Journal of the

WILDFIRE CONSERVANCY

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About the Journal

The Journal of the Wildfire Conservancy is a scientific, peer-reviewed journal supported by the Wildfire Conservancy and the Wildfire Science and Urban Interface Program at California State University San Marcos. We publish a variety of new and innovative papers, articles, and manuscripts that advance our mission of research, education, and outreach, with a focus on wildfires and the wildland urban interface. The primary focus of the Journal is to highlight research that can have practical application and implementation by company officers, firefighters, decision makers, and legislators, to bridge the divide between science and policy. Contributions to this Journal should focus on good science and include practical applications for that science. The Journal contributes to the advancement of three specific areas of emphasis:

- Improving Firefighter Health and Safety
- Advancing Attack Effectiveness
- Promoting Community Resilience and Awareness

The Journal publishes articles focused on basic and applied research in an open-access, online publication that supports innovation and progress toward the advancement of wildland and urban interface fire issues. All content is free to the public to download, copy, and print; this supports our focus of bringing science to the practitioners and decision makers. Articles may include links to informative videos, training modules, data, and supporting posters/brochures that fire departments, local, state, federal, and tribal governments, organizations, and the public can download and use as tools for advancing training and understanding.

As an open-access, online journal, authors are not charged any fees for publication, and the submittal, review, editing, and production are efficient and flexible. We accept articles for the following:

- Original Research Papers
- Literature Reviews and Annotated Bibliographies
- Conference Proceedings
- Opinion Articles and Book Reviews
- Legislative Updates and Analysis
- Student Research Papers and Posters

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THE WILDFIRE CONSERVANCY

The Wildfire Conservancy champions firefighter health and safety, bolsters attack strategies, and fosters community resilience against wildland and urban interface fires. For over two decades, we've been at the forefront of environmental advocacy and leadership training, bridging agencies and individuals to address pressing environmental challenges. Beyond research, we offer comprehensive consultation, training, and expert insights on wildland and urban interface fire policy, planning, and regulation.

Cleaner Cab

Although the comprehensive scientific manuscript describing the Clean Cab research is still undergoing publication, sufficient evidence has emerged to support several preliminary recommendations for Clean Cab practices specific to wildland and wildland-urban interface (WUI) firefighting. Because firefighter occupational exposures continue to occur on every incident, the Wildfire Conservancy believes it is important to begin translating these evidence-based findings into operational practice rather than waiting for final publication. The accompanying poster provides preliminary guidance based on the best available scientific evidence to help reduce dermal and respiratory exposures, minimize cross-contamination within apparatus, and improve firefighter health and safety. As additional research is completed and the scientific evidence continues to evolve, these recommendations will be refined and expanded through future publications and implementation guidance.

To encourage early implementation of these preliminary recommendations, a full-size version of the Clean Cab poster is included in this issue of the Journal of the Wildfire Conservancy and may be reproduced and displayed in fire stations, apparatus bays, training facilities, and other firefighter work environments. The intent of this resource is to provide firefighters with practical, evidence-informed guidance that can be implemented immediately while the full scientific manuscript is undergoing publication. Additional educational resources, research publications, training materials, and implementation guidance are available at http://www.WildfireConservancy.org. Fire departments and organizations interested in obtaining additional materials, collaborating on research, or implementing Clean Cab practices are encouraged to contact the Wildfire Conservancy at mailto:info@wildfireconservancy.org

Cleaner Cab*

THE WILDFIRE CONSERVANCY

Your Air. Your Health.

CLEANING

- Gross decon at end of shift
- Change/clean vehicle air filters regularly
- Sweep or vacuum ash/dust with a HEPA filter (use mask & eye protection)

PROTECT

- Keep contaminated PPE out of the cab (when possible)
- Stock cleaning supplies (wipes, soap, gloves, masks)
- Ventilate often (A/C on, windows open when possible)

HYGIENE

- Wash hands, face, and neck frequently
- Keep food, water, and coolers contamination-free
- Wipe down handles and steering wheel

**If you would like this station poster sent to you, email info@wildfireconservancy.org.*

CLEANER CAB DECONTAMINATION PRACTICES

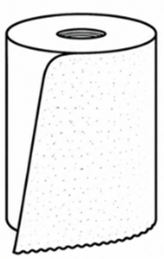
THE WILDFIRE CONSERVANCY

Scan this QR code with your phone's camera to view a step-by-step video on decontamination practices.

Consistent decontamination practices make a difference over the course of a career.

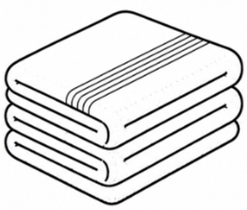
Reducing exposure is the most effective way to protect your long-term health. While contaminants can never be completely eliminated, following consistent decontamination of ash and soot help reduce cumulative exposure throughout your career. Use the steps below to help minimize unnecessary exposure on every incident.

DISPOSABLE PAPER TOWELS



OR

CLOTH TOWELS



NOTE: IF USING CLOTH TOWELS, BE SURE TO WASH THEM AFTER.

MULTIPURPOSE CLEANER, SOAP AND WATER, DISPOSABLE WIPES, OR EVEN WATER ALONE CAN HELP REMOVE CONTAMINANTS.

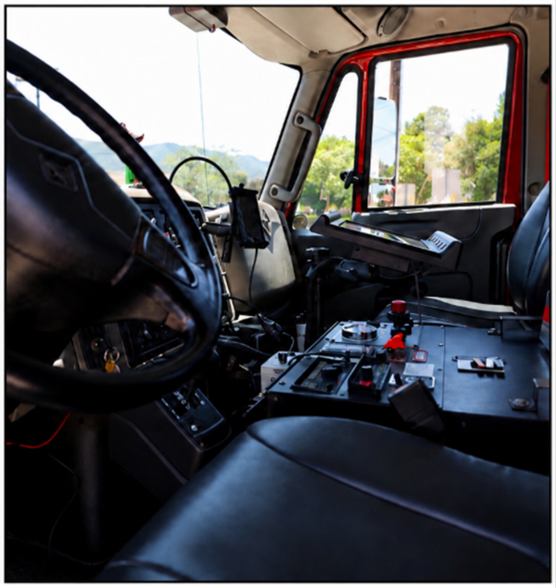
WEAR DISPOSABLE GLOVES AND AN N95 MASK WHILE DECONTAMINATING.

DECONTAMINATION PLACES

REMOVE CONTAMINATED PPE

WIPE DOWN ALL HIGH TOUCH SURFACES INCLUDING

- SEATS
- SEAT BELTS
- HEAD RESTS
- CUP HOLDERS
- ARM RESTS
- WINDOW SILLS
- KNOBS, SWITCHES, CONTROLS
- STEERING WHEEL
- LATCHES
- HANDLES
- CENTER CONSOLE
- SCREENS
- RADIOS
- HEADSETS



OTHER THINGS TO NOTE:

WASH HANDS BEFORE EATING.

BE SURE TO WEAR GLOVES AND N95 MASK IF USING AIR COMPRESSOR TO BLOW OUT CONTAMINANTS.

WIPE DOWN WATER COOLER TO NOT INGEST CONTAMINANTS.

MAKE SURE TO BAG AND DISPOSE OF ANY CONTAMINATED MATERIAL IMMEDIATELY.

For more information on current projects and research visit wildfireconservancy.org.

ICE VERSUS AMBIENT WATER TEMPERATURE'S EFFECT ON FIREFIGHTER HYDRATION, CORE TEMPERATURE, HEART RATE, AND SKIN TEMPERATURE

Aida Rodriguez[A], Matt Rahn[A], Kelcey Stricker[A], Rick Swan[A], Curtis Brown[A], Thomas Spady[B], Arun Sethuraman[B], Tim Edwards[A], and George Broyles[A]

Abstract

Fire suppression causes extreme strain on the cardiovascular system and can lead to cardiac arrest and heat-related illness. The goal of this study was to determine how water consumption with and without ice influenced firefighter hydration status, core temperature, skin temperature, respiratory rate, and heart rate, while evaluating the response-effect that water temperature had on overall physiology. A total of thirty-six firefighters from CAL FIRE were included in this study during training and active fire suppression duties. Results revealed that firefighters regularly exceeded safe physiological conditions. In a subset of the study, twenty-four firefighters were asked to consume either ice or ambient temperature water *ad libitum* while performing their regular duties. Ice water reduced variability in hydration levels and maintained safer hydration levels overall. Ice water was also effective at reducing average and maximum heart rate as well as average and maximum skin temperature. Overall reduction rates of core temperature, skin temperature, respiratory rate, and heart rate were accelerated with ice water consumption. This study suggests that ice water may be an effective way to mitigate cardiovascular strain and thermal stress.

Keywords: firefighters, hydration, core temperature, heart rate, fluid intake, wildland firefighters, thermal stress, cardiovascular stress

Introduction

Over the past decade, wildfires throughout the United States have been setting new and unfortunate records regarding lives lost, property destroyed, and acres burned. Since 1970, the U.S. witnessed an increase from three million to an overwhelming eight million acres burned each year (International Code Council [ICC] & National Association of Resource Conservation and Development Councils [NARCD], 2013). Once thought of as a western U.S. problem, wildfire awareness has become an international concern. Recent research suggests that fire seasons are becoming longer than previously assessed (Belval et al., 2020). These longer fire seasons and more frequent fires have a negative impact on firefighter health and safety.

Across the U.S., local fire departments respond to over 330,000 wildfires each year. The complexity of these incidents creates a diverse and physically challenging environment to work in. On average, one in six incidents engulfs transportation infrastructure and one in ten includes structures (Karter et al., 2013). Nationally, there are over 46 million homes in the wildland urban interface (WUI) (Hamins et al., 2012; ICC & NARCD, 2013). With annual increases in population growth, conditions that support drought, and dramatic expansion into

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the WUI, more frequent and intense fires will continue to occur, and more first responders will be called to fight those fires (Haight et al., 2004; Syphard et al., 2007).

Wildland firefighters' exposures are complex and can involve environmental and physiological extremes beyond which the human body was meant to withstand. Firefighters regularly experience sustained unsafe peak heart rates, dangerously high core body temperatures, rapid respiratory rates, and high levels of dehydration (Rahn et al., 2016). Any one of those conditions is problematic, but in combination it can be devastating. They are also regularly exposed to unsafe levels of high-risk contaminants including trace metals, polycyclic aromatic hydrocarbons (PAHs), perfluorinated compounds (PFCs), benzene, carbon monoxide (CO), nitrogen and sulfur oxides, cyanide, volatile organic compounds (VOCs), airborne acids, and particulates (Rahn et al., 2013).

Fire suppression causes extreme strain on the cardiovascular system. Sudden cardiac death is the leading cause of death among firefighters and accounts for approximately 45% of all on-duty firefighter fatalities (Soteriades et al., 2011; Smith et al., 2013). During a fire, a first responder experiences a combination of emotional stress, intense physical activity, extreme ambient temperatures, and environmental exposures which can increase this risk (Smith et al., 2013). Cardiovascular strain/stress in firefighters is caused by a combination of factors including extreme physical exertion and exposure to hot environments (Hunter et al., 2017; Smith et al., 2001). Research has found that the combination of these factors during fire suppression activate blood platelets, increasing thrombus formation, which may lead to myocardial ischemia (Hunter et al., 2017).

Studies have documented that typical firefighting duties can result in near maximal heart rates that are often sustained for prolonged periods of time (Kales et al., 2003; Kales et al., 2007; Holder et al., 2006; Eglin et al., 2004). In a study conducted by the National Institute for Occupational Safety and Health (NIOSH) for on-duty cardiac-related fatalities, it was reported that firefighting activities often required firefighters to work at near maximal heart rates. The increase in heart rate began with the initial alarm and persisted through the course of fire suppression (Hales, 2005). High temperature working conditions and thermal loading is not only physically dangerous but also decreases the individual's productivity and their ability to perform tasks, leading to higher incidences of on-duty injury (Lin et al., 2009; Ramsey, 1995; Park et al., 2009). This is especially important to wildland firefighters who must respond rapidly to complex and hazardous working environments. It is well documented that personal protective equipment (PPE) and dehydration can significantly increase heat stress and cardiovascular strain (Nunneley, 1989; Birnbaum et al., 1978; Holmer, 2006; Richardson et al., 2001; Selkirk et al., 2004; Smith et al., 1997).

Some studies have examined the cardiovascular responses of structure/wildland firefighters as environmental temperature increases during various fire drills (Barr et al., 2010; Bugajska et al., 2007; Eglin et al., 2004; Horn et al., 2013; Raines et al., 2015; Richardson et al., 2001; Selkirk et al., 2004; Smith et al., 1997; Walker et al., 2014). Increases in environmental temperature in combination with firefighter PPE add to the physiological burden by raising oxygen consumption, body temperature, reducing time to fatigue (faster increases in core body temperature), and increasing dehydration (Barr et al., 2010). It has been found that as environmental temperature increases, core body temperature also increases, leading to elevated levels of cardiovascular strain (Gonzales-Alonzo et al., 1992; Gonzales-Alonzo et al., 1998; Smith et al., 2001; Horn et al., 2013; Raines et al., 2015).

Studies suggest that implementation of proper hydration reduced cardiovascular stress and thermal strain (Walker et al., 2016; Walker et al., 2014; Selkirk et al., 2006; Raines et al., 2013; Raines et al., 2012; Raines et al., 2015). Rehydration/hydration as a potential mitigation tool for firefighters has been a relatively new area of research (Domitrovich, 2007; Murray, 1995; Hostler et al., 2010; Selkirk, 2006; Walker et al., 2016). During active duty/exercise, the consequences of dehydration are potentially life-threatening, leading to measurable declines in cardiovascular and thermoregulatory function (Murray, 1995; Hostler et al., 2010).

Evidence suggests that maintaining normal hydration or incorporating even partial fluid replacement improves performance during exercise and helps maintain cardiovascular and thermoregulatory response (Murray, 1995; Walker et al., 2016; Walker et al., 2014; Selkirk et al., 2006; Raines et al., 2013, Raines et al., 2012; Kenefick et al., 2007). In some cases, it was found that *ad libitum* consumption of water and prescribed water consumption was sufficient in maintaining hydration status, lowering core body temperature, and reducing thermal strain (Tab et al., 2015; Walker et al., 2016; Selkirk et al., 2006; Selkirk et al., 2004; Raines et al., 2015; Raines et al., 2012; Raines et al., 2013). Emerging findings suggest that consumption of cool or slush water may reduce cardiovascular stress and core body temperature (Walker et al., 2014; Brearley et al., 2011; Brearley, 2016). When firefighters were prescribed ice-slush ingestion post-shift, it effectively lowered body temperature and thermal strain (Brearley et al., 2011; Walker et al., 2014).

Methods

This research was conducted in partnership with CAL FIRE and included access to trainings, fuels management projects, and actual wildland/WUI fires. Data were collected on ambient environmental conditions and utilized sensors and biological sampling to monitor the physiology of firefighters. Operating under a memorandum of understanding with CAL FIRE, all research was conducted in a manner that ensured there were no operational impacts on the incident and that the test subjects carried out their normal firefighter duties/activities. All participants were on-duty CAL FIRE firefighters who volunteered to participate.

Data Collection: All Firefighters

A total of 36 firefighters were included in the study during 2018 and 2019. They were outfitted in standard wildland PPE (including jackets, pants, gloves, boots, goggles, and helmets). Each firefighter was equipped with an Equivital™ EQ02 Sensor Belt, assigned an Equivital™ EQ02 SEM (data storage unit), and asked to swallow a VitalSense® Sensor pill to measure core temperature. Firefighters engaged in different types of fire management activities including controlled burns, training events, and vegetation management projects. Sensors were collected from the firefighters at the end of their shift.

The Equivital™ EQ02 Sensor Belt and EQ02 SEM were used to measure heart rate, respiratory rate, skin temperature, activity, and body position (e.g., upright or horizontal). This system is generally regarded as a reliable and robust field-based tool for measuring these factors (Buller et al., 2007; Cuddy et al., 2011; Mol et al., 2010; Welles et al., 2013). Variables were recorded every 15 seconds. The VitalSense® Sensor pill calculated the core temperature of the individual per minute and transmitted data every 15 seconds to the EQ02 SEM. All data from the SEM were downloaded onto a laptop using the compatible software, Equivital™ Manager.

Twenty-four firefighters were asked to participate in an ice versus ambient temperature water consumption study. During this portion of the study, half of the volunteers were randomly assigned to a group where they either consumed ice water or ambient temperature water. Volunteers were asked to consume water *ad libitum* from appropriately labeled coolers containing 16.9 fl oz water bottles.

Firefighters provided a urine sample to establish pre- and post-activity hydration status. Urine specific gravity (USG) was measured using an Ade Advanced Optics Refractometer Units. USG is commonly used to assess dehydration/hydration levels in field studies by measuring the amount of solutes in urine (higher amount of solutes = more dehydrated) (Cheuvront et al., 2011; Oppliger et al., 2002; Szlyk et al., 1989). The refractometer measured urine specific gravity (USG) from 1.000 to 1.060, with values closer to 1.000 indicating more dilute urine and higher values indicating increasingly concentrated urine, which may reflect reduced hydration status (Dempester et al., 2013). This assessment determined whether firefighters were at or near dehydration, which can significantly increase thermal stress and cardiovascular strain.

Two-Day Paired Study: Ambient versus Ice Water Consumption (N=5)

In August 2019, an additional five firefighters were followed for a two-day study. The firefighters worked on a vegetation management project in Riverside County, California clearing vegetation in a high risk burn area for 8 hours a day. All firefighters worked both days removing brush, shrubs, and trees using hand tools, weed trimmers, and chainsaws. On day one, three of the firefighters were randomly assigned to the ice water group, while the other two were given ambient temperature water. On the second day, firefighters switched "water prescriptions;" firefighters who drank ice water on day one consumed ambient temperature water on day two and vice versa.

Data Analysis

The basic statistics (averages, minimums, and maximums) for heart rate (beats per minute [bpm]), respiratory rate (breaths per minute [br/min]), skin temperature (°C), and core body temperature (°C) were calculated each minute. Maximum sustained values were identified as the peak value that was sustained for at least 15 second in any given minute. Minimum values for heart rate were identified as the minimum value sustained for at least 15 seconds in any given minute. Simple linear regression was used to observe heart rate, respiratory rate, and core temperature relationships in all firefighters. Box plots were used to show differences between the various factors and T-tests that assumed equal variances were used to identify any significant differences. Paired T-tests were used to analyze heart rate, respiratory rate, skin temperature, and core temperature data in the two-day paired study. A P-value less than 0.05 was used to indicate statistical significance.

Reduction rates were calculated to observe the effect of water temperature on core body temperature, heart rate, respiratory rate, and skin temperature. This was done by observing the actual time of water consumption and identifying the peak measurement at that moment. This was then subtracted from the trough resulting in the "overall change" *(pre water intake measurement – post water intake measurement)*. This change was then divided by the time difference *(post water intake time – pre water intake time)* it took from the peak measurement to the trough measurement *(pre water intake measurement – post water intake measurement = overall change/ time difference)*.

Results

Between May 2018 and September 2019, data were collected on 36 firefighters at 4 types of firefighter trainings/events in California: six firefighters on duty at Hemet-Ryan Helitack Air Base, seven firefighters during a fire training at Ben Clark Field Base, four firefighters at a controlled burn in Madera, and 19 firefighters on vegetation clearing projects in Lake Elsinore and Alpine. Of the firefighters monitored, 35 were male, one was female, five were captains, and 31 were a rank of Firefighter 1 or 2. Firefighters worked in moderate conditions with temperatures between 23.89°C (75.00°F) and 29.44°C (84.99°F).

Hydration, Heart Rate, Respiratory Rate, Core Temperature, and Skin Temperature in All Firefighters (N=36)

Hydration
The mean start hydration and end hydration for all firefighters was 1.0339 (standard deviation [SD]=0.004) and 1.0340 (SD=0.003), respectively. There was no significant difference in start and end hydration *($P=0.081$).*

Heart Rate and Respiratory Rate
The mean heart rate was 99.36 bpm (SD=24.83), with a calculated sustained heart rate of 104.60 bpm (SD=26.86) (Figure 1). Approximately 14% of the firefighters (at some point during their activity) had a maximum sustained heart rate of 200 bpm or above. Two firefighters reached maximum sustained heart rates of 220 bpm or above. The mean respiratory rate was 22.58 br/min (SD=7.43) and the mean maximum respiratory rate was 24.50 br/min (SD=7.94) (Figure 2). Approximately 36% of firefighters (at some point during their activity) had maximum sustained respiratory rates of 50 br/min or above, with 14% sustaining respiratory rates of 55 br/min or above.

We were able to observe general relationships using linear regression between average and maximum heart rate, respiratory rate, and skin temperature. There was a significant observed regression in average heart rate and average respiratory rate ($P<0.001$) with R^2=33.65%. Similarly, there was a significant observed regression in maximum heart rate and maximum respiratory rate ($P<0.001$) with an R^2=34.13%. In both cases, there was a positive relationship where respiratory rate increased as heart rate increased.

There was a significant observed regression in average heart rate and average skin temperature ($P<0.001$) with an R^2=16.11%. There was also a significant observed regression in maximum heart rate and maximum skin temperature ($P<0.001$) with an R^2=14.67%. In both cases, skin temperature increased as heart rate increased.

Core Body Temperature
The mean core body temperature of the firefighters during the study was 37.32°C (99.18°F) (SD=0.55), with a calculated maximum core temperature (per minute) of 37.33°C (99.20°F) (SD=0.53) (Figure 3). When looking at average or maximum temperatures, there were no significant relationships observed relative to hydration. Nearly 20% of the firefighters had maximum sustained core temperatures (at some point in their shift) of 39.90°C (102°F).

General relationships using linear regression between average and maximum core temperature, heart rate, skin temperature, and respiratory rate were observed. There was a significant observed regression in average core temperature and average heart rate ($P<0.001$) with an R^2=18.32%. Similarly, when looking at maximum core temperature and maximum heart rate, a significant regression was observed ($P<0.001$) with an R^2=17.96%. In both cases, core temperature increased as heart rate increased.

There were significant regression relationships observed between average core temperature and average respiratory rate ($P<0.001$) with R^2=7.34%, and maximum core temperature and maximum respiratory rate ($P<0.001$) with R^2=6.90%. However, the R^2 values were extremely low, indicating that little of the data can be explained by this relationship.

Skin Temperature
The mean skin temperature was 35.89°C (96.62°F) (SD=1.37), with a calculated sustained maximum skin temperature average of 35.92°C (96.66°F) (SD=1.45). Approximately one third of the firefighters had maximum sustained skin temperatures above 38°C (100°F), with 8% above 38.89°C (102°F). Two firefighters had recorded skin temperatures of 39.90°C (103.82°F) and 39.60°C (103.28°F).

There was a significant observed regression in average core temperature and average skin temperature ($P<0.001$) with

R^2=22.63%. Similarly, there was a significant regression between maximum core body temperature and maximum skin temperature (*P<0.001*) with an R^2=23.27%. In both cases, skin temperature increased as core temperature increased.

Ice versus Ambient Water: Hydration, Heart Rate, Respiratory Rate, Core Temperature, and Skin Temperature (N=24)

Hydration

The mean starting hydration level for firefighters who consumed ice water and ambient temperature water was 1.340 (SD=0.001) and 1.330 (SD=0.003), respectively. The mean end hydration for firefighters who consumed ice water and ambient temperature water was 1.340 (SD=0.003) and 1.340 (SD=0.003), respectively. There was no significant difference between ice water start and end hydration levels (*P=0.5*). There was, however, a significant difference between ambient water start and end hydration levels (*P=0.002*). When comparing ice versus ambient start hydration, a significant difference was observed (*P=0.0222).* Ice versus ambient ending hydration had no observed significant difference (*P=0.410).*

Heart Rate

The mean heart rate of firefighters who consumed ice water and ambient water was 95.93 bpm (SD=24.33) and 97.79 bpm (SD=23.20), respectively. A significant difference was observed in ambient versus ice water heart rate (*P<0.001*). The mean maximum heart rate of firefighters who consumed ice water and ambient water was 101.39 bpm (SD=26.70) and 102.65 bpm (SD=25.48), respectively. A significant difference was observed in ice versus ambient water maximum heart rate (*P=0.002*).

Respiratory Rate

The mean respiratory rate of firefighters who consumed ice water and ambient water was 22.21 br/min (SD=6.63) and 22.41 br/min (SD=7.39), respectively, with no observed significant difference (*P=0.095*). The maximum respiratory rate of firefighters who consumed ice water and ambient water was 24.21 br/min (SD=6.91) and 24.30 br/min (SD=8.00), respectively. Again, there was no observed significant difference (*P=0.285*).

Core Temperature

The mean core temperature of firefighters who consumed ice and ambient water was 37.30°C (99.14°F) (SD=0.44) and 37.32°C (99.18°F) (SD=0.42). There was no observed significant difference (*P=0.074*). The maximum core temperature of firefighters who consumed ice and ambient water was 37.32°C (99.18°F) (SD=0.43) and 37.33°C (99.19°F) (SD=0.57), with no observed significant difference (*P=0.081).*

Skin Temperature

The mean skin temperature in firefighters who consumed ice versus ambient water was 35.94°C (96.69°F) (SD=1.01) and 36.09°C (96.96°F) (SD=1.09), respectively, which were significantly different (*P<0.001).* The average maximum skin temperature in firefighters who consumed ice versus ambient water was 36.04°C (96.87°F) (SD=0.99) and 36.17°C (97.11°F) (SD=1.15), respectively, and were also significantly different when compared (*P<0.001).*

Reduction Rates

Reduction rates were calculated to compare ice versus ambient water intake for average core temperatures, average and maximum heart rates, average respiratory rates, and average skin temperatures (Figure 4). Ice versus ambient water average core temperature reduction rates were 0.03 $°C \cdot min^{-1}$ (SD=0.16) and 0.02 $°C \cdot min^{-1}$ (SD=0.02), respectively, and were significantly different (*P=0.009).* Ice versus ambient water average respiratory rate reduction rates were 4.96 $br/min \cdot min^{-1}$ (SD=4.07) and 2.68 $br/min \cdot min^{-1}$ (SD=3.43), respectively, and significantly different (*P=0.003).* Ice versus ambient water average skin temperature reduction rates were -0.028 $°C \cdot min^{-1}$ (SD=0.37) and 0.0318 $°C \cdot min^{-1}$ (SD=1.24), respectively, and no significant difference was found (*P=0.213).* Ice versus ambient water average heart rate reduction rates were 4.96 bpm·min^{-1} and 2.68 bpm·min^{-1}, respectively, and significantly different when compared (*P=0.024).* Ice versus ambient water maximum heart rate reduction rates were 6.43 bpm·min^{-1} and 2.88 bpm·min^{-1}, respectively, and were also significantly different when compared (*P=0.004).* Across all factors, ice water was at least twice as rapid in reducing core temperature, heart rate, and respiratory rate.

Two-Day Paired Study: Ice versus Ambient Water Consumption

On August 26th and 27th, 2019, data were collected on five firefighters. All firefighters were males between the age of 22 and 58. The work conducted each day was at similar locations and durations. Each firefighter performed the same tasks each day and used similar tools. There was no significant difference in weather conditions across days.

Hydration

The mean start hydration for firefighters who consumed ice water and ambient temperature water was 1.341 (SD=0.004) and 1.338 (SD=0.003), respectively. The mean end hydration for firefighters who consumed ice water and ambient temperature water was 1.341 (SD=0.003) and 1.339 (SD=0.003). There was no significant difference between ice water start and end hydration levels in firefighters (*P= 0.449)*, but there was a significant difference between ambient water start and end hydration levels (*P=0.012)*. When comparing ice versus ambient start hydration, there was also an observed significant difference (*P=0.0222).* Ice versus ambient ending hydration had no observed significant difference (*P=0.410).*

Heart Rate

The mean heart rate of firefighters who consumed ice water and ambient water was 103.82 bpm (SD=0.75) and 105.84 bpm (SD=24.05), respectively (Figure 5). A significant difference was observed in ice versus ambient water heart rate (*P=0.002*). The mean maximum heart rate of firefighters who consumed ice water and ambient water was 109.73 bpm (SD=26.37) and 113.00 bpm (SD=27.06), respectively. A significant difference was observed in ice versus ambient water maximum heart rate (*P<0.001*).

Respiratory Rate

The mean respiratory rate of firefighters who consumed ice water and ambient water was 22.72 br/min (SD=6.37) and 20.82 br/min (SD=6.41), respectively (Figure 6). A significant difference was observed in ice versus ambient water users' respiratory rate (*P<0.001*). The mean maximum respiratory rate of firefighters who consumed ice water and ambient water was 24.67 br/min (SD=8.04) and 23.06 br/min (SD=10.14), respectively. There was also an observed significant difference in ice versus ambient water maximum respiratory rate (*P<0.001).*

Core Temperature

The mean core temperature of firefighters who consumed ice water and ambient water was 37.55 °C (99.59°F) (SD=0.51) and 37.60°C (99.68°F) (SD=0.43), respectively (Figure 7). A significant difference was observed in ice versus ambient water respiratory rate (*P=0.002*). The maximum core temperature of firefighters who consumed ice water and ambient water was 37.57°C (99.63°F) (SD=0.28) and 37.61°C (99.70°F) (SD=0.43), respectively. A significant difference was observed in ice versus ambient water maximum core temperature (*P=0.002*).

Skin Temperature

The mean average skin temperature in firefighters who consumed ice versus ambient water was 35.98°C (96.76°F) (SD=1.06) and 35.94°C (96.69°F) (SD=1.09), respectively, and were not significantly different *(P=0.157).* The maximum skin temperature in firefighters who consumed ice versus ambient water was 36.09°C (96.96°F) (SD=1.05) and 36.16°C (97.08°F) (SD=1.01), respectively, and were not significantly different when compared *(P=0.063).*

Discussion

Government agencies and fire departments nationwide are being forced to take notice of the impact wildfires have on the health and welfare of the firefighters. Wildfires are becoming larger, lasting longer, and getting more destructive (CAL FIRE, 2019). More and more firefighters will be called to respond to these dangerous incidents, enduring hazardous exposures, cardiovascular strain, and intense thermal stress. The results of this study provide significant insights into the complex relationships that core body temperature, heart rate, respiratory rate, and skin temperature have in response to these complex working environments and assess the potential value of ice water to help mitigate the physical demands of firefighting.

All Firefighters

When analyzing trends in heart rate, respiratory rate, skin temperature, and core temperature in all firefighters, we observed several statistically significant relationships. Average/maximum heart rate versus respiratory rate, average/maximum core body temperature versus heart rate, average/maximum core body temperature versus skin temperature, and average/maximum skin temperature versus heart rate all displayed positive linear relationships. This is consistent with literature, where it is well documented that heart rate drives respiratory rate and is directly affected by skin and core body temperature (Schipke et al., 1999; Fortney et al., 1985). As internal core temperatures increase, heart rate and respiratory rate increase to promote temperature reduction through thermoregulation (Candas et al., 1983).

In our study, concerns regarding the thermal condition of firefighters were confirmed. Respiratory rates, core temperatures, heart rates, and skin temperatures all exceeded safe limits, demonstrating that firefighters endure conditions well beyond what the human body was meant to withstand. However, it is important to recognize that we never recorded the most extreme values firefighters likely endure. Given our study constraints, we were unable to collect data on firefighters during initial attack or from those directly attacking the most dangerous parts of the fire. Therefore, the risks and exposures we observed here are likely underestimating the actual stresses endured by firefighters during most incidents.

This highlights the need to identify measures to reduce thermal stress and occupational exposures. Lowering core temperatures has a cascading effect by lowering heart rates and respiratory rates. While these relationships are complex and interdependent, if you can reduce abnormally high heart rates, you can reduce cardiovascular stress (which leads to higher coronary calcification and atrial stenosis) and thrombus formation (which leads to ischemia and heart attacks) (Pillutla et al., 2012). Regular water consumption is vital to avoid dehydration, but as we observed, it can also serve as an important mitigation tool for reducing thermal stress and respiratory exposures.

Ice versus Ambient Water Effects

Firefighters that consumed ice water maintained safer and more stable hydration levels, ending their shift well hydrated. Firefighters that consumed ambient temperature water ended their shift closer to dehydration.

Water consumption is also known to help mitigate heart rate (Duvillard et al., 2004). Ice water has been shown to keep average and maximum heart rates significantly lower compared to ambient (Brown et al., 2005; Chiang et al., 2010). We were able to observe a significant difference between ice and ambient water average/maximum heart rate as well as average/maximum skin temperature, where firefighters who consumed ambient temperature water had higher heart rates and skin temperatures on average. This is likely caused by the body working harder to increase evaporative cooling to maintain the body's homeostasis (Xu et al., 2016). It is important to note that although there was no significant difference in firefighters who consumed ice versus ambient water, skin temperatures were slightly higher (by 0.2°C) in those that consumed ambient water. Additionally, there was no observed difference between the respiratory rates of individuals based on water temperature. This is likely explained by the diversity and individuality of breathing patterns (Benchetrit et al., 2000; Bruce et al., 1996; Shea et al., 1987). This may have had an influence in our study and explain why ice respiratory rates were higher.

Other studies have examined ice water as a method for core temperature reduction and evaluated these reduction rates over time (Brearley et al., 2011; Brearley, 2016; Giesbrecht et al., 2007; McEntire et al., 2013; Walker et al., 2014). In these studies, researchers had control of the actions/activities of the firefighters and required them to pause to consume water to observe the effects of ice water on core temperature reduction. Although it is interesting to observe these effects in a controlled laboratory setting, it is unrealistic of what firefighter's experience in the field. In this study, firefighters were allowed to consume water *ad libitum* and continue their operational assignments as usual. Each reduction rate was calculated by minute from the point of where water intake was identified on graphs (usually a peak in the data) to where reduction had noticeably stopped (the bottom/base of the data) (Figure 8). This provided a real-time snapshot of how water affected each physiological factor. In addition, our study produced reduction rates for heart rate, respiratory rate, and skin temperature. This allowed us to see how water intake and water temperature affected physiological responses at the point of consumption.

Water consumption (regardless of temperature) contributed to a significant reduction in all factors measured. Ice water consumption stimulated two to three times more rapid reductions across all factors measured. Increased heart rates over extended periods of time can result in hypertension and increased blood pressure (Conway et al., 1984). Additionally, sustained high heart rates over time can lead to a weakening of heart muscles (tachycardia induced myopathy), which can cause premature heart failure or sudden cardiac death (Nerheim et al., 2004). By reducing heart rate peaks quickly, they can be normalized to safer levels and reduce these risks. Likewise, high ambient temperatures can increase core body temperature and lead to increased dehydration, damaged organs, and increased chance of heat stroke or illness (Jardine et al., 2007). Reducing core body temperatures to safe levels quickly reduces the effects that high temperature environments have on the human body.

Individual Firefighter Analysis

In our two-day paired study of firefighters who alternated between drinking ice and ambient water, hydration levels mirrored the same conditions when looking at the overall population we studied. Firefighters who consumed ambient temperature water were closer to dehydration by the end of the day.

Average/maximum core body temperature in firefighters who consumed ice water were significantly reduced, helping to keep the levels closer to "normal" when compared to ambient water consumption. Additionally, sharper and more sustained decreases were associated with ice water intake versus ambient water. Across all ambient water treatments, there was an observable increase in core temperature by the end of the day from thermal buildup. However, all ice water treatments remained relatively stable throughout the shift and even decreased toward the end. In most cases, skin temperature closely followed core temperature trends in ice and ambient water. The maximum skin temperatures recorded by minute were significantly lower in firefighters who consumed ice water.

There was a significant difference in average/maximum respiratory rate in ice versus ambient temperature water consumption, where ice had a higher respiratory rate. This may be explained by a cold shock response, similar to stepping into an ice bath (Stocks et al., 2004). This causes respiratory rate to increase temporarily upon the initial consumption of water and subside shortly after. This anomaly does not mean that water consumption (especially ice water) is not beneficial at reducing respiratory rates. It was quite the opposite. When looking at respiratory response to water use, an overall reduction occurred post consumption.

Average/maximum heart rate in firefighters who consumed ice water were significantly reduced compared to ambient water. Likewise, heart rates were generally more stabilized in firefighter ice water responses and showed more dramatic reductions overall. Regardless of temperature, water consumption was shown to have a significant effect on our factors of interest. Ice water had a larger mitigation and reduction effect overall, while ambient water showed lower effects (if any).

Conclusion

This study demonstrated that wildland firefighters experience extreme physiological strain while operating in wildfire environments including elevated heart rates, respiratory rates, skin temperatures, and core body temperatures often exceeding safe limits. These findings reinforce the serious occupational health risks wildland firefighters face during wildfire suppression activities and suggest that the physical stress observed in this study may underestimate the true severity experienced during more intense, real-world fire operations.

Our findings also support the importance of hydration as a practical mitigation strategy in the field. While all water consumption contributed to reductions in physiological stress, ice water consistently produced faster and greater reductions in heart rate, core temperature, and skin temperature compared to ambient temperature water. Firefighters who consumed ice water maintained more stable hydration levels during their shifts. These results suggest that ice water may be a simple but effective intervention to reduce thermal strain, cardiovascular stress, heat-related illness, and potentially reduce overall exposures on wildland and WUI fires.

Overall, this study highlights the need for stronger occupational health protections for wildland firefighters. As wildfire incidents continue to increase in frequency, duration, and severity, protecting firefighter health and safety must remain a funding and policy priority. The evidence supports responsible staffing levels. Even more, specific safety protocols must be an intrinsic part of systemic infrastructure. Future studies should continue exploring mitigation strategies that can be implemented during wildfire operations to reduce physiological stress and improve firefighter health.

Declaration of Funding

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Acknowledgments

The authors would like to thank the CAL FIRE firefighters who volunteered for this study. This work could not have been done without their participation.

THE WILDFIRE
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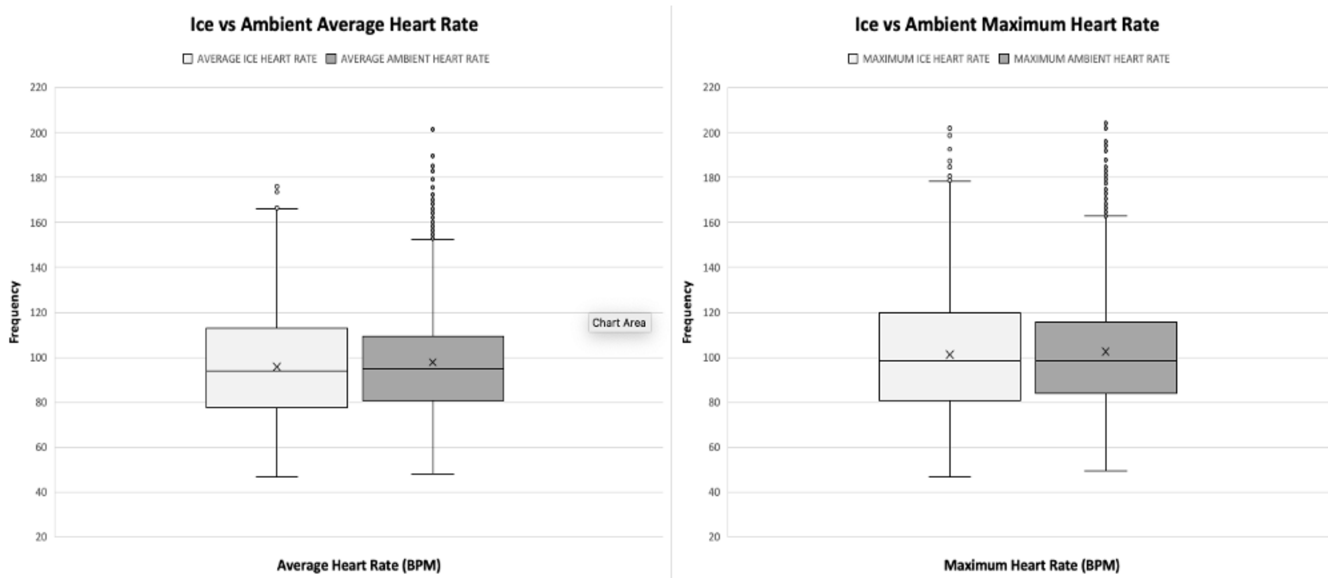


Figure 1. Ice vs. ambient water average and maximum heart rates (bpm).

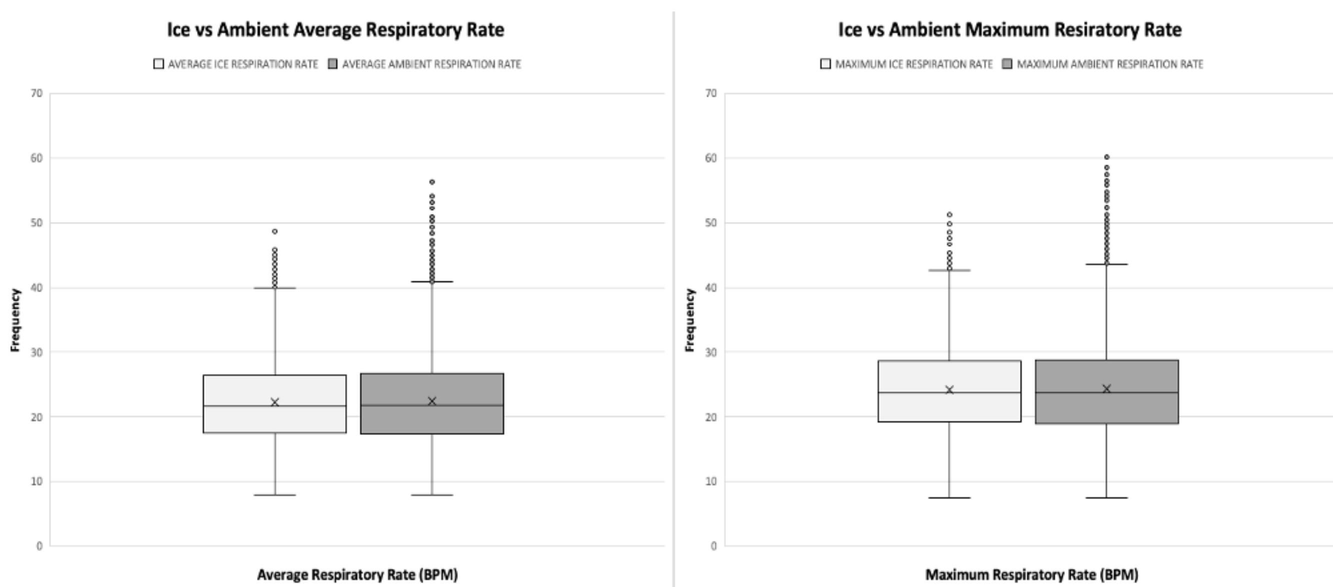


Figure 2. Ice vs. ambient water average and maximum respiratory rate rates (br/min).

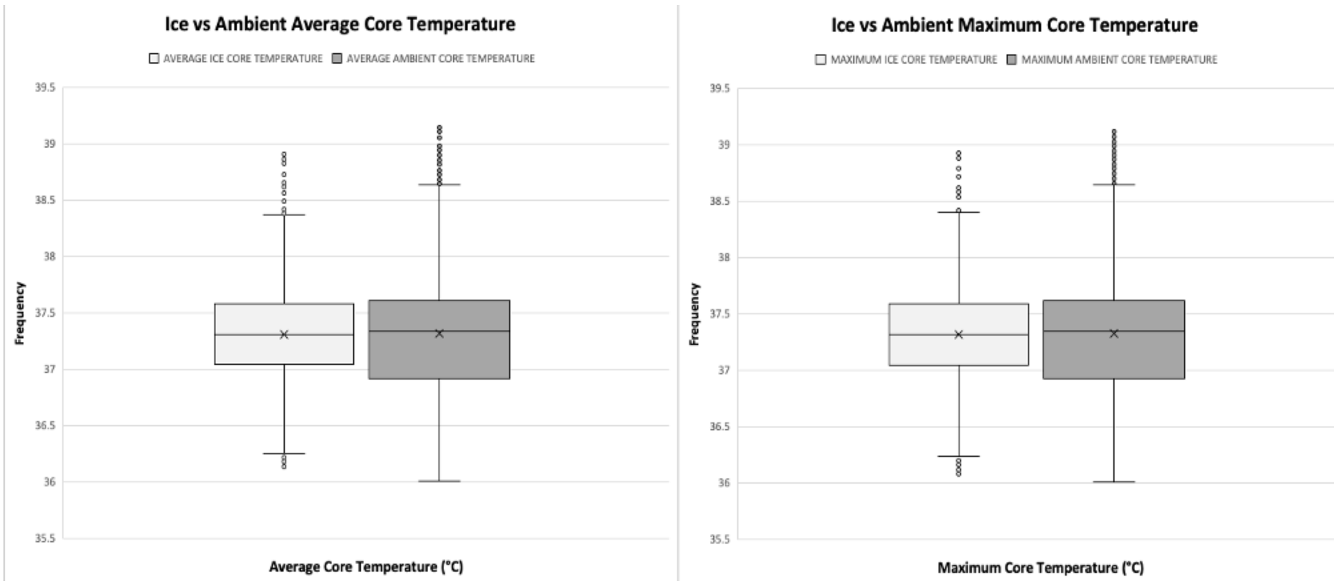


Figure 3. Ice vs. ambient water average and maximum core temperatures (°C).

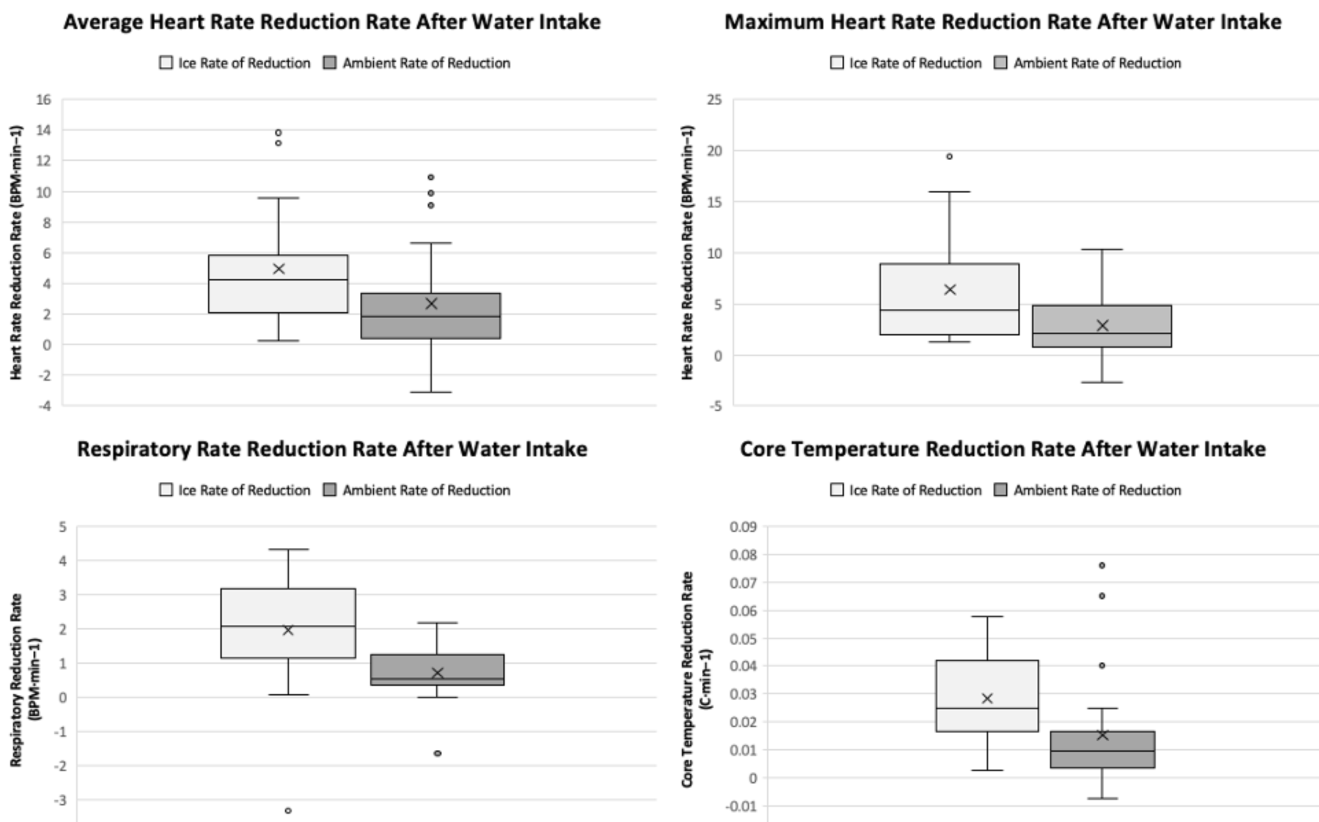


Figure 4. Ice vs. ambient water intake reduction rates for average heart rate, maximum heart rate, average respiratory rate, and average core temperature.

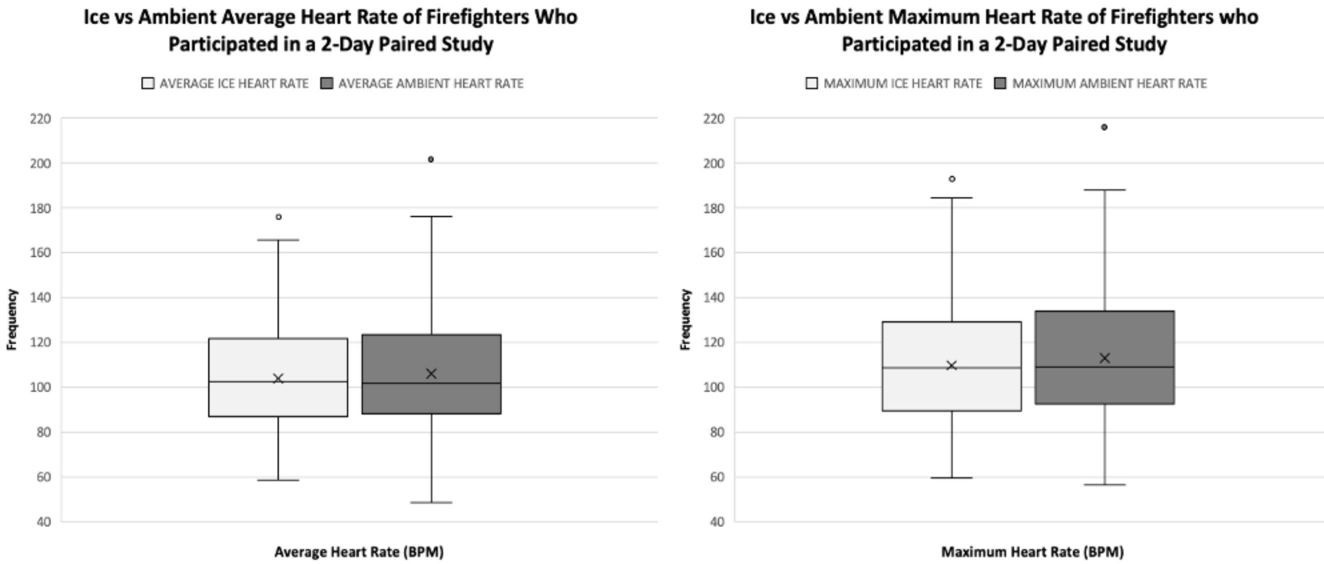


Figure 5. Average heart rate and maximum heart rate in a two-day study where firefighters consumed ice water one day and ambient water the other. There was a significant difference in both average heart rate and maximum heart rate (P=0.002; P<0.001), where ambient heart rate was greater than ice heart rate.

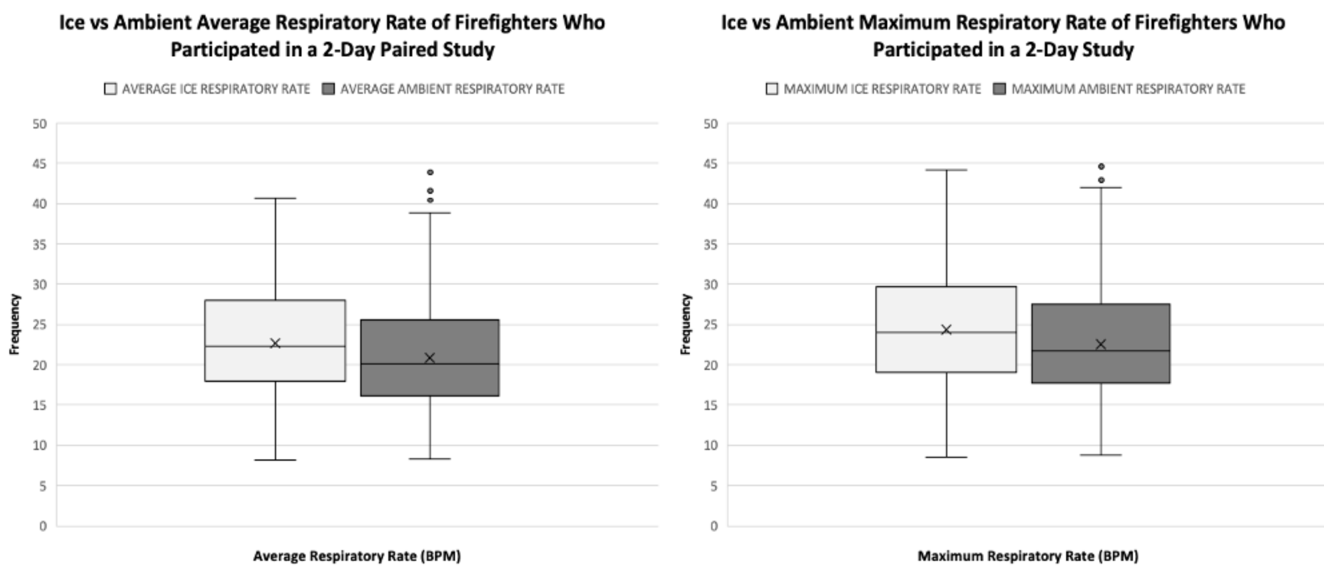


Figure 6. Average respiratory rate and maximum respiratory rate in a two-day study where firefighters consumed ice water one day and ambient water the other. There was a significant difference in both average respiratory rate and maximum respiratory rate (P<0.001), where the respiratory rates of firefighters who consumed ice water were higher than those that consumed ambient temperature water.

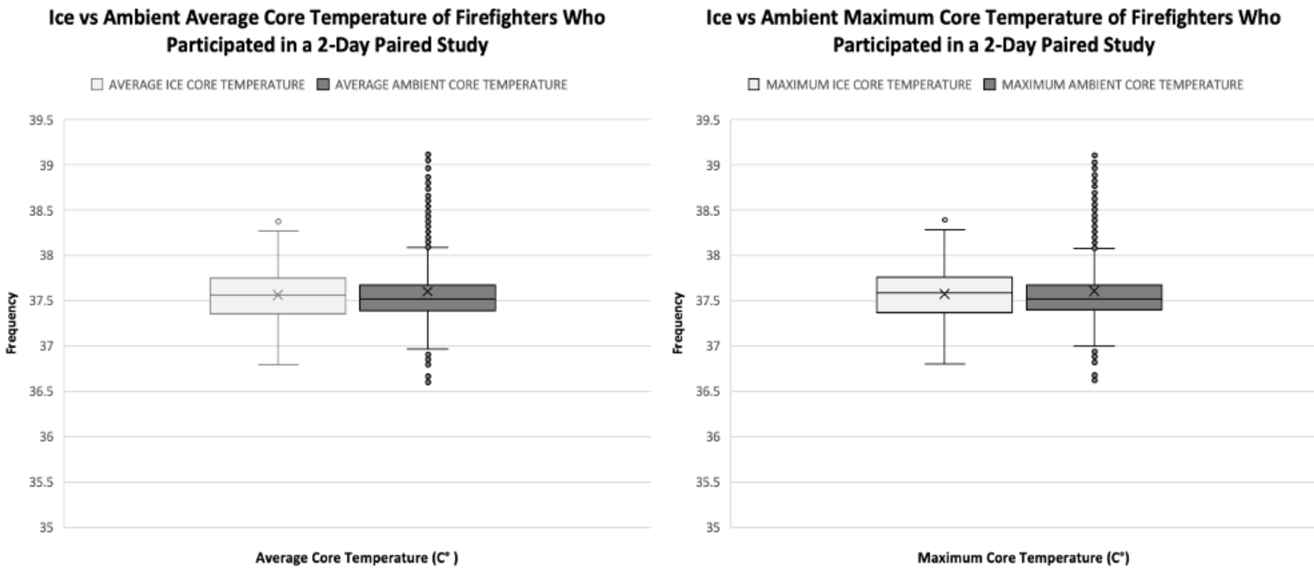


Figure 7. Average core temperature and maximum core temperature in a two-day study where firefighters consumed ice water one day and ambient water the other. There was a significant difference in both average core temperature and maximum core temperature (P=0.002; P<0.002) where ambient core temperatures were greater than ice core temperatures.

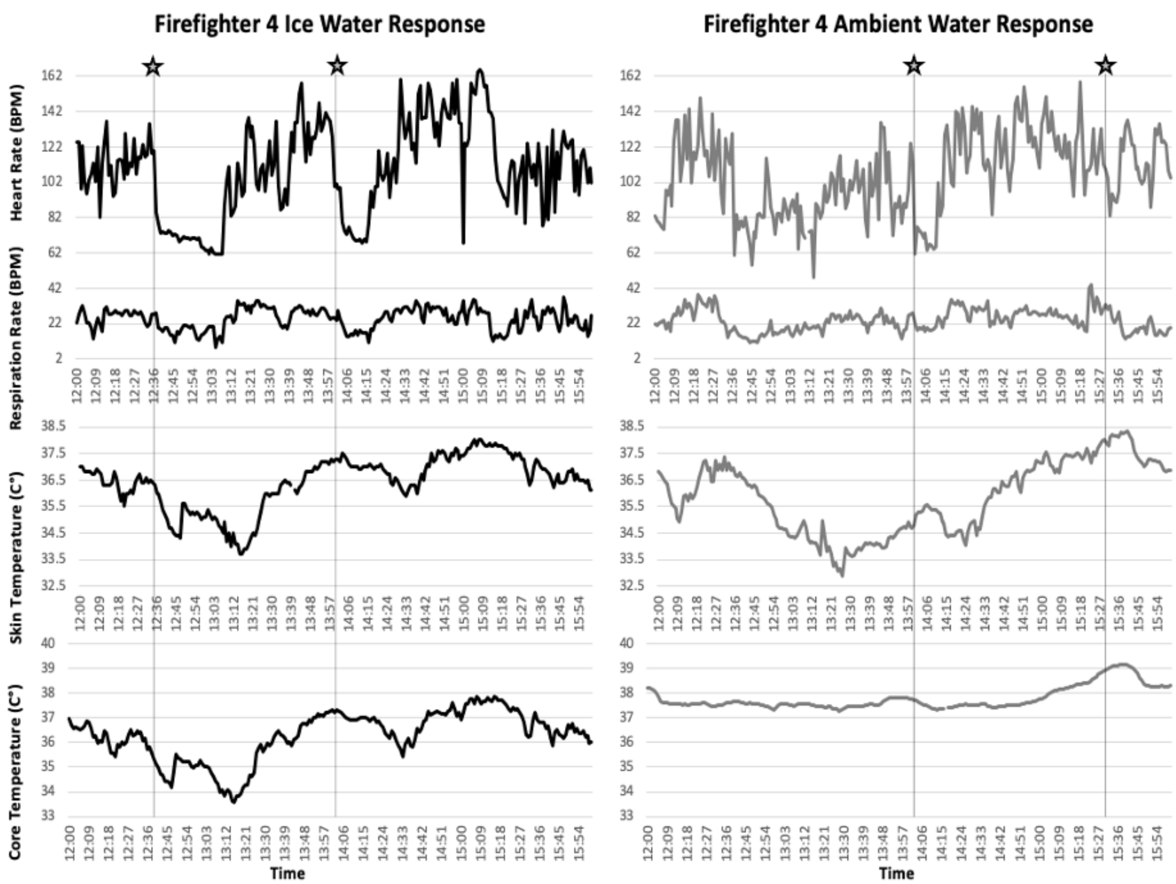


Figure 8. Comparison of ice vs. ambient water intake effect on one participant's heart rate, respiratory rate, skin temperature, and core temperature during peak work times (12:00pm to 4:00pm) over the course of the two-day paired study. Stars indicate a point of water intake.

Hydration

Scientific discovery has little value unless it reaches the firefighters who can benefit from it. While peer-reviewed publications establish the scientific evidence, translating that evidence into operational practice requires targeted education and outreach. Station posters are a simple but highly effective implementation strategy because they place evidence-based recommendations directly into fire stations where firefighters make daily operational decisions. The companion hydration poster developed from this study distills the research into practical guidance that firefighters can immediately apply in the field. By reinforcing best practices for hydration and heat stress management, these materials help translate research into behavioral change, with the potential to reduce heat-related illness, lessen cardiovascular strain, and improve firefighter safety and performance.

To encourage broad implementation of these findings, a full-size version of the hydration poster is included in this issue of the Journal of the Wildfire Conservancy and may be reproduced and displayed in fire stations, training facilities, rehabilitation areas, and other firefighter work environments. The Wildfire Conservancy is committed to translating scientific research into practical tools that improve firefighter health, safety, and operational effectiveness. Additional educational resources, research publications, training materials, and implementation tools are available at http://www.WildfireConservancy.org. Organizations interested in obtaining additional materials, collaborating on research, or implementing firefighter health and safety initiatives are encouraged to contact the Wildfire Conservancy at mailto:info@wildfireconservancy.org

ICE VS AMBIENT WATER

Temperature's Effect on Firefighter Hydration, Core Temperature, Heart Rate, and Skin Temperature

THE WILDFIRE CONSERVANCY

Working on wildland and urban interface fires can involve extreme environmental and physiological conditions. Firefighters regularly experience sustained and unsafe peak heart rates above recommended limits, maintain dangerously high core body temperatures, rapid respiratory rates, and high levels of dehydration. Not surprisingly, sudden cardiac death is the leading cause of on-duty fatalities.1

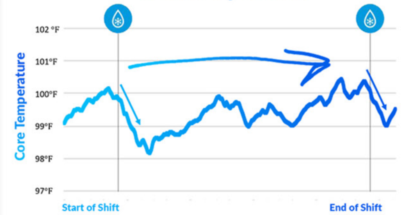
Drinking fluids is important for replenishing electrolytes and maintaining safe hydration levels throughout the day, especially when doing hard, physical work in hot and humid conditions. OSHA encourages workers to drink a liter of water every hour (about one cup every fifteen minutes).2

Drinking water can reduce cardiovascular stress and mitigate rising core body temperatures. It is important to drink enough water to help avoid heat-related injuries and reduce thermal cardiac stress. This can be done through a prescribed hydration regime or through ad libitum drinking (drinking when thirsty).

There is a distinct advantage to drinking colder water. Any water is good water, but iced water is better at reducing core temperatures and heart rates than ambient temperature water and is more protective against cardiac stress. Our recent study demonstrated that firefighters who drank iced water (32°F) had lower heart rates and core temperatures than firefighters who drank ambient temperature water (75°F) across multiple types of duties including trainings, controlled burns, fuels reduction, and wildfire incidents.

- Were less likely to be dehydrated at the end of the shift
- Were more likely to maintain safer levels of hydration throughout the shift
- Had lower heart rates
- Had lower skin temperatures
- Were able to return to "normal" heart rates and core temperatures faster after hard work
- Were able to maintain more "normal" and "stable" core temperatures and heart rates throughout their shift

Relatively Stable



Gradually Increasing

When comparing Iced vs Ambient water consumption on individual firefighters across multiple days we noted several important differences:

1. The core body temperature of firefighters who consumed iced water (32°F) were dramatically reduced, while those that drank ambient water (75°F) gradually increased their core temperatures throughout the day.
2. Iced water consumption helped reduce heart rates and respiratory rates significantly more than ambient water.
3. This has potential implications for mitigating exposures from smoke exposure on wildland and urban interface fires.

Conservancy Research

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To access the full report please visit:
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CULTURAL BURNING IMPACTS ON TRIBAL ECOSYSTEMS

Christopher Wetzel

Abstract

This paper provides a literature review of the impacts that cultural/tribal burning can have on tribal lands and ecosystems. This project examined past practices of Indigenous burning and the benefits that it had on the land, along with the use of cultural burning by tribes in modern times. Also included is an assessment of the possible benefits government and land management agencies could receive by including cultural burning and tribal knowledge as part of their prescribed burn programs.

Keywords: cultural burning, tribal land, prescribed burns

Background

Indigenous people across North America have used fire to manage their landscapes and cultural resources for thousands of years (Adlam et al., 2022). This method, commonly referred to as cultural burning, was utilized as part of a place-based ecological and spiritual practice (Martinez et al., 2023). It was both sophisticated and refined over what some estimate to be thousands of years of practice. The Indigenous people of the North American continent simply did not burn the land in the way many fire suppression agencies do today, but rather used fire as a tool to increase the quality and quantity of desired plant resources, maintain healthy landscapes for all species, fulfill a stewardship obligation, and to maintain the tribes' cultural identities (Adlam et al., 2022).

Indigenous people also learned how to utilize fire in a wildland urban interface (WUI) setting. Many think of WUI fires as a recent problem associated with extensive developments of communities in fire-prone areas, but the WUI is nothing new to Native tribes both past and present. In the fire-prone, dry conifer forests of western North America for example, Native American settlements existed in WUI-like conditions since the adaptation of agriculture and the emergence of village life (Roos et al., 2021). In the Jemez Mountains located in northern New Mexico, the Hemish tribe lived for more than 500 years in the ponderosa pine forests using low-severity surface fires to protect their communities (Roos et al., 2021). This knowledge has continued throughout tribal timelines and is still used by many tribes within the continental United States and Canada today (Christianson et al., 2022).

Many land management agencies utilize prescribed burning as a means of removing fuels to combat fire hazards within WUI communities. The primary objectives of prescribed burns within land management agencies are focused on fire risk reduction with an emphasis on acreage and fuel reduction to minimize catastrophic wildfires. This land management method is effective but primarily focuses on hazard reductions, whereas cultural burning is used as a multi-faceted tool by Indigenous people. It is not just putting fire on the ground. Indigenous people apply fire to the land to renew plants and watersheds for food, wildlife habitats, medicine, basketry, and other cultural uses (Kerlin, 2020).

The benefits of cultural burning can be applied by land management agencies on non-tribal lands with careful use, consideration, and guidance from tribal members. Western fire managers and scientists have called for this more balanced approach as it pertains to the land's relationship to fire (Adlam et al., 2022). The Keepers of the Flame project is a collaboration between fire practitioners from multiple California tribes, land management agencies, community organizations, and a team from the University of California, Davis (UC Davis) consisting of faculty and graduate students (Adlam et al., 2022). A workshop in January and February of 2020 sought to highlight the benefits of Indigenous fire management and created opportunities to exchange valuable knowledge and experience among tribal practitioners to generate momentum towards supporting cultural burning as part of fuels management practices (Adlam et al., 2022).

Research Question

In both historical context and present-day applications, what are the benefits to the use of cultural burning on tribal lands and ecosystems, and how can land management agencies work together with tribes to utilize this tactic as a supplement or alternative to traditional prescribed burn methods?

Methods

Research was done through the California State University San Marcos online library and consisted primarily of scholarly journals. Keywords and phrases used for this research included cultural burning, Native American prescribed burns, Indigenous burning practices, Indigenous cultural burning importance, and Native American fire management. The scholarly journal article publications included the *Proceedings of the National Academy of Sciences*, *Science Direct*, *Fire Science and Management*, *Society and Natural Resources*, *Association of Fire Ecology*, and *Facets*. While there were many journal articles associated with cultural burning, the scholarly journal publications I chose to include provided data and research on past and present cultural burning practices, which were key components for this research paper.

Data from the research included:

- Testing charcoal samples from past Indigenous tribal settlements from 1200 – 1900 AD
- Statistical comparison of four key fire metrics
    - Area burned, fire size, intensity, and tree mortality
- Tables of both flora and fauna species that were managed with Indigenous burning practices in the boreal forest located in Canada
- Basketry stem and hazelnut shrub production used by tribes for basket weaving
- Case studies from the Keepers of the Flame project that included collaboration between fire practitioners and several tribes from California, along with students and teachers from UC Davis
- A table of how non-tribal entities could help support cultural burning

An abstraction table was made and included study design, study population and setting, sample size, data collection, analysis, intervention, outcomes measured, results, limitations, conclusions, and a quality rating. Most of the data that were used for this research came from scholarly journals that had a publication date from no more than five years ago. Historical data of fire use among tribes in North America were also relevant to this research to show how low-intensity cultural burns have been part of the landscape for millennia and have resulted in no known mega-fires. The research highlighted several geographical areas that indigenous people currently occupy and have occupied historically that remain dependent on fire to achieve ecological and social goals (Long et al., 2021).

Results

This study researched the benefits of cultural burning among Indigenous tribes in both historical context and current fire applications. Historically, there was ample evidence and data to support the idea that Indigenous tribes used cultural burning within and around tribal communities for over a millennium. Native American fire management is shown in Figure 1 using charcoal records from six tribal community localities that indicated evidence of enhanced erosion accompanied by enhanced fire activity. Charcoal concentrations were at their highest levels during the last 900 years, coincident with Hemish occupation of the area. Peak charcoal levels also coincided with initial settlement of the area, indicating the probability of tribal use of fire to establish and clear agricultural landscape for incoming Hemish tribal communities (Roos et al., 2021). These sedimentation rates and radiocarbon dates for locations where the Hemish tribe were known to have existed indicated major agricultural settlements in the uplands of the Jemez Plateau. Sedimentation histories for the past 2,000 years are also shown in Figure 1 (Roos et al., 2021).

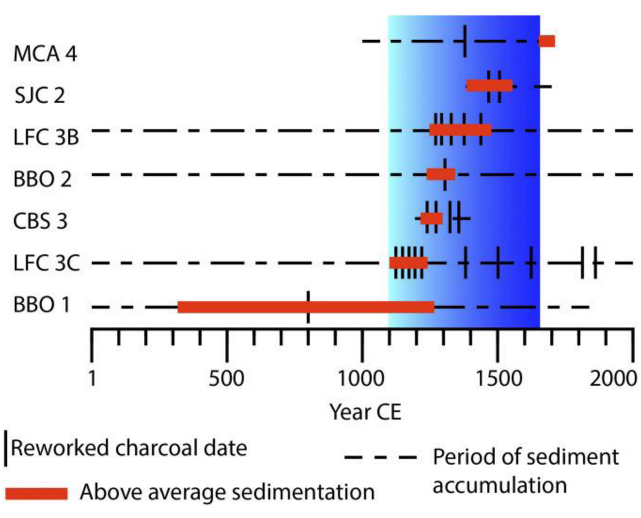

Figure 1. Plot of erosion and sedimentation histories for the past 2,000 years for six dated stratigraphic sections within or adjacent to the Hemish agricultural footprint including Banco Bonito (BBO), Cebollita Springs (CBS), Lake Fork Canyon (LFC), Monument Canyon (MCA), and upper San Juan Canyon (SJC). The graded blue area indicated the major period of agricultural settlement in the uplands of the Jemez Plateau between 1100 and 1650 CE (Roos et al., 2021).

In Figure 2, vegetation and fire modeling of null or no human input and intensive land-use scenarios were compared. The models indicated that areas burned increased with Hemish fire management (Figure 2A). An increase of ignitions showed fire sizes were significantly smaller under Hemish fuel management (Figure 2B). This increased fire frequency and fire size along with wood harvesting meant fire intensity and tree mortality were significantly lower during this same time frame (Figure 2C & D). Maintenance of the cultural landscape after 1300 CE indicated the reduction of fire intensity and fire size in the agricultural landscape, but the Hemish expanded fire use to larger parts of the Jemez Mountains to support foraging and ritual activity. Population collapse and rebound of fuels shown in the 17th century favored surface fires and reduced patch heterogeneity that was previously supported by Native American fire management 500 years prior (Roos et al., 2021).

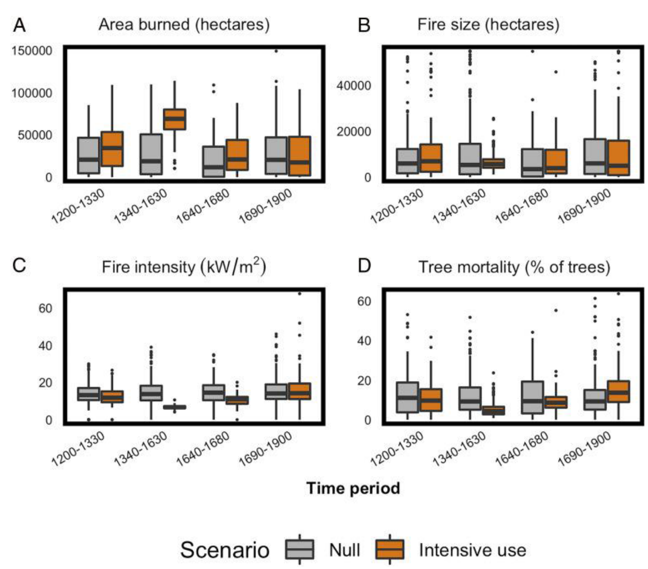

Figure 2. Dynamic vegetation and fire modeling of null and intensive land-use scenarios. Modeling indicated that area burned increased with Hemish fire management (Roos et al., 2021).

In addition to land management, cultural burning among the Karuk and Yurok tribes supported the maintenance and revitalization of northwestern California Indian basket weaving by reducing the costs associated with basketry stem gathering (Marks-Block et al., 2021). Figure 3 shows that cultural burning optimized the production of hazelnut basketry stems as a product of short fire intervals. Cultural burning directly supported the production of basket weaving within the Karuk and Yurok tribes in Northern California who depended on them as a source of income (Marks-Block et al., 2021). As shown in the data, higher basketry stem gathering rates were greater in cultural burn areas and left little incentive to gather in unburned areas.

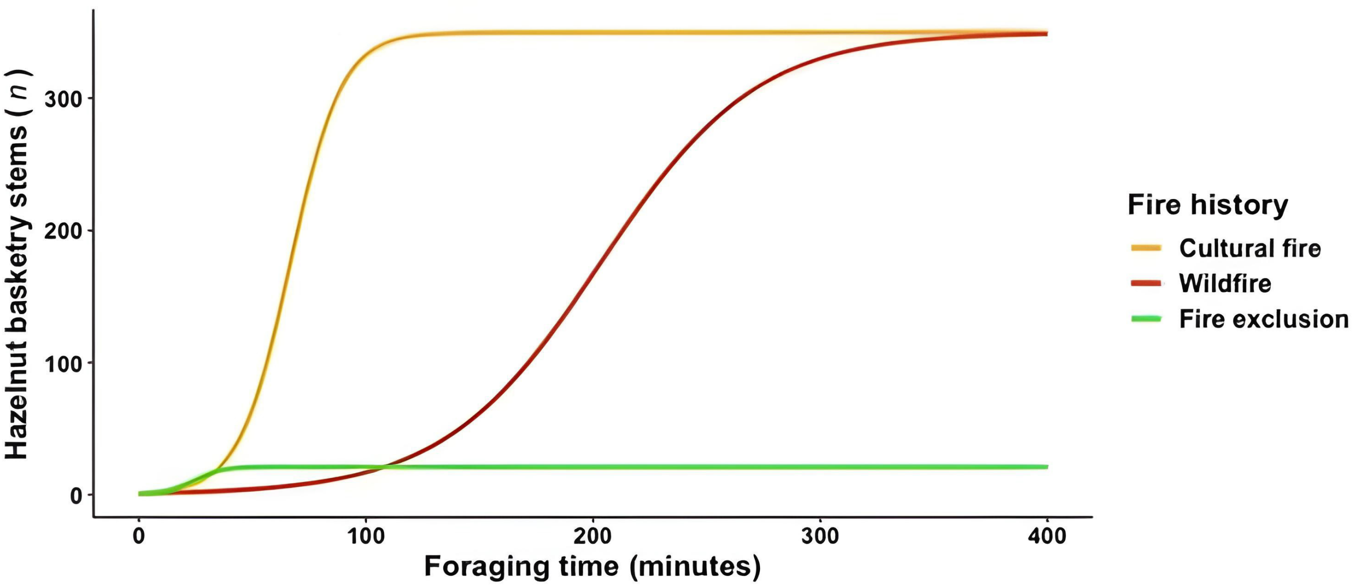

Figure 3. Hazelnut basketry stem gathering rates and fire history for the Karuk and Yurok territories in Northern California from 2015 to 2019. Foraging times included both travel and gathering times for harvesters. Gathering rates (n) were based on average rates observed in 22 cultural burn areas, 4 wildfire areas, and one fire-excluded area (Marks-Block et al., 2021).

Tribal uses of fire also include the management of plant and animal species within the tribal ecosystem. Table 1 shows a partial representation of over three dozen species managed within the boreal forest in Canada. These species ranged from vascular plant species and insects to a variety of mammals and game species (Christianson et al., 2022). The table indicated tribal management using cultural burning promoted the productivity of native plant species within the boreal forest. Cultural Keystone Species (CKS) of the tribes in the boreal forest are considered instrumental in shaping the cultural identity of the tribal people. These communities have used fire to promote the populations of CKS species in a variety of ways (Christianson et al., 2022).

Table 1. Species that are known to have been managed with Indigenous burning practices in the boreal forest (Christianson et al., 2022).

Table 1 Species that are known to have been managed with Indigenous burning practices in the boreal forest

Common name	Species	Indigenous Nation	Indigenous name	Geographical location	Reasons for burning
Lowbush blueberry; Dwarf blueberry	*Vaccinium angustifolium; V. caespitosum*	Anishnaabe; Gitksan and Wet'suwet'en	yintimī? (W) 'myahl(G) miinan (A)	Northwestern Ontario; Northwestern Alberta, Northwestern British Columbia	Creation, maintenance and renewal of productive berry patches, including enhanced berry patch productivity (number of berries), increased berry sweetness, increased size of berries
Velvet-leaved blueberry; Oval-leaved blueberry	*Vaccinium myrtilloides; V. ovalifolium;*	Anishnaabe; Gitksan and Wet'suwet'en	dïndze (W) miinan (A)	Northwestern Ontario; Northwestern British Columbia	Creation, maintenance and renewal of productive berry patches, including enhanced berry patch productivity (number of berries), increased berry sweetness, increased size of berries
Black huckleberry	*Vaccinium membranaceum*	Gitksan and Wet'suwet'en; Nisga'a	digï (W) simmaa'y or sim'maa'y (G)	Northwestern British Columbia	Creation, maintenance and renewal of productive berry patches, including enhanced berry patch productivity (number of berries), increased berry sweetness, increased size of berries, control of pests
Soapberry	*Shepherdia canadensis*	Gitksan and Wet'suwet'en	niwis (W)	Northwestern British Columbia	Creation, maintenance and renewal of productive berry patches
Bilberry	*Vaccinium uliginosum L., V. boreale*	Innu	nissiminanakashi (I)	Labrador	Increased berry production
Mountain cranberry; Lingonberry	*Vaccinium vitis-idaea L*	Innu	uishatshimin(an)akashi (I)	Labrador	Increased berry production
Wild strawberry	*Fragaria vesca*	Dene; Cree	įdziáz (D) otêhimin (C)	Northeastern British Columbia	Increased berry production
Saskatoon serviceberry	*Amelanchier alnifolia*	Dene; Cree	k'įnjíe (D) misâskwatômin (C)	Northeastern British Columbia	Increased berry production
Raspberry	*Rubus idaeus*	Dene; Cree	dakáljíe (D) ayôskan (C)	Northeastern British Columbia	Increased berry production
Riceroot	*Fritillaria camschatcensis*	Gitksan and Wet'suwet'en	c'inkalh (W)	Northwestern British Columbia	Possible burning of floodplain garden sites to enhance bulb production

Table 1 (continued)

Common name	Species	Indigenous Nation	Indigenous name	Geographical location	Reasons for burning
Elk	*Cervus canadensis*	Dene. Cree	dzendhił (D) wâwâskesiw (C)	Northeastern British Columbia	Stimulate new shoot growth as a source of food; creation of productive forage habitat
Horse (wild and domesticated)	*Equus ferus caballus*	Dane_zaa, Dene, Cree	tłęchuk (DZ) łįchok (D) mistatim (C)	Northwestern Alberta. British Columbia	Production of forage
Mink	*Vison vison*	Multiple Nations	Ębaa (DZ)	Northwestern Alberta	Attract animals to traplines
Weasel	*Mustela spp.*	Multiple Nations	taadle (DZ)	Northwestern Alberta	Attract animals to traplines
Fisher	*Pekania pennanti*	Multiple Nations	nǫhgaashe (DZ)	Northwestern Alberta	Attract animals to traplines
Marten	*Martes americana*	Multiple Nations	thah (D) Uuschęą (DZ)	Northwestern Alberta	Attract animals to traplines
Lynx	*Lynx canadensis*	Multiple Nations	nǫdaa (DZ)	Northwestern Alberta	Attract animals to traplines
Beaver	*Castor canadensis*	Multiple Nations	tsá (D) tsaa? (DZ)	Northern Alberta	Stimulate new shoot growth as a source of food in marshes, sloughs and along lakeshores
Fox	*Vulpes vulpes*	Multiple Nations	naghídhe (D) yuuse (DZ)	Northern Alberta	Attract animals to traplines
Ptarmigan	*Lagopus* spp.	Innu	uapineu (I)	Labrador	Create habitat
Rabbit	*Lepus* spp.	Multiple Nations	gah (D) Gaah (DZ)	Northern Alberta	Stimulate new shoot growth as a source of food
Mouse	*Mus* spp.	Dene	dlúne (D) Dlwęą (DZ)	Northern Alberta	Stimulate new shoot growth as a source of food
Wolf	*Canis lupus*	Dane_zaa	ch'ǫne? (DZ)	Northern Alberta	Attract animals to traplines
Deer	*Odocoileus* spp.	Multiple Nations	yáhtųe (D) yaatune (DZ)	Northern Alberta, Northeastern British Columbia	Stimulate new shoot growth as a source of food; creation of productive forage habitat; attract animals to hunting areas

Lastly, collaboration between land management agencies and tribal entities to adapt this knowledge to prescribed burning was researched. A Keepers of the Flame workshop was held in Madera, California, hosted by UC Davis. The workshop included tribal and non-tribal entities such as university researchers, public and land management agencies, funding agencies, organizations, and policymakers. The workshop focused on ways to support cultural burning and establish collaborations between government agencies and tribes to reform land management and implement prescribed and cultural burning. Table 2 shows examples of ways that government and non-government entities alike can support cultural burning. Increased interest in Native American cultural burning techniques was evident from the diverse audience at these workshops. Attendees included fire and land management agencies, environmental organizations, climate and fire scientists, historians, archaeologists, foresters, and air quality regulators (Adlam et al., 2022).

Table 2. Examples of ways to support cultural burning (Adlam et al., 2022).

Entity	Ways to support cultural burning
University researchers	• Investigate ecological and policy issues specific to cultural burning (eg. clarify sovereign right to burn; develop models for ethical research practices and data management; identify prescriptions for managing invasive species with fire) • Facilitate collaborative, capacity-building projects focused on cultural burning through Participatory Action Research by undergraduate and graduate students • Support community-based projects designed by Native American students, including ethnographic and archival research on historic cultural burning practices • Through collaborative experimentation, develop ways of adapting cultural burning practices to ecological changes and climate change • Develop models for predicting impact of climate change on cultural species and changes in fire weather and optimal burn windows
Public land management agencies	• Use collaborative agreements to support Tribal access and management on public lands • Create designated cultural management areas for family-based burning • Restore forest structure in these areas to allow for low-severity cultural burns • Co-produce knowledge through adaptive management and monitoring • Return land to tribes
NGOs, Cooperative Extension	• Educate policymakers, land managers and the public to build social license and support partnerships • Conduct educational outreach through pamphlets, signage, films and social media • Create cultural burn demonstration areas managed by Indigenous practitioners • Convene agency and Tribal representatives to facilitate partnership building • Provide support: technical (eg. design of fuel breaks, invasive species management), planning (eg. mapping, decision-support tools), logistical (eg. equipment) • Develop curriculum that includes Indigenous perspectives and culture • Support land restitution efforts and cultural easements that guarantee long-term access and management to cultural resources on private land • Share examples of successful collaborations
Funding agencies and organizations	• Clarify how existing grant opportunities can apply to cultural burning • Change the way grant applications are reviewed to account for the specific parameters of cultural burning (eg. per acre funding may be inadequate for small but culturally meaningful burns) • Prioritize projects that include Tribal leadership and/or meaningful Tribal involvement
Regulators/policymakers	• Address barriers to prescribed burning, including liability concerns, air quality issues, and permitting burden • Learn about and address issues specific to cultural burning • Allocate funding for Indigenous-led forest restoration/fire crews

Discussion

Current research on traditional burning provides significant insight into the history of cultural burning among North American tribes, current uses of cultural burning among these same tribal members, and the opportunity for land management agencies to utilize cultural burning as a tool for prescribed burns. This research provides strong evidence that the Indigenous people of North America have been using fire as a tool for thousands of years. They used it to manage the land they inhabited for agriculture, to protect their villages against natural fire threats, and to manage the plant and animal species that also inhabited the area. This showed that the Indigenous people had intimate knowledge of how to use fire on the landscape to benefit these Native tribes and the ecosystem. It was the goal of these tribes to not only use fire as a tool to protect their communities, much like today's land management agencies, but to also encourage a return of native flora and fauna that were a crucial part of the tribe's way of life. For ancestral tribes, fire was about bringing balance among tribes and the ecosystems they inhabited with strong cultural and spiritual beliefs behind them.

This knowledge carries on today through tribal use of fire. Native tribes of North America and Canada still apply fire for these purposes and utilize fire to make everyday goods that the tribes use. Frequent low-intensity fires allowed tribes in Northern California and other areas to grow and harvest materials for basket weaving on a larger scale compared to areas without fire. Studies on the tribes of the boreal forest in Canada showed similar results as it pertained to berry production. Their use of fire was beneficial in maintaining a balance in plant and animal species, whether it was for population control or hunting purposes (Christianson et al., 2022).

An important takeaway is that many land management agencies recognize the importance of cultural burning as a tool that allows for the return of native plant and animal species as well as an overall benefit to the ecosystem that these tribes inhabit. Barriers exist, however, primarily in the form of laws and regulations that prohibit the use of cultural burning on many Reservations that seek to use this prescribed burn method. This is particularly the case in California, although many tribes in Canada experience the same regulations and limits on cultural burning.

Additional future studies will likely support cultural burning benefits as well as the results of collaborations between land management agencies and tribes like the Keeper of the Flames workshop. Future studies will provide clear evidence that cultural burning has major benefits on the ecosystem, provides Indigenous tribes a way to maintain their identities and embrace their cultural history, and offers a way to keep our fire-prone areas healthy and robust for future generations.

There were limitations to my research. Although the Keepers of the flame workshop sought to bring collaboration between tribal and non-tribal entities, there have not been significant data collection efforts on the subject, nor have there been indications that these entities are working together on prescribed burns. California's stringent regulations for prescribed burns limit burn opportunities, burn windows, and are monitored closely by California's Air Quality Management District (AQMD) along with the same land management agencies that seek knowledge of burning practices from these tribes. Past regulatory environmental laws are outdated, especially in the fire environment that exist today, and need to be updated with the input and collaboration of California tribes that have the intimate knowledge of how cultural burning works and how it can benefit the ecosystem. I was also unable to find data detailing the percentage of returns for native plant and animal species in areas where cultural burning was practiced. Overall, there was limited data on current cultural burning practices, which made it challenging to show how land management agencies could utilize these cultural burning practices as a supplement to the current prescribed burn methods.

Conclusion

Indigenous people have utilized fire as a land management tool for millennia to protect their tribes from wildfire, benefit the native flora and fauna species, for agriculture, and for spiritual purposes as evidenced by charcoal data found around historic tribal sites. Tribal communities across North America and Canada still adhere to the same principles of cultural burning their ancestors did by using fire to enhance tribal ecosystems. Land management agencies acknowledge the need for prescribed burning to reduce massive wildfires and their encroachment on WUI communities. More recently, these same agencies have begun to recognize the benefits cultural burning had in the past to help balance native plant and animal species that inhabited these areas. With the changing impacts of climate change and the threat of catastrophic wildfires, collaborations between land management agencies and tribal communities with intimate knowledge of their burning practices and the ecosystems that surround them should be at the forefront of future land management endeavors. Land management and fire suppression agencies including the U.S. Forest Service and CAL FIRE do not need to look far to see the benefits of prescribed burn alternatives. Inclusion of cultural burning not only brings another method to the table for effective land management, but it also brings trust, a willingness to work together, and pride to their tribal counterparts that can build long-lasting relationships between these agencies and the communities that surround them.

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CONTAMINATION AWARENESS AMONG WILDLAND FIREFIGHTERS

Christine Croucher

Abstract

The goal of this research project was to bring awareness towards the importance of decontaminating personal protective equipment (PPE) for wildland firefighters. The primary focus was on Nomex® materials which are used to create jackets and pants. The goal of this project was to emphasize the need for education on the risks and hazards associated with PPE when exposed to wildland smoke. This project reviewed results from a survey and information collected from articles related to wildland firefighters, wildland fire smoke, and wildland firefighters' cleaning habits. Reducing exposure is critical to improve the health and safety of wildland firefighters since the International Agency for Research on Cancer (IARC) classified firefighting as a carcinogenic activity to humans due to its occupational exposures (IARC, 2022).

Keywords: wildland firefighters, Nomex®, contamination

Background

Wildland firefighters' personal protective equipment (PPE) consists of many different components. For this project, the primary focus was the clothing items which contained Nomex® materials. Nomex® consists of aromatic polyamide (aramid) fibers, which are used to create jackets and pants worn by wildland firefighters (DuPont, 2019). Jackets are referred to as "yellows" and pants are referred to as "greens." What makes Nomex® such a desirable material is its ability to be flame resistant—it does not ignite and burn in air, nor does it melt or drip. Garments made of Nomex® act as a protective barrier and help reduce burn injury (DuPont, 2019). To clean and care for Nomex® clothing, the manufacturer advises that it "can be laundered or dry cleaned by conventional home or industrial cleaning methods'' (DuPont, 2019, p. 13). However, to maintain the ability to protect the wearer from thermal energy, the material requires routine and proper cleaning. Replacement is recommended whenever abrasions and signs of wear begin to appear on the material. It is also noted that when Nomex® is introduced to flammable contaminants, the fabric can deteriorate and not serve its purpose (DuPont, 2019).

Wildland firefighters engage in occupational duties within the wildland and wildland urban interface (WUI). Depending on the location of incidents, there can often be barriers which prevent the recommended maintenance and care. Structural firefighters generally work 24 or 48-hour shifts and have access to multiple sets of gear or cleaning apparatus, whereas "wildland firefighters may be deployed on long shifts, sometimes 14–21 days or longer," and often go without access to cleaning facilities (i.e. showers, laundry) (McQuerry & Easter, 2022, p. 1669). This results in wildland firefighters wearing their Nomex® clothes for an extended amount of time, which increases their exposure time. Compounds identified within wildland fire smoke can include soot, debris, carbon monoxide, particulate matter, and polycyclic aromatic hydrocarbons (PAHs). Some of these compounds are confirmed or suspected carcinogens (Broyles, 2013). While all substances listed above can provide serious harm or complications to the human body, carcinogens were the primary interest for this project since they can cause cancer.

Routes of exposure to hazardous substances occur via inhalation, dermal absorption, and ingestion (International Association of Fire Fighters [IAFF], 2024). For this project, the primary route of exposure in regard to Nomex® usage was dermal absorption. Wildland firefighters readily accumulate contaminants on their Nomex®. Factors contributing to build up of compounds on Nomex® and/or increases in dermal exposure in wildland firefighters can include: their assignment, opportunities or access to cleaning supplies or services, and personal hygiene (Cherry et al., 2020). With the buildup of such hazards and lack of cleaning, dermal absorption is more likely to occur. It was discovered that carcinogens found in soot and detected on firefighters' gear were often "transferred to the fire fighter's skin either during firefighting activities or while removing contaminated PPE" (IAFF, 2024, p. 2). Dermal absorption can also occur by cross-contaminating Nomex® with personal belongings. The IAFF stated that "soot is the typical exposure source as it transfers to fire fighters' hands and if not washed can then be ingested through eating, drinking, and putting hands in your mouth" (2024, p. 2).

Research Questions

How can wildland firefighters reduce their occupational risk through the cleaning of PPE, specifically, Nomex® ensembles?

Methods

A key source of information for this project were results from a survey I created. I used direct quotes from participants and created graphs from their responses. The focus population for the survey was wildland firefighters. There were a total of 26 questions. Questions inquired about the knowledge of manufacturing Nomex® items, knowledge of hazardous compounds identified within wildland fires, and knowledge of laundering practices. Research was also conducted from keyword searches through the California State University San Marcos (CSUSM) online library and other scholarly websites. Keywords that were searched included: wildland firefighters, firefighters, exposures, contamination, gear, and cancer rates. Data collected from the literature search and review were then inserted into an abstraction table to select and present significant findings within this project.

Results

Survey participants included 19 wildland firefighters with varying ranks. Ranks represented included: one superintendent, four captains, three engineers, three assistant engineers, three firefighter Is, and five firefighter IIs. Years of service ranged from 1 to 24 years, with an average of 11 years of experience. Of those participants, 42% were assigned to a fuels crew, 11% were assigned to a helitack (i.e. firefighters transported to fires by helicopter), and 47% were assigned to an engine.

When asked how many pairs of Nomex® "greens" (pants) and Nomex® "yellows" (jackets) that participants were in possession of, the average was three pairs of "greens" and two "yellows." This led to asking if participants knew the manufacturer of the materials they wore; 79% were unaware and only 21% knew who produced their PPE. As for if any training was provided on how to clean Nomex® materials, 53% answered "yes" and the remaining 47% answered "no." In the comments section, one participant recorded that they were not provided any official training but had learned from others.

Because cleaning facilities can often be limited during incidents, question 13 asked if laundry services were provided, what is the likelihood that participants would use it. The majority of survey participants reported they would most likely not wash their Nomex® clothes using provided laundry

Figure 1. Responses from question 13 of the survey on use of laundering services.

Another significant response was the number of days that passed where Nomex® was worn without being cleaned or washed. The average answer was between 15 to 25 days (Figure 2). However, it is important to highlight that responses varied from 7 to 200 days.

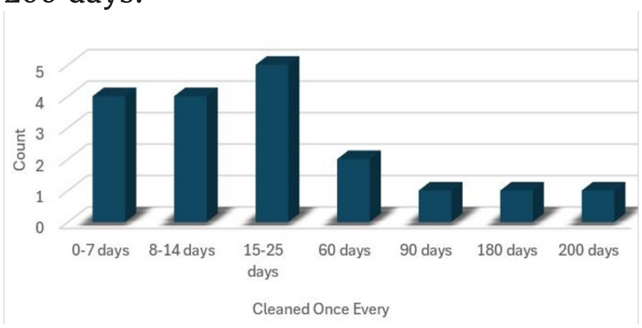

Figure 2. Results of survey question which asked how frequently firefighters were cleaning their Nomex® ensembles.

The last few questions of the survey inquired about the familiarity of hazardous compounds which have been identified in wildfire smoke including: particulate matter (PM), PAHs, benzene, hydrogen cyanide, per-fluorinated compounds (PFAS/PFOA), nitrogen oxides (NOx), sulfur oxides (SOx), and carbon monoxide (Figures 3, 4, 5, & 6). The most recognized compounds were

NOx and SOx. The most well-known compound was carbon monoxide. The least recognized were PFAS/PFOA.

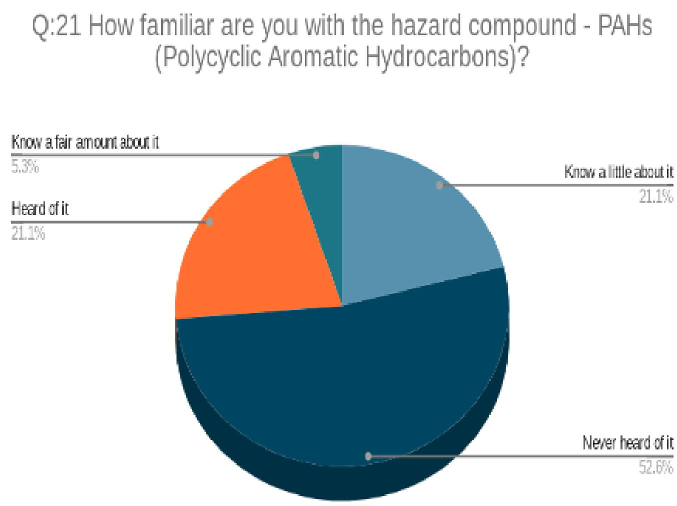

Figure 3. Results of survey question on familiarity with PAHs.

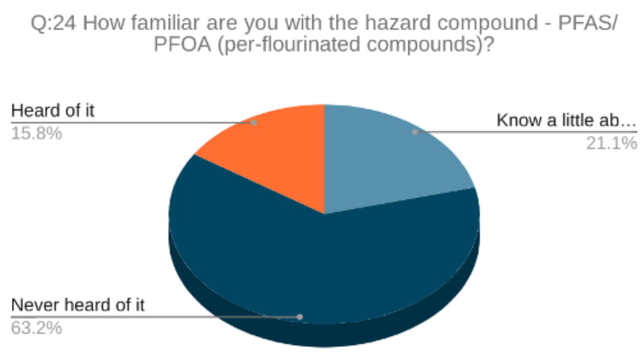

Figure 4. Results of survey question on familiarity with PFAS/PFOA.

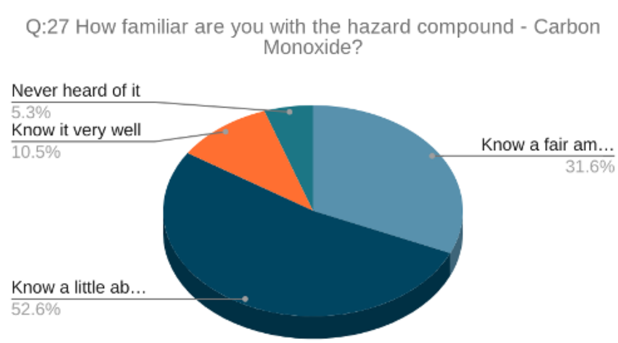

Figure 5. Results of survey question which asked about the familiarity with carbon monoxide.

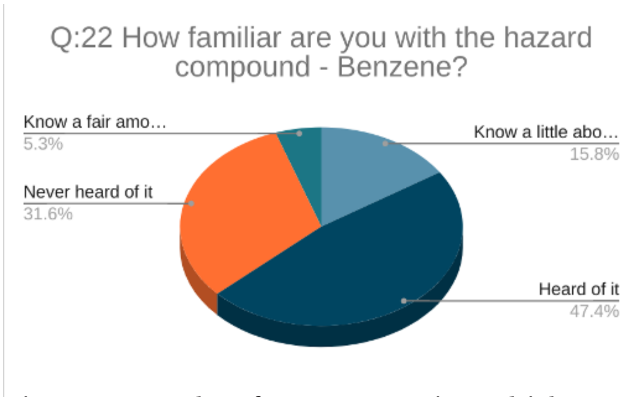

Figure 6. Results of survey question which asked about the familiarity with benzene.

Conclusion

A survey participant wrote in an additional comment that "most people usually just clean them when they start to smell or smell too much (smoke, odor) but never because of harmful compounds." That remark highlighted the motivation behind this project to bring further recognition and understanding of why cleaning and care of Nomex® clothing is necessary. Based on these results from the survey, it is clear there is a need for fire agencies to make changes to develop and implement training and education for cleaning PPE. This will reduce the risk of occupational exposures, while promoting better health and safety for wildland firefighters.

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Recommendations

- Agencies provide more sets of Nomex® jackets and pants.
- Agencies establish mandatory training on how to clean Nomex® materials.
- Require Nomex® to be left at the station to reduce exposure to personal materials and cross-contamination.
- Require Nomex® materials to be washed/cleaned after engaging in fire activities (wildland or prescribed fire).

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IMPROVING WILDFIRE PREVENTION EDUCATION FOR A FIRE RESILIENT COMMUNITY: VENTURA COUNTY, CA

Melissa Brown

Abstract

California encounters extreme fire behavior with an astounding number of acres burned every year. In 2017, Ventura County was home to one of the most devastating wildfires in California history, the Thomas Fire. These fire trends support the need for the wildfire prevention education system to educate the public. Wildfire prevention education is a key factor in establishing safe behavior pre- and post-wildfire. The goal of this study was to identify the barriers and facilitators to defensible space implementation within the wildland urban interface (WUI) of Ventura County, CA. The study focused on the success and failures of wildfire prevention education. Data collection and analysis using a Likert survey helped determine a clear and concise trend. When asked about perceived barriers and facilitators to defensible space implementation, the leading category among respondents was financial incentives and overall costs. The least selected category was lack of information. This suggests that wildfire prevention education is effective in delivering information, but financial constraints prevent individuals from taking action on that education. This study demonstrated how the content of wildfire prevention education needs to be reevaluated. To create a fire resilient community, it needs to be focused on overcoming the barriers that are seen by its residents.

Keywords: defensible space, wildfire prevention, wildfire, education, California, fire resiliency

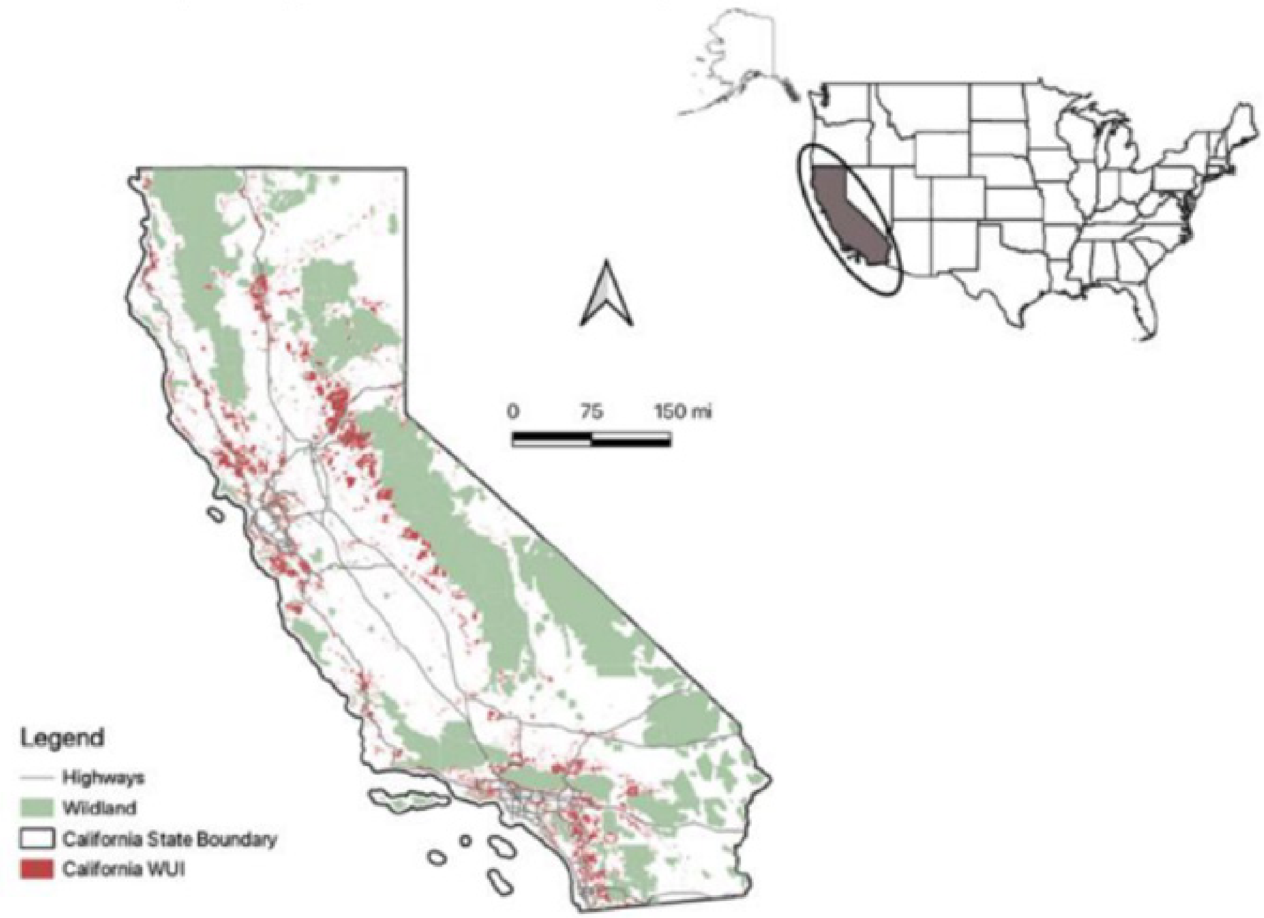
Background

Wildfires are dangerous and life-changing events that happen all too frequently in the state of California. In 2022, California burned 309,287 acres with a total of 7,884 fires, and this was below average. California's five-year average from 2018 to 2022 was 1,474,010 acres burned (National Interagency Fire Center [NIFC], 2022). Wildfires can cause drastic impacts on homes and businesses that reside in the wildland urban interface (WUI). The WUI is an area where building and home developments intermingle with undeveloped wildland vegetation and fire-prone fuels (Karels et al., 2022). The risk to property and buildings from wildfires continues to grow as more homeowners choose to reside in the undeveloped landscape (Figure 1). Nationwide, there was a 33% increase in the size of the WUI from 1990 to 2010 (Radeloff et al., 2018). The current number of homes in the WUI of California is roughly 5.1 million (Radeloff et al., 2005).

In 2017, Ventura County was home to one of the most devastating wildfires in California history. The Thomas Fire consumed over 281,893 acres and destroyed 1,343 homes (Saqui et al., 2018). This wind driven fire carried embers in advance of the flames, which ignited vegetation, causing the fire perimeter to grow rapidly.

One way for homeowners to create fire resiliency around their property is to establish a defensible space. A defensible space is a buffer between the fire prone vegetation of the wildland landscape and property/buildings. This careful implementation of strategic landscape placement along

Figure 1. California wildland urban interface (Thapa et. al. 2023)



with the removal of continuous fuels and low hanging limbs is what helps slow the spread of fire (Maranghides et al., 2022). Not only does this buffer slow the spread of fire, but it also helps keep firefighters safe during suppression operations (California Department of Forestry and Fire Protection [Cal Fire], 2024). This prevention strategy is the responsibility of the homeowner.

Wildfire prevention education has been a major focus of fire agencies and non-profit organizations. There is substantial funding allocated to educate the public about these wildfire prevention tactics. California Governor's Office of Emergency Services (Cal OES) recently partnered with Cal Fire to deliver wildfire prevention education. This was done through the California Wildfire Mitigation Program. The program's goal was to make the public aware of ways they can create fire resiliency on their property through defensible space implementation (Cal OES, 2024). From 2022 to 2023, Cal Fire conducted 274,828 defensible space inspections to educate the public (Cal Fire, 2023). Other funding available for wildfire prevention education comes from a $5 million grant awarded to the California Fire Safe Council (CFSC) by the California Climate Initiative (CCI) (CCI, 2023). The CFSC is a leading resource for wildfire prevention education like defensible space guidance and home hardening awareness.

Public wildfire prevention education is a key factor in establishing safe behavior pre- and post-wildfire. It promotes the understanding of regulations and technologies that lead to the safety of life and property (National Fallen Firefighters Foundation [NFFF], 2010). It is important to streamline wildfire prevention education to ensure efficient delivery of knowledge and encourage maximum community response. The purpose of this study was to determine the barriers and facilitators of defensible space implementation within the WUI of Ventura County, CA. It also demonstrated how wildfire prevention education affects these tactics.

Research Question

What are the barriers and facilitators to defensible space implementation in Ventura County, CA, and how does the wildfire prevention education system affect the barriers and facilitators to this implementation of defensible space?

Methods

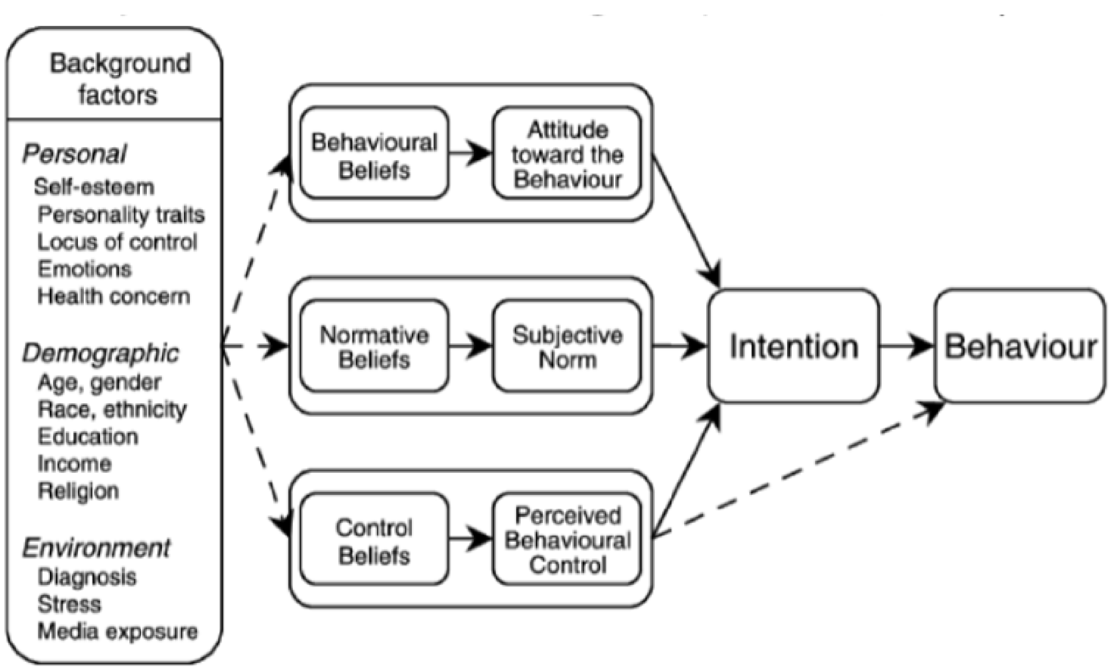
Data Collection

A peer review of literature from the Bren School of Environmental Science & Management, Science Direct, *Society and Natural Resources*, U. S. Department of Agriculture, *International Journal of Disaster Risk Reduction*, *Environmental Advances*, CFSC, and Cal Fire was completed. From the literature review, a 23-question survey was designed to populate a dataset for further analysis. The survey was created using SurveyMonkey®, an online data collection platform. Questions pertained to personal knowledge of wildfire prevention education and wildfire prevention tactics. The Likert survey gathered data on attitudes and opinions of respondents about wildfire related topics (Appendix A). Demographic and socioeconomic factors were also collected. The survey was distributed through social media outlets. The main source of distribution was through groups on Facebook. A selection of community-focused groups, outdoor/hiking enthusiast groups, and business networking groups were used. The survey was also distributed locally in Ventura County through Nextdoor, an online community-focused question and answer forum unaffiliated with Facebook. An abstraction table created in Excel was used to organize data. A pre-existing theory of reasoned action diagram was used as a guide to create the survey questions, develop a hypothesis, and examine the relationship between behavior and intentions of respondents (Figure 2).

Data Analysis

Data were analyzed to acquire demographic variances, community involvement, and income level differences. Additionally, data were analyzed to determine personal expe-

Figure 2. Theory of reasoned action diagram (Fishbein, 1967)



riences with wildfire events, overall opinions about wildfire prevention effectiveness, and outliers. Pie charts and bar graphs were used to demonstrate the respondents' perceived barriers and facilitators to implementation of defensible space. Comparison bar graphs were used to discover how perceived barriers and facilitators affected the implementation of defensible space. A separate analysis was conducted to analyze the effectiveness of the current wildfire prevention education system. A comparison of the collected demographic and socioeconomic factors was completed against the implementation of defensible space.

Results

Respondent Demographics

The research requirements for this study were residency in Ventura County, CA and a minimum age of 18 years old. 144 surveys were completed. The survey was only available to respondents for 30 days. 76% of total respondents were homeowners and 40% of the total respondents lived in the WUI. The majority of respondents were over 39 years old (92%), Caucasian (58%), female (76%), and had an annual income in excess of $80,000 (Figures 3, 4, 5 & 6). This was generally reflective of the Ventura County population, which was 83.3% Caucasian, had a homeownership rate of 64.1%, and a median household income of $102,411 per the U. S. Census (2023). The survey respondents, however, did skew female. Overall, the participants in this study were representative of Ventura County and the results of this study were largely reflective of the community in which wildfire education programs are being delivered.

Community Opinion

A total of 99% of respondents indicated they understood the risk wildfires pose to their property, family, and community. Sixty-five percent of the total respondents have had wildfire impact their lives directly. A follow up question in the survey was

Figure 3. Age of Respondents

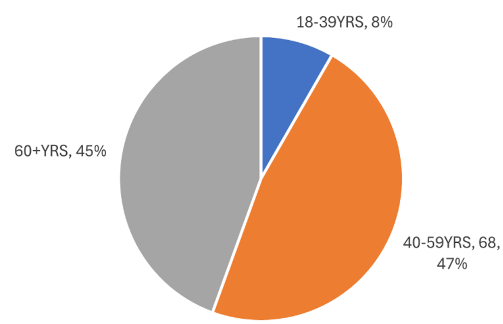


Figure 4. Race of Respondents

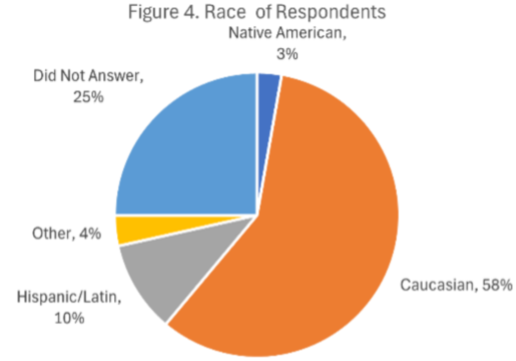


Figure 5. Gender of Respondents

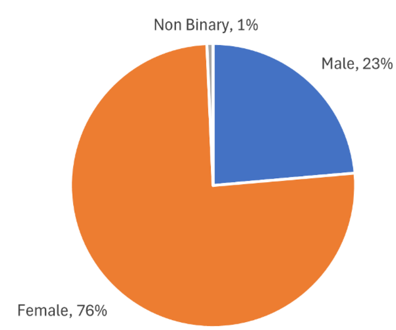
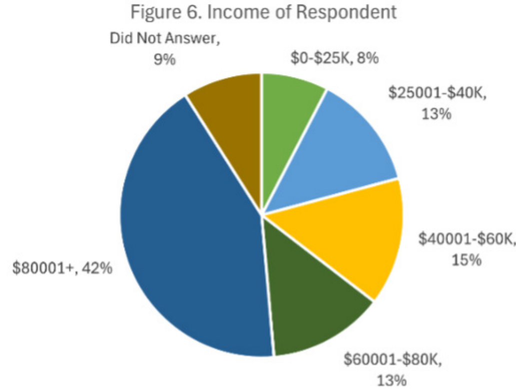


Figure 6. Income of Respondent



available for respondents to categorize how wildfire impacted them directly. This indicated these impacts were caused by evacuation, their home caught fire or was threatened by it, disruption of work or their commute, disruption of social/events, smoke/air quality impacts, loss of homeowners insurance in a fire-prone area, utilities outage during or after fire, and psychological stress. Of those impacted by wildfire, 62% reported implementing defensible space (Figure 7).

Figure 7.
Respondents directly impacted by wildfire that have implemented defensible space on their property

Barriers and Facilitators
Perceived barriers of defensible space implementation were surveyed. Cost of implementation and lack of resources were the leading perceived barriers to implementation of defensible space. Lack of information and knowledge was the least selected barrier to implementation of defensible space (Figure 8). Perceived facilitators of defensible space implementation were also surveyed. Financial incentives and access to resources were the top facilitators to implementation of defensible space. Community support was the least selected facilitator to implementation of defensible space (Figure 9).

Figure 8. Respondents perceived barriers to implementation of defensible space (Note: respondents could select multiple options)

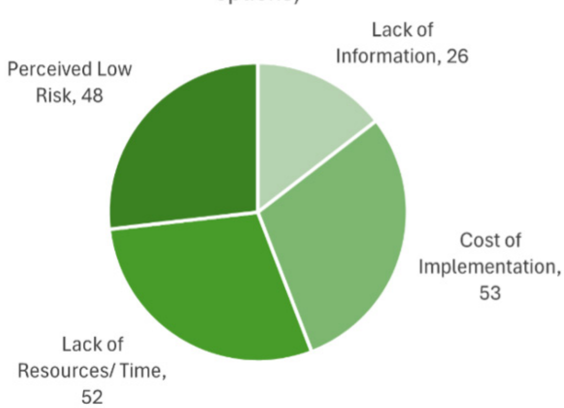
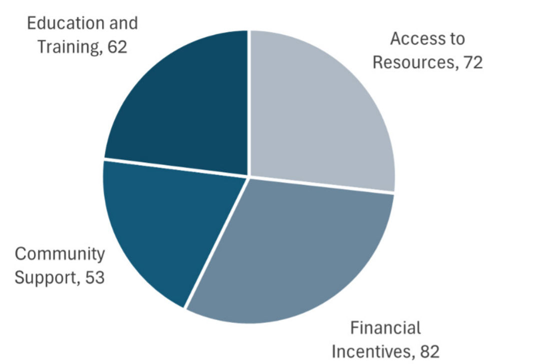


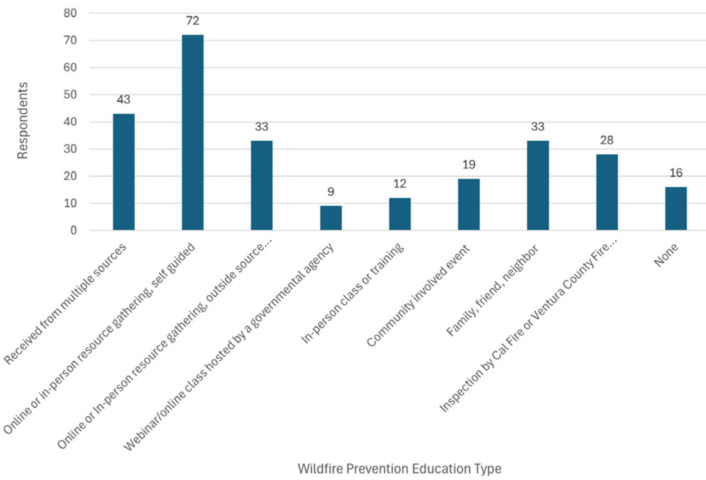
Figure 9. Respondents perceived facilitators to implementation of Defensible Space (Note: respondents could select multiple options)



Wildfire Prevention Education

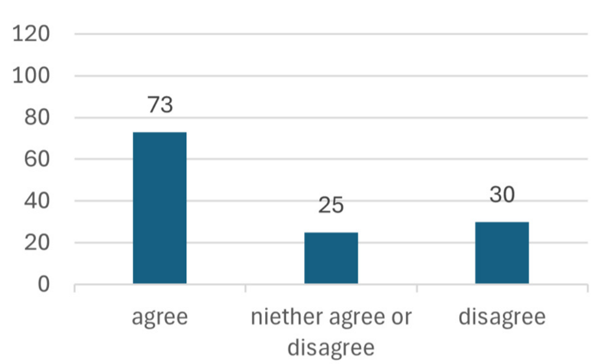
Seven wildfire prevention education types were provided as options for respondents to select from (Appendix B). Eighty-nine percent of total respondents had received some form of wildfire prevention education. Wildfire prevention education types received by respondents varied (Figure 10).

Figure 10. Wildfire prevention education types selected by respondents. (Note: Respondents could select multiple options)



Respondents were able to select multiple forms of education during the survey. Thirty percent of respondents indicated they had received multiple forms of wildfire prevention education. Fifty percent of respondents sought out wildfire prevention education information for themselves through online platforms. A total of 94% of respondents agreed or neither agreed nor disagreed with the statement that they trust the resource or agency that is providing wildfire prevention education. The wildfire prevention education system and respondents' opinion of its effectiveness were also surveyed. Forty-three percent of respondents that received some form of wildfire prevention education indicated they did not learn from the wildfire prevention education they received (Figure 11).

Figure 11. Respondents that learned from the wildfire prevention education they received. (Note 128 respondents received wildfire prevention education)



Discussion

The requirement of defensible space implementation is the responsibility of the homeowner. Agencies placing these requirements should make every effort to provide the knowledge needed to promote the completion of wildfire prevention tactics. Addressing the barriers and facilitators to defensible space implementation will ensure the wildfire prevention education system is streamlined to meet the needs of the community.

The WUI is the main area of concern when considering defensible space implementation as a wildfire prevention tactic. Thus, the main areas of research were centered around Ojai, Piru, Santa Barbara, and Camarillo, all California cities within the Ventura County area. The areas selected for distribution were determined by the need to gain opinions and information from individuals that faced challenges when considering defensible space implementation. Urban areas of development are not normally required to maintain defensible space and do not normally encounter elevated threats from wildfires. To conduct this research, the survey was distributed to selected community-based groups through social media. These groups represented connections with the WUI of Ventura County, CA. The Nextdoor platform allowed for a broader outreach to communities. Use of Facebook community-focused forums along with outdoor enthusiast groups like "Save Lake Casitas" and "Hiking in Ventura County" allowed for respondents that had mutual benefit from wildfire prevention to be included in the survey. The selected areas and groups were not limited to areas impacted by wildfire. However, due to the volume of wildfires seen throughout California and the implications of the Thomas Fire in 2017, many of these areas have been directly impacted. Wildfire prevention education material provided by the Ventura Regional Fire Safe Council (VRFSC) as well as inspections completed by Ventura County Fire Department and Cal Fire targeted these same geographic areas.

The Ventura County general census reports from 2023 did not align with the respondents of the survey. The respondents represented in the survey contained a higher percentage of females and Caucasian ethnicity, with a lower percentage of Hispanic ethnicity (U.S. Census, 2023). This was due to the survey sources and region of distribution. Urban development was not heavily represented in the survey distribution. A study by Mulder et al. suggested that women were more likely to participate in surveys (2019). However, the mean income levels of survey respondents were aligned with the demographics of the census reports, demonstrating that the survey respondent demographics were aligned with WUI demographics (U.S. Census, 2023).

A common theme among the respondents of the survey was the overwhelming understanding that wildfires pose inherent risks to life, family, and property. There was also a consensus that wildfire danger presents a need for mitigation tactics that lead to fire resilient communities. The value of defensible space implementation was not solely determined by the wildfire prevention education a person receives. Rather, it was a combination of overall experiences with wildfire, persons and communities impacted, innate intuition about wildfire danger, and the effectiveness of wildfire prevention.

During the survey, respondents were given the opportunity to select from designated perceived barriers and facilitators to the implementation of defensible space. When reviewing the barriers selected by respondents, lack of information was the least selected option. This suggested that wildfire prevention education was reaching respondents and not contributing to the barriers of implementation of defensible space. The most selected options by respondents were cost of implementation and lack of resources. Lack of resources was not clearly defined. Respondents were left to determine what lack of resources meant to them. This could mean lack of financial means to acquire resources or inability to obtain viable resources. Further studies are needed to pinpoint the precise barrier to implementation of defensible space. When reviewing the facilitators selected by respondents, community support was the least selected option. Community involved wildfire prevention programs were not recognized as potential promoters of implementation of defensible space. The most selected option by respondents was financial incentive, followed closely behind by access to resources. Further studies are also needed to pinpoint a precise facilitator to implementation of defensible space.

Wildfire prevention education is reaching most homeowners across the WUI. During the survey, respondents were asked to select from a pre-set list of seven wildfire prevention education types (Appendix B). The delivery method of this education included online and in-person classes, printed literature, video media, self-guided and outside influences, and agency inspections by Cal Fire or the local fire department. The similarity across all these wildfire prevention education types was the content they delivered. Education materials contained the end goal for homeowners. This was done by promoting prevention tactics such as defensible space implementation. The current effectiveness of the wildfire prevention education system is measured by a communities' understanding of these tactics. There is currently no education being provided to give homeowners tangible next steps they need to complete for defensible space requirements. This lack of information caused a high percentage of respondents to indicate that they have not learned from the education they received. Through this study, it was determined that an individual receiving wildfire prevention education was not the problem. The barriers and facilitators expressed by the community are not being overcome.

Recommendations

1. Address the barriers and facilitators of defensible space implementation as perceived by the community to promote widespread implementation of defensible space.
2. Allocate resources to reformat the content of wildfire prevention education materials being delivered across all formats.
   - Inform the community about step-by-step procedures that guide them through defensible space implementation.
   - Inform the community about the tools that are needed and how to use them safely to diminish fire risk.
3. Allocate resources that provide financial assistance and/or tax breaks for yearly defensible space implementation.
   - Inform the community about low-cost or financial assistance programs that offset costs of defensible space implementation.
   - Inform the community about tax breaks available for completion of defensible space.
4. Create a lending program that offers low- or no-cost tools to homeowners for defensible space implementation.
5. Create a list of licensed and insured companies who offer services that meet defensible space requirements.

Conclusion

The current wildfire education system is only efficient in delivering knowledge about the requirement of wildfire prevention tactics such as defensible space implementation. It does not overcome the financial barriers to implementation perceived by the community. Redesigning education materials and addressing the financial aspect would have a positive impact on overall implementation of defensible space and may be the key to creating a fire resilient community.

The importance of improving defensible space implementation among homeowners in the WUI cannot be overstated. In addition to slowing the spread of wildfire events, which can allow for more effective containment and thus reduced overall acreage burned and increased structure defense, defensible space and reduced fuel loads also keep firefighters safe while they do their job. Future research efforts should focus on what kinds of financial incentives and support would be most effective in Ventura County and similar communities throughout California.

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Appendix

Appendix A. 23 Wildfire prevention education survey question

1. Do you rent or own your home?
2. Do you live in the wildland urban Interface?
3. Do you live in Ventura County?
4. Have you been directly impacted by wildfire in your community?
5. I understand the risks that a wildfire can pose to my property, family and my community.
6. I am aware of the wildfire prevention education efforts in the wildland urban interface of California?
7. What form of wildfire prevention education have you received?
8. I learned a lot about wildfire prevention strategies through the wildfire prevention education I received.
9. It's important that all the members of my community are educated on ways to prevent wildfires.
10. Current wildfire prevention education efforts are in the wildland urban interface are effective.
11. trust the resources that provide wildfire prevention education.
12. What type of wildfire prevention strategies are you familiar with?
13. I have implemented a defensible space strategy on my property.
14. I feel like a part of my community when I implement wildfire prevention strategies.
15. What are the main barriers preventing you from implementing defensible space in the
16. What factors would facilitate your implementation of defensible space in the wildland urban interface?
17. What are the key challenges you face in implementing defensible space in the wildland urban interface? (open ended)
18. What additional support or resources do you believe would be helpful in improving/ wildfire prevention education in your area? (open ended)
19. Gender?
20. Age Range? (18-40yrs, 41-60yrs, 61+yrs)
21. Ethnicity? (Caucasian, Hispanic, Other)
22. Yearly Income Level? ($0-$25k/yr., $25001-$40k/yr., $40001-$60k/yr., $60001-$80k/ yr., $80001k+/yr.)
23. Group or Club Affiliations? (open for input)
24. Registered Voter?

Appendix B. Seven wildfire prevention education types

1. Online or in-person resource gathering, self-guided (i.e. you sought out information on your own)
2. Online or In-person resource gathering, outside source influenced (i.e. booth at a fair, event or community mailer)
3. Webinar/online class hosted by a governmental agency (i.e. Regional Fire Safe Council, Fire Department, CAL FIRE or US Forest Service)
4. In-person class or training (i.e. CERT training or other school formatted experience)
5. Community involved event (i.e. town hall meeting, trail maintenance event, community clean up)
6. Family, friend, neighbor told you about it
7. Inspection by CAL FIRE or Ventura County Fire Department

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