

Californian Wildfires and Associated Human Health Outcomes: An Epidemiological Scoping Review

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ABSTRACT

Background: Over the last decade, the frequency and severity of wildfires have notably increased as a result of climate change, posing a significant threat to human health.

Objective: This review answers the question: “What are the health outcomes associated with wildfires in California?”

Methods: PubMed, Ovid MEDLINE, Web of Science, EBSCO Host, and JSTOR were searched to identify 407 articles using keywords such as “Health” OR “Health Outcomes” AND “Wildfires” AND “California”. A total of 48 sources were reviewed and thematically analyzed after examining the data for duplicates, full-text articles, and relevancy.

Results: Eight negative implications of wildfires on human health are described in the literature: respiratory illnesses, cardiovascular diseases, mental health issues, physical health effects, burns and temperature-related illnesses, infectious diseases, cancer, and mortality. Research and evidence on the impacts of wildfires pertaining to specific vulnerable individuals and the ecosystem are limited.

Discussion: By highlighting the adverse health effects associated with wildfires, this review provides a summary of known health outcomes that can inform preventative measures to combat this issue. Subsequently, this will enable the global community to work towards achieving Sustainable Development Goal (SDG) 3 (good health and wellbeing), SDG 13 (climate action), and SDG 15 (life on land).

KEYWORDS: *wildfires, California, climate change, health*

INTRODUCTION

Climate change is a major contributor to the frequency, duration and severity of wildfires. The average global temperature increased significantly by 1°C between 1983-2017, which has caused the frequency of wildfires to multiply by four times on the West Coast of the United States of America (USA) (Rossiello & Szema, 2019). As temperatures continue to rise, the occurrence of wildfires is expected to increase as well (Rossiello & Szema, 2019). To mitigate the health impacts of wildfires and ensure the utmost safety of affected communities, it is important to clarify the health impacts of wildfires.

The frequent occurrence of wildfires has raised concerns for the health and wellbeing of humans. Wildfires have been associated with several adverse health effects, most of which are related to upper and

lower respiratory issues (Forsberg et al., 2012). Other health outcomes, including cardiovascular diseases, mental health issues, physical health effects, burns and temperature-related illnesses, cancer, and mortality, have also been determined to be related to wildfire occurrences, particularly in California (Holm et al., 2020; Rossiello & Szema, 2019; Shusterman et al., 1993). Not only do wildfires have a direct impact on human health through the release of pollutants, but they also indirectly affect humans by increasing the spread of infectious diseases (Karmarkar et al., 2020). Such indirect impacts on health have been documented during the current COVID-19 pandemic, with wildfire pollutants exhibiting a positive association with total cases and deaths in California (Karmarkar et al., 2020; Meo et al., 2020).

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This scoping review provides an analysis of the existing evidence on the health outcomes of wildfires in California. California is an important focal point for the study of wildfire impacts on human health, as there has been a high incidence of wildfires within the West Coast since 2018. In 2020, more than 3,154,107 acres of forest were burned due to wildfires; this has resulted in about a 20% increase in destroyed forest area since 2018 (Isaacs-Thomas, 2020). An increase in wildfire severity and duration may be attributable to a rise in the incidence of heatwaves in California (Rossiello & Szema, 2019). As such, the increase in temperature and a drier atmosphere in the state have created an environment for readily occurring and destructive wildfires (Rossiello & Szema, 2019). Given that wildfires continue to increase in frequency, duration, and severity, it is crucial to review existing evidence and the gaps in knowledge pertaining to the health impacts of wildfires. Many professionals in the global health community are committed to achieving Sustainable Development Goals (SDG), and attending to the health impacts of wildfires can support achievement of SDG 3 (good health and wellbeing), SDG 13 (climate action), and SDG 15 (life on land).

This scoping review aims to be pragmatic in the sense that the summary of key proven impacts on health in the Californian context can serve to inform the creation of realistic policies and interventions to reduce the adverse effects of wildfires in that context, and, by drawing attention to gaps, guide future research. While this review is focused on California, it is anticipated that results may be useful to supporting individuals and organizations working in other jurisdictions already facing or expecting to face threats to their populations' health due to wildfires.

Methods

The five-stage scoping review process proposed by Arksey and O'Malley (2005) was used to conduct this scoping review. Each step of this process is described below.

Stage 1: Identify the research question

We formulated the following research question: "What are the health outcomes associated with wildfires in California?"

For the purpose of this review, 'health outcome' was defined as: short-term or long-term health implications, including changes to one's physical and mental/psychological health.

Stage 2: Identifying relevant studies

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework was used to identify and select literature that focuses on the health outcomes associated with wildfires in

California, USA. The databases used to search for literature include PubMed, OVID Medline, Web of Science, EBSCOhost, and JSTOR. In order to find relevant articles, the following search terms were used: "Health" OR "Health Outcomes" AND "Wildfires" AND "California." Grey literature and secondary research articles related to wildfires in California such as policy manuals, thesis dissertations, guides, magazine articles, and reputable blog posts were also used to find additional information related to this topic.

Table 1 Summary Table of Search Terms Used During Literature Search

Key Word	Related Terms
Health Outcomes	Physical health, mental health, neurological health, behavioural changes, child health, seniors' health, occupational risks, acute effects, short-term health impacts, long-term health impacts, adverse consequences
Wildfires	Forest fires, fires, bushfires, climate change, global warming, air pollution, particulate matter, heatwaves, temperature

Stage 3: Study Selection

Following the literature search, results from each database were reviewed by four reviewers and duplicate results were removed prior to screening (n=68). Titles and abstracts were then screened to ensure that they met the selection criteria which entailed that the words "California," "Wildfires," and "Health," were present within the title and/or abstract. All results that did not meet inclusion criteria were excluded from full-text screening (n=158). Full-text articles retained were then screened for eligibility (n=131) to ensure that they were relevant to the topic of interest. Articles that were not specific to Californian wildfires or did not mention human health outcomes due to wildfires were excluded as they were irrelevant to this scoping review (n=50). To strengthen the robustness of our search strategy, references of included articles were then reviewed to identify potential additional relevant papers. This process resulted in the identification of an additional 15 articles, of which 9 met inclusion criteria. A PRISMA table summarizing the screening process provides a visual summary of the screening process (see Figure S1).

Stage 4: Charting the Data

For all of the articles screened, key information such as the authors, publication year, type of study, and key findings were extracted. The majority of the studies used for the purposes of this paper were

systematic reviews and meta-analyses that highlighted various health outcomes post wildfire exposure in California.

Stage 5: Collating, Summarizing and Reporting the Results

Two reviewers analyzed each study to identify recurring themes which were used to inform the structure of the results. Eight major and distinct themes were identified and will be explored further in the results.

Results

After screening all eligible articles and their references, 33 studies were ultimately retained for analysis along with 15 sources of grey literature and secondary research articles. The majority of the studies used were systematic reviews and meta-analyses that highlighted various health outcomes post-wildfire exposure in California. Several associations between fires and human health outcomes are noted in the scientific literature. These include adverse short-term and long-term health effects, as well as direct and indirect impacts on health. Eight outcomes emerge as key documented health implications of wildfires in the Californian context. Each of these is described below.

Outcome 1: Respiratory Illnesses

The most commonly cited health impact of wildfires on human health in the literature referred to respiratory illnesses. Wildfire smoke contains contaminants detrimental to human health, such as acrolein, benzene, carbon dioxide, carbon monoxide, formaldehyde, polycyclic aromatic hydrocarbons (PAH), respirable particulate matter (PM), and soot (Adetona et al., 2016; Naeher et al., 2007).

PM is a by-product of wildfires and one of the most critical contributors to air pollution due to the presence of because it contains harmful fine particles and other toxic chemicals (Richmond, 2019). PM₁₀ is one of the major pollutants that is emitted from wildfires (Lee et al., 2009). These pollutants pose the most serious threat to human health due to their diameter being less than 10 microns (PM₁₀), allowing them to evade the immunological defences of the human body present in the nose and throat (Lee et al., 2009). PM deposits more deeply in airways than other larger particles resulting in negative consequences for the lungs (Holm et al., 2020).

According to the Centers for Disease Control and Prevention (CDC), the number of emergency department visits generally increase by approximately 91% for asthma and 132% for bronchitis following a wildfire (CDC, 1999). Lee et al. (2009) reported that the Indigenous community of Hoopa in northern

California had an increase in clinical and emergency room visits for respiratory conditions during a severe wildfire in 1999. Health outcomes in Hoopa were significantly associated with the level of daily particulate matter (PM₁₀) (Lee et al., 2009; Mott et al., 2002). In a study examining the health effects of PM₁₀ from forest fires, Emmanuel (2000) found that an increase in PM₁₀ levels from 50 to 150 µg/m³ was associated with a 19% increase in asthma among outpatient visits. A similar study analyzing the effects of bushfires found that more patients visited hospitals for asthma treatment when the PM₁₀ levels were above 40 µg/m³ compared to days when the PM₁₀ levels were below 10 µg/m³ (Johnston et al., 2002).

Since the 1980s, particulate matter has increased in all regions of the United States, excluding the American Northwest, and it has been linked to increased respiratory illnesses and mortality rates (Richmond, 2019). Combining the statistics of all ER patients within six Californian counties after large scale wildfires in 1987, the number of patients with non-infectious respiratory conditions, such as asthma or Chronic Obstructive Pulmonary Disease (COPD), significantly increased (Duclos et al., 1987). Increases in laryngitis, sinusitis, and other respiratory diseases in communities near wildfires were found by Duclos et al. (1987). A study conducted by Liu et al. (1992) found that 63 Californian firefighters experienced large declines in lung and respiratory functioning post-wildfire season compared to their baselines before the season had started. Other studies have had similar conclusions with firefighters having lower respiratory function associated with the high levels of exposure to wildfire smoke (Gaughan et al., 2014a).

Outcome 2: Cardiovascular Diseases

The majority of cardiovascular-related health emergency visits in California occurred in regions that were heavily affected by wildfire events. This was mainly observed in adults, during dense smoke days, and persisted beyond the initial high-exposure period (Hutchinson et al., 2018; Wettstein et al., 2018). These visits pertained to cases of myocardial infarctions, ischemic heart diseases, heart failures, dysrhythmias, pulmonary embolisms, ischemic strokes and transient ischemic attacks (Wettstein et al., 2018).

Firefighters and other frontline workers who are exposed to toxic air pollutants when suppressing fires are increasingly susceptible to cardiovascular diseases (CVDs) (Navarro et al., 2019). Firefighters who were exposed to wildfires for 49-98 days annually with careers spanning 5-25 years in California had a 30% increase for CVDs (Navarro et al., 2019). There is a significant association between the time span that

firefighters work to suppress wildfires and the diagnosis of hypertension and/or heart arrhythmia (Semmens et al., 2016). If individuals are exposed to PM for any period of time, there is a greater association with the increased risk of myocardial infarctions, strokes, and arrhythmias (Atkinson et al., 2015). Lee et al. (2009) have suggested that exposure to higher levels of PM₁₀ is predictive of patients seeking clinical care for coronary artery disease. Overall, studies confirm that exposure to PM increases the overall risk of CVDs (Brook et al., 2017; Pun et al., 2017).

Outcome 3: Mental Health

Mental health effects may arise due to the stress and trauma that wildfires pose on individuals (Holm et al., 2020). Wildfires often necessitate immediate evacuations, which can lead to trauma and psychological distress (Holm et al., 2020). In addition, post-traumatic stress disorder (PTSD) and difficulty adjusting to life post-fire are often prevalent after being displaced from one's home (Holm et al., 2020). The damage from the fire can also result in physical and economic losses that are challenging and often impossible to recover from, leading to increased emotional strain in individuals (Rossiello & Szema, 2019). Additionally, this effect is heightened by the high degree of uncertainty in those who had to evacuate their homes due to concerns about shelter and the safety of their family and friends (Afifi et al., 2012).

Wildfires often lead to exacerbations of pre-existing psychiatric disorders, grief and situational stress (Shusterman et al., 1993). Moreover, anxiety and stress in pregnant women during these events can have negative impacts on the fetus (Kessler, 2012). Holm et al. (2020) suggested that because of air pollutants and exposure to PM from wildfires, children were observed to have various neuropsychological effects, which in turn had downstream adverse effects on ADHD, autism, memory, and performance at school (Oliveira et al., 2019; Suades-González et al., 2015). These health effects are important to note because mental health problems tend to be underestimated when faced with a high number of emergency visits (Shusterman et al., 1993).

Outcome 4: Physical Health Outcomes

Wildfires can also result in negative physical outcomes in humans, specifically in children, as exposure to detrimental substances from fires can hinder child health and development. For example, infants in the womb during the 2003 southern California wildfires had lower birth weights compared to those who were born in that same region

prior to and months after the fires (Holstius et al., 2012). Generally, this weight varies by trimester as the average birth weight was approximately 7.0 grams lower when the wildfire occurred during the third trimester, 9.7 grams lower during the second trimester, and 3.3 grams lower during the first trimester (Holstius et al., 2012). This poses a disadvantage as lower birth weight predisposes infants to an increased risk for poor health outcomes (Kessler, 2012). Since prediction models have projected that wildfires will continue to increase in frequency, duration, and severity, it is expected that the number of babies born with low birth weights (less than 2500 grams or 5.5 pounds) will rise (Kessler, 2012).

Alternatively, when high levels of PAHs are exposed in the air, children have significantly higher body weights compared to those with less exposure (Rundle et al., 2012). Holm et al. (2020) express concerns over these outcomes, primarily because early life exposure could reprogram bodily mechanisms involved with metabolism, structure, and cell signalling. These changes may result in lifelong impacts because unfavourable metabolic effects and growth in children are likely to develop into poor cardiovascular health during adulthood (Holm et al., 2020). Additionally, it has been hypothesized that PM exposure may lead to decreased height and an increased risk of obesity (Holm et al., 2020).

Furthermore, smoke produced from the fire can cause headaches, corneal abrasions, wheezing, and irritations of the nose, throat, and eyes (Künzli et al., 2006; Lee et al., 2009; Mirabelli et al., 2009; Shusterman et al., 1993).

Outcome 5: Burns & Temperature-related Illnesses

Burns from direct contact with fire pose a threat to humans. This is a serious health impact, given that patients with major burns had a fatality rate of 81% (Shusterman et al., 1993). The extent of burns can be worsened if the fire spreads rapidly and if individuals are unable to outrun the flames or escape the building that they are trapped in (Shusterman, Kaplan & Canabarro, 1993).

Heatwaves allow wildfires to spread rapidly over large regions by producing fuel in the form of dry organic matter. The heatwaves in California were observed to have a significant effect on the incidence of dehydration and heat-related illnesses, as noted by increased hospital visits (Rossiello & Szema, 2019). Additionally, patients with pre-existing non-communicable diseases (NCDs) and conditions such as hypertension, heart disease, diabetes, and obesity are at risk and more vulnerable to the heat than others

(Rossiello & Szema, 2019). Due to the heatwaves, the risk of cardiac arrests was reported to increase by 14% and hospital admissions increased by 7% when temperatures reached a peak (Rossiello & Szema, 2019).

In recent decades, NCDs have surpassed infectious diseases as the major cause of morbidity, mortality, and disability-adjusted life years (DALYs) (Institute for Health Metrics and Evaluation [IHME], 2017), 2018). As of 2016, the leading causes of death in the United States of America (USA) were attributable to NCDs, as they accounted for 89% of deaths and 85% of DALYs (IHME, 2017). Therefore, increasing frequency of wildfires can exacerbate the deleterious effects of NCDs on the global population and health system.

Outcome 6: Cancer from Trace Metals and Carcinogenic Effects

One longer term effect on human health of wildfires that is noted in the literature pertains to cancer. As explained by Odigie & Flegal (2014), trace metal contaminants are sequestered in sediment, organic matter, and forests. Wildfires cause trace metal contaminants to be released in a more labile form (Odigie & Flegal, 2014). The Los Angeles Metropolitan area has a population of ~17 million and is close to many sources of industrial contaminants; thus, this area is one of the most contaminated metropolitan areas in the United States (Odigie & Flegal, 2014). Odigie & Flegal (2014) posit that forest fires in the Los Angeles Metropolitan area would remobilize large amounts of lead and other trace metals from nearby industrial sources into the water and open air. For example, stormwater collected in an urban community in southern California, 20 km from a wildfire, had three times the amount of normal concentrations of copper, lead, nickel, and zinc due to ash fallout (Odigie & Flegal, 2014). Trace metals can have deleterious effects on human health outcomes; for example, copper can create reactive oxygen species (ROS) that can interfere with cell replication, thereby increasing the risk for cancer (Matés et al., 2010; Odigie & Flegal, 2014).

Various studies (Hejl et al 2013; Swiston et al. 2008; Booze et al. 2004) have found that extended exposure to benzene, formaldehyde, acrolein, and PM_{3.5} can lead to an elevated risk for developing cancer. Furthermore, the smoke from forest fires contains harmful levels of PM_{2.5} (2.5 denotes size in microns) and other carcinogenic particles (Richmond, 2019). Greater exposure to PM_{2.5} has also been associated with an increased risk of lung cancer (Hamra et al., 2014). Firefighters who had been working for 5-25 years and were exposed to wildfires for about 49-98

days annually during their careers had an 8-43% increased risk of lung cancer (Navarro et al., 2019).

Furthermore, 1,3-Butadiene (BD) is found within forest fire smoke and is a carcinogen that is associated with an increased incidence of lymphoma (Sangaraju et al., 2016). If bioactivated through inhalation, BD turns into 3,4-epoxy-1-butene, which can cause DNA mutations, leading to the disruption of DNA replication (Sangaraju et al., 2016). This ultimately contributes to an increased risk of uncontrolled cell growth, which is synonymous with cancer.

Outcome 7: Infectious Diseases

One of the more recent impacts of wildfires on human health described in the literature pertains to the connection between wildfires and susceptibility to infectious diseases. The environmental pollution from wildfires is toxic and can perpetuate the spread of infectious microorganisms and diseases among populations, especially among evacuees (Karmakar et al., 2018; Meo et al., 2020). This phenomenon occurred after California's deadliest wildfire which transpired in November 2018, when outbreaks of acute gastroenteritis occurred in two evacuation shelters. The cause of this outbreak was suspected to be the norovirus, which is a highly contagious and resistant virus (Karmakar et al., 2018). Oftentimes, these shelters serve as temporary accommodations and overcrowding is prone to happen when natural disasters strike. Due to the people's close proximity to each other in these camps, norovirus was easily transmitted through contaminated food and beverages, and close contact with infected individuals (Karmakar et al., 2020). As a result, approximately 120 people acquired the norovirus infection (Rossiello & Szema, 2019).

A recent study aimed to examine the association between the number of cases and deaths that occurred during the COVID-19 pandemic due to Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) and the daily levels of environmental pollutant particulate matter in San Francisco, specifically PM_{2.5} and CO (Meo et al., 2020). Meo et al. (2020) concluded a positive association between the two variables, signifying that as wildfire pollutants increase, the case and death count from SARS-CoV-2 would also increase in the San Francisco area. This finding shows the interconnectedness between environmental pollution and human health outcomes.

Outcome 8: Mortality

Johnston et al. (2012) highlight that as temperatures increase and wildfires become more common in Western nations, high mortality rates due to landscape fire smoke (LFS) may occur, particularly in forest

regions such as California. A study of wildfires between 1997 and 2004 found that there was a 5% increase in non-accidental mortality during days when PM and other contaminants were high (Finlay et al., 2012). Another study regarding the 2003 Southern California wildfires determined that 133 excess cardio respiratory-related deaths were caused by wildfire smoke exposure, and one billion U.S. dollars were needed to cover the mortality-related expenses (Kochi et al., 2012). Overall, it is evident that adverse human health outcomes, which threaten the livelihood and survival of surrounding populations, can be attributed to wildfires, and these effects subsequently pose a significant economic threat and health burden on the Californian healthcare system.

Discussion

The purpose of this scoping review is to amalgamate data on Californian wildfires and their effects on human health. Understanding the health-related consequences of wildfires can galvanize action to address and reduce the threat of wildfires as a public health emergency rather than purely environmental or disaster management issue.

It is clear from the literature that wildfires have diverse and concerning implications for California's health system and citizens due to the resulting exacerbation of NCDs, which are non-infectious and non-transmissible diseases. The leading NCDs in the USA are cardiovascular disease, cancer, chronic respiratory diseases, diabetes, mental health disorders, and substance use (IHME, 2017). Based on our findings, it is evident that wildfires apply additional pressure to already highly overwhelmed health systems by contributing to the prevalence of NCDs. As wildfires continue to increase in frequency and severity, it will be important to find preventative measures to mitigate health effects in order to better manage the impact of NCDs in California.

In addition to increasing the risk of NCDs, the effects of wildfires on infectious diseases are a critical concern. This was noted during the current COVID-19 pandemic, as the spread of infectious diseases escalated during the wildfire events. Wildfires have been raging in California during the COVID-19 pandemic, and preliminary studies have indicated that there is a positive correlation between environmental pollutants and the number of daily COVID-19 cases (Meo et al., 2020). The possibility that wildfires influence the spread of infectious diseases, whether indirectly (i.e., evacuation camps) or directly (i.e., pollutants), highlights that immediate action must be taken to implement preventative measures and adequate health policies.

There is a notable gap in the literature regarding the interventions that are in place to protect vulnerable populations from the negative health impacts of the Californian wildfires (Lee et al., 2009). Children, Indigenous populations, seniors, and firefighters have been identified as being at an increased risk for health complications associated with wildfires (Holm et al., 2020; Mott et al., 2002; Shusterman et al., 1993). However, short-term health outcomes in the research literature reviewed tend to focus primarily on frontline workers, such as firefighters (Lee et al., 2009). While attention to the impact on this population is crucial for developing strategies to protect frontline workers during wildfires, this population is not representative of the broader communities in which they reside. Future research is required in order to document and advance our understanding of the negative health effects of wildfires that are observed in the entire population, with a focus on vulnerable and at-risk groups. Children are of particular concern, as there is little known about the long-term impacts of wildfires on their health. Children are most vulnerable to wildfire incidents because they inhale more air relative to their body weight than adults, and are still developing (Holm et al., 2020). Therefore, protecting their health is essential to ensuring good health and wellbeing later in life. Currently, knowledge about the long-term effects of wildfires on child health is limited to neuropsychological effects (i.e., ADHD, autism, etc.), metabolic/growth effects, decreased birth weight, and increases in obesity (Holm et al., 2020). Further information regarding the long-term health effects of wildfires on children will be required to develop interventions that will reduce the risk of negative health outcomes that persist later in life.

There is also a lack of literature discussing wildfire health risks, in the Californian context, related to ecosystem health (or "One Health" [CDC, 2018]). Ecosystem health considers ecological, animal, and human health as interrelated factors, rather than isolated silos. This paper focuses on human health, but there are significant health effects on vegetation and animals as a result of wildfires (Brook et al., 2017; Pun et al., 2017). Exploring the interrelatedness of human, animal, and ecological health regarding wildfires would allow for policy and interventional opportunities that consider the ways in which ecosystem health chain reactions indirectly affect animals, plants, water sources, and humans. Understanding this relationship may allow an upstream "One Health" approach to be taken for reducing the negative health outcomes associated with wildfires (CDC, 2018).

Future Directions

Health impacts of wildfires in California will not be ending in the near future. Researchers have established that climate change and wildfires will continue to be a pervasive issue in the future (Rossiello & Szema, 2019). In California, there has been an increase in the frequency and severity of wildfires (Rossiello & Szema, 2019). While there is no doubt that upstream strategies to reduce the occurrence of wildfires are of utmost importance, it is also important that jurisdictions facing health risks from wildfires understand and plan for potential or current impacts on their populations' health.

Developing preventative measures now may mitigate future implications of worsening human health related to wildfires. Currently, it is known that some behaviours and practices, including mask-wearing, are able to mitigate some of the negative health effects of wildfires (Holm et al., 2020); however, in this context mask-wearing will only go so far to address the complex public health issues and impacts of wildfires. Effective interventions and preventative measures that can be utilized to reduce the risk of adverse health outcomes must be informed by evidence. More research must be done on the community-wide health impacts of wildfires to enhance the understanding of the extent, severity, and distribution of indirect and direct adverse health outcomes related to wildfires. More information about children and other vulnerable populations (i.e., elderly, and Indigenous populations) will be critical to informing these interventions, as these individuals experience the most severe consequences of wildfires. The interrelations and connectedness of human, animal, and vegetation health in regard to wildfires have been minimally researched, and also merit further attention. Understanding more about the mechanisms and impacts of wildfires on the affected communities and ecosystem health will enable appropriate policy and health interventions to be implemented and subsequently reduce adverse health effects (Zelikoff et al., 2002).

Strengths and Limitations

There are some notable strengths to this review. First, this paper reviewed a wide range of literature in order to thoroughly outline the currently known short-term and long-term health effects of wildfires in California. This provides an abundance of information that policymakers and public health officials can use to mitigate the adverse health effects related to wildfires. Additionally, we utilized an array of study types, including case reports and cross-sectional studies, to ensure both qualitative and quantitative information was available. This will allow readers to produce

evidence-based interventions and policies to protect affected populations from wildfires.

However, there are a number of limitations to this scoping review. The health effects discussed in this scoping review are specific to California, meaning that the research summarized here may only be generalizable to California and, possibly, other West Coast states in the USA. Additionally, this paper focused solely on how wildfires affect human health but did not recognize animal and ecological health effects. While this was out of the scope of this review, there are important implications and interrelations between ecology, animals, and humans that could provide insight into creating future interventions.

Conclusion

Overall, wildfires threaten human health and will become more significant as climate change and global warming continue to progress. Climate change, urbanization, agriculture, and forest management are significant contributing factors in the development of wildfires. Major changes addressing these factors need to be implemented in order to reduce the number of wildfires and their associated health outcomes. Upstream preventative measures to protect communities from the health effects of wildfires will directly work towards achieving SDG 3, as well as indirectly influence SDG 13 and SDG 15. Thus, this scoping review should serve as a summary of health effects that can inform new preventative measures and interventions to protect the health of affected populations, reduce the economic burden of wildfires, and mitigate the strain on healthcare systems.

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