Wildfire in the Wildland-Urban Interface: Public Attitudes, Behavior, and Policy

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Dedication

This dissertation is dedicated to my mom and dad, Joan and Solly Fingerman.

Abstract

As the wildfire problem in the U.S. escalates -- with increasing length and severity of wildfire seasons, increasing fire suppression and structure protection costs, and increasing loss of homes and impact to human lives -- it becomes imperative to understand the public's attitudes and behaviors in order to work with them concerning actions they can take to reduce their chances of becoming wildfire statistics. This dissertation first gauged public attitudes and beliefs on a U.S. national scale using computer content analysis of national and regional news media. This study found that public debate about the Healthy Forests Initiative and Healthy Forests Restoration Act was reframed as a need for regulatory reforms to reduce the risk of catastrophic wildfire. The second study also used computer content analysis of news media to gauge public attitudes and beliefs, but with a focus on individual actions that may be taken rather than on national policy. This study examined the public's understanding of defensible space and other actions homeowners can take to protect their property from wildfire. We found a paucity of discussion in the news media about positive actions that homeowners could take. Such actions were grossly overshadowed by media coverage of wildfires and their destruction. With news media as a primary information source for residents in the wildland-urban interface, this study highlighted an opportunity for more effective messages about homeowner actions that can be taken. The third study in this dissertation examined a unique case study – wildfire preparedness on the Gunflint Trail in northern Minnesota – through

the lens of diffusion of innovations theory. Applicability of this case study to other locations is limited by a locally prevalent availability of water sources and social and demographic characteristics of the area, but the case does highlight ways in which diffusion of innovations theory can be useful in evaluating how wildfire preparedness innovations become part of a homeowner's response to risk. Together, these three studies highlight challenges and opportunities for communicating with the public about ways they can mitigate their risk of wildfire.

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Prologue

Conservation biology is an interdisciplinary field of study that addresses the biology of species, communities, and ecosystems "that are perturbed, either directly or indirectly, by human activities or other agents" (Soule 1985, p. 727). Conservation biology can be more broadly defined to include "new and integrated natural and social science approaches" to inform appropriate environmental management (Jacobson et al. 1995). In the context of conservation biology, forest fires have become a primary disturbance that due to their increasing severity threatens both human and natural systems. They are a key process that influences forests and rangelands across much of North America (Pyne 1982) and public attitudes and behaviors influence the way wildfire is managed, which in turn influences the ecological integrity of forest ecosystems (DellaSala et al. 2004). Wildfires, wildfire management, and public attitudes about and responses to wildfires therefore are an important concern for the interdisciplinary field of conservation biology.

Today's wildfire problem in the United States can be largely explained as the result of U.S. policies that focused on wildfire suppression, leading to an increase in fuels, combined with the growth of human development in and adjacent to wildfire-prone locations or the wildland-urban interface (WUI) (Radeloff et al. 2005). Global climate change may be exacerbating the problem as evidenced by what appears to be a lengthening of the fire season (Fried et al. 2004; Westerling et al. 2006; McKenzie et al. 2004; NWCG Executive Board 2009). The increased length of the fire season, number of

acres burned, and people living in the path of wildfires in the WUI has stretched the resources of firefighting agencies in the U.S. (NWCG Executive Board 2009). Because public attitudes and behaviors ultimately affect wildfire management and forest ecosystem integrity, this dissertation focuses on this topic at three levels.

The first chapter, published in *Journal of Environmental Policy and Planning* (Johnson et al. 2009), examined public attitudes in the U.S. toward a national policy response to wildfires using computer content analysis of national and regional news media. Specifically, the chapter examined the nature and evolution of the news media debate about the Healthy Forests Initiative (HFI) and the Healthy Forests Restoration Act (HFRA). Signed by President George Bush in front of a backdrop of destructive and mediagenic wildfires in the western U.S. in 2002, the HFI and HFRA represent major policy and legislative responses to the wildfire problem in the U.S., and shifted the framing of the wildfire discussion to a legal and fuels management problem. Research by communications and public opinion researchers has found that the news media both shape and reflect public attitudes and beliefs about a wide range of social issues (Burgess 1990, Fan 1988, McCombs 2004), including environmental issues. The research questions for this chapter are, (1) what are the main favorable and unfavorable beliefs about the HFI and HFRA expressed in the news media discussion?, (2) what is the relative frequency of expression of these favorable and unfavorable beliefs?, (3) how has the discussion of the HFI and HFRA in the news media evolved

over time?, and (4) how do the attitudes toward and beliefs about the HFI and HFRA in news media discussion compare to various measures of public opinion about these policies?

The second chapter, published in a shortened form in *The Public and Wildfire Management: Social Science Findings for Managers* (Johnson et al. 2006) also used computer content analysis of news media, but the method was used to examine public attitudes about activities individual residents could undertake to protect their property from wildfire. While policies were being implemented on public lands, a consensus was developing that individuals should take at least partial responsibility for making their homes safer from wildfire destruction (USDA 2006b, NWCG Executive Board 2009). The wildfire problem was being reframed by some as a "home ignition problem" (Cohen 2000). Defensible space was the term used to describe the activities such as clearing vegetation, which residents could take to mitigate wildfire hazard around their properties. The research questions for chapter two are, (1) is the public aware of the need to assume a degree of wildfire protection by implementing defensible space as evidenced by the portrayal of defensible space in the news media?, and (2) how simplified or complex is the defensible space discussion in the news media?

The third chapter drills deeper into a specific case study of wildfire preparedness on the Gunflint Trail, Minnesota, U.S., which was tested by the Ham Lake fire in 2007. This chapter uses a lens of diffusion of innovations theory to examine the widespread use of wildfire sprinkler systems and to a

lesser extent, other wildfire preparedness activities in the area. The research questions for this chapter include, (1) how can diffusion of innovations theory explain the widespread implementation of wildfire sprinkler systems on the Gunflint Trail?, (2) are there lessons from applying diffusion of innovations theory to this case that can be applied more broadly to other locations for wildfire hazard mitigation?, and (3) what were the technical issues and social challenges associated with widespread use of the wildfire sprinkler systems?

Each of the chapters in this dissertation were written as free standing papers that either have already been published, or will be submitted to journals. I use the term “we” in each of the chapters to reflect the collaboration that took place in the various research teams.

Chapter 1: U.S. policy response to the wildfire fuels management problem: An analysis of the news media debate about the Healthy Forests Initiative and the Healthy Forests Restoration Act

The Healthy Forests Initiative (HFI) and Healthy Forests Restoration Act (HFRA) represent major policy and legislative responses to the wildfire fuels management problem in the United States. This study examined the nature and evolution of the news media discussion and debate about these policy initiatives. Computer content analysis was used to analyze favorable and unfavorable beliefs about HFI / HFRA expressed in about 2,800 news stories and editorials published from August 1, 2002 through December 31, 2004. The most frequently mentioned favorable beliefs that emerged included the view that HFI / HFRA will (1) reduce the risk of catastrophic wildfire, (2) protect people, communities, and property, and (3) cut red tape and speed up decision making processes. The most commonly expressed unfavorable beliefs included the view that HFI / HFRA (1) is an excuse to increase logging, (2) will weaken environmental protections, and (3) will reduce public input. Some evidence was found of a gradual shift in the media discussion to a more favorable view of HFI / HFRA over time. The Bush administration's framing of its Healthy Forests Initiative as essential for reducing dangerous levels of fuels in forests and lowering the risk of catastrophic wildfires slowly gained ground and became the dominant discourse, but mistrust was found to be an ongoing issue as the HFRA is implemented.

Introduction

Wildfire management policy in the United States in the form of wildfire suppression arose out of the perceived need to conserve timber resources in the early 1900's (Keiter, 2006; Pyne, 1982). After several unusually large and destructive fires in the late 1800's to early 1900's, total fire suppression became the goal of federal policy, which eventually viewed all wildfire as destructive (Dombeck *et al*., 2004; Keiter, 2006; Williams, 2000; Pyne, 1982; DellaSala *et al*., 2004). By 1935, the "all fires out by 10 a.m." policy was adopted by the United States Forest Service (Pyne, 1982; Keiter, 2006), and the stage was inadvertently set for the "fuels problem" and wildfire predicament of today. Aggressively putting out every wildfire created a long term buildup of fuels (flammable organic material) that otherwise would have been cleared out by periodic wildfires. The 10 a.m. policy was not modified until 1968, when the National Park Service began allowing some natural fires to burn and the Forest Service announced that some prescribed fires would be allowed to burn in wilderness areas within tightly specified parameters (Keiter, 2006).

The decades of the 1980's and 1990's saw a growth in catastrophic wildfires and, in the 1980's, an attempt under President Ronald Reagan to establish the predominance of extractive natural resource management values (Kraft & Vig, 1984), values that were threatened by increasing wildfires. In 1985, wildfires in the US destroyed 1400 structures and killed 44 people, the most severe wildfire losses of people and property of the century

to date (Vaughn & Cortner, 2005). The wildfires in Yellowstone National Park in 1988 and Los Alamos, New Mexico in 2000 helped propel the wildfire issue to the political forefront.

Increasing development of homes in forested areas combined with the continued growth of catastrophic wildfires has increased the salience and media coverage of wildfire. The 2000 fire season saw almost 8.5 million acres burned. Over 7.1 million acres burned during the 2002 fire year (more than twice the 10 year average), claiming the lives of 21 firefighters. Over $2 billion was spent at the federal level that year for fire suppression (Vaughn & Cortner, 2005; Keiter, 2006).

The response to the growing wildfire problem included funding by Congress in 2000 of the National Fire Plan, proposed by President Clinton, focusing on firefighting preparedness, working with communities at risk or damaged by wildfire, and ecosystem restoration (USDA, 2000a). The Western Governors Association adopted an implementation strategy in 2001 which emphasized federal, state and local collaboration around goals of wildfire prevention and suppression, reducing hazardous fuels, and restoring ecosystems (USDA, 2001).

In June 2002, after the election of President George W. Bush, the United States Department of Agriculture (USDA) Forest Service released a document entitled, “The Process Predicament: How Statutory, Regulatory, and Administrative Factors Affect National Forest Management” (USDA, 2002). This report stated that regulatory and administrative problems along

with court injunctions effectively prevented the Forest Service from addressing issues of forest health and delayed efforts needed for wildfire management. The Bush administration responded to this report with the Healthy Forests Initiative (HFI) to expedite hazardous fuel treatment projects through administrative revisions to internal appeal processes contained within the National Environmental Policy Act (NEPA) and the Endangered Species Act (ESA) (Keiter, 2006; Vaughn & Cortner, 2004, 2005). The HFI was introduced on August 22, 2002 in a speech by President Bush near the site of the Biscuit Fire in Oregon, the state's largest in history and a mediagenic backdrop to unveil this major initiative. In the HFI, "The fire problem was recast as a litigation problem" (Keiter, 2006: 312). The goal was to streamline and shorten administrative and public review processes, and also limit appeals processes, thereby expediting the implementation of fuels management projects. Specific objectives of the HFI were to (1) speed up the review process for fuels-management projects, (2) change the rules governing appeals of projects to hasten their review, and (3) set time limits for judicial responses to legal challenges of projects (Stephens & Ruth, 2005; Vaughn & Cortner, 2004). The proposed procedures were designed to enable forest-thinning projects to proceed within one year.

Many of the proposals contained in the HFI were enacted in the Healthy Forests Restoration Act (HFRA) compromise which passed Congress in late November of 2003 and was signed into law by President Bush on December 3, 2003. According to some observers, the speed with which the

US House of Representatives and Senate reached a compromise on this legislation was due to massive wildfires burning in southern California during the fall of 2003 as the congressional negotiations took place and the resulting intense political pressure to act (Davis, 2006; Vaughn & Cortner, 2004). The HFRA authorized $760 million annually for hazardous fuel treatments on federal lands, limited the environmental assessment and appeals processes for those lands, and restricted the judicial review process.

The HFI and HFRA represent major policy and legislative responses to the wildfire problem in the United States, and shifted the framing of wildfire discussion to that of a legal and fuels management problem. This study examined the nature and evolution of the public discussion and debate about these policy responses, as expressed in the news media. Research by communications and public opinion researchers has found that the news media both shape and reflect public attitudes and beliefs about a wide range of social issues (Burgess, 1990; Fan, 1988; McCombs, 2004), including environmental issues. For example, Elliott *et al*. (1995) found a significant impact of changes in media coverage on the level of public support for environmental protection, with more media coverage of environmental concerns associated with increased support for additional spending on environmental protection. Cockerill (2003) found that variations in the tone and language in local media coverage of flooding had a significant impact on public attitudes toward river management and policy.

Part of the explanation for the influence of the news media on public attitudes is the importance of the media as the primary information source for public policy issues, including forestry and other environmental issues. For example, a survey in Oregon found that "The most important sources of information about forestry issues tend to be newspaper and television, followed by radio, other printed materials, friends and relatives, and interest groups. Only 16 % overall considered natural resource agencies to be important sources," (Shindler *et al*., 1996: 7).[1] The news media have also been found to be important information sources with respect to wildfire. In a study of public support for fuels reduction strategies in forest-based communities in eastern Oregon and Washington, respondents rated newspapers and magazines as the most useful information sources (Shindler & Toman, 2003).

Beyond serving as a primary information source, the two main theories proposed by communications scholars of the effects of the news media on shaping public perceptions are agenda setting and narrative framing. Agenda setting has been defined by Iyengar and Kinder (1987: 16) as follows: "Those problems that receive prominent attention on the national news become the problems the viewing public regards as the nation's most important." In other words, the relative emphasis that the media gives to issues shapes the public's perception of the salience or importance of those issues. Many

[1] In Europe, the Eurobarometer surveys have found that television news and newspapers are the main sources of environmental information, and that environmental protection associations, scientists and television are the most trusted (European Commission, 2008).

studies have found that the news media strongly influence agenda setting for public policy issues (Dearing *et al.*, 1996; McCombs, 2004).

The second main theory of media effects is narrative framing, which refers to the ways in which media organize and communicate frameworks or guides for understanding and making sense of issues. Journalists present their information in stories or narrative packages, and these packages structure our understanding of the world (Shanahan & McComas, 1999). As Gamson and Modigliani (1989: 2) state, "media discourse is part of the process by which individuals construct meaning." Over time, the cumulative effect of repeated exposure to certain narrative packages tends to produce agreement in an audience with the opinions and view of the world expressed in those packages (Gerbner *et al.*, 1986; Shanahan, 1993).

Given the influence of the news media on public attitudes and the importance of the news media as an information source about wildfire, fire managers and policy makers need a better understanding of the ways in which fire and fire policy are discussed in the media. Lichtman (1998: 4) argued that building support for fire policy will require paying close attention to the ways in which wildfire is portrayed in the media discourse. This paper contributes to this understanding by analyzing the news media discussion of the Healthy Forests Initiative (White House, 2002) and the Healthy Forests Restoration Act of 2003. The following section describes the data and methodology used in this study, followed by a discussion of the main findings. A final section discusses conclusions and implications.

Methodology and Data

This analysis involved five main steps: (1) identifying news media stories dealing with HFI / HFRA and downloading them from an on-line commercial database, (2) "filtering" the text to eliminate irrelevant news stories, (3) identifying favorable and unfavorable beliefs about HFI / HFRA contained in the stories, (4) developing computer instructions to score the paragraphs for the identified beliefs, and (5) assessing the accuracy of the scoring. These steps are briefly described in the following paragraphs.

Data for this study consisted of the text of articles from 225 U.S. news sources downloaded from the LexisNexis® online data base. A consistent set of news sources that were available continuously throughout the entire analysis period was used to avoid bias or distortions that might be introduced from additional news sources becoming available online over time. A search term to identify articles about HFI / HFRA was developed to find paragraphs within articles that contained the phrases "healthy forest" or "forest restoration" within the same paragraph as terms such as "plan," "act," or "initiative." The time frame for the analysis covered August 1, 2002 (the month in which the Healthy Forests Initiative was first proposed) through December 31, 2004. The downloaded stories included both straight news and opinion pieces (editorials and letters to the editor), because straight news is full of expressions of opinions (e.g., quotations from opinionated stakeholders, reporters summarizing the arguments for and against an issue, as well as the bias of reporters that may come through). Expressions of favorable and

unfavorable beliefs regarding HFI / HFRA were not more prevalent in opinion pieces, but were found throughout the straight news stories as well.

Second, the downloaded text was filtered using the InfoTrend™ method and software (described briefly below) to remove news stories that were not about the HFI or HFRA. For example, individual state forest plans or restoration projects that did not mention HFI or HFRA were excluded from further analysis. After deleting irrelevant stories, about 2,800 stories remained for analysis.

The third step was identifying favorable and unfavorable beliefs about HFI / HFRA contained in the stories. The specific beliefs analyzed in this study were not predetermined, but emerged from analysis of the textual data. Favorable and unfavorable beliefs about HFI / HFRA were identified by carefully reading and analyzing a random sample of several hundred news stories from the database of 2,800 stories. The InfoTrend software allows the user to view a random sample of stories from the database. Each author read the text and separately developed lists of important and recurring beliefs about HFI / HFRA. Differences between these lists were then reconciled through discussion and further refinement of belief categories. Eight main favorable beliefs and seven unfavorable beliefs were identified. Taken together, these beliefs encapsulate the media debate about HFI / HFRA. The specific favorable and unfavorable beliefs are discussed in the Findings and Discussion section.

Fourth, scoring the text for expressions of the favorable and unfavorable beliefs was done using the InfoTrend computer content analysis method and software. An algorithm was developed to score the text, that is, to count the number of expressions of each of the beliefs. Briefly, this involved development of a *lexicon* (composed of a list of ideas related to the favorable and unfavorable beliefs, and groups of words and phrases associated with each idea) and a series of *idea transition rules* (computer instructions specifying how pairs of ideas in the lexicon are combined to give new meanings).

For example, one favorable belief that was expressed in the news stories and scored in this analysis is that HFI and HFRA will reduce the risk of wildfire. For this belief, a set of lexicon terms such as “avert,” “control,” “curb,” “eliminate,” “decrease,” “risk of,” etc., was developed and used to identify expressions of the concept of *reduce risk*. Another set of terms such as “blaze,” “burn,” “fire,” etc., was used to identify expressions of the concept *wildfire*. An idea transition rule was then developed specifying that when a *reduce risk* term and a *wildfire* term are in close proximity of each other and within a paragraph that mentions HFI or HFRA, then one expression of the belief that HFI / HFRA will reduce wildfire risk is counted. For example, the statement “With 190 million acres at high *risk of* catastrophic *fire* across the country, this is the kind of partnership we need if we are going to conserve forests…” (Norton, 2003: B7) connects the ideas “wildfire” and “reduce risk” in the context of a paragraph discussing HFI / HFRA, and was scored by our

algorithm as one expression of the belief that HFI / HFRA will reduce the risk of wildfire.

The same process was used to identify expressions of the opposite belief that HFI or HFRA do not reduce the risk of fire, but with the addition of a set of *negation* terms (for example, “not,” “won’t,” “can’t,” “fail”). If a *negation* term appeared in close proximity to an expression that HFI or HFRA reduces wildfire risk, this changed the meaning of the original statement. For example, the statement “the Healthy Forests Initiative *wouldn’t* have done squat to *prevent* our *fires*…” (Lopez, 2003) is an example of connecting “prevent” and “fires” and then negating that concept with “wouldn’t” to count as one expression of the belief that HFI / HFRA will not reduce the risk of wildfire.

Our coding rules were structured such that a single paragraph or sentence could be coded for multiple concepts, and this was a common occurrence. For example, the phrase “… endangered species are getting less priority while environmental reviews and public appeals are being reduced…” (Heilprin, 2003) was coded as one expression of the belief that HFI / HFRA reduces environmental protections, as well as an expression of the belief that HFI / HFRA limits public input.

Finally, an assessment of the accuracy of the scoring was carried out by multiple coders who evaluated a random sample of scored paragraphs to check the accuracy of the computer-coded results. After final refinements in the lexicons and idea transition rules, accuracy rates for the scoring of beliefs

about HFI / HFRA were all in excess of 80 %, which is often used as an acceptable accuracy level in content analysis (Krippendorff, 2004).

Findings and Discussion

We found approximately 2,800 news stories about HFI / HFRA for the analysis time period August 1, 2002 through December 31, 2004. To put the number of stories in perspective, for the same time period and for the same set of news sources, there were more than 45,000 stories about wildfire. News media discussion of HFI / HFRA was only about 5 % of the volume of all wildfire discussion. Figure 1 shows the most commonly expressed favorable beliefs about HFI / HFRA that were identified from analysis of these news stories. In order of prevalence, these included the beliefs that HFI / HFRA: (1) will reduce the buildup of fuels in forests and reduce the risk of catastrophic wildfire, (2) will cut red tape, streamline bureaucracy, and speed up decision making processes, (3) will protect people, communities and property, (4) will restore "forest health," (5) will help deal with insect infestation and disease, (6) will create economic benefits, such as job creation and sustaining the local economy in forest-based communities, and (7) involves a collaborative approach with community involvement and partnerships.

In addition to these seven specific favorable beliefs about HFI / HFRA, we found many non-specific favorable expressions, such as the belief that HFI was "a step in the right direction" or HFRA was a "common sense"

approach. A “general favorable” category was created to count all of these non-specific expressions of support for HFI / HFRA. There were also a number of infrequently expressed favorable beliefs, such as the views that HFI / HFRA will help protect wildlife and wildlife habitat, that it is an efficient policy because it will pay for itself through the sale of timber that is cut to reduce the fuel load, and that HFI / HFRA is based on sound science. These beliefs were not tracked in this analysis because they were rarely expressed.

Figure 2 shows the share of each favorable belief as a per cent of all expressions of favorable beliefs about HFI / HFRA in our database. The most frequently expressed favorable belief was “reduces fire risk,” the view that HFI / HFRA will reduce fuel buildup and thereby reduce the risk of catastrophic wildfire. This belief accounted for 38 % of all expressions of favorable beliefs. An example of an expression of this belief scored by our computer content analysis algorithm is: “If signed, the bill will give foresters the funds and tools they need to prevent catastrophic wildfires from threatening homes and watersheds, supporters say,” (deYoanna, 2003: B1). This example was also scored as an expression of the belief that HFI / HFRA will “protect people, communities, and property.”

“General favorable” expressions about HFI / HFRA was the second most frequently expressed favorable belief, accounting for 26 % of the total. An example of an expression of this belief is, “President Bush’s healthy forest plan is a step in the right direction. It restores common sense through a balanced approach…” (Wyoming Tribune Eagle, 2003: A2). “Cuts red tape”

was the third most frequently expressed, followed by “protects people, communities and property,” and “restores health.” The other three favorable beliefs were not often expressed and were not a significant part of the media discussion.

The most commonly expressed unfavorable beliefs that emerged in the news media debate are shown in Figure 3. These included the beliefs that HFI / HFRA will: (1) be an excuse to increase logging and is really a subsidy to the timber industry, often referred to in the news media discussion as “stealth logging,” (2) reduce or weaken important, long-standing environmental protections, (3) reduce public input and threaten citizens’ right to be involved in decision-making on US national forests, (4) fail to reduce the risk of catastrophic wildfire, (5) fail to protect people, communities and property, and (6) fail to restore forest health.

There were also many general, non-specific unfavorable expressions related to HFI / HFRA, including unfavorable characterizations of HFI / HFRA such as “deceptive,” “double-speak,” “smoke and mirrors,” and so on. These were coded as “general unfavorable.” In addition, there were a number of infrequently expressed unfavorable beliefs, such as the views that HFI / HFRA will be too costly and will waste taxpayers’ money, will result in more roads in national forests, will harm wildlife habitat due to increased logging, and that HFI / HFRA is not based on sound science. These infrequently expressed unfavorable beliefs were not formally analyzed in this study.

Figure 4 shows the share of each unfavorable belief as a per cent of all expressions of unfavorable beliefs. The most frequently expressed unfavorable belief was the view that HFI / HFRA is primarily about logging and subsidizing the timber industry ("stealth logging"). This belief accounted for 32 % of all unfavorable beliefs. An example of an expression of this belief is: "The "Healthy Forests Restoration Act" passed by the U.S. House this week has nothing to do with healthy forests and everything to do with a return to environmentally reckless, taxpayer-subsidized timber cutting," (The Columbian, 2003: C8).

"General unfavorable" expressions also accounted for 32 % of all unfavorable beliefs (fig. 4). An example of a general unfavorable expression is, "Rey's portrayal of the Bush administration's Healthy Forests Initiative is *misleading*…" (The Oregonian, 2003: B7). "Reduces environmental protection" was the third most frequently expressed unfavorable belief, followed by the belief that HFI / HFRA "limits input" in decision making processes. The other three unfavorable beliefs – which were each negations of favorable beliefs – were not often expressed and were not a significant part of the public discussion as reflected in the news media.

Figure 5 shows another perspective on the evolution of media debate about HFI / HFRA – an aggregation of all favorable and all unfavorable beliefs expressed in the news media over time. Peaks in the volume of discussion are associated with major events. The biggest spike in discussion occurred in August, 2003 and coincided with President Bush promoting the Healthy

Forests Initiative while large wildfires were burning in the western US. Other spikes in coverage are associated with the introduction of HFI by President Bush in August, 2002, the passage of HFRA by the U.S. House of Representatives in May, 2003, Senate passage of HFRA in October, 2003, and the signing of HFRA by President Bush in December, 2003. The Senate passage coincided with dramatic wildfires in southern California that burned over 750,000 acres and destroyed 3,600 homes (Keiter, 2006: 311). Since that time, there has been a significant drop in the volume of news media discussion of HFI / HFRA.

The shares of favorable and unfavorable beliefs about HFI / HFRA as a percentage of total expressions of beliefs are shown in Figure 6. In this way, relative trends through time can be observed. Over the 29-month period, the share of expressions of unfavorable beliefs appears to have decreased relative to favorable beliefs. Logit analysis was used to test the significance of the trends in favorable and unfavorable beliefs over time. The logit form of regression was appropriate because the dependent variable is the relative frequency or proportion of expressions of each attitude (favorable or unfavorable). The use of logit analysis ensures that the predicted value of the dependent variable is constrained to be positive and less than 1, thereby not violating its interpretation as a relative frequency. We found a positive relationship between time (month of publication) and the proportion of favorable expressions about HFI / HFRA ($P<0.001$). Thus, there is evidence of a gradual shift in the media discussion to a more favorable view of HFI /

HFRA over time. The administration's framing of its Healthy Forests Initiative as essential for reducing dangerous levels of fuels in forests and lowering the risk of catastrophic wildfires slowly gained ground and became the dominant discourse.

We also found anecdotal evidence in our database of HFI / HFRA news stories of increasing salience of this issue on the public agenda, in the form of many expressions of consensus about the fuel buildup problem and the need to deal with it. Although we did not develop computer instructions to explicitly identify expressions of this idea, mounting consensus was evident in many of the news stories we examined. For example:

> "There's strong consensus that the forests, particularly the federal forests, are in fuel conditions that are unnatural because of fire suppression and past management choices. There's probably strong consensus on what can be done," (Cruz, 2002: B1).
>
> "We have serious reservations about some details of the President's Healthy Forests Plan. But we have no lingering doubts about the need for Congress to approve fire legislation," (Oregonian, 2003: B1)
>
> "It doesn't matter your race, religion or political beliefs – you have to make sure you don't have a forest fire in your backyard," (Ratt, 2004).

Other researchers have argued that there is a growing consensus among many stakeholders that fuel buildup and the risk of catastrophic wildfire is of great concern in the US, especially in the wildland-urban interface (Vaughn & Cortner, 2005).

Finally, a common dimension of public and media debates about environmental policy issues is discussion of “sound science” vs. “junk science.” Characterizing scientific findings in media discourse as sound or unsound has been widely used to defend or denigrate a policy position in an effort to influence public and policy views (Herrick & Jamieson, 2001; McCright & Dunlap, 2000). As mentioned earlier, we did find some expressions of the belief that HFI / HFRA is based on sound ecological science, as well as the contrasting view that it is not based on sound science. But these views were rarely expressed and constituted an insignificant part of the media debate. The negligible discussion of “sound science” arguments in the HFI / HFRA media debate may be an indicator of the successful framing of the issue by the administration as a process and litigation problem rather than a science problem.

Conclusions and Policy Implications

This study examined the national debate about the Healthy Forests Initiative and Healthy Forests Restoration Act as reflected in the news media. A primary conclusion is that the Bush administration has been successful in framing the issue and setting the public agenda by connecting the Healthy Forests Initiative and the Healthy Forests Restoration Act with the need to reduce the risk of catastrophic wildfire and excess fuel buildup. The most frequently expressed belief in the news media discussion and debate, either favorable or unfavorable, was the administration’s argument that HFI / HFRA

was a key to reducing the risk of wildfire. Reducing wildfire risk has been the main selling point of HFI / HFRA and it has resonated loudly in the media discourse, perhaps in part due to the "authority-order" journalistic norm which may lead journalists to rely heavily on government officials and other authority figures who reassure the public in times of crisis that order and safety will be restored (Boykoff & Boykoff, 2007). Large wildfires burning in the western United States provided the backdrop for discussion of the Healthy Forests Restoration Act, and kept the focus on wildfire risk.

The unfavorable belief that the HFI / HFRA would not reduce wildfire risk was only 6 % of the unfavorable statements in the news. The other unfavorable beliefs did not address the risk of wildfire. Given the context of the 2003 wildfires burning in the western United States, discussion of the need to reduce wildfire risk prevailed over all other arguments surrounding the healthy forests legislation. Combined with the evidence we found of a gradual shift over time to a more favorable view of HFI / HFRA, this confirms the thesis of Vaughn and Cortner (2005) that the Bush administration has been successful at reframing the public debate about wildfire management in the United States, from an emphasis on the need for ecological approaches to restoring forest health to the urgent need for regulatory reforms (the "cuts red tape" belief) to deal with an imminent threat of destructive wildfire.

It is notable given the phrase "healthy forests" in the titles of the HFI and the HFRA that there was very little discussion of the favorable belief "restores health" in the news media discussion. Even if the "bugs and

disease" belief were combined with "restores health" in a broader forest health category, this would still only rank fourth in frequency of expression among the favorable beliefs. The media discussion focused much more on the destructive potential and danger of wildfire to people and property, which fit with news values such as drama, visually compelling events, conflict and human interest. Traditional news values such as these play a key role in determining what environmental stories are selected as news and how stories are framed (Corbett, 2006). Forest health is a complex concept that has long eluded precise and universal definition by forestry professionals (Allen, 1994) and does not correspond well with basic news values. As a result, more nuanced debates on forest health are a minor feature of the media discourse.

The most frequently expressed unfavorable belief, "stealth logging," indicates a lack of trust in the legislation, the administration's motives, and in the Forest Service's implementation of the HFRA. In addition, the terms used to identify "general unfavorable" expressions about HFI / HFRA also conveyed deep distrust. Examples of these terms include "cynically named," "deceptive," "dishonest," double-speak," "duplicitous," "insidious," "misleading," "Orwellian," "pernicious," "smoke and mirrors," "untruthful," and so on. Winter *et al*. (2004) have noted the vital role of building and maintaining trust in fuels management, suggesting that mistrust may be an ongoing issue as the HFRA is implemented.

A follow-up LexisNexis search of US newspapers for the three and a half year period January 1, 2005 through June 30, 2008 yielded only 354

stories, suggesting that this issue has fallen “off the radar” of media and public attention since passage of the HFRA legislation. Although largely absent from the public eye in terms of news media reporting, implementation of HFI and HFRA has been assessed by academic and government sources as well as environmental advocacy groups. The official “Healthy Forests and Rangelands” Web site (http://www.forestsandrangelands.gov) and a 2008 report (USDI & USDA, 2008) have promoted the success of the HFI / HFRA by noting an increase in number of acres treated, number of projects which have been implemented using the expedited environmental review processes embodied in the legislation, and collaboration as evidenced by the number of Community Wildfire Protection Plans that have been developed. On the other hand, an audit by the USDA Office of the Inspector General (2006a) identified numerous flaws with implementation of the HFI / HFRA. Problems included lack of a consistent process for assessing the risk that communities face from wildland fire, lack of controls for ensuring that the highest priority fuels reduction projects are funded first, and defective performance measures and accomplishment reporting. Others have noted that there has been minimal impact to date on the amount of litigation associated with fuels reduction projects (Evans & McKinley, 2007), a key goal of the HFI.

The wildfire policy debate in the U.S. is not over because, as some observers have pointed out, the United States still does not have a comprehensive wildfire management policy (Franklin & Agee, 2003; Stephens & Ruth, 2005). It may be useful to update our analysis, comparing the media

discussion related to the extensive wildfires of 2007 and 2008 in California with the 2003 California wildfires that hastened Senate passage of the HFRA. Results of such an analysis could show further shifts in framing of the debate as the issue continues to evolve over time. A preliminary examination of news media discussion of the recent California wildfires found almost no discussion of HFI / HFRA. Aside from the usual reporting about firefighting efforts and destruction of property, media discussion appears to have shifted toward the inevitability of wildfires and what the public must do to protect themselves and their property. This is an area for future research.

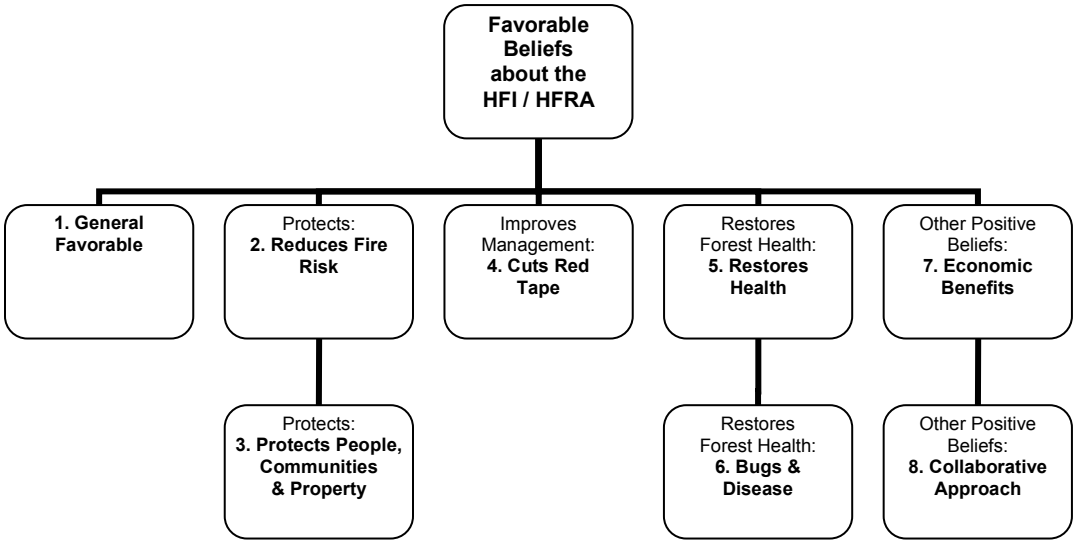

Figure 1. Coding categories for favorable discussion of the Healthy Forests Initiative and Healthy Forests Restoration Act in the news media.

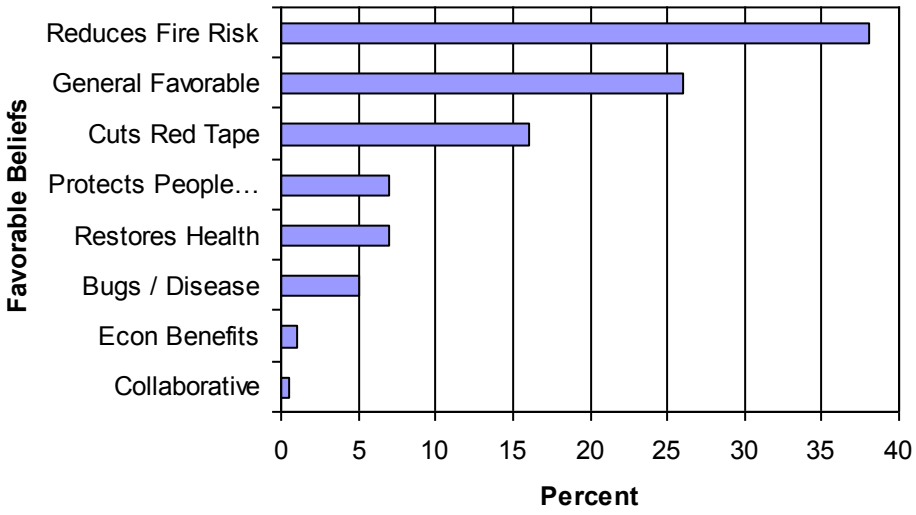

Figure 2. Share of favorable beliefs about the Healthy Forests Initiative and Healthy Forests Restoration Act, August 2002 through December 2004.

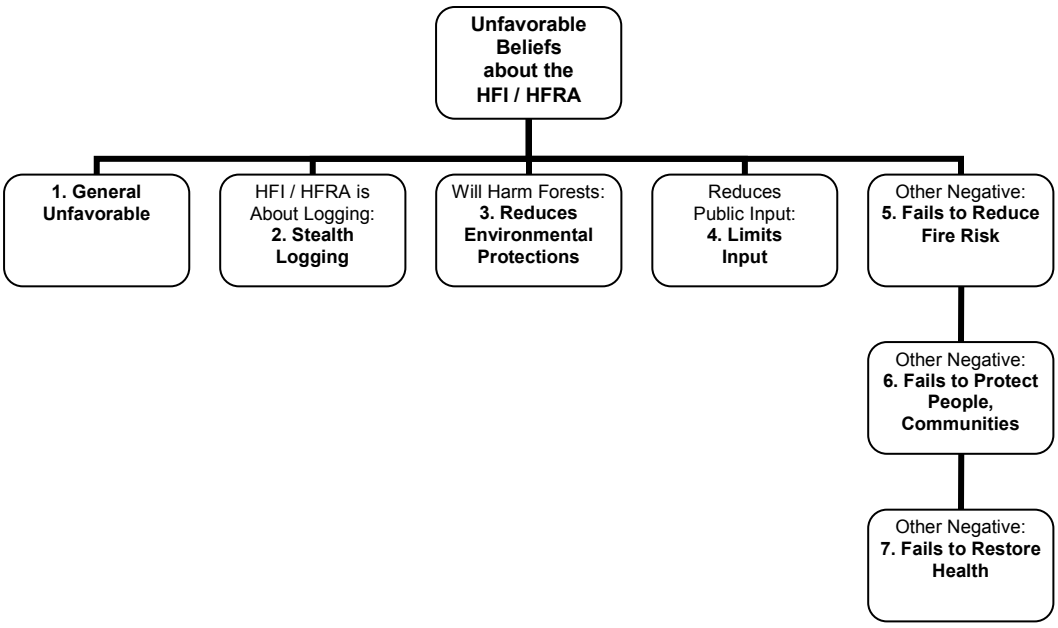

Figure 3. Coding categories for unfavorable discussion of the Healthy Forests Initiative and Healthy Forests Restoration Act in the news media.

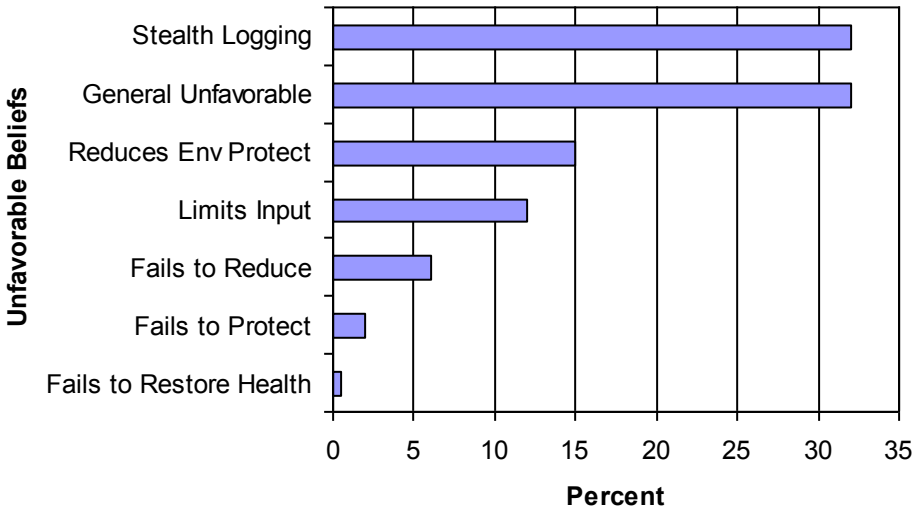

Figure 4. Share of unfavorable beliefs about the Healthy Forests Initiative and Healthy Forests Restoration Act, August 2002 through December 2004.

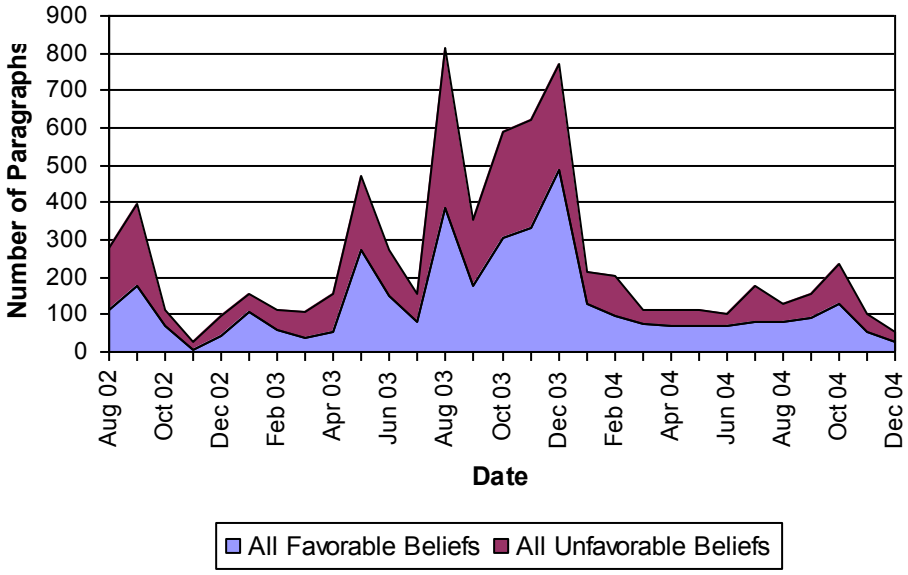

Figure 5. All favorable and all unfavorable beliefs about the Healthy Forests Initiative and Healthy Forests Restoration Act, August 2002 through December 2004.

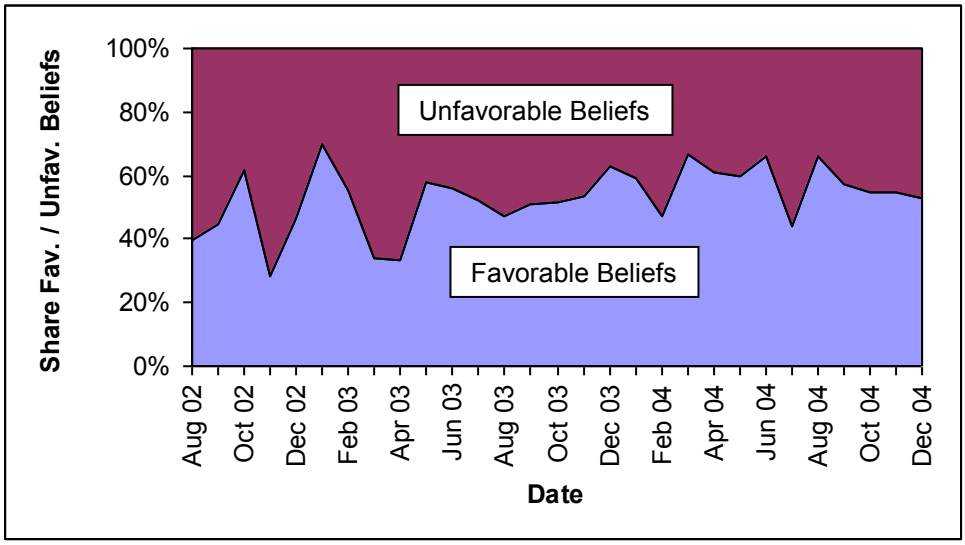

Figure 6. Share of favorable and unfavorable beliefs about the Healthy Forests Initiative and Healthy Forests Restoration Act, August 2002 through December 2004.

Chapter 2: Defensible Space in the News: A Computer Content Analysis

Public discussion of defensible space information to mitigate risk of wildfire destruction of private property was examined using computer content analysis of about 77,000 stories from 225 national news media sources over three years. The goal was to gauge the general dissemination and the dimensions of defensible space information, both nationally and in selected wildland-urban interface (WUI) areas. We found that while the number of defensible space messages in the news media was low compared to all wildfire coverage, the proportion of paragraphs discussing defensible space was significantly larger in selected WUI areas than was found nationally. Coverage of the multiple dimensions of defensible space concepts was low in all areas, which may lower the likelihood that the information will be acted upon by the public.

Introduction

Today's wildfire problem in the United States can be largely explained as the result of U.S. policies that focused on wildfire suppression, leading to an increase in fuels, combined with the growth of human development in and adjacent to wildfire-prone locations or the wildland-urban interface (WUI) (Radeloff et al. 2005). Global climate change may be exacerbating the problem as evidenced by what appears to be a lengthening of the fire season (Fried et al. 2004; Westerling et al. 2006; McKenzie et al. 2004; NWCG Executive Board 2009). Figure 1 shows the trend of increasing acres burned in wildfire in recent years.

The increased length of the fire season, number of acres burned, and people living in the path of wildfires in the WUI has stretched the resources of firefighting agencies in the U.S. Current policy at federal, state, and municipal levels emphasizes the role of individual residents for assuming responsibility for wildfire preparedness and protection. The wildfire problem has been reframed by some from a problem of burning forests that waste timber resources to what is now described as a "home ignition problem" (Cohen 2000). According to Brookings Institution research, there is growing awareness of the limitations of public agency fire suppression capabilities, and "the WUI may well become synonymous with "the Fireburbs" as there's more awareness of the potential wildfire threat in this new era of large wildfires," (Brookings Institution 2008, 20).

When forests burn in wilderness or backcountry far from human development, there is less widespread perception of crisis or catastrophe and fewer resources are expended for fire suppression. But with the increasing number of fires, length of the fire season, and homes in the WUI, requirements for fire suppression dollars and firefighter resource needs exceed capacity, and there is general consensus that individuals must take at least partial, if not primary, responsibility for making their homes safer from wildfire destruction (USDA 2006b; NWCG Executive Board 2009). According to a 2006 GAO Audit Report, increasing firefighting suppression costs are being largely driven by efforts to protect private property in the WUI (USDA 2006b). As McCaffrey (2004, 509) stated, “although the ecological effects of decades of fire suppression are important components of the current hazard, the immediacy of the problem results from the growing number of people moving into wildland areas who are putting more human lives and property at risk every fire season.”

Cohen (2000) used experimental fires to demonstrate ways in which homes ignite and burn when in the vicinity of approaching wildfire. Since those experiments were conducted, much has been published on how to limit risk of property destruction in the face of an oncoming wildfire (e.g., Firewise 2005; Cohen 2008). One of the primary findings of this research was that clearance of flammable vegetation within 30 to 100 feet of a property was one of the activities that would be most effective for preventing wildfire destruction. In addition, fire resistant building materials and other flammable

material within this space will determine whether blowing embers ahead of a fire front will ignite a structure fire (Cohen 2008). Taken together, the actions suggested by research that homeowners should take to protect their property from wildfire destruction have been associated with implementation of "defensible space."

Several organizations have formed with similar goals of educating property owners about their responsibility with regard to wildfire protection and steps individuals can take to mitigate their risk of property damage in the event of a wildfire (e.g., FireWise, Fire Safe, FireFree, FireSmart). Many studies have evaluated the effectiveness of efforts to educate homeowners about the need for protection and assessed the extent to which homeowners have taken action. Most of these studies have used surveys, focus groups, and interviews. A selection of studies that look at defensible space as part of the research is summarized in Table 1. Because of methodological design, each of these studies focus on a specific geographic area at a point in time. Areas studied that are shown in Table 1 include the western U.S. (Collins 2005; McCaffrey 2002; McCaffrey 2006; and Weisshaupt et al. 2007), the southwestern U.S. (Jacobsen et al. 2001; Nelson et al. 2005; and Winter, et al. 2006), the northeast U.S. (Ryan et al. 2006) and midwestern U.S. (Bright and Burtz 2006; Nelson et al. 2005; Winter and Fried 2000; and Winter et al. 2006). The studies examined personal experiences with wildfire, personal values related to landscapes and wildfire, and risk perception. Additional aspects were examined that were not generalizable across studies. Results of

the studies were mixed. For example, some studies found that direct experience with wildfire was not correlated with fuel reduction or other risk mitigation activities (Jacobsen et al. 2001; Winter and Fried 2000), while others showed a correlation between wildfire experience and fuels management support (Ryan et al. 2006; Winter et al. 2006).

This study examined the nature and evolution of the U.S. public discussion of defensible space expressed in the national and local news media as an indicator of public attitudes and awareness of individual responsibility for wildfire protection. Research by communications and public opinion researchers has found that the news media both shape and reflect public attitudes and beliefs about a wide range of social issues (Burgess 1990; Fan 1988; McCombs 2004), including environmental issues. For example, Elliott et al. (1995) found a significant impact of changes in media coverage on the level of public support for environmental protection, with more media coverage of environmental concerns associated with increased support for additional spending on environmental protection. Cockerill (2003) found that variations in the tone and language in local media coverage of flooding had a significant impact on public attitudes toward river management and policy. Jacobsen et al. (2001) found that public opinion about the benefits of prescribed fire closely matched the benefits identified in the local news media. The news media also strongly influence the agenda for public policy issues (Dearing et al.1996; McCombs 2004). In other words, there is a relationship between the relative emphasis given by the media to issues and

the degree of salience these topics have for the general public. Therefore, analysis of the public debate about social issues contained in the news media is a window into the broader social debate and a means to gauge, indirectly, public knowledge, attitudes, and beliefs.

Part of the explanation for the influence of the news media on public attitudes is the importance of the media as the primary information source for public policy issues, including forestry and other environmental issues. For example, a survey in Oregon found that “The most important sources of information about forestry issues tend to be newspaper and television, followed by radio, other printed materials, friends and relatives, and interest groups. Only 16 percent overall considered natural resource agencies to be important sources,” (Shindler et al. 1996, 7). The news media have also been found to be important information sources with respect to wildfire. In a study of public support for fuels reduction strategies in forest-based communities, Shindler and Toman (2003) asked respondents to rate the usefulness of information sources. Newspapers and magazines were rated as most useful, and the percent of respondents who rated the USDA Forest Service as a useful source dropped from 60 percent in 1996 to 48 percent in 2000. Other studies have also shown that the news media are an important source of information about wildfire (Nelson et al. 2004; Winter and Fried 2000; Jacobsen et al. 2001).

The news media have also been shown to influence behavior when prescriptive information is presented. There have been numerous studies in

the field of public health that have demonstrated news media influence on behavior. Examples include studies about youth smoking (Niederdeppe et al. 2007), cocaine use (Fan and Holway 1994), and skin cancer prevention (Stryker et al. 2005).

Given the strong influence of the news media on public attitudes and the central importance of the news media as an information source about wildfire, fire managers, educators, and extension specialists working to increase awareness and adoption of defensible space practices need a better understanding of the ways in which fire and defensible space are discussed in the media. Lichtman (1998) argued that building support for fire policy would require paying close attention to the ways in which fire is portrayed in the news media.

This paper contributes to this understanding by analyzing the news media discussion of defensible space concepts as a proxy for public attitudes and awareness about individual responsibility for wildfire protection. The following section describes the data and methodology used in this study, followed by a discussion of the main findings. A final section discusses conclusions and implications for public education on issues related to wildfire, especially in the WUI in the United States.

Methodology and Data

This study used the InfoTrend® method and software to analyze the public discussion about defensible space expressed in the news media. The

InfoTrend method has been used to successfully predict public opinion, attitudes, beliefs and values based on analysis of news media discussion of diverse issues (e.g. , Fan and Cook 2003; Bengston et al. 2001; Shah et al. 2002). The analysis involved four main steps: (1) identifying news media stories dealing with wildfire and downloading them from an on-line commercial database, (2) "filtering" the text to eliminate irrelevant news stories, (3) developing computer instructions to score the paragraphs for the concepts of interest, and (4) assessing the accuracy of the scoring. These steps are briefly described in the following paragraphs.

Data for this study consisted of the text of articles from 225 U.S. news sources downloaded from the LexisNexis® online database. A consistent set of news sources that were available continuously throughout the entire analysis period was used to avoid bias or distortions that might be introduced from additional news sources becoming available online over time. Newspapers included in our database ranged from national papers such as the New York Times, to regional papers such as the Arizona Republic, to local papers such as the Lakeland Ledger in central Florida. A search term was used to identify articles about wildfire that were published from January 1, 2002, through January 31, 2005. Approximately 77,000 stories from 225 newspapers, newswires, television and radio news transcripts, and news magazines were downloaded. We examined a random sample of the downloaded news stories to determine whether or not they were "on topic." A small percentage of irrelevant stories were identified and deleted using the

InfoTrend software. For example, stories that contained the term “like wildfire,” as in “the computer virus spread like wildfire,” were deleted, as were all mentions of songs, television shows, and sports teams that contained the term “wildfire” in their titles.

Defensible space concepts and terms to be used in the computer coding were identified by carefully reading and analyzing a random sample of several hundred news stories, and by considering key concepts discussed in the defensible space literature, such as clearing brush around a property, moving flammable debris away from a structure, using less flammable building materials, etc. (Firewise 2005; Cohen 2000). An algorithm was developed to score the text, that is, to count the number of expressions of each of the concepts of interest. Briefly, this involved development of a lexicon (composed of a list of ideas related to the concepts, and groups of words and phrases associated with each idea) and a series of idea transition rules (computer instructions specifying how pairs of ideas in the lexicon are combined to give new meanings).

To examine the extent to which multiple dimensions of defensible space are expressed in the news media, we categorized and coded four aspects of defensible space. “Defensible Space - Land” included discussion of land treatments such as clearing, thinning, or trimming vegetation around a structures. “Defensible Space - Other” included a variety of other treatments such as using fire-resistant building materials, chimney spark arresters, or moving woodpiles away from structures. We also coded the number of

paragraphs with general references to defensible space – e.g., terms such as Firewise or FireSafe – labeled “Defensible Space – General.” Finally, expressions of the idea “Defensible Space - Community Level” were coded to account for discussion of defensible space actions that applied to an entire community or neighborhood rather than an individual private property. This included activities such as clearing land or trimming vegetation on public lands surrounding a community.

Examples of words and phrases which identified concepts related to the “Defensible Space - Land” category included clearing, trimming, and thinning terms such terms as “30 feet,” “fire-scape,” “ignition zone,” “thinning trees close,” “vegetation management,” etc. The following quotation from our database of news stories contains two references to “Defensible Space - Land” (“30-feet” and “flammable vegetation”):

> “Defensible space means an area within *30-feet* of a structure that is clear of extremely *flammable vegetation*…” (Palmer 2004, A9, emphasis added).

Examples of words and phrases which were used to categorize “Defensible Space - Other” concepts included terms like “spark arresters,” “metal roof,” “needles on,” “clear of pine needles,” etc. The following example expresses the concept “Defensible Space - Other”:

> “…perhaps most important, replace that cedar shake *roof* with *metal*” (Vaugh 2003, C1, emphasis added).

Terms such as “fire-proof,” “firewise,” “home assessment,” and “defensible space,” were used to identify expressions of the “Defensible Space - General” category when not used with further specificity, and were counted when found in examples such as:

> “That's how Knight ended up knocking on doors on Elk Ridge Road, recruiting homeowners to his *defensible-space* campaign,” (Devlin 2002, A33, emphasis added).

> “In Show Low, 40 miles east, the city mailed out brochures telling homeowners how to make their properties more fire-safe,” (Arrillaga 2002, A33, emphasis added).

Our coding rules were structured such that a single paragraph or sentence could be coded for multiple concepts, and this was a common occurrence. For example, the following sentence would code for both “Defensible Space - Land” because of the term “clear brush” and also for “Defensible Space - General” because of the term “firewise.”

> “Forest officials said they also have a program called ‘Firewise’, where they encourage residents to clear brush and bring it to a wood chipper provided by forest officials,” (Arora 2003, B15, emphasis added).

Finally, an assessment of the accuracy of the scoring was done by evaluating a random sample of paragraphs to check the precision of computer-coded results. After final refinements in the lexicons and idea transition rules, accuracy rates for the scoring of beliefs about defensible

space were all in excess of 80 percent, which is often used as an acceptable accuracy level in content analysis (Krippendorff 2004).

Note about the data

We attempted to update the data to look for changes in media discussion of defensible space concepts, using the same search terms to find and download news stories from the same set of news sources. After downloading the stories, we discovered that the number of stories discussing defensible space concepts was significantly lower than expected based on our earlier download. Further research helped to explain why this was the case.

In 2001, a legal case about copyright infringement of newspaper stories in news aggregator services such as LexisNexis resulted in a gradual decrease in the number of stories which were propagated to such data aggregators. In New York Times Co., Inc. v Tasini, the United States Supreme Court issued a ruling that supported the copyright rights of freelance authors. The court held that print publishers could not provide copies of works by freelance writers to electronic databases such as LexisNexis without the prior consent of the author (Vakil 2003). The ruling resulted in a gradual decrease in the comprehensiveness of data aggregators' electronic databases. Therefore, the news databases became less able to provide a complete picture of news stories that had been published, as news stories were retroactively deleted from the databases. That is, older stories that were contained in the aggregator databases, and that we had been able to

download with our initial searches, have been removed if they did not conform to the new copyright requirements. What this means to our analysis is that while there was a more complete picture of the news media landscape in 2005, our database of news media stories cannot currently be updated using the same methods we used in 2004 – 2005.

Despite the Tasini decision, the data we use in this paper present a relatively complete picture of the news landscape of the time. Fan (2009) has shown that analysis of news media discussion of the economy can still be used to accurately predict consumer sentiment, despite the change in input text resulting from the Tasini decision. New techniques are available to gather news stories from the various sources, such as electronic news clipping services. The online archives from individual news sources could also be used to gather news stories for analysis, but this is labor intensive and expensive if archived articles are only available for a fee per article.

Findings and Discussion

Wildfire and dramatic accounts of fighting fires attract significant media attention. News media coverage of wildfire and other natural disasters often focuses on immediate and dramatic events, rather than on the broader context in which they occur (Reid 1989, Smith 1992). Not surprisingly, we found that news media discussion of wildfire is dominated by coverage of firefighting, and defensible space is a minute fraction of total wildfire-related coverage. Over the three years examined in this study, all discussion of

defensible space accounted for only 4.3 percent of the news media discussion of wildfire (4,549 paragraphs on defensible space vs. 104,676 paragraphs on all wildfire). Discussion of defensible space was barely visible when plotted on the same graph as firefighting (Figure 2). This figure also shows the dramatic peaks in media coverage of wildfire that corresponded to major fires. Peaks occurred in June 2002, July-August 2003, October 2003, and July 2004. In the summer of 2002, for example, the Hayman Fire in Colorado and the Rodeo-Chediski Fire in Arizona destroyed over 1000 structures, and the Cedar Fire in California in October 2003 claimed 15 lives with over 2400 structures destroyed (NIFC 2008).

Six geographic areas were selected for individual scrutiny based on their proximity to wildfire risk, diversity of fire regimes and ecosystems, and wildland-urban interface (WUI) configurations. These areas, and the newspapers that are predominantly relied upon by local residents, were initially selected as part of a larger study of which this study is a part. The six WUI areas and their main newspapers include Flagstaff, AZ (*Arizona Republic*), San Bernardino, CA (*San Bernardino Sun* and *Los Angeles Times*), Boulder, CO (*Denver Post* and *Rocky Mountain News*), Sarasota, FL (*Sarasota Herald Tribune*), Hamilton, MT (*The Missoulian*), and Reno, NV (*Reno Gazette Journal*).[2]

[2] *The Missoulian* was the newspaper selected to represent Hamilton, MT and was unavailable for retrieval through LexisNexis. Paragraphs from *The Missoulian* were retrieved using the newspaper's online archives and formatted for input to the InfoTrend software.

Figure 3 shows the number of expressions of firefighting and any defensible space over time for the combined newspapers representing the six WUI locations. When combining the news media for the six areas, results appear similar to the national cross-section of media. As shown in Figure 3, defensible space coverage in the news media for the six WUI areas was still minor compared to overall wildfire and firefighting coverage, accounting for only 5.5 percent of the news media discussion of wildfire (650 paragraphs on defensible space vs. 11,871 paragraphs on all wildfire). We had expected to observe increased discussion of defensible space concepts in the news media near WUI communities, and our results verified this. Using a normal approximation test for differences in proportions (Ott and Longnecker 2001), we were able to conclude that the proportion of paragraphs that discuss defensible space is significantly larger in the news media for the six WUI areas combined than for the national set of newspapers (p-value < 0.01).

Figure 4 shows the volume of news media discussion of defensible space plotted alone. When viewed at this scale and compared with Figure 2, media discussion of defensible space clearly follows the peaks and valleys of the overall firefighting discussion. This makes sense when we consider that the imminent threat of wildfire encourages media coverage about steps property owners could take to protect their property. Figure 5 shows the number of paragraphs for all defensible space for the news media representing the six WUI areas over time. Once again, results follow the pattern of the total national news media paragraphs.

Several studies have noted that residents are less likely to implement defensible space if they have only general, highly simplified information which conflicts with other values they hold, such as the desire for privacy and solitude and the desire to be "in the woods" (Daniel et al. 2002; Nelson et al. 2005; Bright and Burtz 2006; Hodgson 1993). We looked in more detail at the defensible space discussion in the news media to determine the extent to which multiple dimensions of defensible space concepts are being conveyed in news media messages. As described in the preceding section, we categorized and coded defensible space actions as either land treatments ("Defensible Space – Land") or other treatments ("Defensible Space – Other"). We also coded the number of paragraphs with a general reference to defensible space ("Defensible Space – General") and community-level defensible space actions ("Defensible Space – Community Level").

As shown in Figure 6, there was almost twice as much discussion of land treatments for defensible space as "other" actions (41 percent, compared to 24 percent). If general reference to defensible space is understood to be comprised of primarily land treatments, the amount of defensible space discussion devoted to land treatments was even higher, suggesting the primary message being conveyed to the public was the highly simplified message that implementing defensible space primarily meant clearing vegetation around one's home. Community-level defensible space was mentioned infrequently, with only 20 percent of all defensible space references mentioning any aspect of defensible space around a community.

Figure 6 also shows that land treatments dominate the discussion of defensible space in the news media representing the six WUI areas.

Finally, we examined “Defensible Space - Other” as a percent of the combined defensible space discussion (the sum of “Defensible Space - Other,” “Defensible Space - Land,” and “Defensible Space – General”) as an indicator of the complexity of the defensible space media discussion. The greater the share of the diverse concepts represented in “Defensible Space – Other,” the greater the complexity in defensible space messages. “Defensible Space - Other” accounts for 31% of the defensible space discussion in the national cross-section and 33% in the local WUI news media discussion, with no significant difference between national and local WUI community news media (p-value = .40). Thus, while a disproportionate share of firefighting stories and stories mentioning defensible space appear in the selected WUI news media, “Defensible Space - Other” was not mentioned with greater frequency for the local WUI media than it was in the national cross-section. This suggests that even at a local level where more specificity would be expected, the media simplifies the defensible space message, which may make it less likely that defensible space messages will be acted upon by residents in fire-prone WUI areas.

Conclusions and Implications

With a longer wildfire season, high fuel load, changing climate, and expansion of homes and neighborhoods in the WUI, wildfire prevention and

suppression can no longer be the only response to the problem of wildfire. An increasing percentage of wildfire management dollars are spent protecting structures in the WUI, and there is a growing view that WUI homeowners must assume responsibility for protecting their homes from wildfire. Many studies have assessed homeowners' knowledge and acceptance of defensible space practices (Table 1). This study was conducted to gauge how the defensible space message has been portrayed in the national news media and in the news media in WUI areas.

We found a paucity of news media coverage of defensible space concepts compared to news about firefighting in general, suggesting continued emphasis on fire suppression rather than homeowner responsibility. The defensible space coverage we did find emphasized clearing vegetation near homes and generally did not contain the other aspects of defensible space tailored to locations or homeowner's values, which would be more likely to be implemented by homeowners and communities.

The news media are a key information source for educating homeowners about the need to take responsibility for decreasing their risk from wildfire. At the same time, analysis of the news media can serve as an indirect measure of public opinion and awareness that provides a snapshot of the success of the dissemination of defensible space messages. This can be useful for developing messages for the public, targeting the messages to specific communities, and evaluating who is getting what messages and at

what points in time. McCaffrey (2002) discusses diffusion of innovations, or theories about how changes are adopted and implemented, and points out the difficulties associated with getting people to adopt innovations without a clear perception of benefits. News media coverage of wildfire destruction of property can provide what McCaffrey refers to as 'trigger points' to spur people to action by highlighting a clear benefit of saving homes from destruction. At the same time, the news media can provide a forum for spreading the technical knowledge that needs to be adopted as these trigger events are occurring.

This study has shown that news media coverage of defensible space concepts is highest when major wildfires are occurring and homes are being destroyed. In fact, very little coverage occurs when wildfires are not burning. This is not necessarily counterproductive because this is when questions of how to mitigate fire risk are most salient and when homeowners are more likely to be receptive to the information. But even during major wildfires, the news media coverage of defensible space is limited and simplified. This suggests the need for those working to get the word out about defensible space and homeowner responsibility – non-governmental organizations, extension professionals, fire managers, etc. – to develop new and creative ways to spread their messages. The use of social media is likely to be a promising approach, as well as working closely with traditional media to ensure the communication of a more comprehensive conception of defensible space.

Author(s)	Method	Location (state)	Main Findings
Bright and Burtz 2006.	Mail Survey	MN	Attitudes about defensible space activities were the strongest predictor of intentions to implement them. Influence of values on perceptions and behavior: community-oriented groups are more likely to implement defensible space; they also prefer the aesthetic of defensible space.
Collins 2005.	Case Study	Forest Ranch, CA	Confirms significance of risk perceptions, amenity value conflicts, institutional incentives, and political-economic constraints in household risk-management decision-making
Jacobsen, et al. 2001	Phone Surveys, Media Analysis	FL	Direct experience with wildfire is not correlated with taking action; media coverage did coincide with public opinion about benefits of prescribed burning.
McCaffrey 2002	Mail Survey and Case Study	NV	Shows a connection between risk perception and sense of responsibility; "higher risk perception does appear to lead to taking some degree of action." (p.161); newspaper and magazine articles were the most frequently cited source of information about defensible space.
McCaffrey 2006	Focus Groups	CO, AZ, MT, NV, CA	Residents' perception of wildfire risk is balanced against benefits of living in environment.
Nelson, et al. 2005	Survey, Interviews	MN, FL	Discusses links between landscape values and implementation of defensible space.
Ryan et al. 2006	Survey	NY, MA	Stressed importance of experience and knowledge about wildfire and fuel hazard reduction ion support for fuel mgmt strategies by local residents.
Weisshaupt, et al. 2007	Focus Groups	MT, WA	Consensus that individuals need to take primary responsibility for protecting their own property.
Winter and Fried 2000.	Focus Groups	MI	Direct experience with uncontrolled wildfire resulted in WUI residents unlikely to take risk mitigation action; suggest that media information may be more influential
Winter, et al. 2006	Survey, Focus Groups	CA, FL, MI, MO	Identified correlation between experience with and support for fuels management approach

Table 1. Summary of selected US studies of public opinion related to defensible space and private property protection in the wildland-urban interface (WUI).

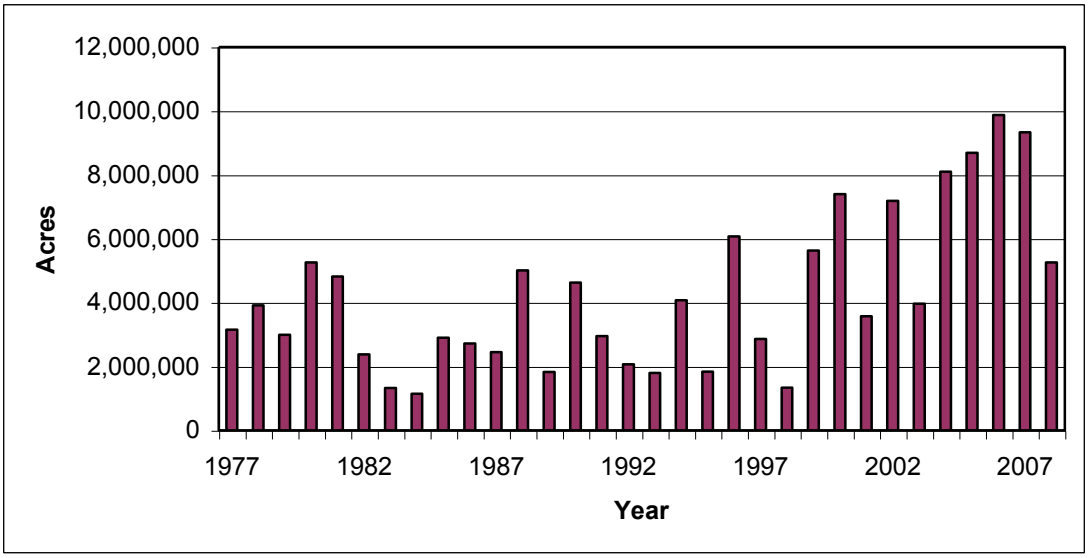

Figure 1. Total acres burned in wildfire by year, 1977-2008. (Source: NIFC 2008). Note: Excludes prescribed burn and wildland fire use (WFU) acreage burned.

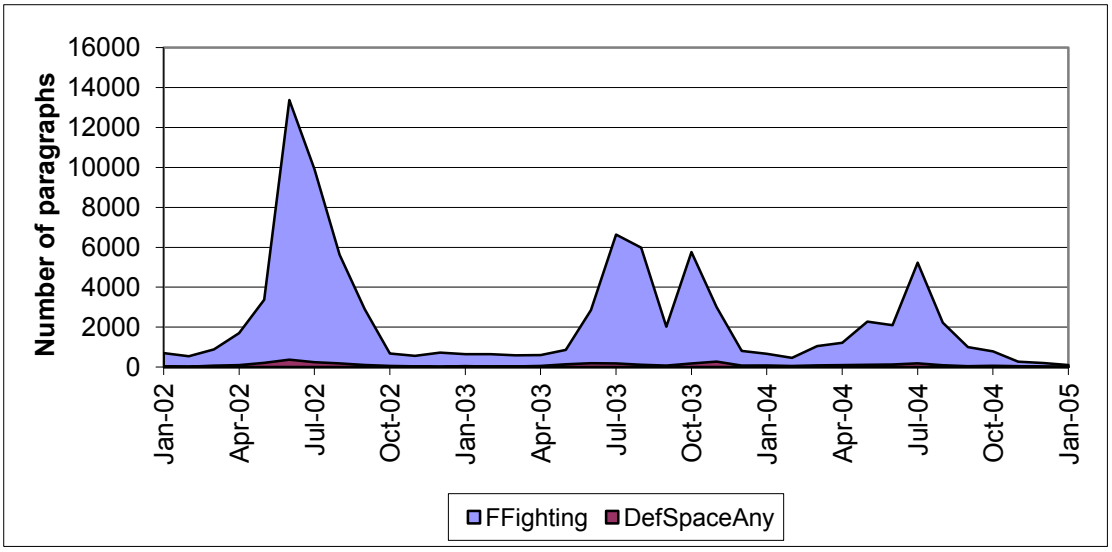

Figure 2. Number of paragraphs that mention firefighting and any defensible space for all 225 news media sources, January 2002 – January 2005.

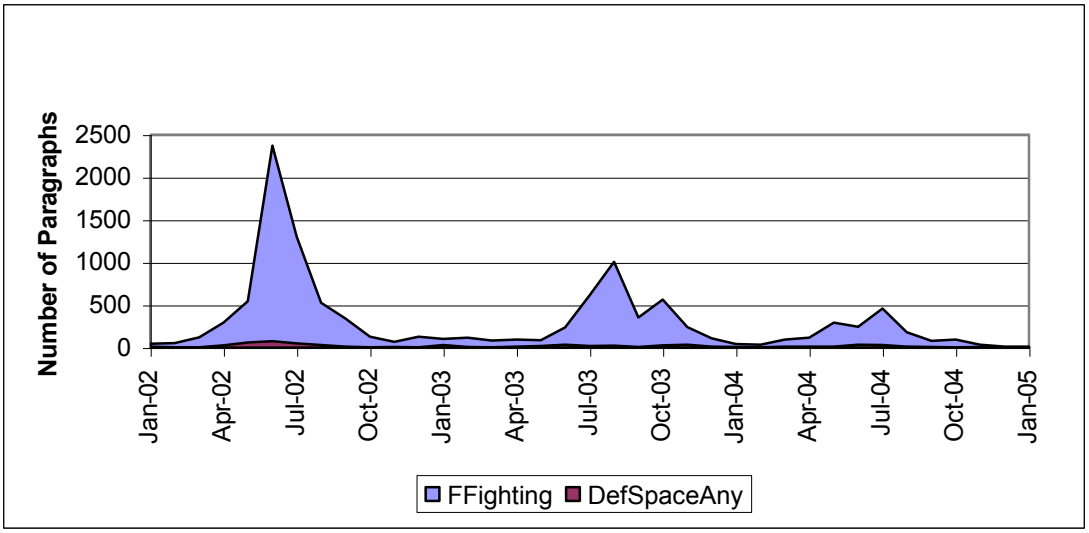

Figure 3. Number of paragraphs that mention firefighting and any defensible space for news media sources representing the six WUI areas, January 2002 – January 2005.

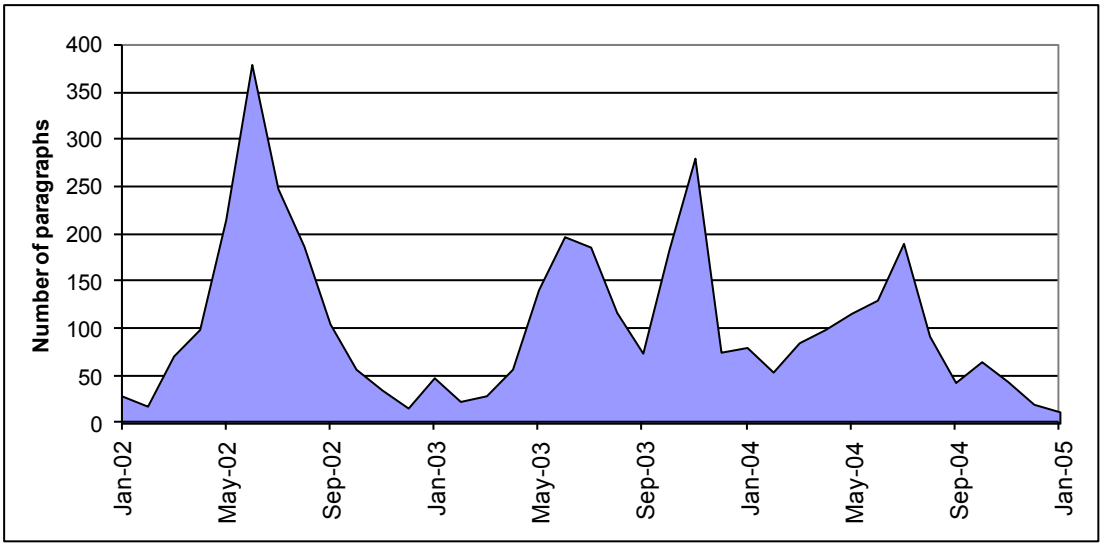

Figure 4. Number of paragraphs mentioning defensible space concepts for the 225 national news media sources, January 2002 – January 2005.

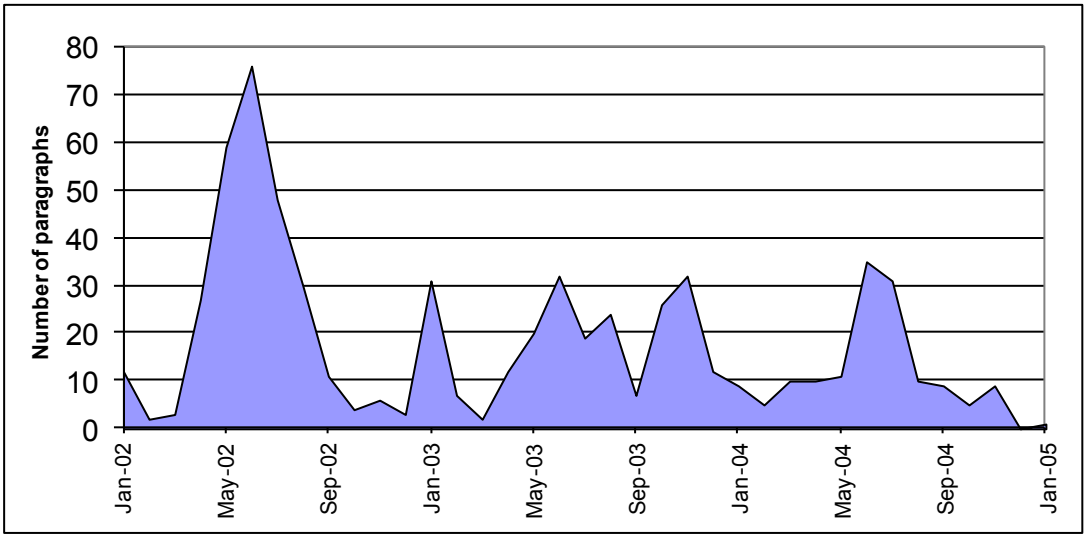

Figure 5. Number of paragraphs mentioning defensible space concepts for the news media sources representing the six WUI areas, January 2002 – January 2005.

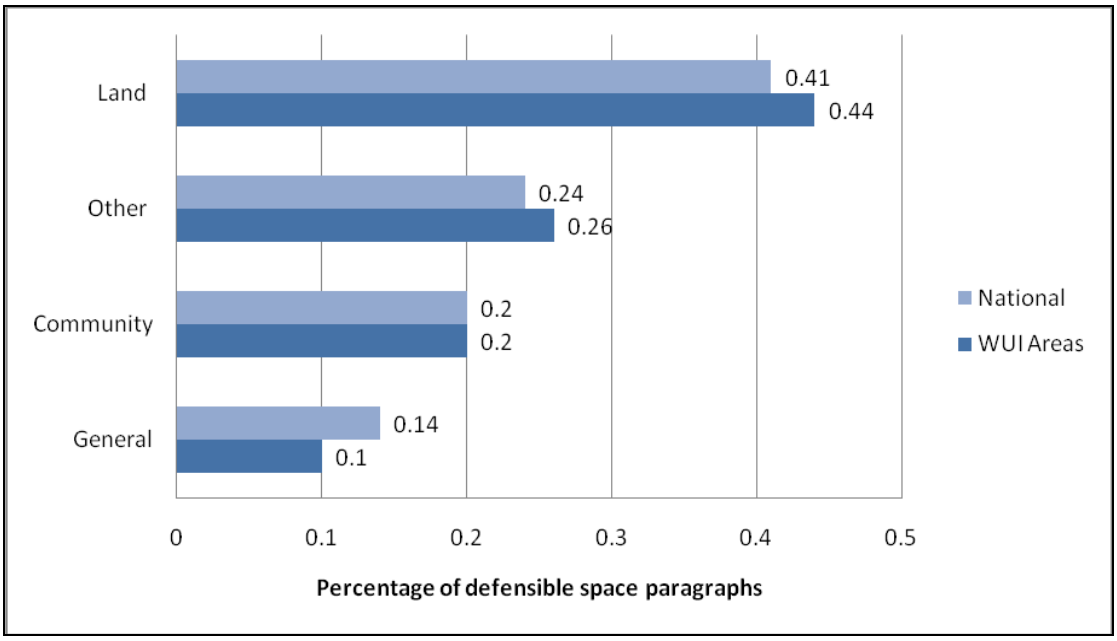

Figure 6. Percentage of defensible space paragraphs by category for all 225 news media sources and for the six WUI areas, January 2002 – January 2005.

Chapter 3: Diffusion of Innovations for Wildland Fire Mitigation: A Case Study of Wildfire Sprinkler Systems in Northern Minnesota

Diffusion of innovations is a long-established field of study, commonly used to explain the dissemination of new products, technologies, and ideas. More recently, it has been applied to many fields to help explain why new ideas are or are not adopted. Specifically, it has been used to help managers understand why they are having a difficult time getting homeowners in the wildland-urban interface (WUI) to take actions to protect their homes from wildfire hazards. This case study documents one location's experience with a new wildfire hazard mitigation technology, wildfire sprinkler systems, used for wildfire preparedness by WUI homeowners. In May 2007, the Ham Lake fire burned approximately 76,000 acres across northeastern Minnesota and Canada, initially burning through the Gunflint Trail area in Minnesota, populated with homes, cabins, and businesses. Due to a unique set of circumstances, this area had more than 100 structures equipped with wildfire sprinkler systems. While wildfire sprinkler systems have been used extensively outside the US and by wildland firefighters, they are rarely used within the US by homeowners for structure protection. The observable and widely noted success of the sprinkler systems provided the trial and confirmation of sprinkler system effectiveness -- necessary precursors for wide spread diffusion of this innovation. Compatibility, another key characteristic of a successful innovation, was also demonstrated, with green vegetation remaining around homes that had functional sprinkler systems. A

Federal Emergency Management Agency (FEMA) Hazard Mitigation Grant for homeowners provided a strong financial incentive, which also increased the relative advantage of this innovation. Together, the elements of diffusion of innovations theory assessed for this case study resulted in this new tool being implemented widely by a majority of homes in the area. The Ham Lake fire experience, with sprinkler systems as one component of wildfire preparedness, demonstrated that sprinkler systems can be effective in protecting structures and the vegetation surrounding the structures.

Introduction

In recent years, preparedness for wildfire events has taken on growing importance. Due to increasing suppression costs, higher intensity wildfire seasons, and a growing wildland-urban interface (WUI) population, there has been a policy shift from strictly fire suppression to a more complex agenda that includes suppression, mitigation, community assistance, and preparedness (Jakes and Nelson 2007). Cohen (2000) went further by stating that the "wildland-urban interface fire loss problem can be defined as a home ignitability issue largely independent of wildland fuel management issues" (p. 20). Dozens of studies have been undertaken to better understand WUI residents' awareness of and willingness to implement wildfire risk mitigation measures. These have looked at associations between education efforts and awareness and behaviors (e.g. Monroe and Nelson 2004 and Sturtevant and McCaffrey 2006), perceptions of risk (e.g. Cortner et al. 1990; Winter and Fried 2000; Nelson et al. 2004; McCaffrey 2006; Brenkert-Smith et al. 2006), values and attitudes of homeowners (e.g. Hodgson 1993; Daniel et al. 2002; Nelson et al. 2004; Weisshaupt et al. 2007; Gordon et al. 2010; McCaffrey et al. 2011) and natural hazard and diffusion of innovations theory (McCaffrey 2002; McCaffrey 2007; Sturtevant and McCaffrey 2006).

While homeowners in the WUI are commonly instructed to clear vegetation around their property to create defensible space, wildfire sprinkler systems are a new and innovative tool for wildfire preparedness by

homeowners in the US WUI. This paper examines the adoption and use of wildfire sprinkler systems on the Gunflint Trail in northeastern Minnesota, USA as a unique case study where the sprinkler systems were deployed during a major wildfire, by examining the implementation of the sprinkler systems through the lens of diffusion of innovations theory. It joins a large body of literature that has used diffusion of innovations theory to explain why new technologies or ideas are or are not adopted.

In the spring of 2007, along the Gunflint Trail in northeastern Minnesota, proactive preparedness measures taken by some residents, business owners, and emergency response personnel were tested by the Ham Lake fire. The fire consumed many homes, but many more were saved. In the aftermath of the fire, we worked with the Minnesota Department of Natural Resources (DNR) Firewise Program to assess the community's experiences with the systems in order to better understand where sprinkler systems worked, where they didn't work, and to identify issues and challenges surrounding their use. For this paper, diffusion of innovations theory is used to help explain how widespread use of the sprinkler systems developed along the Gunflint Trail. The paper also documents findings about the Gunflint Trail's experiences with the use of the sprinkler systems that suggest a series of lessons learned that can be shared with communities considering sprinkler systems as one option in their wildfire preparedness strategy.

The success of the sprinkler systems in saving homes experienced by residents after the Ham Lake fire led to increased acceptance and more wide-spread use of this innovation by the Gunflint Trail population. Local media and neighborhood focus on the benefits of sprinkler systems combined with new FEMA Hazard Mitigation Grants, increased awareness and provided incentives for further implementation of wildfire sprinkler systems. (pers. comm. Cook County Emergency Manager, 2012).

Literature Review

Diffusion of Innovations

The field of diffusion of innovations was primarily developed by E. M. Rogers, a rural sociologist who synthesized research to produce a theoretical framework for the adoption of innovations (Rogers 2003). Initially applied to agricultural innovations, diffusion of innovations theory is extensively used for marketing, as well as public health, education, and rural sociology. More recently, scholars have applied diffusion of innovations theory to help understand the adoption of wildfire risk mitigation measures by WUI residents. (McCaffrey 2002; McCaffrey 2007; Sturtevant and McCaffrey 2006).

Rogers defines diffusion as “the process in which innovation is communicated through certain channels over time among members of a social system” (Rogers 2003, p. 5). Figure 1 identifies the primary

components of diffusion of innovations theory: elements of diffusion; attributes of an innovation; the decision to adopt process; and categories of adopters of an innovation.

The four main elements of diffusion that are defined include: 1) *the innovation*, or new idea; 2) *communication*, or the means by which messages about the innovation are disseminated; 3) *time*, or relative speed with which the innovation is adopted; and 4) *the social system*, or the social structure of the system within which diffusion occurs.

It is the characteristics of *the innovation* itself that influence the rate at which it is adopted. These attributes are: 1) *relative advantage*; 2) *compatibility*; 3) *complexity*; 4) *trialability*; and 5) *observability* of its effect. *Relative advantage* is the degree to which an innovation is perceived as preferable to its alternatives, and has been found to be one of the best predictors of adoption (Rogers 2003).

Some innovations are adopted to lower the probability of an unwanted future event, rather than increasing the probability of a positive outcome. Rogers describes these innovations as preventive innovations. The rewards from adopting a preventive innovation are often delayed, are relatively intangible, and the unwanted outcome may not occur anyway (Rogers 2002). Incentives or subsidies can help speed the adoption of preventive innovations by increasing the relative advantage of the desired innovation (Rogers 2003). Because of the uncertainty surrounding a preventive innovation, the motivation to adopt is relatively weak. There can also be specific triggers that

occur at a point in time, or what Rogers calls a “cue-to-action”, as influencing a decision to adopt an innovation. A cue-to-action can be created by a change agent or change agency to influence adoption.

Compatibility is the degree to which an innovation is consistent with the existing values and beliefs and past experiences of potential adopters. *Complexity* is the degree to which a potential innovation is difficult to understand and use, and is negatively related to the rate of adoption (Rogers 2003). *Trialability* refers to whether a potential innovation can be tested on a limited basis. *Observability* refers to the degree to which others can see the outcome of an innovation.

The second element important to the diffusion process is *communication*. Communication sources (individuals or organizations) and communication channels (e.g. mass media and interpersonal communications) play different roles depending on whether the stage of the innovation is creating knowledge versus persuading individuals to change attitudes about an innovation. Mass media is able to reach a large audience and spread information rapidly about a new idea, but is only able to influence weakly held attitudes. Interpersonal channels of communication are more effect at influencing strongly held attitudes or in persuading late adopters to try an innovation.

The third element of diffusion of innovations is *the rate* at which an innovation is adopted – the time factor. Adopters are categorized as innovators, early adopters, early majority, late majority, and laggards.

Innovators, comprising 2.5% of a target population, are the risk-takers, and generally have financial resources to absorb losses if they occur. *Early adopters* (13.5%) tend to be opinion leaders and have respect in the community. This group is most influential for subsequent groups in adopting an innovation. Potential future adopters look to the early adopters for advice and information. The *early majority* is one of the largest categories of adopters, comprising slightly over a third of adopters. They are deliberate in their willingness to adopt but tend not to be opinion leaders. The *late majority*, also a third of all adopters, is the group of skeptics, who only adopt once the uncertainty surrounding an innovation has been resolved. *Laggards* (16%) are the last to adopt an innovation, have relatively traditional values, and tend to be suspicious of innovations and change agents (Rogers 2002; Rogers 2003).

The fourth element of diffusion of innovations is *the social system* within which an innovation is adopted. The structure of the social system influences the diffusion and rate of adoption of the innovation. It has been noted that adoption of wildfire preparedness practices are predicated on social factors as well as technologies. Key factors that have been identified with such behaviors include leadership, networks and relationships, local knowledge and skills, and a strong sense of place (Lang et al. 2006; Kruger et al. 2003). In addition, change agents and opinion leaders may be part of a social system. Change agents, according to Rogers, are a key link between a new idea or innovation and the people to whom the innovation is targeted.

Opinion leaders are a part of the target group that others in the group respect and look to for advice and recommendations. Champions, or individuals who provide enthusiastic support for an innovation, also play a key role in introducing technological innovations (Markham and Aiman-Smith 2001).

The innovation-decision process model is comprised of the stages an individual (or organization) goes through before fully adopting the innovation. The stages include *knowledge* or awareness, *persuasion*, the *decision*, *implementation*, and *confirmation*. The *knowledge* stage occurs when an individual is first exposed to an innovation but lacks information about it. A general understanding is attained at the knowledge stage. *Persuasion* occurs when the individual's attitude toward the innovation is formed, either favorable or unfavorable. The *decision* stage occurs when an individual makes a choice and begins taking action to adopt an innovation. *Implementation* occurs when the innovation is in use. *Confirmation* occurs when the individual receives reinforcement that the decision to implement was the correct one. The innovation can still be rejected at the confirmation stage if there is not sufficient reinforcement that the choice to implement was the correct one (Rogers 2003).

Wildfire Risk Perception, Responsibility, and Values

The first stage of the diffusion-decision process is knowledge or awareness of the innovation (Rogers 2003). Perceived need for the technology is a necessary, but not sufficient condition for adoption. Awareness of wildfire risk and a sense of individual responsibility for

mitigation are preconditions of homeowners adopting defensible space and other mitigation measures such as wildfire sprinkler systems. Without a perceived need to assume responsibility, there would be little motivation to mitigate risk (McCaffrey 2004).

Wildfire risk perception and responsibility for mitigation have been widely studied over the past two decades. In 1990, Cortner and others described low homeowner awareness of fire risk (Cortner et al. 1990), and Winter and Fried (2000) found low motivation for individual responsibility for wildfire risk mitigation. More recent studies, however, have found both increased awareness of wildfire risk and homeowners assuming greater responsibility for risk mitigation, primarily through defensible space creation around their homes. Throughout the US, a sophisticated understanding of wildfire risk based on local geography, weather, and vegetation was found in several articles, for example, Nelson et al. (2004) in northeastern Minnesota and Central Florida; McCaffrey (2006) in Boulder, Colorado, Flagstaff, Arizona, Hamilton, Montana, Reno, Nevada, and San Bernardino, California; Brenkert-Smith et al. (2006) in Colorado; Jarrett et al. (2009) in Alabama, Florida, Georgia, Mississippi, and South Carolina.

Homeowners' sense of personal responsibility for mitigating wildfire risk on their property has also been increasing. While it is commonly perceived that homeowners believe that protection from wildfire is a government responsibility, several studies have found that homeowners are assuming more responsibility for their own protection from wildfire risk

(McCaffrey et al. 2011; Brenkert-Smith et al. 2006; Kruger et al. 2003). Weisshaupt et al. (2007) found a general consensus among focus groups in the western US that individuals should take primary responsibility for their own properties.

Compatibility, or the degree that an innovation is consistent with existing values and beliefs, is an important characteristic that determines whether or not an innovation will be adopted. One theme that recurs in the literature is that conflicts with other values – especially landscape preferences – prevent many homeowners from taking action. Daniel et al. (2002) describe the decision to implement wildfire risk mitigation measures as a tradeoff between fire safety and aesthetics/amenity values. "The challenge is to design effective fuel reduction treatments that better reflect the safety-aesthetic value tradeoffs that wildland-urban interface residents desire and that they are more likely to actively support" (p. 42). Hodgson (1993) found that knowledge and awareness of defensible space and belief in its efficacy are not the inhibiting factors that prevent people from implementing defensible space. Rather, values such as aesthetics, as well as cost and/or ability to implement defensible space, are what prevent its implementation. Monroe and Nelson (2004) found that reducing the risk of wildfire was valued less than providing wildlife habitat or privacy. In both Minnesota and Florida, Nelson et al. (2004) found homeowner preferences for "naturalness", wildlife, and privacy, alongside a sophisticated awareness of wildfire risk. These values were associated with a "deep in the woods" landscape preference

(Nelson et al. 2005). Gordon et al. (2010) interviewed forest managers in northern Minnesota and northeastern Pennsylvania who noted that "landscape preferences were incompatible with natural wildfire cycles" (p 464). McCaffrey et al. (2011) concluded that the "reasons residents may recognize the risk but choose not to mitigate are generally associated with resource availability and conflicts with other values, such as landscape preferences" (p. 477). Brenkert-Smith et al. (2006) found in their Colorado study that despite being able to identify sources of wildfire risk, many participants did not want to alter their landscapes unnecessarily.

McCaffrey et al. (2011) noted that "most participants brought up natural features such as, trees, scenery, wildlife, recreation opportunities, etc… Many participants appreciated their rural setting, particularly the privacy of their property" (p.480). They did find that aesthetics motivated some homeowners toward adopting defensible space, but this is found much less frequently in the literature.

The literature supports the idea that values and preferences of WUI residents tend to conflict with the vegetation clearing requirements for creating defensible space. "A central challenge is to productively engage the directly affected stakeholders and the general public so approaches to wildland fire management reflect not only the best available scientific/technical knowledge on the subject, but also the values and lived experiences of stakeholders" (Weisshaupt et al. 2007, p. 179).

Building on the wildfire preparedness literature, the research described below assesses the attributes of diffusion of innovations for the specific case of wildfire sprinkler systems on the Gunflint Trail. With the growth of the WUI and anticipated increased frequency of wildfire, an understanding of successful diffusion of this innovation can contribute to mitigation of the costs and human impacts associated with wildfire disasters.

Background

The Gunflint Trail is a 63-mile dead-end county highway that heads northwest out of Grand Marais, Minnesota (Figure 2). Public lands, including the Superior National Forest and the Boundary Waters Canoe Area Wilderness, surround private property along the Gunflint Trail. Many homes are relatively isolated, with approximately 700 homes and businesses within the 197 square miles of the Gunflint Trail Volunteer Fire Department (VFD) service area (Prom 2010).

Homeowners outside of the US have previously used wildfire sprinklers (Merson 2006, SA Country Fire Service 2000, Mitchell 2006), with several companies marketing the systems in Canada and Australia (e.g. FPA Australia 2000). In addition, they are commonly used by wildland firefighting personnel for structure protection and fire line reinforcement (Campbell 2011), but wildfire sprinkler systems are relatively unknown as a wildfire hazard risk mitigation tool for individual property owners in the US WUI. While not a new

technology, there is little scientific research available that has studied the effectiveness of sprinkler systems, nor is information available that examines the extent and experiences of sprinkler systems in use in the US or globally. Research on sprinkler systems is ongoing in western Canada by a consortium of industry and government representatives (see e.g. Large 2010), though most evidence for the effectiveness of sprinkler systems is in the form of anecdotes and case studies. Acknowledging widespread use in Australia, the 2009 Victorian Bushfires Royal Commission (2010) recommended that standards needed to be developed for use of wildfire sprinklers by residents. Though use of wildfire sprinkler systems by homeowners rarely occurs in the US, the Gunflint Trail in northeastern Minnesota is an exception that provides a first analysis of the diffusion and effectiveness of this technology in a US wildfire preparedness and suppression system.

Method

The case study presented here was initially undertaken to understand the effectiveness of sprinkler systems and wildfire preparedness during the Ham Lake fire. Immediately following the fire, anecdotal evidence suggested that wildfire sprinkler systems were highly effective in protecting homes during the fire. To validate this, we conducted 18 in-depth interviews during the summer of 2007. We identified firefighters from the Gunflint Trail VFD, the Minnesota DNR, and the USDA Forest Service who worked on the Ham Lake

fire. One of the authors of this paper is a resident of the Gunflint Trail and selected initial informants based on personal knowledge of the area and the Gunflint VFD. At the end of each interview, each informant was asked who else they thought it would be helpful to talk to. This was not intended to be a random sample. Rather, these key informants all had direct experience with the wildfire sprinkler systems during the fire. Additionally, we interviewed local, state and federal agency personnel selected based on their involvement with wildfire emergency preparedness along the Gunflint Trail. We also interviewed residents and business owners selected because they had experience with implementation and use of the sprinkler systems. Firefighters and residents were asked a series of open-ended questions about their experiences with the sprinkler systems during the fire to get their opinions about how well the systems worked, where and why they did not work, and issues and challenges that arose during the firefighting period. Table 1 shows the list of questions asked of firefighters. Data for structure survival in the Seagull and Saganaga Lakes area (the populated area most heavily impacted by the fire) was obtained from residents and firefighters who were actively firefighting in that location. Interviews with agency personnel without first-hand knowledge about the sprinkler systems focused on the broader aspects of wildfire preparedness and suppression issues and challenges. Interviews were recorded and transcribed. Each interview averaged 90 minutes in length, ranging from 30 minutes to 3 hours. Because of the qualitative nature of the interviews, information gathered was not quantified, but instead was

analyzed for patterns across respondents as well as unique experiences that can only come from being present at the moment a wildfire moves through a property with a sprinkler system. In addition to interviews, we conducted site visits to over 15 homes and businesses in and around the burned areas. Accompanied by firefighters and fire behavior experts, we assessed structures with and without sprinkler systems. Site visits included homes that survived the fire with and without sprinkler systems, sites that were completely burned, as well as lines of vegetation where the fire was stopped by the sprinkler system. The data gathered from the interviews and site visits provided an initial assessment of structure survival, sprinkler system functionality, and the overall preparedness efforts along the Gunflint Trail.

Findings

Our data support the anecdotal evidence that wildfire sprinkler systems worked to protect homes and their surrounding vegetation during the Ham Lake fire. We explore this case study using diffusion of innovations theory as well as an applied reflection about lessons learned about the sprinkler systems and the social system needed for wildfire preparedness. Wildfire risk mitigation by home owners falls in the category of preventive innovations. Actions are taken to prevent one's home from being destroyed in the event there is a future wildfire at this exact location (Sturtevant and McCaffrey 2006). As preventive innovations, wildfire hazard mitigation

measures in general have low relative advantage (inherent in a preventive innovation), questionable compatibility, and low trialability and observability, so it is easy to see why adoption has been slow.

Wildfire Sprinkler System as Innovation

The wide-spread adoption of sprinkler systems on the Gunflint Trail can be examined through the lens of diffusion of innovations theory (Table 2). Sprinkler systems for wildfire protection can be viewed as a new technology that could be adopted by homeowners in locations at high risk of wildfire, and diffusion of this innovation focuses on the attributes of implementation and use of the technology by the ultimate users.

Some of the key factors that encouraged initial adoption of sprinkler systems on the Gunflint Trail included financial incentives provided by the Federal Emergency Management Agency (FEMA) Hazard Mitigation Grant Program, and consistency between the residents' self-identified values of wanting to live "in the woods" and the sprinkler systems purported ability to protect vegetation around homes in addition to the structures themselves. The initial FEMA Hazard Mitigation Grant was a cue-to-action to install sprinkler systems on the Gunflint Trail.

The installation of sprinkler systems along the Gunflint Trail is due in part to a 1999 derecho wind event known locally as 'the blowdown,' which left tens of thousands of acres of downed fuel on public and private land (Moser et al. 2007). The Superior National Forest which surrounds the Gunflint Trail is a fire-dependent ecosystem, so wildfire risk was not new to the nearly 700

property owners who live there (Nelson et al. 2004), but the blowdown heightened awareness among residents about wildfire risk and provided an opportunity to learn about ways residents could mitigate their risk. With the increased fuel load, community and homeowner efforts were undertaken to improve risk awareness and hazard mitigation planning, and included preparation and testing of Gunflint Trail evacuation plans, Minnesota DNR Firewise efforts, and the installation of wildfire sprinkler systems (Jakes and Nelson 2002).

One Gunflint Trail resident who was a volunteer firefighter, became the change agent who played a key role in researching and developing the wildfire sprinkler systems for use by residents in the Gunflint Trail area. With the assistance of this firefighter and the state of Minnesota, Cook County received a Hazard Mitigation Grant from FEMA in 2000, which enabled the widespread installation of wildfire sprinkler systems in the Gunflint Trail community. The FEMA Grant provided 75% of the cost of installation to all property owners who applied by the required date.

Attributes of the innovation

The *relative advantage* of wildfire sprinklers was fairly weak due to the high cost of installation. But a primary advantage was a decrease in discomfort associated with the awareness of wildfire hazard risk. Sprinkler systems provided residents with some “peace of mind” during times when fire danger was very high and there was local media coverage of potential fire danger, especially with the extra fuel load from the 1999 wind event. The

initial FEMA Hazard Mitigation Grant had a significant influence on homeowners, alleviating the weak relative advantage and high cost. It also served as a trigger or cue-to-action for the decision to adopt sprinkler systems.

Compatibility, or consistency with existing values and beliefs, gave sprinkler systems an edge. Many Gunflint Trail residents, both seasonal and full-time, valued the privacy and "naturalness" of living in the woods, and some were reluctant to clear vegetation, especially after they lost so many trees in the blowdown (Nelson et al. 2005). The FEMA Grant stipulated that clearing vegetation for defensible space must be implemented as a requirement for getting the sprinkler grant, but the local perception was that not as much clearing would be necessary with the sprinklers. This perception was confirmed during site visits after the Ham Lake fire: sprinkler systems were seen on surviving homes that had more vegetation within thirty feet of the structure than defensible space guidelines would prescribe for cleared vegetation.

Complexity, which is negatively correlated with diffusion, was higher with sprinkler systems than with its alternatives, though not excessively so. As a fairly isolated community with no local governing body (the Gunflint Trail is an "unorganized territory"), residents see themselves as very self-reliant, with a "can-do" attitude (Jakes and Nelson 2002). A sprinkler system was viewed as just a pump, a bunch of PVC pipe, and some sprinkler heads. Especially for members of the community who were firefighters, the sprinkler systems

were easy to understand: “Firefighters have to be plumbers: basic water-in–water-out. So they picked that up easily – they had lots of capability and knowledge. Once they saw one system, they just went with the flow and were good at trouble shooting. They all knew how to cut and glue because that was a plumbing issue” (Gunflint Trail VFD member). There were maintenance issues, however, such as previously broken water pipes that hadn’t been repaired, and challenges (discussed below) in keeping sprinkler systems running during the fire. Complexity can be an issue with wildfire sprinkler systems.

Trialability of the sprinkler systems was problematic. Observation of the systems in action was possible, but whether or not they worked to protect against wildfire was difficult to evaluate without the ultimate test under fire, and as a result there was initial skepticism. “There were lots of skeptical people that thought this was kind of a joke. There’s people that have been fighting fires their whole lives that say, I never would have guessed… People that have come from out west that were pretty impressed…. [a firefighter]… has a little log cabin up here... He didn’t have sprinklers, but his neighbor just south of him did. He said, “their sprinkler saved my place”. He said he couldn’t believe how good it worked” (Gunflint VFD firefighter). In terms of *observability*, seeing whether wildfire sprinkler systems would work to protect homes from oncoming wildfire was not possible unless there was a wildfire. The Ham Lake fire satisfied the requirement for observability.

Communication is a critical element of the diffusion process, and communication about sprinkler systems was greatly enhanced due to the existence of the FEMA Grant. Mailings and emails were sent from the county office administering the Grant, and notices were published in the local newspaper. In addition to the mass media communication, the local firefighter who developed the sprinkler system design in use on the Gunflint Trail was also an entrepreneur who was well respected in the community and became a champion for the idea, using many opportunities to tout the systems.

Social systems are another element of diffusion of innovations theory, and social networks, made up of lakeshore associations, a local business association, and the Gunflint Trail VFD, had long worked together on a variety of projects (Jakes and Nelson 2002). Along the Gunflint Trail in Minnesota, the local volunteer fire department members in particular played a strong leadership role, providing information on preparedness activities (Jakes and Nelson 2002).

With the 2000 FEMA Grant financial incentives as a trigger, combined with the enthusiasm of the change agent and strong social networks, more than 130 sprinkler systems were installed for homes and business on the Gunflint Trail. With a few businesses installing multiple systems to protect larger properties, 130 sprinkler systems is close to 16% of the population, a percentage generally associated with *early adopters*. Even among these early adopters, there was skepticism noted during interviews as to whether the sprinkler systems would be effective.

All of the elements discussed above factored into the diffusion of innovations decision process: communications created knowledge and awareness; strong social networks and opinion leaders focused the persuasion; the FEMA Grant increased the relative advantage which spurred the decision to adopt and implementation. Finally, the effectiveness of the sprinkler systems during the Ham Lake fire provided trialability and confirmation that the innovation would work under the Ham Lake fire conditions.

Experience with the sprinkler systems on the Gunflint Trail

The interviews with local and agency firefighters provided a wealth of data on how well the sprinkler systems worked during the Ham Lake fire. It is these observations that led in part to the continued diffusion of sprinkler systems after the fire. "It was amazing. One of the things that impressed me the most is that they saved all the trees in the protected area. The value in the properties up here is in the location of the property with the vegetation and the trees – not in the structure. You can have a fish house or shack on Sag and it's worth $250,000. You can have a big beautiful house and it's worth $350,000. You can't get an insurance check and put in a new 75-year-old tree. Unlike Firewise (defensible space vegetation clearing), the sprinkler systems saved the trees" (Gunflint Trail VFD member).

Prior to the Ham Lake fire in May 2007, a few wildfire sprinkler systems were deployed during three separate fire incidents in northern Minnesota that affected Gunflint Trail properties: the Alpine Lake fire in 2005, the Cavity Lake

fire in 2006, and the East Zone Complex fire in 2006. Several homes were threatened by these fires, and sprinkler systems were started for homes that had them, but the fires did not reach these properties so the sprinkler systems were not tested by the wildfires. Residents discovered a secondary advantage to having the sprinkler systems: Similar to agricultural irrigation systems, they could be used for irrigation on the dry forestlands near their homes in times of drought even if no wildfire was threatening. By 2007, as residents saw the sprinkler systems in action, their number on the Gunflint Trail more than doubled, with the number of systems estimated to be approximately 300 (pers. comm. with installers and Cook County Assessor 2007). In diffusion of innovations theory, rates of adoption are categorized with one-third of the population of adopters or social system comprising the *early majority*. With 300 sprinkler systems implemented by 2007 for the 700 homes and business in the area, the early majority had adopted sprinkler systems.

On May 5, 2007 during an exceptionally warm and dry spring, an incompletely extinguished campfire at a USDA Forest Service camp site on Ham Lake started one of the worst wildfires in Minnesota history (Baran 2011). It burned approximately 75,000 acres in the US and Canada before it was declared contained two weeks later on May 19. The area that burned is a mosaic landscape characterized by numerous lakes, separated by areas of uplands interspersed with wetlands and streams. Much of the area contained downed and dead trees due to the 1999 blowdown. The burned area is

predominantly jack pine and aspen-birch, with scattered red and white pine in uplands, and also has spruce-fir, lowland conifers, and lowland shrubs (Fites et al. 2007). While post-fire assessments showed the majority of area fire severity as low, the Gunflint Trail corridor where private properties are located were characterized as moderate to high severity according to Burned Area Emergency Rehabilitation Classification (BARC) indices (Fites et al. 2007).

The fire threatened approximately 342 parcels with 759 structures, from Poplar Lake, half way up the Gunflint Trail, to the end of the Trail, a distance of approximately 25 miles. One hundred forty structures were lost, including 15 year-round residences, 60 seasonal structures, and several commercial businesses. (HSEM 2008). In the Seagull-Saganaga Lakes area, the area most directly hit by the Ham Lake fire, 56 homes, cabins and businesses had sprinkler systems (personal interviews 2007). Based on site visits and interviews in the Seagull Lake and Saganaga Lake areas of the Gunflint Trail, of the threatened structures on the Gunflint Trail that burned, only one had a working sprinkler. Of the threatened structures that survived, 72% had working sprinklers (Table 3). All properties that had working sprinkler systems survived the fire, with one possible exception.[3]

Nine properties that were lost had sprinkler systems that were not working. Some of these systems were not started or were started but the pumps did not work. Other problems included:

[3] In the discussion about this particular system, there has been speculation about why the system may have failed, including a burned or broken water pipe, or an ember blown into a dry area under a deck. With the ultimate destruction, no definitive conclusions have been reached.

- broken water lines prior to the fire that had not been repaired
- in-take pipes did not reach the water due to very low water levels
- systems that were still in winter storage.

Wildfire sprinkler systems appeared to protect structures along with their surrounding vegetation regardless of fire behavior, intensity, fuels, weather/wind, or amount of clearing for defensible space. On Seagull Lake, with some of the highest fire intensity and extreme fire behavior (Fites et al. 2007), all 17 structures with working sprinkler systems survived the fire. Ten out of 28 structures without working sprinkler systems also survived. These were all homes with either nonfunctioning systems or no system present. In this area, fire destroyed a total of 18 structures. One firefighter reported, "On Sea Island Road, that soil's been sterilized. That was hot through there. Air Ops from the Type I Team was flying over us… They were sure we lost those houses, based on the rolling fire behavior and 120-foot flame lengths… They thought, no way would these survive, and they did. They were just amazed…. The sprinklers worked regardless of fuel type, fire behavior, topography…"

Post-fire analysis of sprinkler system success and failure

Though there is debate about the reasons for success, firefighters on the fire generally believed the wildfire sprinkler systems on the Gunflint Trail worked by creating a humid microclimate and by cooling ambient air temperature.[4] Firefighters reported that some sprinkler systems ran for as little as two hours before the fire arrived and the house survived. Prior to this

[4] An alternate theory is that while strong winds present during a wind-driven wildfire will quickly dissipate the humidity, these same winds will tend to pool water from the sprinklers in the same location that flying embers will be blown (Mitchell 2006).

experience, it was thought that systems would need to run many hours longer to fully hydrate fuels. This was not the case with the Ham Lake fire. Witnesses indicated that with the cooler, moister environment created by the sprinklers, embers were suppressed before they were able to ignite the fuels, whether structures or vegetation.

Where the sprinkler systems were successful, one outcome was a resulting “island” of standing, burnable fuel for the fire that surrounded it. In the case of the Ham Lake fire, shifting winds over the course of more than a week meant the remaining fuels inside the burned area had to be kept cool and hydrated to prevent ignition from hotspots that surrounded the green area. Firefighters and homeowners ran sprinklers for up to seven days following the initial fire, which presented additional challenges for the systems.

How these challenges were successfully addressed is an important condition of the management requirements. Conforming (standardized) systems enabled structure protection firefighters to refuel, maintain, and repair minor malfunctions in an efficient manner. Propane tanks were routinely replaced through a plan developed by the local fire department, and engine oil was checked and added as needed. Standardization meant that extra system parts were also available when needed if and when system components began to fail.

The most prevalent reasons for system failure mentioned in interviews were that a system was not yet set up due to the early spring or due to a

general lack of maintenance. Because the Ham Lake fire began on May 5, which is early spring for northern Minnesota, many sprinkler systems were still in their drained, winterized state. Most systems did not yet have the suction hose set in the water, and in some cases pumps were locked in garages or sheds with their seasonal-resident owners far away. Neighbors and/or firefighters attempted to set up the sprinkler systems, but in many cases this was not possible. In addition, lake water levels were very low due to ongoing drought, and in several cases, rigid suction hoses did not reach the water. In other cases, PVC water pipes had broken the previous fall or winter and had not been repaired. While this can be attributed somewhat to the unusual nature of an early spring fire in this location, firefighters reported similar experiences with the Cavity Lake Fire that had burned the previous July.

For systems that were working, firefighters and managers reported many problems:

- pump/engine failures for unknown reasons
- broken flappers on sprinkler heads due to inadequate component strength
- system design that left water pipe uncovered by sprinklers and exposed to burning
- propane starting problems (sticking diaphragm in regulator) on dual-fuel systems
- sprinkler heads clogged with debris from lake water intake

Finally, homeowners ran sprinklers in many areas that were evacuated and/or threatened, but not directly hit by the wildfire. Similar issues occurred in these areas as in areas overrun by the fire. In the evacuated areas, sprinkler systems were kept running and were maintained by local and mutual aid fire departments. When the systems were run extensively, sprinkler heads did break and get clogged with debris. One pump burned out after extensive use. Using the quasi-experiment of sprinklers running where fire occurred and where it did not, it appears there are common challenges that need to be managed in a running system and that all malfunctions can not be attributed to fire stress.

The question remains as to what role defensible space played for structures. While the main focus of this study was not an evaluation of defensible space, we do have very limited information about sprinkler systems, defensible space, and structure survival. Anecdotal evidence suggests mixed results: based on firefighter comments some homes with reasonable defensible space survived without sprinkler systems, though there were also instances where homes without defensible space survived, and homes with defensible space that were lost.

We have an extremely limited sample of homes in the burned area from a previous Gunflint Trail study, with a rating of their defensible space for comparison (Nelson et al. 2005). In that study, we conducted interviews and site visits with homeowners on the Gunflint Trail to develop “landscape types” that indicated the amount of vegetation removal as defensible space for a

given property. Six properties from the 2002 study were in the Ham Lake fire burned area. Of these six properties, three had sprinkler systems and all three of these survived the fire. Of these three, two properties had been categorized as having some defensible space (clearing on some but not all sides of the house), and one had been categorized as deep in the woods with no defensible space. In addition, the other three homes from the 2002 study that were in the Ham Lake fire burned area did not have sprinkler systems and were all lost in the fire. Of these three, two had been categorized as deep in the woods with no clearing or defensible space, and one was categorized as having reasonable defensible space with clearing all around the house. This is the only empirical data we have on defensible space vegetation types prior to the Ham Lake fire but five years had passed between the vegetation evaluation and the fire. We did not find any systematic information on the status of a structure's defensible space within a year of the Ham Lake fire. We also do not have any systematic information on building materials of structures that were destroyed. Homes and cabins in the area are typically wood frame or log cabins with asphalt shingle roofs.

After the Ham Lake fire

Wildfire sprinkler systems that functioned appeared to work well at protecting structures during the Ham Lake fire in 2007. Several of the firefighters on the Ham Lake fire were some of the strongest skeptics about how well the sprinkler systems would work. After the fire, the diffusion of innovations' characteristic of *observability* had finally been met, and the

results exceeded the expectations of many witnesses. The last element of diffusion of an innovation is the *confirmation* stage to reinforce the decision to adopt. In this case, the adoption of sprinkler systems was confirmed.

With the observable success of the sprinkler systems, additional FEMA Hazard Mitigation Grants were obtained by both Cook County and a regional association of counties in northeastern Minnesota. Many homeowners who could afford to do so installed sprinkler systems prior to the next round of FEMA Grants being approved. In 2009, almost 200 new sprinkler systems were installed using FEMA Grant dollars, and by 2011, another 115 systems were installed in Cook County (pers. comm. Cook County Emergency Manager, 2012). When added to the 300 sprinkler systems installed prior to the Ham Lake fire, the *late majority* of property owners on the Gunflint Trail now had sprinkler systems installed on their properties.[5]

Consequences of Innovations

In his book *Diffusion of Innovations*, Rogers devotes a chapter to the concept of consequences of innovations – both desired and undesired consequences and direct and indirect consequences (2003). The direct result of working sprinkler systems was that homes and their surrounding vegetation survived in the path of wildfire – a very visible outcome. But there were several unanticipated consequences to this innovation as well. There is concern among Cook County wildfire preparedness leaders that the success

[5] The total number of sprinkler systems on the Gunflint Trail is slightly over-stated because the number includes systems installed in other areas of Cook County not on the Gunflint Trail, though this is thought to be minimal (pers. comm. Cook County Emergency Manager). The number is under-stated by the number of sprinkler systems installed without FEMA Grant assistance.

of sprinkler systems may act as a disincentive for other defensible space activities. Defensible space, which refers to the management practice of clearing vegetation around homes to provide a firebreak, is a fairly common wildfire preparedness tool in the US. National programs such as Firewise Communities USA, as well as state programs such as FireSafe in California, FireFree in Oregon (Sturtevant and McCaffrey 2006), and Minnesota DNR's Firewise (Minnesota DNR 2012), promote defensible space as a reasonable action homeowners can take to reduce their wildfire risk. Even so, tensions exist for many homeowners who have conflicting values about clearing vegetation around the home to reduce fire risk and the desire to maintain a "natural" or "deep in the woods" feeling on their property (Nelson et al. 2004). Many residents of the wildland urban interface and in more isolated areas have chosen to live there because they prefer landscape attributes such as "naturalness", wildlife, and privacy (Nelson et al. 2005). With residents' increased sense of safety from the sprinkler systems, there is concern that they will not have incentive to clear vegetation.

One lesson from the sprinkler systems that failed to function during the Ham Lake fire was that it is important to keep vegetation from blocking sprinkler head motion or from hiding the pump, which can make it difficult to find or start, and that dense vegetation surrounding the pump or water lines can also add to the risk that parts of the system will be vulnerable to an approaching wildfire. All of these lessons support the notion of creating defensible space. There is anecdotal evidence that with the diffusion of

sprinkler systems throughout the community, along with the number of recent local wildfires, residents have become more willing to create defensible space, if only to protect the sprinkler system pipes from burning. Further research is needed to confirm this.

Additional consequences were identified related to the success of sprinkler systems. While not openly discussed during interviews, there were several references to liability issues associated with firefighters running privately-owned sprinkler systems. On the Gunflint Trail, the VFD has stated to residents that they will attempt to start wildfire sprinkler systems wherever feasible, but they provide no guarantees, and the property owner has ultimate responsibility for their system. It should be made clear to the property owner that if they want firefighters (or anyone else) to start or maintain their system, the property owner and not any firefighting agency will be responsible for system problems or loss due to system failure.

The design of the sprinkler systems on the Gunflint Trail includes using propane as the fuel of choice for running the pumps for long-term, unattended use in the event of an evacuation. The use of propane fuel has been a big issue for the Gunflint Trail VFD in all of the fires where sprinkler systems have been used. Because propane has not been supplied by federal or state firefighting agencies on a wildfire, both the cost of the propane and the logistics of propane supply in a wildfire zone must be carefully considered. Volunteer fire departments seldom have the financial resources to pay for

propane, so homeowners must be billed or costs negotiated with another agency in the aftermath of the fire.

Another issue was the influence that the existence of operating sprinkler systems had on property owners' behavior when there was an evacuation order. During the Ham Lake fire, some residents refused to evacuate in order to keep their system and their neighbors' systems running. These people are viewed as local heroes for saving homes, yet they caused additional work for and increased risk to firefighters, whose highest priority is public and firefighter safety. In addition, some emergency preparedness personnel are concerned that with the success of the sprinkler systems, residents who are not physically and/or emotionally equipped to stay on their property will fail to follow orders to evacuate the area because of a perceived safety zone under the sprinkler system. These considerations will have to be addressed as the US reflects about the concept of "leave early or stay and defend" used in Australia and how it does or does not fit with our wildfire protection efforts.

Discussion

The purpose of this case study was two-fold: to examine the utilization of wildfire sprinkler systems on the Gunflint Trail through the lens of diffusion of innovations theory; and to determine the success and failures of the use of the sprinkler systems during a specific wildfire.

Diffusion of innovations case study

Overall, characteristics of the Gunflint Trail and this case study fit well with successful diffusion of innovations suggested by Rogers' theory (Rogers 2003). A local champion, a highly educated population, strong *social networks*, and effective *communication* channels all contributed to the diffusion of wildfire sprinkler systems on the Gunflint Trail. In addition, many residents had the financial resources and physical capabilities to implement wildfire hazard mitigation projects. Heightened *awareness* of wildfire risk was enhanced by the 1999 blowdown and ensuing education campaigns, as well as by several recent wildfires in the area. Ability to obtain a Federal Grant which provided 75% of the cost of the sprinkler systems for residents improved *relative advantage*. Because of the grant process, adoption rates did not exactly follow the bell curve predicted by diffusion of innovations theory, but did come remarkably close. The ability of the sprinkler systems to protect vegetation surrounding a structure, an important value noted in other cases (Hodgson 1993, Daniel et al. 2002, Nelson et al. 2004, Weisshaupt et al. 2007, Gordon et al. 2010, McCaffrey et al. 2011), provided the *compatibility* necessary for diffusion. The trend toward residents assuming more responsibility for wildfire risk mitigation, as found by McCaffrey et al. (2011), Brenkert-Smith et al. (2006), Kruger et al. (2003), and Weisshaupt et al. (2007), was also evident in this case study. Finally, the success of the sprinkler systems during the Ham Lake fire provided *confirmation* to skeptical area residents that the systems could work. Even with these limitations,

diffusion of innovations could be more frequently considered for “marketing” wildfire hazard mitigation activities in the US wildland-urban interface (WUI) where residents are at risk from wildfire. Examining wildfire mitigation decisions through the lens of diffusion of innovations contributes to the broad wildfire management literature by providing another means to examine decision-making processes by residents in the WUI.

Wildfire Sprinkler Systems on the Gunflint Trail

While providing support for diffusion of innovations theory in the form of an additional case study, there are limitations to the generalizations that can be made to other areas because of the unique characteristics of the Gunflint Trail and of this case study. In addition to the social factors present, the area has numerous water sources, and the sprinkler systems designed for use on the Gunflint Trail all relied on lakes adjacent to properties for their water. Sprinkler systems are currently being installed with alternative water sources, using holding tanks or swimming pools as the water sources, using wetting agents such as foam or aqueous gel (Walkinshaw and Ault 2005). Cook County, Minnesota is in process of applying for a new FEMA Hazard Mitigation Grant that specifies a holding tank for a minimum of 300 gallons of water for sprinkler systems for properties without other water sources (pers. comm. Cook County Emergency Manager 2012). There is little research available to determine the success rate of these “low water” systems, however, and their effectiveness needs to be assessed prior to any recommendations for widespread use.

Experience with the Ham Lake fire in northeastern Minnesota demonstrated that wildfire sprinkler systems can be highly effective at protecting structures and their surrounding vegetation from wildfire damage and destruction under certain conditions. However, sprinkler systems are not a panacea. They must be regularly tested and maintained, and even then, are not guaranteed to be 100% effective. Since the sprinkler systems needed to be manually started, there is a question as to how well they can be utilized by part time cabin owners.[6] An additional consideration for sprinkler system installation is that the system itself and the water source must be independent of a municipal power grid since power will likely be off in the event of a wildfire.

When effective, there are several management challenges during wildfire events that need to be addressed, including getting property owners to evacuate when warranted, and supplying propane or other fuel to run the systems. Homeowners, firefighters, and agencies must remember that sprinkler systems are just one of many structural responses to wildfire preparedness. Lessons that can be applied more broadly include the role of wildfire sprinkler systems as a wildfire hazard mitigation tool and the traits that helped diffuse the systems so broadly in the Gunflint Trail community. Observation of the systems' effectiveness, combined with financial incentives that provided a relative advantage, supplied necessary components of diffusion in this location. The study by Winter and Fried (2000) found that in

[6] Research is currently under way by a local vendor, among others, on having sprinkler systems capable of being started remotely.

Michigan, residents observed that damage from wildfires was essentially uncontrollable and random, resulting in their being unlikely to take steps to safeguard their properties. The reverse situation occurred in Minnesota with the Ham Lake fire, and the success of sprinkler systems could be used as a demonstration for other areas.

Conclusion

This case study highlighted several points related to the usefulness of diffusion of innovations theory for improved understanding of wildfire hazard mitigation projects. Diffusion of innovations has been used extensively for marketing consumer products (e.g., Cheng et al. 2004, Takada and Jain 1991, Ghosal and Bartlett 1988, Bass 1980, among others). This study demonstrates that the theory's components may be useful in planning and evaluating wildfire mitigation strategies. On the Gunflint Trail, the attributes of the innovation of a wildfire sprinkler system – especially financial incentives for relative advantage, compatibility with residents' values, and observability of effectiveness -- combined to diffuse sprinkler systems to a majority of homes in the area.

The Gunflint Trail is not necessarily representative of WUI communities across the US. The socio-cultural and socio-demographic traits of the Gunflint Trail made that community well-suited for application of diffusion of innovation components, such as strong social networks and communication networks, as

well as possessing necessary financial resources and a “can-do” attitude. A geographic area replete with water sources enabled an effective sprinkler system design. Finally, the impact of financial incentives from the FEMA Hazard Mitigation Grants for widespread implementation of sprinkler systems in this area cannot be understated.

Under the Ham Lake fire conditions, the wildfire sprinkler systems were effective in saving homes and their surrounding vegetation from destruction, but they are not without limitations. Periodic maintenance and testing will be critical, and defensible space needs to be part of any implementation. In addition to the need for defensible space to help protect sprinkler systems during a fire, sprinkler systems can fail as can any mechanical system, and defensible space is an important backup as well as an adjunct to the systems.

This study contributes to an understanding of resident decision-making processes for wildfire hazard mitigation projects as well as insights into critical components of the social system that supported diffusion and successful functioning of the sprinkler systems. In the end, the study’s contribution will be improved and effective use of wildfire sprinkler systems for saving homes and their surrounding vegetation during a major wildfire.

Table 1. Firefighter Interview Questions.

1) Regarding the sprinkler systems, what worked well? What worked ok (e.g. worked but could have been better)?

2) What didn't work? (System design, engineering/hydraulics, maintenance, malfunction, stress from over-use)

3) How could systems be improved? (Ideally, realistically?)

4) Other issues, comments, concerns? (portable systems?, firefighters not familiar with systems?)

5) Recommendations to homeowners?

6) Other recommendations?

7) What haven't I asked about?

8) Who else should I talk to?

Table 2. Diffusion of Innovations: Key factors in the case study of wildfire sprinkler systems on the Gunflint Trail, Minnesota.

Elements of Diffusion of Innovations					
The Innovation[7]	**Relative Advantage:** + FEMA Financial Incentive + Decrease in perception of risk (decrease in discomfort)	**Compatibility:** + consistent with land preference values	**Complexity:** + easy technology to understand - maintenance issues - problems that arose during wildfire event	**Trialability:** + can use during test and to irrigate - cannot test under wildfire	**Observability:** - effectiveness not observable until a wildfire occurs + Ham Lake fire provided observability
Communication	**Mass Media:** 1999 blowdown resulted in increased awareness of fire danger; Blowdown resulted in FEMA grant that was well publicized	**Interpersonal:** Local promoter / change agent Opinion leaders			
Rate of Adoption	**2000 FEMA grant:** 100 sprinkler systems (early adopters)	**2007 Ham Lake fire:** 300 sprinkler systems (early majority)	**2008 FEMA Grant after Ham Lake fire:** 600 sprinkler systems (late majority)		
Social System	Lack of institutions on the Gunflint Trail VFD is only local "agency"	Homeowner Associations strong	Starting sprinkler systems a problem for isolated homes		

[7] A plus sign (+) indicates an attribute that positively influences adoption of the innovation; a minus sign (-) indicates an attribute that discourages adoption of the innovation.

Table 3. Ham Lake fire burned area: structure survival and loss, Seagull and Saganaga Lakes area, Gunflint Trail, Minnesota, USA.* (adapted from Johnson et al. 2008)

	Sprinklers		No sprinklers	Total:
	Worked**	Failed		
Structure Survived	46	1	18	65
Structure Lost	1	8	30	39
Total	47	9	48	104

***** These numbers differ from other reported numbers due to the definition of a structure. For these purposes, a structure is defined as a major, livable structure, primarily a home or cabin. Other reports include any structure, such as boathouse, shed, or outhouse.

****** There is disagreement among firefighter observers over whether one structure that burned had a working sprinkler system or not. For purposes of this report, this system is included as working.

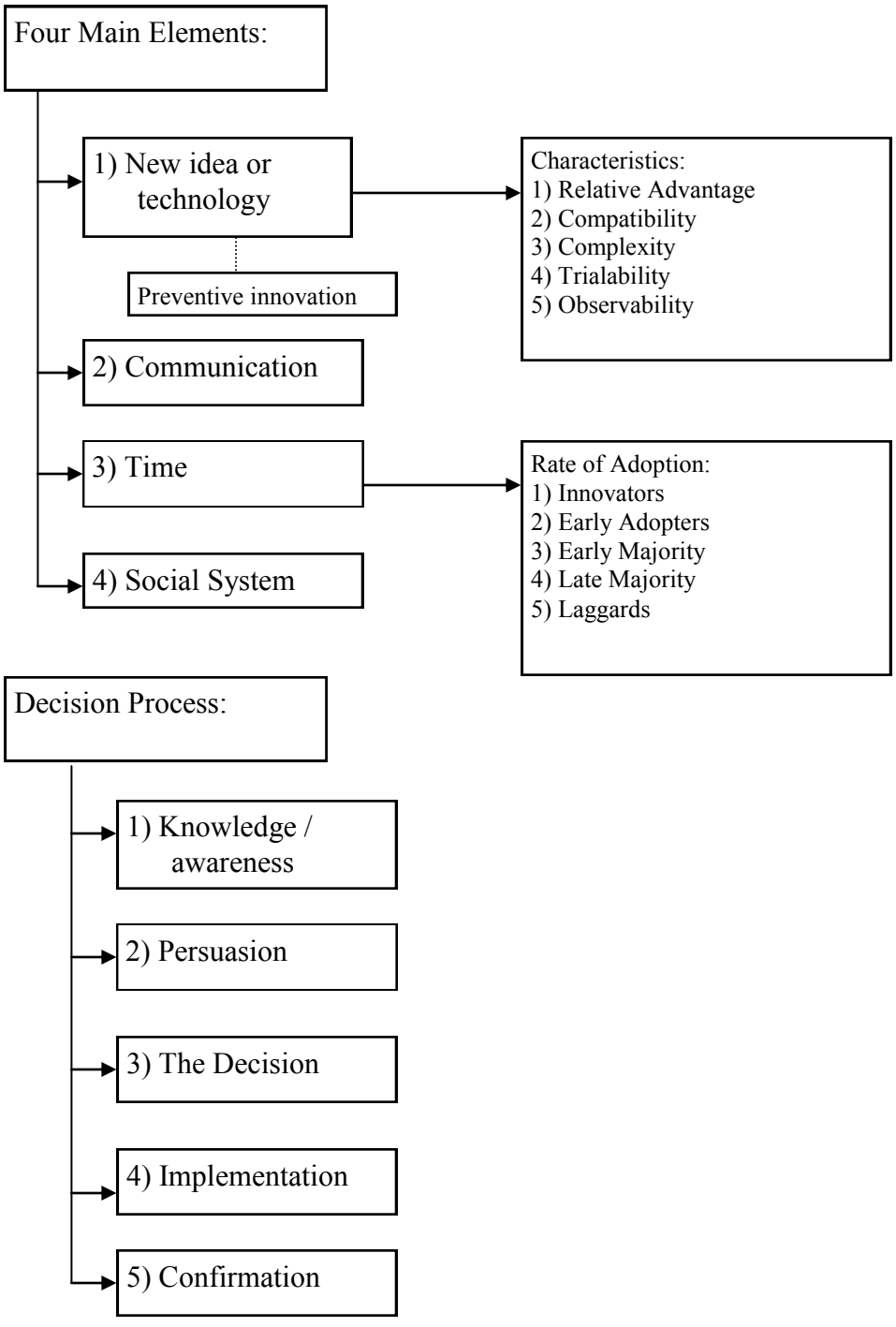

Figure 1. Diffusion of Innovations Model (adapted from Rogers 2003)

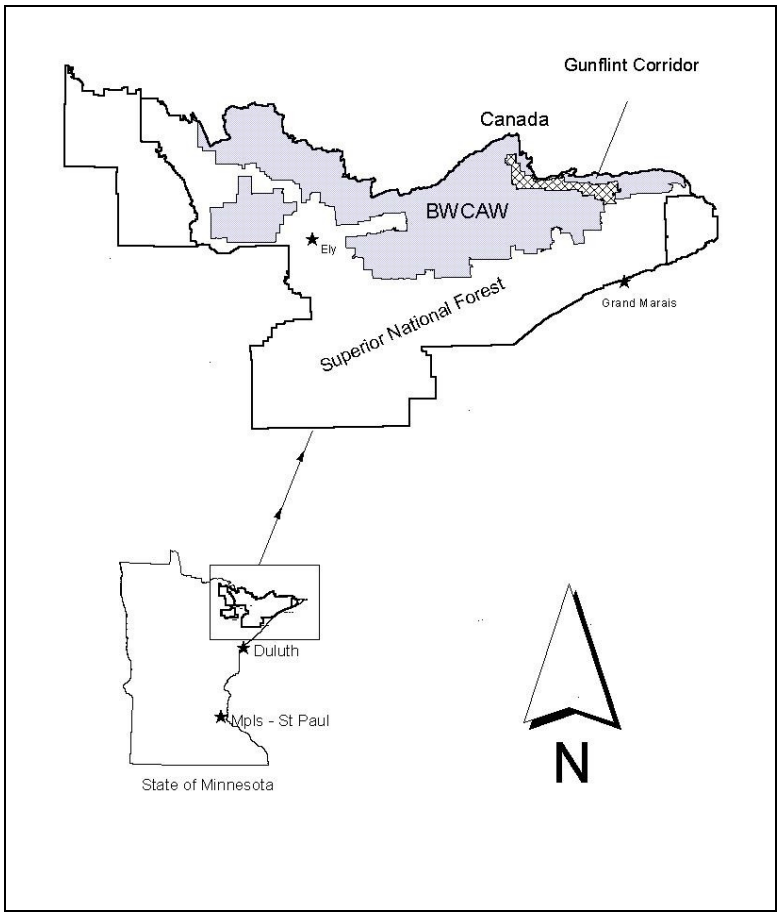

Figure 2. Study area location map (adapted from USDA Forest Service 2000b).

Epilogue

With a longer wildfire season, high fuel loads, global climate change, and expansion of homes and neighborhoods in the wildland-urban interface (WUI), wildfire prevention and suppression can no longer be the only responses to the problem of wildfire. This dissertation examined levels of public attitudes, beliefs, and actions. Computer content analysis of news media was used to gauge public attitudes and beliefs about the HFI and HFRA as a national policy response to the wildfire problem, and to examine public understanding of actions they could take to protect themselves from wildfire. Diffusion of innovations theory was used to analyze a case study of a specific community's wildfire preparation, focusing on wildfire sprinkler systems, after a wildfire occurred in the area.

Public attitudes and beliefs are important factors influencing what the public is willing to do to take responsibility for wildfire protection, especially in WUI communities and households. During a conversation with a Gunflint Trail resident, I was asked if we should clear or thin all of the trees in their forested neighborhood up to the boundary of the National Forest in order to decrease the risk of destructive wildfire. With a need to preserve the ecological integrity of our forests, including a role for fire in the forests, understanding public attitudes and beliefs lays a foundation for education that needs to continue. Diffusion of innovations theory provides insights to better inform how and where such education may take place.

In chapter 1, we found that the Bush Administration was successful in setting the public agenda by framing the HFI and HFRA as needed to reduce the risk of catastrophic wildfire and excess fuel buildup. The most frequently expressed belief in the news media discussion and debate, either favorable or unfavorable, was the administration's argument that the HFI / HFRA was a key to reducing the risk of wildfire. Against the backdrop of the western wildfires, the administration was able to reframe public debate about wildfire management from an emphasis on the need for ecological approaches to restoring forest health to a need for regulatory reforms to deal with the wildfire threat (Vaughn and Cortner 2005). The most frequently expressed negative belief, "stealth logging," suggested a lack of trust in the legislation and motives behind the legislation.

Future research using news media computer content analysis could provide insight into the ongoing debate about wildfire management and wildfire hazard preparedness and could identify pervasive gaps in knowledge and understanding of wildfire by the public. This chapter used three years of data, from 2002 – 2004. A limitation of this study was that it looked only at traditional news media. With the dynamic state of news sources and the internet, additional and alternative news sources should be used. The computer content analysis using the InfoTrend® method and software is still useful for analyzing large amounts of data, and could be used for examining longer-term trends in public attitudes and beliefs.

In chapter 2, we found a paucity of news media coverage of defensible space concepts compared to news about firefighting in general, suggesting continued emphasis on fire suppression rather than homeowner responsibility. This study showed that news media coverage of defensible space concepts is highest when major wildfires are occurring and homes are being destroyed. The usefulness of this study was limited by the U.S. Supreme Court ruling that supported the copyright rights of freelance authors (Vakil 2003), which resulted in many of the news stories we originally used being removed from the LexisNexis® database. Since news media are a key information source for educating homeowners about the need to take responsibility for decreasing their risk from wildfire (Shindler and Toman 2003, Nelson et al. 2004, Winter and Fried 2000, Jacobsen et al. 2001), the use of non-traditional news sources and social media are a promising approach for gauging public attitudes and beliefs.

In chapter 3, we found that diffusion of innovations theory could be used in large part to explain the widespread use of wildfire sprinkler systems on the Gunflint Trail. In particular, the success of the sprinkler systems during the Ham Lake fire provided necessary confirmation to encourage further adoption. With the addition of financial incentives from the FEMA Hazard Mitigation Grant, the vast majority of homes in this area are now equipped with wildfire sprinkler systems. Diffusion of innovations theory has been effectively used for many years to market consumer products, and more can be done to use this theory to design effective programs that work with and influence residents to take responsibility for wildfire preparedness. There are limitations in this case study

due to several unique characteristics of the Gunflint Trail. Abundant water sources, an affluent and educated population, and strong social networks may limit the applicability of the results of this study to other locales. The use of sprinkler systems, while highly successful in the Gunflint Trail area, requires more research to look at low water sprinkler systems, overall standards for sprinkler systems, and their role within the toolkit of activities that homeowners should use for wildfire preparedness. Further research could provide insight into other activities and locations using diffusion of innovations theory to promote defensible space and other wildfire preparedness actions.

Recent scholarship in conservation biology challenges us to imagine sustainable human and natural systems. To maintain the ecological integrity of fire-adapted forest ecosystems as humans increasingly live within and adjacent to them, it will be necessary to arrive at wildfire management policies and individual behaviors that recognize the role of fire in forests, and how people can co-exist within fire-adapted ecosystems.

> *"But if never ultimately resolved, our relationship to fire suggests that accommodations can be made, that it is possible to live with great natural processes. If our ancestors, with little more than river cobbles and chipped flint, could seize fire, surely modern mankind can cope with its own versions of the forbidden flame"* (Pyne 1982, p. 532).

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