The Dangerous Middle: Situational Awareness and Worker Perception of Beetle Kill

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Abstract

Forest workers, including loggers, foresters, and wildland firefighters, are regularly exposed to some of the most fatal occupational environments in the United States. These hazardous work environments may become even more complex and dynamic when subject to bark beetle outbreaks that have resulted in significant tree mortality. The impacts of tree death from bark beetles are significant, with the cumulative 17-year (2000–2016) footprint for bark beetle caused tree mortality estimated at 54 million acres. However, how workers think about and act in these environments is understudied. This study, therefore, approaches the issue of beetle kill and forest worker safety by examining the perspectives or workers themselves. Its contribution is to leverage ethnographic research to provide insights that can generate new research questions, better inform outreach, and ultimately improve worker safety outcomes. The resulting insights show that beetle kill was understood by workers as a hazard that increased the complexity and dynamism of the work environment, making situational awareness both more necessary and more difficult to maintain. While much research about situational awareness focuses on hazardous situations, it is suggested that building adequate situational awareness should also include broader considerations of organizational communication, as well as training and experience considered over the course of entire careers.

Keywords

Beetle kill; forestry; situational awareness; wildland fire; worker safety

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Introduction

Forest workers, including loggers, foresters, and wildland firefighters, are regularly exposed to some of the most fatal occupational environments in the United States (US).[1,2] These dangerous environments, however, may become even more complex and dynamic when subject to bark beetle outbreaks that have resulted in significant tree mortality, with trees killed by bark beetles commonly referred to as "beetle kill" or the adjectival "beetle-killed" (e.g., beetle-killed forests) in both scholarly and popular literature. Recent infestations of bark beetle species, including mountain pine beetle, have occurred at faster than normal rates, over longer time periods, and beyond historically recorded ranges.[3-5] The cumulative 17-year (2000–2016) footprint for tree mortality from mountain pine beetle and all bark beetles is estimated to be 26 million and 54 million acres, respectively.[6] The extent of beetle-killed forest area has raised reasonable concerns about potential impacts on the health and safety of workers.

Research on the effects of beetle-killed forests on forest worker health and safety has primarily focused on firefighters and loggers.[7-12] Wildland firefighting may be one of the most dangerous jobs in the US, both generally and among firefighting professions. The US Fire Administration estimates there are approximately 1.2 million firefighters (professional, volunteer, seasonal, etc.) in the US, and it is estimated that about 30,000 of them engage in wildland activities.[13-15] Volunteerism and crossover between specializations make wildland fatality rates difficult to calculate.[16] However, it can be estimated from available data that wildland firefighters have a fatality rate 3–5 times greater than other firefighting professionals.[1] While pine beetle outbreaks may not lead to more acres burned, they are often thought to create more severe fires and less predictable torching and crowning behavior relevant to firefighter safety.[8-10,17,18] Fallen trees and snags also present challenges for fire suppression strategy and for access to resources and escape routes on roadways.[10] Although not directly comparable with wildland firefighting, logging is listed as the most dangerous occupation in the US in 2015, incurring fatality rates of 132.7 per 100,000 according to the Bureau of Labor Statistics.[2] This is more than double commercial fishing, the next occupational group. Tree conditions in beetle-killed areas, before and after fire, are believed by some to affect logger safety by increasing the number of hazardous trees.[19] It is unclear, however, that an increased number of hazardous trees necessarily leads to more injuries among loggers, firefighters, foresters, or other forest workers, because injury due to beetle kill is also a function of human perception of, and behavior within, those environments. For example, workers may choose not to enter beetle-killed stands on windy days, and organizations, such as the US Forest Service, may adopt policies to limit exposure to hazardous trees (see Results).

While social science research is crucial for understanding workers' relationships with beetle kill, insights into the human dimensions of forest worker health and safety in beetle-killed areas is sparse, and calls have been made for additional research.[7] Knowledge about how workers think about beetle-kill hazards specifically is even less represented in the literature. This is true despite limited ethnographic work with hand fellers in British Colombia, showing that the policy and organizational environment of logging affects workers' sense of uncertainty and, as a result, how they negotiate risk, including risks from beetle

kill.[20,21] This article, therefore, approaches the issue of beetle kill and worker health and safety by trying to understand the perspectives of workers themselves. This perspective, classically referred to as "the emic point of view" in anthropology, is the core driver of ethnographic research and is a response to recent calls within the agricultural health and safety literature for anthropological approaches that can ground insights about safety within the actual experiences of workers.[22-25] The contribution of this article, then, is to leverage ethnographic research to provide insights that can generate new research questions, better inform outreach, and ultimately improve worker safety outcomes. Ethnography can generate new insights, questions, and interventions, because it allows workers to speak in an open way about their concerns with minimal interference from researchers in the form of structured questionnaires and interview protocols. In the beginning, ethnographers start with open-ended questions (in this case: what do forest workers think about beetle kill?) and allow participants to guide the direction of research.

In the course of this project, a potentially useful insight was generated when analysis showed that forest workers consistently spoke about beetle kill in terms of the need to maintain "situational awareness (SA)." This thematic pattern is salient, because while workers were not asked directly about SA, they spoke about it often. Furthermore, despite worker interest in SA, there is surprisingly little research linking it specifically to forest worker safety. An important exception, however, is recent literature showing how emerging technologies, such as Global Navigation Satellite System – Radio Frequency, may be used to enhance SA among loggers.[26-28] This growing body of work provides a potential path to enhanced SA by using new technologies to mediate between work habits and the immediate work environment. Furthermore, the ethnographic approach explained in Methods can be seen as complementary to this technologically focused research. Through open ended interviews and other qualitative data sources, workers spoke about how SA is not only dependent on the immediate work environment that can be mediated by new technologies, but also about institutional environments and types of on-the-job experience that impact their capacities to remain situationally aware.

Methods

Qualitative, ethnographic fieldwork methods were used to gather data across four research sites located near Custer, SD, Laramie, WY, Missoula, MT, and Grangeville, ID. Sites were chosen based on (1) presence of significant beetle-killed forest area, (2) presence of forest workers exposed to potential hazards from beetle kill, and (3) representation of a diversity of habitat types and pine species. Ethnographic approaches were used, including direct observation (e.g., of mechanized logging in beetle kill), participant observation (e.g., a ride along with a United States Forest Service [USFS] forester to mark a timber sale in beetle kill), informal interviews (e.g., strategic conversations with forest workers), document collection (e. g., archived agency materials, trade publications, and popular media), and semi-structured interviews with those that work directly in forest environments. Direct observation was recorded in fieldnotes and video, while participant observation and informal interviews were recorded as field-notes. Semi-structured interviews were captured with a digital audio recorder and transcribed verbatim. Research activities were approved through the University of Wyoming Institutional Review Board (Protocol #20160923TD1305).

In total, 20 semi-structured interviews lasting from 25 min to 2 h, with most lasting from 1 to 1.5 h, were recorded with 23 participants. One interview with a wildland fire crew was conducted as a group interview at the request of the participants. Interviews were distributed across research sites as follows: Montana (4), Idaho (3), Wyoming (3), South Dakota (9), and California (1). A criterion sampling scheme was used to select participants who had experience working in beetle kill. Additional participants were found using snowball sampling. Participants represented a diversity of careers and skill sets and included a safety management consultant, a supervisory forester in the Montana Department of Natural Resources and Conservation, a process engineer responsible for making biofuels, a biochar manufacturer, USFS and state agency wildland fire fighters (e.g., an assistant fire manager, engine captain, and district chainsaw coordinator), a USFS district ranger, a lumber mill sawyer, and a forest safety management consultant. Initial analysis of early-stage interviews (informal and semi-structured), direct observation, and participant observation showed that participants working in fire and forest management were most concerned with beetle-kill hazards, while loggers tended to view beetle kill as adding little to no significant risk. Therefore, a second round of data gathering, including semi-structured interviews and documentary sources, focused more directly on firefighters and foresters. Participants were asked open-ended questions about their experience working with beetle kill and how they viewed the impact of beetle kill on their ability to remain safe. They were not asked questions about SA. All interviews were conducted by the corresponding author. Participants were not incentivized, and job titles have been disassociated from site locations to protect the anonymity of participants.

Semi-structured interviews and documentary sources were subjected to detailed thematic analysis in Atlas.ti qualitative data analysis software. Thematic analysis is a foundational inductive method for identifying, analyzing, and reporting meaningful patterns (themes) in qualitative data that is used across social science disciplines.[29,30] Importantly, ethnographic methods and thematic analysis allow researchers to privilege the voices and perspectives of participants while minimizing their own assumptions.[30,31] Analysis was concluded when central themes reached saturation, which in this case means that no additional information was added through additional coding of the data set. The strength of this approach rests in its ability to produce grounded insights from rich participant-centered data. However, it is also limited by a relatively small number of participants, as well as time and labor-intensive fieldwork. Therefore, this approach often works best as a means of generating new insights and research questions that can promote additional quantitative and mixed-methods research or better design of worker outreach.

Results

Most participants believed that beetle kill constituted a hazard in some circumstances. However, loggers tended to show little concern with the potential hazards of beetle kill, either because they worked in enclosed logging equipment or did not work in beetle kill at all due to its low commercial value. One hand feller who had worked in beetle kill described the harrowing experience in an informal interview and simply said he would never do it again. One lumber mill sawyer was not concerned about working with beetle kill, because he only processed recently killed, and therefore structurally sound, logs. Wildland firefighters,

non-production hand fellers, and foresters were most concerned and tended to have most exposure to beetle-kill hazards on the job. Most who were asked to rank job hazards reported that beetle kill was most concerning, followed by driving. Participants mentioned increased risk of falling limbs, also known as widow makers. Others cited increased risks of slips, trips, or falls when traversing a large number of fallen trees. A perceived increased risk or severity of forest fire was also a common theme.

Mitigations associated with beetle kill were directly related to how beetle-killed trees were perceived as hazardous. Strategies were primarily limited to existing options, such as carrying saws to cut snags that may fall across roadways, staying in communication with others about planned travel in beetle-killed areas, and avoiding beetle-killed stands during windy days or if snags showed signs of increased potential to fall. Firefighters noted a clear shift toward indirect attack, increased use of mechanized felling, and more willingness to disengage a fire in beetle-killed areas. In many of these cases, working as safely as possible around beetle kill was said to require heightened and consistently maintained SA. For example, some participants recounted being in potentially hazardous situations, such as walking in a thick stand of beetle kill on a windy day, because they were not paying close attention to their surroundings.

Situational awareness

SA emerged as a central theme related to beetle kill safety that is characterized by intersubjectivity and several factors that can result in either enhanced awareness or complacency. The term "SA" was extremely common along with "vertical awareness," especially in relation to beetle kill, "awareness," and "attention." In these cases, participants were referencing the ability to be holistically aware of their surroundings, including the potential consequences of their own actions, the actions of others, and potential natural occurrences that could impact their own or others' wellbeing. SA is not only necessary for working in beetle-killed areas but is made even more salient by the presence of multiple overhead hazards (see Table 1, quote 1). Furthermore, overhead hazards are compounded by fallen and partially fallen snags that increase the risk of most activities. Finding reliable escape routes during a fire and avoiding slips, trips, and falls were both mentioned by several participants as more difficult in stands with fallen snags.

A related theme was the tension between SA, which is holistic, and being task focused or mission oriented. Felling a tree was commonly mentioned as an activity that requires focus on the task at hand and detracts from a worker's ability to pay attention to surroundings (see Table 1, quote 2). Accomplishing a particular goal, such as cutting a specific amount of fire line before dark or marking out a timber sale, was the focus of participant narratives in which they or their colleagues found themselves in dangerous situations (see Table 1, quote 3). These limits of individual attention made interpersonal communication and collaboration in hazardous environments critically important. That is, participants did not always speak about SA as only a subjective state that occurred in an individual's mind, but also as an intersubjective process that occurs among and between individuals through communication and cooperation (see Table 1, quote 4). The intersubjective nature of SA was not limited only to the working environment but extended to institutional practices, such as training and

collegiality more generally. For example, the responsibility to ensure dangerous situations are properly perceived can be institutionalized when a safety officer takes on the role of "devil's advocate" by consistently drawing others' attention to potential hazards (see Table 1, quote 4).

Intersubjective SA was considered necessary, because hazardous situations, especially on fires, are more complex than an individual can reliably process alone. Beetle kill was considered only one hazard among many, although an important one that can increase the complexity of a situation. As will be shown below, the ability to maintain SA is not seen as only limited to individual and intersubjective engagements with forest environments, but also depends on broader institutional structures, values, and practices. Of central importance is how forest workers gain experience and the cultural norms that influence how they speak to each other about potential injury and risk to life (Figure 1).

The dangerous middle: work experience, complacency, and acknowledgment of danger

Participants did not uniformly express that more job experience is necessarily associated with increased safety. Instead, the quality of experience and how it impacts individual and group capacities to maintain SA was of primary importance. One wildland firefighter made this point clear by connecting awareness with the process of talking through work experiences with colleagues. He said, "I think it's all about awareness, it's all about experience, and it's all talking about those experiences that you've had and this kind of stuff" (Interview 5). Importantly, experience gained from negative outcomes (e.g., hanging up a tree, near accidents, or knowing people who were injured or killed) was seen as most effective, because it not only created additional experience but also tended to fight against complacency and a false sense of security (see Table 1, quote 5). This sentiment was echoed in a cartoon in Fire Management Today depicting a crew narrowly escaping the 1990 Dude Fire in Arizona. The caption reads "A good scare is always worth more than a [sic] good advice."[32]

If negative outcomes were seen as resulting in heightened SA, what we refer to as "the normalization of hazards and bad habits," as well as failure to explicitly acknowledge the riskiness of the job, emerged as contributing to a false sense of security. The normalization of bad habits refers to the idea that repeating risky behavior tends to make that behavior seem more normal and less risky. For example, a USFS firefighter in Idaho worried that the epidemic level of beetle-killed trees in some forests led to a false sense of safety as people became used to working within those hazards on a regular basis. This normalization of beetle kill or other hazards is problematic, because it leads people to take risks they would otherwise avoid. Similar issues arise from the normalization of bad habits, a process through which recognizably less safe practices become accepted, leading to the belief that newer workers can be safer than those with more years on the job (see Table 1, quotes 5 and 6). Because several participants associated complacency roughly with the intermediate stages of a career, we have named this theme "the dangerous middle" (see Table 1, quotes 5 and 7). As one USFS Assistant Fire Management Officer said, "You know that they say that the most dangerous point of a firefighter's career is the point I'm at right now. It's the middle of your career" (Interview 11). The dangerous middle describes participants' evocation of

a point at which additional on-the-job experience with hazards results in less caution or attention to those hazards. "Middle," then, is relative to amount and kinds of experience and does not refer to the chronological midpoint of a person's career. In other words, the dangerous middle could occur in year 3 of a 20-year career.

From this perspective, the dangerous middle is not only about a lack of appropriate attention to potential hazards, but also about how workers acquire practical experience. For example, mid-career hand fellers may be overly confident because they (1) have a growing set of necessary experiences and skills that they are comfortable with but (2) not enough experience with different situations to always recognize when this experience is inapplicable. This implies that they misrecognize one type of situation for another (see Table 1, quote 7). However, they can only acquire the experience that makes them safer by engaging directly with the kinds of hazardous situations they have not yet encountered. This is compounded by the recognition that the same situation is never encountered twice. Knowing that "every tree's different" and that things could always go wrong is a recognition that even the safest workers, making the best possible decisions, can get hurt.

Several participants also believed that not openly acknowledging danger, meaning significant potential for injury or death, contributed to less safe working conditions. These participants believed that this encouraged a false sense of security that contributed to decreased SA among workers who must engage hazards (see Table 1, quote 8). Firefighters in particular tended to openly express the view that explicitly acknowledging the inherent danger of their job was important for keeping crew members out of harm's way. Specifically, they said the fact that lives are at risk should become an explicit part of institutional conversations, training, and safety briefings. Furthermore, they did not believe that this emphasis on danger would eliminate risk but may help firefighters, and others working in dangerous situations, pay closer attention, to be aware of their surroundings, and to maintain focus when tempted to let their attention wander.

Discussion

Research is clear that immediate hazards tend to decrease SA, because individuals hyper-focus on objects or events perceived as threatening.[33,34] This is consistent with participant beliefs that being mission focused or task oriented negatively affects their ability to be situationally aware. This perceptual limit of an individual's ability to remain attentive to complex and dynamic environments highlighted the importance of group cooperation and communication. That is, SA is a social phenomenon and, because it is social, it is open to institutional (social) structures and cultural practices that affect group dynamics. Participants emphasized two broad kinds of institutional or cultural influences that can negatively affect SA. The first is concerned with the relationship between kinds of work experience and awareness, including complacency resulting from hazard or bad habit normalization. What we have called "the dangerous middle" highlights the potential effects of career history and experience on environmental perception. Previous research has examined the relationship between career stage and SA and has focused on reasons firefighters in different career stages do not voice safety concerns, thus limiting SA by reducing communication about the environment.[35] While this is an important insight, participants also made connections

between kinds of experience, as a rough approximation of career stage, and SA. This experience is grounded in training (hence, is institutionalized), communication among colleagues (hence, is cultural), and is further developed by directly engaging complex environments. Participants described a process in which new workers with fresh training were attentive to potential dangers but lacked experience. Then, as experience and skill increased, potentially leading to a false sense of security, awareness may decrease. Commonly, negative experiences, such as near accidents, embarrassing mistakes, or the misfortune of others prompted workers to become more vigilant.

Second, participants involved in firefighting tended to believe that a failure to explicitly tell workers that they are risking their lives missed an opportunity to raise SA. Although the term was not used by participants, these sentiments have strong resonance with an active conversation in the wildfire community about the so-called "big lie."[36] The big lie refers to the idea that the inherent danger and risk to life entailed in fighting wildfire is not explicitly acknowledged within organizational culture. However, participants did not directly blame any specific group, such as administrators, but pointed to a cultural milieu to which they also contribute. Significantly, participants drew a direct line of influence between institutional failure to explicitly acknowledge danger and risk to life and their own ability to raise and maintain SA across a broad spectrum of work situations (Figure 2).

Conclusion

Beetle kill was understood by forest workers within already existing safety frameworks and discourses about complex and dangerous environments. It was one hazard among many others, but also one that increased the complexity and dynamism of the work environment that made SA both more necessary and more difficult to maintain. Surprisingly, participants spoke about SA without being prompted by researchers and connected the concept to broader cultural and social conditions, such as not speaking openly about risk to life and the cumulative effects of work experience over entire careers. While most research about SA focuses on performance in, specific training for, or technological adaptation to hazardous situations, our analysis suggests that attempts to build adequate SA should also include broader social and cultural considerations.

These insights suggest questions that can lead to additional mixed-methods research and improved worker health and safety outcomes. The first question is: how does experience considered over an entire career impact SA? Participants suggested that careers can tend toward complacency with regard to hazards under circumstances discussed above. How widely is this experience shared by workers, and what measures can be taken to mitigate this dangerous middle? Second, participants believed that making risk to life an explicit part of work conversations may increase their ability to remain safe. Does the act of clearly and openly telling workers that their job is dangerous and that they are risking their lives result in heightened and more enduring SA? Third, because ethnographic research is always, if only implicitly, comparative, to what extent can we ask these questions of other dangerous occupations, such as farming, ranching, or fishing? In short, how does understanding environmental perception and action as social and cultural help create workers who are more aware and ultimately safer?

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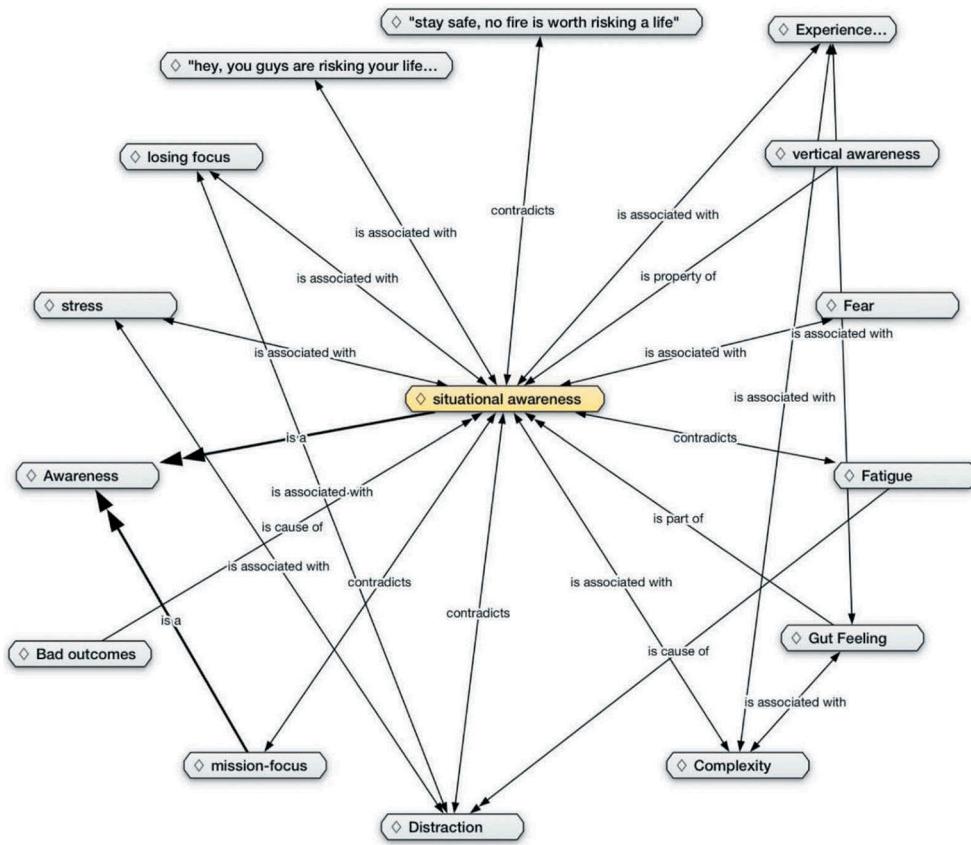
Figure 1.

Situational awareness code map. A simplified code map showing how relationships among codes comprising the theme "situational awareness" are represented in Atlas.ti during the process of analysis.
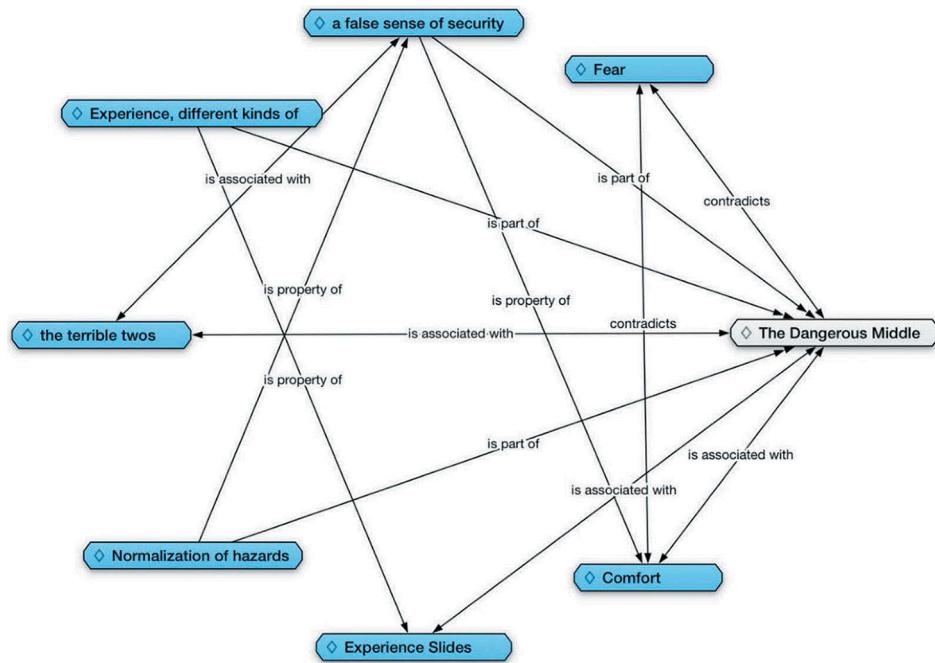
Figure 2.

Dangerous middle code map. Simplified code map showing how relationships among codes comprising the theme "the dangerous middle" are represented in Atlas.ti during the process of analysis.

Table 1.

Representative quotations.

Quote 1	"…what really becomes a challenge with beetle kill in general is it's no longer singular dead trees. … So not only is the tree you're working on hazardous, but potentially everything around you is in the same boat. It's all… you know, this goes back to what [other participant's name] was talking about with the situational awareness and not paying attention to what's going on around you." (Interview 13, USFS fuels technician/district chainsaw coordinator)
Quote 2	"Everyone gets mission oriented and then their head just stays down because they're digging line. So, their head is always down but we always encourage people, you know, when you take a sip of water, when you're doing whatever, just look up all the time. If you start seeing some flame in some trees, and then speaking up is the other thing. Like notice it and speak up because we could have missed something and then just, encouraging them to be aware of what's going on and making them know that sometimes we do miss stuff and they're eyes and ears out there too." (Interview 5, USFS fire crew member)
Quote 3	"You're in a massive wind storm that blows in and you're sitting in the woods, it's happened to me I know, and you're like I walked down the wrong… I didn't really think about it, you know, because I was out there looking… set up a very small sale over there. I've walked in, did a couple of things, and I had to go someplace else and I remember I stepped over a log on the way out and I was like, "I don't remember that. I don't think that was here." I'm walking down this straightaway, and ahead of me was somebody's timber sale that they'd done like two years ago or something, and suddenly it was like "poof, poof, poof, poof." The whole hillside came down, and at that point in time it was like "oh God!" And until you see how easy trees can tip over, you know, in one of those high wind areas, I don't think it really clicks. Trees are always vertical, right? Yeah until they go "wham!"" (Interview 2, state agency supervisory forester)
Quote 4	"Whatever we do. It's situational awareness. How well we communicate, how aware we are, you know? … So you know, somebody's tracking them or willing to speak up or, you know, somebody behind them is playing the devil's advocate. There's quite a few of our folks who, let's have a devil's advocate. That's sometimes the role of the safety manager or the safety officer on the fire or safety operations, is to play devil's advocate." (Interview 4, USFS safety and occupational health director)
Quote 5	"So if they're [new firefighters]… more scared, they're safer because they might question things more than someone that has more experience and has fought fire 50 years and thinks they've seen it all and can do it, but then on the same token you get people like my boss who have been here, I don't know, he's probably been fighting fire close to 30 years or so, and… just because he's seen firefighters die, experienced having to to get them out and stuff, he's just more, uh, just worries more about people, and I think is more cautious on implementing things and putting people in there to fight the fire and especially if it's very far in and someone gets hurt and you can't get them out quickly. Maybe it's the middle, middle ground… they've seen a lot of fire so they're comfortable fighting fire. They might think they know what they're doing, that nothing's going to happen to them, that kind of thing. … But I think the more comfortable you get fighting fire, then sometimes it's harder to see some of the things that other people might see." (Interview 9, USFS fire planner)
Quote 6	"Sometimes I think the new people are better off, cause it's fresh in their head and the more you do a job there's that tendency to normalize everything that you see and maybe you've done something that you know it not exactly safe a few times and you've had good luck doing it so that just makes it normal that, every time you deviate from something you know to be correct is bad." (Interview 15, USFS fire engine captain)
Quote 7	"I see people that kind of get themselves in sticky situations is at that intermediate level. You know, they may… they may feel really comfortable running the chainsaw and they may have done a lot of practice and developed a lot of good skills, but they may not have seen every situation, or a lot of the situations that can be hazardous or give you problems without understanding until it happens sort of thing. Um… so… I would say that… you know across the board that's generally where you see it is kind of that mid-level range of qualification, for folks that maybe have been cutting for that, in that 5 to 10-year range where they've got a good skill set, they're good sawyers, but they might get overconfident in situations they may not understand, may have never seen before, been in before. And find themselves in a bad spot." (Interview 13, USFS fuels technician)
Quote 8	"I think it's… it's pretty well acknowledged that the best way to keep folks safe is higher situational awareness. Everybody being more aware of what's really going around. So, tell me, how would you be more aware, what would make you pay more attention? Somebody give you a briefing and said "yeah, there's some snags up there, we're not going to risk anything, be safe today," or if I said "hey there's a lot of snags on this hill, steep hill there's a lot of rolling rocks. Every one of these things can kill you. You are risking your life today. Pay attention out there" What's going to wake you up and make you look around more? Probably if somebody tells me, if I hear that, "hey you're risking your life today. You might die. Pay attention to what's going on." (Interview 11, USFS fire management officer)