling reliability in the data.

Findings

The purpose and historical importance of spring burns are well understood by the Flint Hills community members. Multiple participants noted that prescribed fires have been a persistent practice in the Flint Hills, dating back to when Native Americans began managing the tallgrass prairie (e.g., Participants 6, 7, 9, 12, and 18). Fire is employed to manage invasive species, such as sericea lespedeza (*Lespedeza cuneata*) and red cedar, and to provide nutrition for cow-calf operations. The rocky composition of Flint Hills soil is not conducive to crop farming, so cattle ranching has become the primary agricultural practice. Among methods for maintaining the grassland ecosystem, fire has been found to be the quickest, easiest, cheapest and, for three landowner participants, most fun land management practice (e.g., Participants 1, 6, 10). Over the last 50 years, however, prescribed burning in the Flint Hills has primarily occurred in the springtime. This is due to research led by Kansas State University in the 1960s and 1970s (e.g., Anderson, 1965; Anderson et al., 1970), which found that burning in April had the greatest impact on cattle weight gain, due to a spike in the nutritional value of the grass after its “green-up,” i.e., post-fire growth. Previous research documents that burning only in mid-April has become a culturally-ingrained process in Kansas land management, despite newer research indicating that restricting burning to just a few weeks in April is not as critical as previously thought (Towne & Craine, 2016). The following findings complement this existing research by capturing the cues that are present in community members’ recall of burns and how their perspectives may be affected by their social networks.

Environmental Cues

The environmental cues for spring burning most commonly reported by participants were seeing and smelling smoke. For example, Participant 3 described detecting burns by both sight and smell:

Oh, you can smell it and you can see them. Like for, I don't know, depending on the weather, but from like the middle of March until maybe the first of May. Like we may not have any blue skies in that time, just because it's so hazy.

Participant 13 also described detecting burns by sight: “I know there’s times I've driven along I-70, when they've been actively [burning]. And there’s been times I’ve driven through there and can’t see, because smoke has been really thick.” When asked how they know burns are happening, all 18 participants mentioned sight, smell, or both. When probed further about other ways they knew burning had started, participants then discussed social cues.

Social Cues

Participants reported communicating when they and others were conducting burns within personal and professional networks. Word of mouth was one of the most common social cues participants cited when asked how they knew burns were occurring. As Participant 12 explained, “Generally, there's, you know, kind of a good neighbor policy to let folks know.” Participant 1 also described communication and coordination between neighbors:

Oh, yeah. They all stay in contact. [...] And ranchers talk to each other, and they get together and they coordinate and work together on the fires. So they're always talking. And it's usually, I mean, everybody knows. We're coming to that time we feel right now. Where everybody's thinking about burning. And so they'll call the neighbor and say, ‘Hey, when would you like to burn?’

In addition to social communication, participants spoke about knowing burns were going to occur simply by the time of year. Participant 1’s statement about “coming to that time” points to this broader type of social cue, which Participant 16 highlighted as well: “You know, it is the burn. It’s the time of year when we burn.” Participants described a pattern of communication and coordinated planning that naturally arose in the community every April, the same way that back-to-school talk naturally arises as August or September approaches. Prescribed burns are no less integrated into the Flint Hills community’s annual calendar than the school year, to the point that there is no formal social cue to alert community members to prepare for fires.

Impacts of Prescribed Burning: Risk Perceptions and Effects

Participants raised a wide variety of risks, benefits, and other effects that arise from prescribed burning. Affected areas included human and animal health, safety, community identity, industry and finance, and ecological health.

Risk Perceptions: Threats to Life and Property

Fire is dangerous and unpredictable, and participants acknowledged the risks posed by prescribed burns to life and property in the immediate area. However, they also discussed the risks of refraining from burning. In fact, despite the risks that inherently accompany fire, all but one participant reported support for the practice of prescribed burning, with many perceiving a greater risk to life, property, and ecology if there were *not* prescribed burns. Participant 18 provided one example of the general support found for the practice:

With prescribed burns, there are not as many risks [as there are with wildfires]. But prescribed burns, by my definition, are planned out well ahead of time: You have a burn plan, you have coordination, you have communication, and you have reserve equipment. You really follow that plan and make your best effort to make it happen the way you want it to happen, so that reduces a lot of risk. If you just go drop matches and hope it works out, there's a whole lot more risk there.

Most immediate risks to life or property that participants described involved losing control of a burn. Prescribed fires that become uncontained can threaten human and animal life as well as property; as Participant 9 described: “if they get out of control, which sometimes they do, you can burn where you don't want to burn. Actually, people have died from that. Their house burns down or something like that.” People, livestock, and pets were described as all being of equal importance to participants who had firsthand experience with prescribed burning. For example, Participant 18 described losing cows and calves to a burn from neighboring land that got out of control, “Some people started burning south of us that shouldn't have. Certainly not on that day, with 60 mile an hour winds. And it burned up, it killed, oh, 20 cows and probably 50 calves of ours.” In addition to the risks posed by fire, smoke can also endanger other smaller animals, even when fires are responsibly managed. For example, Participant 2 described losing her chickens during a prescribed burn:

With my chickens, I make sure that they're well away and that they have air because when I lost [my flock] was when they got scared and they all ran into their coop, and then the smoke got into the coop and they all asphyxiated.

Risk Perceptions: Health, Smoke, and Downwind Communities

While participants from rural communities overwhelmingly, though not exclusively, emphasized the risks associated with fire, participants in urban, downwind communities were primarily concerned with the risks associated with smoke exposure. Participants explained that in rural areas, air quality was not a major concern, as the smoke from a prescribed burn is a relatively short-lived event, with wind carrying it off in a matter of hours. That same smoke,

however, was perceived as lingering in downwind urban communities for longer periods of time, and air quality is therefore of greater concern to members of those communities. Participant 10 described the health risks that are carried with the smoke:

One of the problems with the smoke in the Flint Hills is it gets done for about 2 million acres in 10 days. So you've got smoke for a whole week. And a lot of it. And what happens more often than not, to us, is that if you burn late in the evening, the smoke doesn't take off and go because the winds tend to die down and it sits and then the next morning it's headed north and Nebraska calls and yells and screams because it's in Lincoln and Omaha and schools have to shut down recess, and anybody with problems, with COPD, have to stand to the side and so forth. So it's really a big deal and it's mostly a health risk.

Three participants noted that respiratory conditions such as COPD, asthma, and the aftermath of COVID-19 were exacerbated by the smoke (Participants 4, 7, and 9). These descriptions are supported by research as well: while smoke from burns impacts everyone, it has demonstrable effects on those with cardiovascular and respiratory health conditions (Black et al., 2017). When participants brought up vulnerable populations that are negatively affected by the smoke, they alluded to those groups that were also living in the cities. However, participants that worked in the health sector in both rural and urban areas of Kansas noted that respiratory issues were exacerbated in all areas during the spring burns. For instance, Participant 14 explained:

If I remember correctly, from my days working with emergency management and paramedic stuff, Kansas has about a 10% population that has asthma problems or breathing related issues.... We saw a certain percentage of an increase [of EMS calls] during those time periods.

Risk Perceptions: Losses to Local Culture and Industry

Prescribed burns are deeply entwined into the Flint Hills culture and industry. There are entertaining aspects of fire that characterize the area, such as when local restaurants name burgers after the burns, or when droves of people come to watch the “spectacle” of the fire. However, participants also described serious risks if prescribed fires were ever to be stopped in the Flint Hills. Most cited the impacts on the cattle industry, which benefits greatly from burning and is one of the largest industries in the state. Participant 10 explained just how important burns are to this industry: “If you didn’t burn in the Flint Hills, that would be a billion-dollar loss of beef production.... A fair amount of ranches would cease to exist if they couldn't burn.” Changes to burning affect ranch profits through gains in cattle weight from grazing, as well as in the other operations.

In addition to the direct impact that burns have on the cattle industry by increasing yearling weights, a thriving cattle industry is critical to the entire Flint Hills economy, as Participant 17 explained:

[The Flint Hills is a] really, really rural area. Well, most of those people are dependent upon those ranchers. They buy feed, they buy fertilizer, they buy groceries there.... You

got to make sure that you can maintain a viable and sustainable ranching operation for those communities to survive, otherwise they'll go by the wayside.

Participants also discussed the industry that surrounds burning itself, which again extends to the broader Flint Hills economy. Professional burners, for instance, are private contractors hired to conduct burns and run the drip line (line of flaming fuel from torch) safely, and they carry insurance and use their own equipment, which they contract with local mechanics to maintain. This industry would be at a major risk if there were shifts to how burns can be carried out, which would have rippling effects into the surrounding communities that depend on the income from their contracts.

Risk Perceptions: Ecological Health and Maintenance

The tallgrass prairie is a treasured facet of the landscape of the Flint Hills, and many participants viewed prescribed burning not as a risk, but as a preventative measure to protect the prairie. For many participants, ecological and environmental health were the highest priority. A majority of participants described invasive species takeover as a major risk to the land. Woody encroachment, which is an increase in woody plants, bushes and shrubs at the expense of grasses and forbs, threatens biodiversity that depends on tallgrass (Twidwell et al., 2021). Prescribed burns protect this biodiversity by controlling invasive woody plants, as Participant 1 explained:

We have several invasive species coming into the Flint Hills. Now, there are a variety of reasons, one of which is invasive species, particularly woody species, eastern red cedar, and osage orange and honey locust are coming into the edges and even to the center of the Flint Hills. And there's a term that they're using now, 'green glacier,' that's moving across the Flint Hills. The cedar tree invasion is an epidemic...and it will cause the loss of the rangeland if we don't burn.

The ecological and cultural value attached to maintaining the prairie was described by many participants, and disappearance of the tallgrass would be a major loss for the area. As Participant 9 summarized, "What a lot of us are concerned about is, first of all, destroying the prairie. And then the smoke."

Protective Actions

Participants identified a wide range of protective actions, corresponding to the equally wide range of perceived risks. These included actions taken to protect personal health; education and training to fight grass fires more effectively; and preemptive land management practices.

Personal Health

Rural participants reported taking fewer actions to protect personal health than their urban, downwind neighbors did. A few rural participants, such as Participant 3, lived life as normal during burns: "We still open the windows, and we still go on walks, and we still go look at the fires. But no, I don't do anything different. Maybe an extra puff now and then [of the inhaler]." Rural participants with health conditions who participated in burns, however, did report taking protective actions. As Participant 1 explained, "if you live in the Flint Hills, you're

just aware of it. You're used to it. You plan for it. If you have breathing issues, then you just take [the] precautions you need to take.” These precautions could include keeping an inhaler close during burn season, staying indoors and closing windows when smoke is apparent, and using air purifiers or HEPA filters. For example, Participant 12 described ways they protect their home:

We do have a couple of HEPA filters. And we actually put those in not for smoke, but for—we have three dogs and just dust and the dust from the road and stuff like that. But it's good during smoke season, too, to have that going.

Participant 8, like others who participated in burning, reported wearing a mask or bandana when operating the drip line as a protective action. Several participants explained that masks had become more available in the last few years, and while they had not necessarily worn masks during past burns, they wore them now because they already had them (e.g., Participants 11, 14, 15, and 18). Other research has confirmed that there is an increased familiarity now with the effectiveness of respiratory protection due to the COVID-19 pandemic (Kodros et al., 2021).

Education and Training

Several participants discussed the importance of education and training to mitigate the risks associated with prescribed burns. Having an effective fire suppression strategy was at the forefront of the minds of community members as a protective action. Many ranchers run their own burns and could benefit from additional training, as Participant 16 outlined:

I do think that...more ranchers should have more education as far as burning goes.... Like, they're really good at lighting stuff on fire, and keeping it somewhat where they want. They're really good at that. But as far as safety practices, there's a major lack of training.

Training must, however, be specific to prescribed grass fires, rather than wildfires and forest fires. However, there are inconsistencies in how people are trained to conduct prescribed burns. Four participants either currently or previously served as volunteer firefighters, but the training they received was not directly for the prescribed burn setting. Participant 18 explained that in the last 20 years, firefighters have been trained to fight grass fires like forest fires:

After 9/11, local fire firefighting groups started getting FEMA training. And so they go for federal training. And they learned to fight fire like forest fires get fought. And that's not how you fight grass fires, that just doesn't work well. You can't, you know, jump in and hit the head—head fire and all that. You have to work from the ends... And now, you know, two old ranchers in the Flint Hills can put out a lot more fire than most fire departments because the old ranchers go to the black [burned area] where it started, and then just work their way slowly until they get it out.

Updating the firefighting training to be more appropriate for tallgrass would increase the protectiveness of fire management tactics, addressing the risks from out-of-control fires.

Preemptive Land Management

Several participants discussed actions and practices they adopt to decrease the risks associated with prescribed burns before they occur. For example, three participants discussed adding water lines or mowing around their property to provide a buffer zone to control the fireline (Participants 2, 3, and 11). Participant 2 explained how she has been proactive in changing the way the county conducts burns next to her land to mitigate risks to her own livestock and property:

They burn a field that is adjacent to my house. Like, literally 25 feet away from the house. And so—and it's county land, so the county fire department comes out, the volunteer fire department comes out and burns it... This year we—they mowed first and then they burned, and that was way better.

Two participants mentioned using alternative land management practices to reduce the risk of uncontrolled fires: Participant 4 employed biosecurity by having horses eat down the grass so low that there was nothing to burn, and Participant 8 described cutting a firebreak around a 400-square-foot pile of felled cedar trees and then waiting for heavy rain, so when the logs were burned, the fire would not spread. However, the most commonly raised preemptive protective action was checking the weather for wind conditions, with all but one participant mentioning that they personally monitored high winds to decide when to burn safely.

Patterns of Information Transmission

Participants began to allude to how information flowed between communication channels in their community, whether informally between neighborhood networks or from formal sources, such as county offices. Exploring the communication channels participants used during burns uncovers patterns of how information moves throughout the community. Within SARF, information sourced from personal experience, direct communication, and indirect communication feeds into individual information channels, as well as channels of informal social networks and from professional information brokers. Information is then attenuated in these channels and spread to other social stations. The following sections outline the ways in which information regarding prescribed burns is currently being communicated through each of these channels in the Flint Hills.

Informal Social Networks

Not all participants reported being aware of when burns occur in their area in the first place, but those who did relied far more on informal social networks, usually networks of immediate neighbors, than they did from personal information seeking or hearing from professional sources, like the state or county. Participant 16, for instance, explained, “I do call—we have one neighbor—I always call them and tell them, but I don’t tell anyone else. I just don’t feel like there’s anyone I need to notify.” However, even this was not universal. Participant 8, for instance, said, “I’ve never had anybody call me on any of our three properties and say, ‘Hey, by the way, we’re gonna burn next to you.’ I’m sure—but I’ve never had it happen. I’ve never had anybody call me.”

In addition to neighborhood networks, two participants described small, informal groups of young Flint Hills ranchers that have developed in the last 20 years, which have extended information sharing beyond networks of immediate neighbors (Participants 1 and 10). These groups facilitate discussions around innovations to ranching practices, including prescribed burning. Conversations within these groups have stretched information sharing between ranchers in different counties, outside of the immediate neighboring ranch domains. While these groups are a relatively recent development, the participants involved in these groups noted that they were increasing in popularity in the region.

Pairing of Personal Experience With Checking Professional Information Broker Sites

Information sourced from personal experience highlighted a culture of fire that runs deep within the Flint Hills community. For three participants, going for drives to look for active burns was an annual pastime (Participants 3, 6, and 8). In some cases, participants took information sourced from personal experience, such as fire chasing, and paired it with information acquired through their professional work. Participant 6 highlighted how this pairing enables him to stay well-informed:

Prescribed fires are, you know, part of my everyday job. You know, I'm obviously looking at, you know, satellite data and things like that throughout the day, when weather conditions are favorable for burning, just to see what's going on. I do air quality forecasts.... If I'm driving home and there's a prescribed fire not too far away, I seek out information by usually just driving next to the fire and seeing what's going on.

Participants would pair this personal experience from observing fires with confirming information from websites that display active fire information. When participants wanted to become more apprised of burns, nearly every participant reported checking the ksfire.org website, which is an interactive site with a smoke modeling tool and forecast map. The map is updated daily, showing potential smoke impacts in different areas based on the air quality monitoring data. The modeling tool enables users to predict the trajectory of smoke if a burn were conducted at a given location that day. Participants attributed these resources primarily to KDHE and Kansas State University, as these were the main sources from which they received formal communication regarding fires.

Inconsistency of Communication Between Counties

The ksfire.org website is part of the Kansas Flint Hills Smoke Management Plan, which aims to balance the benefits of prescribed burning with concerns about downwind air quality. Use of the smoke management resources is voluntary, and it is up to individual counties to regulate burning. Participants' descriptions of their local county's practices demonstrated that there is no consistency across the Flint Hills; while some participants were required to obtain a permit before conducting a prescribed burn, others simply called the sheriff to let them know they wanted to burn that day. Our participants did not view the lack of a formal, consistent regulation over burning as negative.

Participants discussed multiple methods of self-regulation, including the formation of prescribed burn associations and establishing alternative burning practices, because government

regulations overseeing prescribed burns vary greatly between counties. Participant 18, for instance, stated, “We need to form these [prescribed burn] associations and be more responsible and be more aware and kind of set regulations before the regulations are put on us.” On the individual level, participants were open to shifting their personal burning habits. The alternative burning practices that participants discussed involved adjusting the schedule or extent of their burns, such as by spreading burns across other seasons, or practicing rotational or patch burning, in which one burns only a section of land each year and rotates that section from year to year. Four participants stated that employing late summer and early fall burns was a more effective long-term land management practice to control woody encroachment, while multiple additional participants further suggested patch burning as a method of reducing the total volume of smoke produced each spring without risking the loss of tallgrass from invasive species (e.g., Participants 2, 3, 7, 9). Since there were mixed communication strategies between the state, county, and city levels, participants emphasized a preference for communication among their networks over adopting general regulations.

Discussion and Conclusions

The interview data revealed that annual prescribed burns are tightly woven into the local culture and community. Many within the Flint Hills community rely on the financial, ecological, and social benefits that come from burning the tallgrass prairies, both historically and today (Hoy, 1991). Fire was described as a prominent feature of the region; Participant 6 captured this overall sentiment:

Fire’s always going to be there. And whether it's going to be prescribed fire, or if we decide to let it go to a forest, well, we're gonna deal with forest fires, and those become much more difficult, and those produce a lot more smoke.

Participants repeatedly expressed concern for the ecological health of the tallgrass prairie, as well as a deep knowledge of prescribed burning as a land management practice for the prairie. Previous social science efforts have shown that the public does have a sophisticated understanding of the ecological role of fire, much like our participants (McCaffrey & Olson, 2012). Most participants also described in accurate, scientific detail the threats facing the ecological health of the prairie, including invasive plant species and the best ways to manage them, which was confirmed with previous studies that assessed the risks and vulnerabilities with tallgrass rangeland management (Liu, 2014; Twidwell et al., 2021). Through their interviews, the Flint Hills community showcased that they had an extensive understanding of how prescribed fire is used and impacts different sectors of their society. This knowledge was also often talked about with a protective tone to affirm that they wanted to maintain their ecological and civic ways of life with fire, even with the health impacts.

These findings provide a greater awareness of the variety of concerns and risk perceptions regarding prescribed burns throughout the Flint Hills community, which can inform and improve communication efforts on two different levels. First, recognizing and addressing the conflicting interests among community members is valuable for communication, which can in turn overcome differences and strengthen ties in a community that is so strongly based on a culture of fire. Second, outside efforts to communicate to the Flint Hills community about prescribed burn practices and potential protective actions can be tailored on the high levels of

knowledge and expertise already possessed within the community, as well as the risks and concerns surrounding prescribed burns that are most important to local community members, in accordance with general practices of tailored communication (Kreuter & Farrell, 2000).

RQ1 and RQ2: Perceived Risks and Protective Actions

Despite the benefits of the burns, the community also identified that there are risks associated with burning, though the perceptions of these risks differ between urban and rural communities. Studies of wildfire and prescribed burns rarely address both urban and rural areas, though both geographical classifications can experience the impacts of fire (Dup  y & Smith, 2018). In this study, urban community members would more often discuss the risks of prescribed fire in terms of negative health impacts due to smoke lingering in the cities. Rural community members perceived the greatest risks came from threats of uncontrolled fires, which can lead to destruction of life, property, and land. Rural participants therefore reported that they took direct actions to reduce the likelihood of prescribed burns growing out of control. These actions included staying up-to-date on wind and weather conditions, preparing sections of land to better restrict fires from spreading to other areas, and properly training and educating those conducting burns. Many of these community members viewed regular and planned burning as the most effective protective action both for mitigating the risk of wildfire and for combating the spread of invasive plant species, reflecting the current land management practices being recommended to ranchers in practice (Kansas Department of Health and Environment, 2010; Twidwell et al., 2021). Due to rural areas' primary focus on the immediate risks and long-term benefits of fire, secondary risks from smoke inhalation were not often seen as a concern. Despite not being perceived often as a risk by participants, smoke emitted from prescribed burns and its impacts are understudied and may have broad impacts on the health and welfare of the region (Starns et al., 2020). This study identifies a gap in the health risk perceptions around prescribed burning, which could lead to gaps in risk communication strategies that are targeted for this area.

RQ3: Communication of Information Regarding Prescribed Burns

It appeared from the data that most of the conflict between rural and urban communities surrounding prescribed burning was due to lack of cross-community communication and information sharing. Urban residents in particular were unaware of ongoing efforts among ranchers to innovate and adopt new approaches to prescribed burning, such as burning biannually instead of annually, patch burning instead of burning entire plots each year, and spreading burns out to additional months and seasons. While these were highlighted as especially popular practices among young ranchers, most rural participants proposed at least some of these alternative practices to regulate burning. The efficacy and impacts of differing fire frequencies, such as through practices like patch burning or rotational burning, are still relatively newer in scientific studies and thus may not be in as many formal land management strategies as spring prescribed burns (e.g., Ricketts & Sandercock, 2016; Bruckerhoff et al., 2020). Finding that private ranchers communicated about their burn strategies amongst themselves is an encouraging finding that this group seeks information about updating their land management practices and spreads this throughout their personal networks.

There is a nearly universal lack of formal information regarding when and where burns were occurring across the Flint Hills, as well as a lack of readily available air quality

information. Most counties had no standard practices in place to alert community members when a burn was occurring, and air quality monitors were either not available or were too far away for residents to track smoke patterns on their own. Access to real-time air quality information can be an engaging method to encourage people to learn about the environmental effects of poor air quality, as well as encourage them to protect their health through their actions (Delmas & Kohli, 2021). Increasing access to smoke information, either from professional information brokers directly to the community or via personal access online, would only benefit how the Flint Hills attains and attenuates information during burn season. Consistent, targeted messages about prescribed burns and their impacts would likely be effective for both Flint Hills community members and downwind urban communities. Targeted messages about air quality have been preliminarily shown to increase engagement with air quality information and protective behavioral intentions (Delmas & Kohli, 2021).

Limitations

Following SARF, participants were collected from multiple social stations to capture a comprehensive community perspective. However, there are possible limitations to the data from the participants sampled. Including more participants from urban or downwind areas, or even those from populous cities in neighboring states could provide a broader perspective on the downwind impact of the smoke from prescribed fires. Additionally, interviewing more women and participants from racial minorities could provide additional socioeconomic perspectives from underrepresented community members. Despite these limitations, which should be addressed in future research efforts, the authors feel the findings from this study accurately reflect the perspectives on prescribed burning within the Flint Hills.

Future Research

This study aimed to describe the risk perceptions, protective actions, and communication around prescribed burns of community members in the Flint Hills region of Kansas. This study integrated the social amplification of risk theoretical framework (SARF) and protective action decision model (PADM) together to capture multiple aspects that inform how individuals perceive their risks, including environmental and social cues, their personal characteristics, and information-seeking behaviors (Lindell & Perry, 2012; Kaspersen et al., 1988). Additionally, we were able to collect information on how the community interpreted protective actions for both individual protective (e.g., health behaviors) and collective protective behaviors (e.g., fire management), which afforded the opportunity to gain a better insight into the different ripple effects and subsequent impacts that were priority in the community. These insights can be used to test frames in health or risk communication that may more effectively tailor strategic messages around prescribed burning tailored communication (Kreuter & Farrell, 2000). Using SARF and PADM together was an effective theoretical framework for this study, and we recommend using both together in future communication studies on community-level risks.

The emergent themes from the findings in this study reflected a cultural importance surrounding animal, human, and environmental health and welfare. These three aspects are critical tenets of the One Health approach, which is defined by the CDC as a “collaborative, multisectoral, and transdisciplinary approach—working at the local, regional, national, and global levels—with the goal of achieving optimal health outcomes recognizing the

interconnection between people, animals, plants, and their shared environment” (CDC, 2022). While the connection between public health and environmental and animal health is not a new concept, there has been a growing body of research in recent years that employs this approach for risk assessment, as well as response and control plans (Mackenzie & Jeggo, 2019). Future work in the Flint Hills around prescribed burns should consider using the One Health approach to further explore community perspectives on risks across the animal-human-ecosystems interface since these tenets naturally came up in their reflections on their area and prescribed burn practices. Additionally, as informal communication networks were the predominant channel participants reported using to share information about burns, future communication research could take a more cultural or hermeneutic theoretical approach since the dissemination of information within these groups was highly local.

Practical Recommendations

It would be remiss to study patterns of communication across different channels and within social stations concerning prescribed burning without making practical recommendations for future burn seasons. There are many important communicators during the burns, including individuals such as public information officers at various levels of public agencies or extension agents. Understanding that each county has different considerations to make for its constituents, we recommend that risk communication producers such as health or environmental agencies work with county and state officials to instate more uniformity in their formal communication about fire across the Flint Hills. For example, university extension agents and agencies such as KDHE could plan a series of workshops with members from different social stations in the Flint Hills to prototype risk communication materials and modalities to more currently reflect community risk perceptions. Findings from these workshops could be used to update the next iteration of the Flint Hills Smoke Management Plan.

Additionally, downwind communities may benefit from educational communication materials regarding potential health protective actions when they experience smoke. For example, including infographics on websites that community members access can provide one way of disseminating health and risk communication messages in a visual format. Currently the health tab on ksfire.org, which many of our participants visit, links to fact sheets, websites, and other text-centric documents. More visual messages, as opposed to text-based messages, have been shown to be more persuasive and stimulating, which can improve users’ recall of health information and sense of self-efficacy (Harrison, 2002; Houts et al., 2006). Infographics have a high engagement online in social media channels and can be an effective tool for public organizations and agencies to relay public health and risk messages (Malik et al., 2021).

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