Exploring Local Complexities of Human-Caused Wildfire Ignition Risk and Prevention in Flagstaff, AZ

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Abstract

Human-caused wildfire ignitions are introduced by a diversity of public land users and prevention is increasingly called upon as an effective yet underutilized ignition reduction method. However, existing literature oversimplifies the role of various public land users in human-caused ignition risk and few efforts have explored the effectiveness of wildfire prevention strategies. The research presented here aims to address these gaps by characterizing public land users and their role in human-caused ignition risk and identifying opportunities and challenges for place-based wildfire prevention. We conducted focus groups with 45 members of the public and fire and land management professionals in Flagstaff, AZ, a community with a history of impactful human-caused wildfires ignited from various causes. Participants characterized five public land user groups perceived to introduce varying levels of human-caused ignition risk driven by unique landscape relationships which are used to formulate user group typologies. While members of the public displayed strong support for a range of existing and novel prevention approaches, support from local managers was limited to low-complexity strategies that are not inhibited by systemic funding and staffing barriers within land management agencies. We conclude with practical recommendations for integrating the above lessons in both land management and scientific advancement. We suggest that user group typologies should be assessed in diverse locales to create a more comprehensive understanding of human-caused ignition risk, and advocate for innovation and increased resource allocation in wildfire prevention to address the growing human-caused wildfire problem.

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1. Introduction

Wildfires in the United States (U.S.) are predominantly ignited by human causes, which are not only more prevalent than naturally caused fires but threaten societal values including life and property to a greater extent (Balch et al., 2017). Unlike natural ignitions which are more common in remote areas, human-caused ignitions typically occur in densely populated, developed spaces; as a result, 97% of residences threatened by wildfire in the U.S. are attributable to human-caused wildfires (Mietkiewicz et. al., 2020). In conjunction with anthropogenic factors such as climatic warming and fire suppression, human-caused wildfires have expanded the historic occurrence of wildfire both spatially and seasonally beyond what was once considered a fire "season," placing a growing proportion of human communities at risk (Nagy et al., 2018). Reducing unwanted human-caused wildfires necessitates comprehensive understanding of an array of ignition sources and the diverse human actors that introduce those risks on both private and public lands.

Human-caused ignitions are non-random; they exhibit patterns that reflect region specific biophysical factors and land use trends (Sturtevant & Cleland, 2007). For example, power line ignitions are a dominant source of wildfires in Southern California, attributable to extensive electrical infrastructure and Santa Ana winds (Syphard & Keeley, 2015). In contrast, agriculture is the most effective predictor of human-caused ignitions in Washington's coastal forests, whereas in the Great Basin and North American Desert, proximity to railroads is the strongest determinant (Fusco et al., 2016). The U.S. Southwest displays yet another human-caused ignition pattern: an average of 44% of human-caused wildfires on public lands since 2001 were ignited by abandoned campfires in this region (Evans, 2018; Short, 2022). This existing research highlights distinct regional variability in land use patterns and user groups contributing to

human-caused ignitions. However, within regions, previous social science has shown community-level variation in wildfire risk factors driven by local social context, suggesting that sub-regional dynamics are likely also at play (Jakes et al., 2007; Paveglio et al., 2009; Carroll et al., 2004). Together, these findings set the stage to examine human-caused ignition risk as a product of local culture at the community scale.

Humans interpret and interact with their environments in complex manners, and a vast body of literature documents how this diversity influences wildfire risk perceptions, forest management strategies, and homeowner mitigation actions, among other risk management processes (e.g., Martin et al., 2009; Winter et al., 2002; McCaffrey, 2010; Wu et al., 2022; Dickinson et al., 2015). These complexities emphasize that one-size-fits-all approaches to reduce human-caused ignitions are inadequate; to be successful, they require a melding of local culture with individual behaviors (Reilley et al., 2023). Prevention, defined here as the administration of educational, engineering, and enforcement interventions designed to modify human behavior and reduce undesirable human-caused wildfires, is one such approach that requires strategic application (NWCG, 2021). Prevention preferences are highly variable within the U.S. Southwest alone, indicating the need for case studies employed at the local level to develop place-based understandings of wildfire prevention approaches to bolster effectiveness (Devenport & Edgeley, 2025).

While current prevention efforts are recognized as worthwhile investments for reducing human-caused ignitions (Prestemon et al., 2010; Abt et al., 2015), recent literature has identified knowledge gaps that inhibit prevention effectiveness at the local level (Edgeley, 2023; Hesseln, 2018; Devenport & Edgeley, 2025). Here, we address these shortcomings by exploring community perceptions of human-caused ignition risks from diverse public land users and

related prevention approaches to mitigate these risks. We conducted focus groups with residents and professionals in Flagstaff, Arizona, to better characterize diverse user groups and the perceived ignition risks they introduce, in addition to examining barriers and opportunities to enhance local-level prevention strategies. This research serves two primary purposes: (1) to provide insights into the complexity of ignition risk informed by diverse human behaviors, and (2) to investigate place-based understandings of wildfire prevention strategies to inform more nuanced guidance for actionable prevention.

2. Literature Review

2.1 Human-caused Wildfires: Ignition Sources and Public Land Users

Human-caused wildfires originate from an array of human actions and intentions as shown in Table 1. Most of these fires are ignited unintentionally from sources including equipment use, debris burning, and smoking (Ganteaume & Syphard, 2018; Prestemon et al., 2013; Short, 2022). Another common source of unintentional ignitions is escaped and abandoned campfires, particularly in the U.S. Southwest, as demonstrated by the campfire-ignited 2011 Wallow Fire which burned over 500,000 acres and remains the largest wildfire in Arizona's history (Evans, 2018; Waltz, 2012). Wildfires are also frequently ignited intentionally and result in substantial impacts to human values, exemplified by the arson-caused 2024 Park Fire which consumed 700,000 acres and destroyed over 700 structures (Cal Fire, 2025). While these examples highlight the connection between unwanted human-caused ignitions and impactful wildfires, other ignitions, such as those purposefully ignited to achieve land management objectives, originate from positive intent yet can result in destructive outcomes nonetheless. For example, the 2000 Cerro Grande Fire was an escaped prescribed fire that destroyed 235 homes in

the town of Los Alamos, NM (Lonnie et al., 2000). While these distinguished wildfires highlight catastrophic impacts from various ignition sources on a national level, they fail to capture the granularity of ignition risk at local scales, shaped by place-based social contexts that are intrinsically linked with wildfire risk, mitigation, and adaptation (Paveglio et al., 2015).

Table 1: Human-caused ignition cause classes and number of ignitions in the U.S. from 1992 – 2020

Cause classification	**Number of ignitions**
Missing data/not specified/undetermined	597,933
Debris and open burning	535,851
Arson/incendiarism	320,814
Equipment and vehicle use	190,319
Recreation and ceremony	99,473
Misuse of fire by a minor	66,280
Smoking	63,783
Railroad operations and maintenance	37,292
Power generation/transmission/distribution	32,652
Fireworks	18,599
Other causes	10,517
Firearms and explosives use	2,734

Note. Table from metadata in: Short, Karen C. 2022. Spatial wildfire occurrence data for the United States, 1992-2020 [FPA_FOD_20221014]. 6th Edition. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2013-0009.6

Recent studies illustrate societal factors that drive human-caused ignition risks, including regional land use trends, proximity to wildland urban interface areas, and socioeconomic conditions, yet the influence of diverse groups of people who use public lands remains largely

undocumented (Fusco et al., 2016; Mietkiewicz et. al., 2020; Grala et al., 2017). Despite an array of ignition sources identified by spatial data that indicates a diversity of public land users contributing to human-caused ignition risk, fire-related perceptions and behaviors of user groups remain understudied (Short, 2022). The National Wildfire Prevention Strategy emphasizes 'identifying responsible entities' as a critical component of developing well-informed prevention, however, it is unclear whether these efforts are being conducted or documented (NWCG, 2021). Literature that explores land users and associated ignition risk is limited and tends to focus on just three groups - recreationalists, children, and arsonists, each explored in turn below - which is likely an oversimplification of the diversity of human actors at play in local landscapes.

Upward trending visitation to U.S. public lands indicates growing numbers of recreationists engaging with these spaces, and wildfires unintentionally ignited by these public land users are common nationwide (USFS, 2023; NPS, 2023; BLM, 2022; Short, 2022). Recreation literature identifies heterogeneity among recreationists, documenting behavioral and demographic distinctions that define subgroups including off-highway vehicle riders, backcountry campers, vehicle-based campers, hunters, and mountain bikers among other groups that interact with public lands in various ways (Smith et al., 2021; McIntyre & Pigram, 1992; Grisham, 2018; Black, 2017; Bordelon & Ferreira, 2019). These distinctions suggest that recreational subgroups contribute to ignition risk differently; for example, off-highway vehicle riders likely pose a higher risk of vehicle caused ignitions near roads, while backcountry campers may introduce elevated ignition risk through escaped and abandoned campfires in remote areas (Kil et al., 2012; Reid & Marion, 2005). While these trends are reasonable assumptions, existing literature lacks analysis of ignition related behaviors from recreational subgroups, and spatial ignition data aggregates all recreation ignitions into a single cause-class, limiting the ability to

differentiate subgroup specific patterns (Short, 2022). Instead, current literature only documents spatial and temporal patterns that characterize this group as homogenous. For example, frequent human ignitions align with high densities of recreational visitors, and are often spatially concentrated near features including roads, campgrounds, trails, and other points of interest (Jenkins et al., 2023; Narayanaraj & Wimberly, 2012; Benefield & Chen, 2022). Temporally, human ignitions frequently occur during common recreation periods including holidays and weekends that extend the duration of historic wildfire seasons (Jenkins et al., 2023; Balch et al., 2017).

Children frequently cause fires that significantly impact human values; from 2007 to 2011, U.S. fire departments received an average of 49,300 reported fires from child play, responsible for annual averages of 80 deaths, 860 injuries, and $235 million in property damages (Campbell, 2014). Child fire setting has been recognized as a dangerous societal trend in the U.S. for several decades, prompting significant literature documenting the factors and patterns associated with this behavior (Brady, 1986). Children most commonly ignite wildfires out of curiosity as opposed to malevolent intent, lacking an understanding of the dangers associated with their behavior (Gaynor & Hatcher, 1987). Child fire setting has also been linked to psychological disorders and behavioral issues including antisociality, depression, impulsivity, aggression, and similar behavioral patterns (Lambie & Randell, 2011). While the impacts of child-ignited fires and the psychological factors associated with this behavior are well documented, existing literature does not account for how land ownership may influence these patterns. As a result, it remains unclear whether the impacts and behaviors specified above apply equally to wildfires ignited on public lands or are only reflective of fires on private property.

Arsonists ignite over 500,000 fires annually in the U.S. resulting in billions of dollars in damages to private and public resources alike, and literature documenting the patterns and behaviors of this group has been consistently published since the 1950's (Tridata Corporation, 1997; Lewis & Yarnell, 1951). Studies that explore motivations of arsonists point to numerous driving factors including profit, animosity, vandalism, crime concealment, political objectives, and psychopathological factors (Kocsis, 2002; Kocsis & Irwin, 1997; Rix, 1994; Kapardis et al., 1983). Wildfires ignited by arsonists are spatially predictable, most commonly occurring in wildland urban interface areas with heavy fuel loading and clustered around recent arson incidences (Prestemon & Butry, 2010). Temporal patterns also emerge; elevated arson ignition risk prevails several days after an initial event, and periods of weather conditions that increase the probability of wildfire spread such as temperature, precipitation, and drought have been found to increase arson frequency (Prestemon & Butry, 2010). The applicability of these findings to regions with varying land use patterns and values at risk is uncertain, particularly in the U.S. Southwest where arson research is notably scarce.

The literature reviewed above likely oversimplifies the complexity of human-caused ignition risk by failing to capture behavioral nuances of diverse user groups. Recreationists are categorized as homogenous despite behavioral and demographic distinctions that presumably influence ignition risk from recreational subgroups. Similarly, existing research on children and arsonists does not account for how land use patterns and place-based socio-geographic characteristics shape ignition-related behaviors in varied landscapes. These shortcomings warrant further research that explores the behaviors and perceptions of various user groups on public lands to build upon these groups and identify others that are not represented by current literature.

2.2 Current Prevention Approaches

U.S. wildfire management and policy efforts aimed at mitigating the impacts of catastrophic wildfire have historically focused on fire suppression and fuels management (Butry, 2009). More recently, researchers and practitioners alike have increasingly pointed towards fire prevention as a tool for human ignition reduction, but prevention literature to inform application is scarce (Edgeley, 2023; Devenport & Edgeley, 2025; Prestemon et al., 2010; Abt et al., 2015; Reilley et al., 2023; Syphard & Keeley, 2015). One method used to classify current prevention approaches is the fire prevention triangle, a framework originally borrowed from traffic safety programs by the U.S. Forest Service in the 1960's, and later adopted by the National Wildfire Coordinating Group (Riebold, 1967; NWCG, 2021). This framework categorizes prevention interventions employed to reduce unwanted human ignitions into three categories: education, engineering, and enforcement, collectively managed via various administrative approaches. This section will summarize literature detailing prevention approaches and, where available, their effectiveness.

Prevention education encompasses a range of interventions designed to modify human behaviors by increasing awareness of fire-related risks and providing tools to reduce ignition occurrence. Many educational strategies disseminate information to large and diverse audiences through unidirectional (i.e. passive, one way) communication such as fire prevention signage, printed materials, and media efforts ranging from mass TV and radio announcements to social media posts (NWCG, 2021). Other educational approaches are interactive (i.e. two-way), employing face-to-face communication strategies tailored to specific audiences from knowledgeable professionals during community meetings, visitor center interactions, classroom presentations, volunteer events, and similar settings (Toman & Shindler, 2006).

Educational interventions are effective at preventing human-caused ignitions from a variety of ignition sources and land ownership designations, signifying that they are worthwhile economic investments (Butry et al., 2010; Prestemon et al., 2010; Abt et al., 2015). Early prevention literature underscores the importance of combining education approaches with adequate enforcement to change public behavior (Riebold, 1967; Donoghue & Paananen, 1984). More recent studies point towards additional factors that increase the success of prevention education, including messaging that aligns with audiences' attitudes and beliefs, occurs over extended temporal scales, and utilizes a combination of educational approaches (Manning, 2003; Abt et al., 2015; Prestemon et al., 2010). Interactive education is more effective than one-way approaches because it facilitates relationship building between managers and the public and allows educators to deliver information tailored to an audience's questions and concerns (Monroe et al., 2005; Toman et al., 2006). While one-way education efforts including prevention signage, media announcements, and printed signage are also recognized as effective tools, literature analyzing specific success factors of these approaches is limited and often outdated (Prestemon et al., 2010; Folkman, 1973). Education to enact fire-related behavioral change is most effective if it is site-specific, highlighting the importance of educational prevention approaches tailored to local context (Devenport & Edgeley, 2025; McCaffrey, 2006).

Engineering interventions aim to reduce the probability of wildfire ignitions by modifying the environments that humans interact with in ways that prevent unwanted behaviors (Folkman, 1970). Most engineering approaches prevent recreation-related ignitions through infrastructural modifications such as campfire rings to inhibit fire spread, water sources made available to extinguish campfires, fences built to limit access or discourage camping, development of designated shooting areas, and spark arrestors required on vehicles (NWCG,

2021). These approaches are commonly implemented in high-use recreational areas such as campgrounds and access roads to prevent human ignitions that occur at high rates in these locations (Jenkins et al., 2023; Benefield & Chen, 2022). Other engineering interventions target human ignitions from developed infrastructure and include modifications to utilities, electric lines, and railway tracks (NWCG, 2021).

Research investigating the effectiveness of engineering approaches is particularly scarce, limited to a few studies that evaluate campfire-related interventions. The establishment of campfire rings has been found to decrease the number of campfire sites created by public land users (Reid & Marion, 2005), and a study evaluating campfire ring tolerance in wilderness found higher acceptability from managers than public land users (Shelby & Shindler, 1992). Additionally, a recent study by Devenport and Edgeley (2025) highlights that engineering interventions are preferred by campers or recreationists in remote locations. While these studies may serve as a jumping-off point for additional engineering-prevention research, they do not directly measure the role of campfire interventions in preventing unwanted human-caused ignitions, and research investigating the effectiveness of other engineering approaches is scarce.

Enforcement involves implementing restrictions and regulations to limit activities and access that introduce unwanted human-caused ignition risk. These interventions are commonly enforced through fines or criminal charges (NWCG, 2021; Aslan et al., 2021). Many enforcement approaches such as campfire permits, law enforcement patrols, and failure to comply citations exist on a permanent basis, while others are implemented temporarily under adverse conditions like high-fire danger or limited suppression resources, including stage restrictions, area closures, and burn bans (NWCG, 1998). The enforcement of prevention regulations is typically conducted by law enforcement officers under the jurisdiction of local law

and land management agencies. The implementation and regulatory terms of enforcement interventions may vary by the issuing agency, which can cause confusion or contrasting interpretations in jurisdictionally complex areas (Donoghue & Paananen, 1984).

The effectiveness of enforcement interventions is primarily documented in the context of action by law enforcement officers. Early prevention research pointed towards increased enforcement presence and scheduling patrolling efforts on high-risk days as effective approaches to decrease illegal ignitions (Fraser, 1937; Reynolds, 1941). Modern studies build on these findings by documenting reductions in both arson and accidental ignitions through increased law enforcement and indicate the role of arson-related arrests in reducing intentional fire setting (Thomas et al., 2012). These reductions in ignitions are likely a result of an elevated perceived risk of potential offenders being caught and the removal of offenders from the intentional fire setting population (Prestemon et al., 2010). The effectiveness of preventative restrictions and regulations has garnered less attention in the literature. The issuance of campfire permits has been identified as an effective preventative measure because it creates accountability paired with an interactive education opportunity (Tymstra et al., 2020). Similarly, campfire bans and designated campfire regulations are documented as successful in reducing the number of illegal campfire sites (Reid & Marion, 2005). In one study, forest closures were recognized as a productive human ignition prevention tool by managers, but they cautioned that this approach negatively impacts tourism (Tymstra et al., 2020). While these studies indicate the usefulness of preventative regulations and restrictions, quantitative evaluation of the effectiveness of these approaches is missing. Additionally, research frequently points to the usefulness of enforcement paired with educational interventions, indicating that enforcement alone may be insufficient in preventing unwanted human-caused ignitions (Riebold, 1967; Wetherill 1980).

In summary, existing literature provides limited insight into place-based wildfire prevention strategies and their role in reducing unwanted human-caused ignitions, particularly in the U.S. Southwest. Furthermore, current research has only documented ignition-related behaviors and perceptions of recreationists, arsonists, and children, which is likely an oversimplification of ignition risk given the diversity of sources and activities from which human-caused wildfires originate. Additional studies that investigate ignition risks and prevention approaches are critical as human-caused wildfires increasingly threaten human values and prevention is progressively called on as a risk reduction method. This research aims to address the needs outlined above by exploring public and managerial perceptions of diverse human-caused ignition user groups and various prevention strategies in a community vulnerable to human-caused ignitions. The following research questions drive our efforts:

1) How do members of the public and managers in Flagstaff characterize different public land user groups and the ignition risks they present?
2) To what extent do members of the public and managers in Flagstaff support existing and new approaches to local human-caused ignition prevention?

3. Methodology

3.1 Study Area

Flagstaff, Arizona is a community of approximately 77,000 residents situated near the Grand Canyon, San Francisco Peaks, and Coconino National Forest, two hours north of the Phoenix metropolitan area that supports a population of nearly five million people (U.S. Census Bureau, 2023; Maricopa Association of Governments, 2023). The greater Flagstaff area has an extensive fire history characterized by impactful human-caused wildfires as shown in Figure 1.

While anthropogenically driven wildfires are increasingly common in the Western U.S., Flagstaff's fire history is particularly notable because of the diversity of public land users that have introduced these ignitions (Balch et al., 2017). For instance, the 2022 Pipeline Fire that burned over 26,000 acres adjacent to Flagstaff was ignited by an unhoused person camping in the foothills of the San Francisco Peaks. This ignition reflects a rapid growth in Arizona's unhoused population, increasing by 23.4% from 2020 to 2022 (U.S. Department of Housing and Urban Development, 2022). The cause of the Tunnel Fire, which also occurred in 2022 and destroyed over 30 homes adjacent to the community, remains undetermined after a multi-year investigation, reflecting an immensity of wildfires in the U.S. in which the specific cause is never resolved. Three years prior, the 2019 Museum Fire prompted evacuations and extensive area closures across the Coconino National Forest, ignited by contracted thinning equipment conducting restoration work in Flagstaff's Dry Lake Hills. This restoration work was funded by the Flagstaff Watershed Protection Project, a voter approved bond-funded forest treatment project aimed at reducing the risk of catastrophic wildfire adjacent to the community (Mottek-Lucas, 2015). The 2010 Schultz Fire, Arizona's largest 2010 wildfire accompanied by severe post-fire flooding, was ignited by a recreationalist's abandoned campfire. While the Schultz Fire was notable, recreation-related ignitions are not novel to the area; the 1977 Radio Fire was also ignited by an abandoned campfire and caused regional communications disruptions and permanently changed the appearance of Mount Elden, and Flagstaff is a hotspot for recreational negligence ignitions as shown in Figure 2. (Fox, 2016). These recreation-related wildfires reflect the intense visitation that Flagstaff receives, commonly for outdoor recreational purposes and during Northern Arizona's peak fire season that exacerbate concerns over future human-caused ignitions from similar sources (Arizona Hospitality Research & Resource Center, 2019). This array of impactful

human-caused wildfire events underscores the presence of diverse groups that occupy the area's public lands and present human-caused ignition risk from varying sources, making Flagstaff an ideal location for this study.

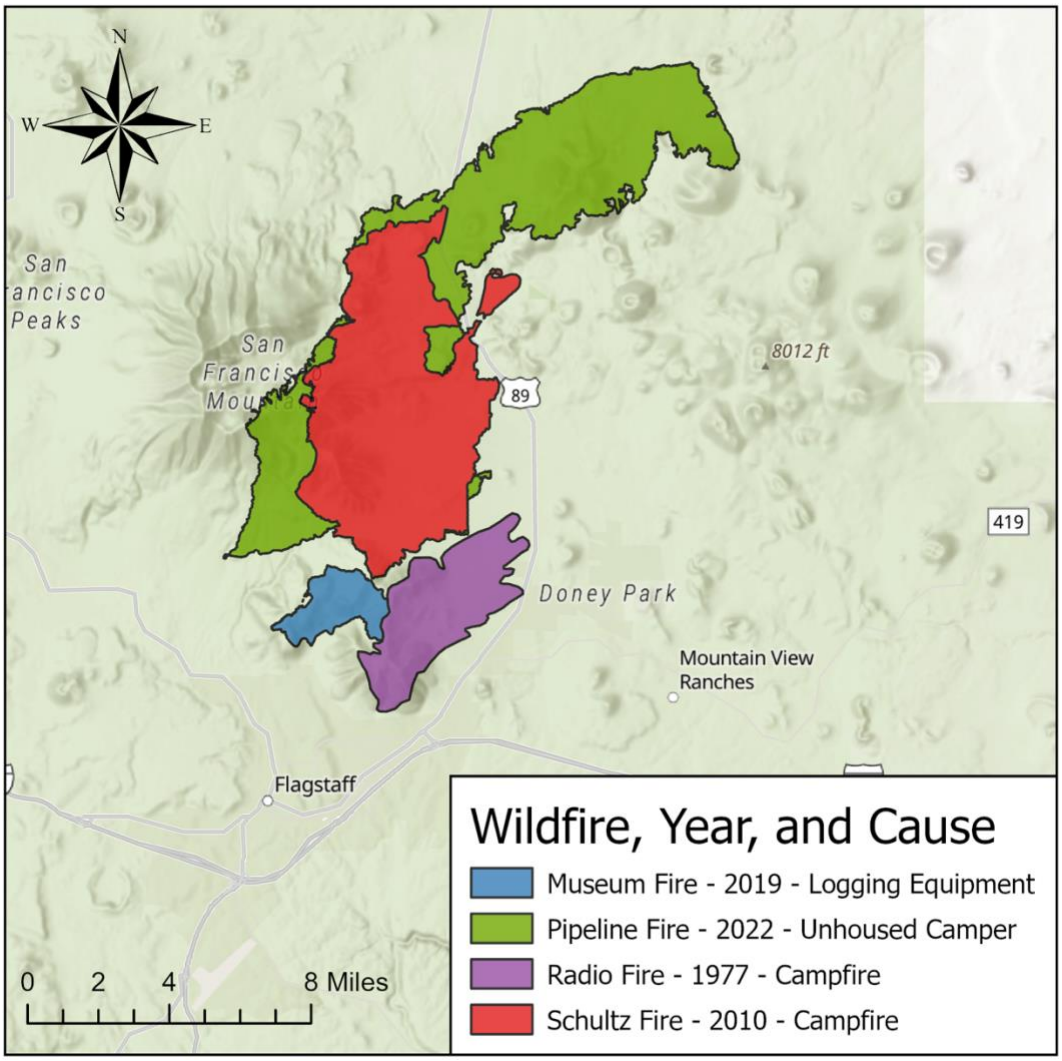

Figure 1: *Notable human-caused wildfires near Flagstaff, Arizona, ignited by diverse causes and land users*

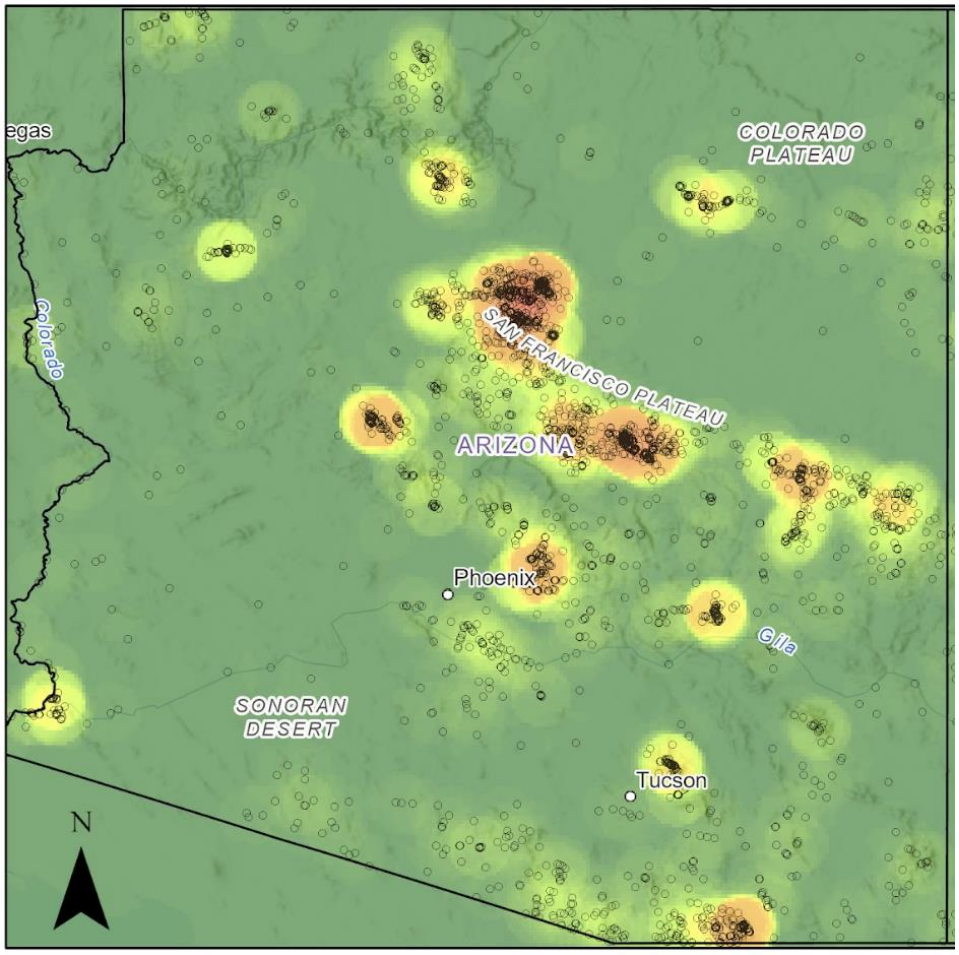

Figure 2: *Recreational negligence ignition hotspots in Arizona. Map created by Zander Evans.*

3.2 Approach

Data was collected via focus groups, a qualitative social science methodology in which participants with certain characteristics engage in a facilitated discussion (Krueger, 2014). Focus groups were chosen because it allowed researchers to observe collective attitudes and concerns of participants based on shared experience in the same landscape, and this methodology is underutilized for wildfire social science in the U.S. Southwest (Edgeley, 2023). Five focus groups were conducted with a total of 45 participants with each group consisting of 6 to14 participants and discussions lasting between 1 h 20 minutes to 1 h 47 minutes. Three discussions

were held with a total of 21 members of the public and two with a total of 24 fire and land management professionals, conducted separately to encourage uninhibited and unbiased discussion. Professional participants, referred to as 'managers' from this point forward, were selected because their occupations intersected with human-caused ignition prevention and management. These participants were employed by federal, state, county, and city fire and land management agencies. Members of the public who engaged in focus group discussions were both long- and short- term permanent residents to the Flagstaff area. Researchers employed a semi-structured protocol comprised of open-ended questions intended to prompt discussion centered on (1) impactful human-caused wildfires in the Flagstaff area, (2) perceptions of varying sources of human-caused ignition risk in the area, and (3) the management of human-caused ignitions and risks including suggestions for their prevention. Topics and questions in the protocol were informed through local knowledge and needs identified in relevant literature.

A combination of theoretical and snowball sampling was used to identify participants. First, theoretical sampling – the identification of individuals with relevant expertise – was used to select knowledgeable managers and community leaders through publicly available information sources including employee databases and media articles (Coyne, 1997). These individuals were contacted and asked to recommend other potential manager and public participants, a process known as snowball sampling, which continued with each recruitment interaction (Parker et al., 2019). This strategy widened our sample population and ensured representation from various groups. Researchers continued recruiting participants and holding focus groups until theoretical saturation was reached, in which new perspectives and themes no longer emerged (Glasser & Strauss, 1968).

3.3 Analysis

Each focus group was recorded with participant consent and recordings were later transcribed verbatim. Researchers discussed emergent themes following each focus group that established a foundation for coding. Qualitative coding, an approach in which text is systematically categorized to uncover patterns or themes, was then implemented using QSR NVivo software (Auerbach & Silverstein, 2003). During the initial coding process, researchers employed intercoder reliability in which a subset of transcripts was coded by each researcher to ensure consistency in interpretation (Saldaña, 2016). Two cycles of coding were then implemented: descriptive followed by thematic. Descriptive coding involved assigning focus group content to broad descriptors to categorize key topics, and thematic coding employed focused codes that allowed researchers to develop specific themes from the data (Saldaña, 2016). Themes that emerged from second cycle coding allowed researchers to directly inform the results section of this paper. Finally, representative quotes were extracted from focus group transcriptions and incorporated in this paper that support findings drawn from emergent themes.

4. Results

4.1 Characterizing Public Land Users and Ignition Risks

Focus group discussions revealed five distinct groups that participants perceived as presenting human-caused ignition risk on public lands surrounding Flagstaff. These groups were: voluntary unhoused persons, involuntary unhoused persons, transplants, tourists, and locals. This section reviews each in turn, summarizing how focus group participants characterized each group and the perceived level of ignition risk they introduced to the Flagstaff area.

4.11 Unhoused Populations

Participants described a recent uptick in unhoused persons living on public lands in the Flagstaff area, driven by both lifestyle choices and necessity. A local manager summarized:

> *Since COVID, [there are] more people, they're staying there longer, they're burrowing back further. In Oak Creek Canyon off two of the popular roads, you find these little two tracks and you go back there and there's like 10 RVs, 10 campers, it's a mini city. You'd never see that before.*

Under the umbrella of unhoused populations, participants characterized two subgroups: (1) voluntary unhoused persons who lived on public lands by choice seeking a nomadic lifestyle, and (2) involuntary unhoused persons who lived on public lands out of necessity, which were the predominant focus in conversation. Participants described behavioral distinctions between voluntary and involuntary unhoused populations that led to differing perceptions of ignition risks. The voluntary unhoused population, often labeled 'van-lifers' by participants, was described as a new generation of unhoused persons who lived and worked out of their mobile vehicles on public forest lands. This sub-group was described as seeking comforts including water, power, and cell phone service, and had little need to have campfires. These behavioral patterns led participants to describe the voluntary unhoused population as presenting significantly lower human-ignition risk and more relatable land use behaviors compared to those who were unhoused involuntarily. One local manager explained:

> *What I've seen is [van-lifers] are not our fire risk people. Typically, they're looking for, 'Hey, I want water. I want power. And I want a good cell signal so that I can continue to work on my laptop remotely.' They're not out building fires. It's the other guy... It's Bob driving a '62 Winnebago that looks like it's seen better days, and it's got 45 things hanging off the back.*

When discussing the involuntary unhoused population participants highlighted broader societal factors that had led to the high presence of these persons living on public lands. Managers described Flagstaff's overwhelmed social services (like emergency shelters) lacking

capacity to accommodate growing numbers of unhoused persons as a driver for public land use in this manner. They also noted that Flagstaff's housing costs had risen significantly in recent years, limiting the living options available to unhoused persons, making occupation of local public lands an alternate option. Participants felt the involuntary unhoused population acted irresponsibly towards the public lands they occupied and often suggested they were the cause of the neglected state of forest lands surrounding unhoused encampments. Participants equated this perceived irresponsibility from unhoused persons with a heightened threat of starting wildfires, often citing the Pipeline Fire ignited by an unhoused person to support their claims. One manager perceived the deterioration of public lands from this group to perpetuate ignition risk in new locations:

> *It's like, 'Well, this place has turned nasty. I did it, but I'll just drive down the road to another spot. So, if I accidentally start a wildfire here, I know I can just get in the car and leave.'*

Participants thought this group possessed similar attitudes towards fire restrictions; they described involuntary unhoused persons as unconcerned and negligent towards prevention measures including campfire bans, stage restrictions, and forest closures designed to mitigate human-caused ignition risk. Local managers suggested that this group was commonly aware of these preventative measures yet stereotyped the group as acting carelessly towards them nonetheless:

> *It doesn't point towards them not knowing that the forest is in closure or there are restrictions that are in place. They just don't care, or they're too intoxicated to not do it.*

Discussions highlighted several factors that helped explain perceptions of heightened ignition risks from involuntary unhoused persons. While participants expressed concern over this group intentionally igniting fires, they were sympathetic towards this behavior due to adverse circumstances at play. Participants described involuntary unhoused persons lighting fires for

warmth or cooking hot meals in Flagstaff's frigid high elevation climate. These utilitarian fire uses indicated that these people were simply doing what was necessary to survive, regardless of ignition risks and fire restrictions. Participants also suggested that involuntary unhoused persons were more likely to have adverse mental and emotional states and possibly under the influence of substances, all factors that could inhibit their ability to responsibly manage personal ignition risk:

> *They're going to have a fire because they think they need it to survive. And often they're not in the best mental or emotional place to take care of something like that. And [they] just move on to the next place and leave the fire.*

4.12 Transplants

Participants described the community of Flagstaff as highly transient, referring to the continuous influx of new permanent residents with varying levels of familiarity with wildfire moving to Flagstaff from around the country. Both members of the public and managers believed transplants introduced an elevated risk of accidental ignitions compared to long-term residents and described this group as commonly exhibiting hazardous and ill-informed fire-related behaviors. Attitudes of heightened ignition risk were attributed to a lack of knowledge regarding the environmental conditions that make the Flagstaff area prone to impactful human-caused wildfires. Additionally, participants perceived this group as unaware of fire restrictions employed to mitigate human ignitions and uninformed as to where this knowledge could be obtained. As one local manager explained:

> *I get a lot of calls from folks that have recently moved here, and they don't understand why there are fire restrictions. You have to explain, especially [to] folks that move from the East coast or Midwest. Folks don't know, and they also don't know where to find the information.*

Discussions revealed several factors that explain perceptions of elevated ignition risk from transplants. First, participants suggested that many regions of the U.S. have vastly different environmental conditions that foster low ignition risk compared to the Flagstaff area, so

transplants who have exclusively lived in dissimilar regions were described as ignorant to local conditions, as explained by one member of the public:

> *In the early spring, the forests are just a complete tinderbox. So, if you grew up with forests that were in a swamp, you probably became accustomed to fire being something that wasn't that big of a deal or was easy to manage. But with the winds that we experience around town, I think people don't always have the same sensitivity to just how dry [it is] and how readily fire can establish.*

The perceived lack of awareness about fire restrictions from this group was explained by participants noting that such prevention measures are absent in many regions of the U.S. They believed this knowledge was typically gained through years of living in a fire-prone environment, as summarized by a life-long Arizona resident:

> *Anybody moving from the East Coast, they don't know about fire restrictions, they're not checking the website to see if fire bans have started yet, whereas anybody that's grown up here, as soon as it's May and someone [says], 'Oh, let's go camping,' I'm like, 'All right, see if campfires are allowed.' And if you're not from here, you're not paying attention to that.*

Participants also described varying cultural customs regarding the use of fire as a driver of increased human-caused ignition risk from transplants. They saw this group as introducing hazardous fire-related customs that might have been acceptable in their former localities but introduce ignition risk to the Flagstaff area, as one participant explained:

> *There can be vast differences in what a person was taught is good forest etiquette depending on where they grew up. There are places in the U.S. where the etiquette is to burn your toilet paper. If you're from those areas and that's what you were taught and you don't know about differences in climate and the environment, when you come here, [you] might think that's the right thing to do.*

4.13 Tourists

The high concentration of tourists who visit Flagstaff, particularly during peak fire season and for outdoor recreational purposes, was a leading concern for participants in terms of human-caused ignition risk. As a manager summarized:

> *The lightning caused fires aren't the problem. It's the human caused fires. It's people that come from out of town and don't know what they're doing here.*

Like transplants, tourists were perceived to lack knowledge of both environmental conditions that put Flagstaff at high risk of impactful human-caused wildfires and the fire restrictions employed to prevent these events. Unlike transplants, however, participants saw tourists as completely careless towards environmental considerations and fire restrictions alike. Tourists visiting from the Phoenix Metro area were described to view Flagstaff's public lands like a theme park designed for their enjoyment without rules or consequences. One manager described tourists from 'the valley,' a colloquialism for the Phoenix area, treating Flagstaff as a lawless area:

> *I heard someone at a meeting [say] they get the impression from people in the Valley that Coconino National Forest [is] like Vegas, and that what happens in Vegas stays in Vegas. The rules don't apply.*

Tourists were described as having non-negotiable recreational expectations when visiting Flagstaff and participants believed these attitudes resulted in campfire ignitions under adverse circumstances and similar reckless fire-related behaviors. Participants noted the significant financial costs and long travel distances that tourists undertake for a vacation in Flagstaff that creates pressure for this group to maximize their visits. These attitudes were described to make prevention strategies like social media messaging and road signage ineffective for this group, as summarized by a manager:

> *Nobody from Phoenix is looking at the Coconino County Instagram account before they come up here. Those signs over the road are one thing, but a lot of people don't pay attention to those [either].*

4.14 Locals

At the onset of focus group discussions, participants who were self-described locals commonly placed blame on other groups for introducing human ignition risk rather than

themselves. One lifelong Flagstaff resident expressed this belief in relation to shutting down Interstate 17, the travel corridor connecting the Phoenix to Flagstaff:

> *If we were to shut the I-17 down, for a certain amount of months we wouldn't have any problems. All the locals would be no issue. It's everybody outside.*

As discussions progressed, however, participants increasingly acknowledged that locals are not exempt from presenting human-ignition risk, as explained by one member of the public who recalled witnessing irresponsible fire-related behaviors from a group of Flagstaff children:

> *All that said, I've seen some locals do some boneheaded things. Like a group of kids trying to light a campfire in the middle of a residential area after seven days of red flag warnings. It's like, 'what are you doing?'*

Accompanying the acknowledgement that locals do in fact present ignition risks participants suggested two factors that increase risk from locals compared to other groups. First, they described this group spending more time on public lands near the community compared to other groups simply because they live in Flagstaff year-round, increasing their chances of unintentionally igniting wildfires. Second, managers described locals possessing an attitude of entitlement towards using public lands under fire restrictions, an attitude that may justify disobedience of restrictions under high fire-risk conditions, as described by one manager:

> *When we close the forest down, there's a whole, 'oh, they're closing the forest to everybody except the locals.' And that's not true. It's everybody.*

Despite these factors, participants still described ignition risk presented by locals as insignificant relative to other groups because they held a deep understanding, developed through years of experience, of how to live safely in a fire-prone environment. Participants described this understanding as including knowledge of local fire ecology, awareness of changing environmental conditions, recognition of annual patterns in fire restrictions, and familiarity as to

where fire prevention information is accessed. One member of the public explained locals' knowledge of fire restrictions as follows:

> *I would think we're all in a routine now. We know that come May, maybe even early May, we're starting to button down on things and watch them, if we're going to a no coal situation soon, and then we might go to a no gas situation soon. It's routine if you're local. This is just the nature of the season.*

Participants also suggested that differing public land use explains low ignition risk from this group. They explained that locals are commonly utilizing public lands for 'low-risk' activities including dog-walking, mountain biking, and trail running, instead of 'high-risk' activities like igniting illegal campfires or permanently residing on public lands. Participants believed these behaviors originate from a spatial and social attachment to the Flagstaff area as their permanent home, along with a lack of need for utilitarian fire uses, enabling them to navigate public land use and ignition risk responsibly.

4.2 Opportunities and Challenges for Human Ignition Prevention

Focus group participants expressed strong support for current strategies employed to prevent human-caused wildfires from the user groups described above but identified gaps in the current suite of approaches available to them. This section classifies prevention recommendations into two groups by comparing perceptions of the public and managers: low complexity strategies in which participants did not perceive significant barriers to implementation, and high complexity strategies in which significant barriers were identified.

4.21 Low Complexity Strategies

Members of the public described roadway signage, an educational intervention designed to communicate fire restrictions, as a common prevention approach in the Flagstaff area and expressed support towards this mechanism. Members of the public supported this strategy

because many had personally acquired fire-related knowledge through roadway signage and perceived this approach as preventing ignition risks from tourists who were a foremost concern. To increase the effectiveness of this intervention, the public suggested strategically installing roadway signage along Interstate 17 to inform tourists traveling from Phoenix of fire restrictions as early as possible, as one member of the public explained:

> *Put them [further] down the freeway, or even on the way out of Phoenix, that say 'Coconino National Forest is Closed' or 'Campfires Prohibited.'*

Managers also expressed nearly unanimous support towards roadway signage as a human-ignition prevention mechanism. They saw current signage as effective and advocated for strategically increasing its presence along tourism travel corridors. Several manager participants from varying backgrounds had personal experience administering roadway signage, indicating that an array of local, state, and federal agencies are capable of implementation. Managers described some limitations to this approach, including limited funding, short temporal access to signs, and frequent signage failure, but because these barriers were feasible to address at the local level, managers believed that further investment into this strategy was a promising avenue for improved human-caused ignition prevention.

Members of the public supported implementing a geographic alert system, also known as a geofence, to reduce human-caused ignition risk. They described this mechanism as a location-based messaging system that could distribute cell phone alerts communicating fire restrictions to all phones present within the Flagstaff area. The public supported implementing a geofence because they suggested the system could disseminate real-time fire restrictions to all public land users, emphasizing that tourists would receive alerts as they traveled into the Flagstaff area, increasing this group's knowledge of fire restrictions before visiting local public lands.

Like the public, managers were supportive of implementing a geofence and cited preventing ignition risk from tourists as a primary factor enhancing their support. One manager articulated that this strategy was currently under development by City officials, allowing federal fire managers to take a hands-off approach in implementation. One manager articulated that the geofence under development would disseminate fire-related information through visitors' social media platforms, targeting cell phones that originate from outside the Flagstaff area code:

> *[It's called a] 'geofence.' If somebody comes in without a 928 number, their social media will start getting ads about fire danger and stuff.*

4.22 High Complexity Strategies

Members of the public described forest closures as a prevention strategy employed infrequently under extreme fire danger conditions in the Flagstaff area. They perceived this strategy as highly effective because public land access was eliminated for all user groups which drastically reduced the chances of human-caused ignitions. Public participants expressed a desire for more frequent forest closures, particularly during periods of high tourism that aligned with fire season including July 4th and Memorial Day weekends. The public acknowledged that frequent forest closures likely conflict with economic benefits driven by tourism but felt that using this strategy to prevent human-caused ignitions was more important than economic gains. Members of the public saw other limitations to frequent forest closures, including the decision to close the forest being made at the federal level instead of by local managers, and that forest closures were an arduous effort, as summarized by one member of the public:

> *When it gets to the point, many of us are saying 'Just close it.' And the answer I get [is] 'We have to go through Washington [DC], and it takes so much time and resources to close it.' And I said, 'I will drive out in my pickup and push those gates shut and lock them.' We can mobilize enough volunteers who will get out there and close those roads.*

Despite these limitations the public remained steadfast in their desire for more frequent forest closures, and many voiced a willingness to volunteer their time to assist in implementation.

Managers also saw forest closures as an effective ignition prevention mechanism because, like the public, they viewed this strategy as restricting National Forest access which reduces public land use, and in turn, human-caused ignitions. Despite perceiving this strategy as effective, however, managers identified several limitations to increasing the frequency of forest closures that led to their unsupportive attitudes. First, they described difficulties in deciding that a forest closure is appropriate; a determination that often takes weeks to execute as it requires consensus at the local, regional, and federal levels. Once decided upon, managers saw implementing a forest closure as an exceptionally rigorous effort requiring advanced coordination and placing a demanding workload on local staff, as one manager described:

> *I've only personally seen one full forest closure. And I know that those things are a throw down, drag out effort on the district level to your regional supervisor's office. It's not an easy thing to get done.*

Managers also identified behaviors from public land users during forest closures that inhibit this strategy's effectiveness. First, they described users commonly disobeying forest closures by cutting locks and removing barricades. Additionally, managers believed that public land users frequently redirect their access to state-owned lands during forest closures, which displaces rather than eliminates human-caused ignition risk under high fire danger conditions. Managers also described a high-volume displacement of unhoused persons during forest closures that places heavy pressure on the social services and local businesses of Flagstaff to support these people.

Members of the public suggested a campfire permit system as a novel human-caused ignition prevention mechanism for the Flagstaff area and were supportive of implementation.

The public described this system as an effective prevention approach employed on California's national forests, therefore they perceived that it could be easily replicated locally. They supported this strategy because they perceived it to limit the number of campfires on public lands, and permitted campfires would be spatially and temporally accounted for which could inform managers on the distribution of campfire-related ignition risk. Permits were also seen as an educational opportunity, integrating information about campfire risks and etiquette into the permitting process. Members of the public suggested that funds generated through a campfire permit system could be applied to local budgets to strengthen other wildfire prevention strategies or fund additional prevention staff positions. Despite strong support, members of the public described two constraints that could inhibit the success of a campfire permit system. First, they suggested that this approach may fail to garner widespread public support, and second, they cited inadequate staffing for enforcement of this approach.

Unlike the public, managers were hesitant to implement a campfire permit system as they perceived significant limitations to this approach. One manager described:

> *"I always thought, 'why don't we issue permits for campfires?' With that permit comes a little bit of education… But again… Who has the capacity to do that?"*

Managers described inadequate capacity as a major limitation to a campfire permit system and voiced concerns over federal agency ability to create, implement, and most notably, enforce this prevention strategy. When prompted about potential funds generated by campfire permits, local U.S. Forest Service participants described how the current budget structure made it difficult to channel recreation-related funds into fire prevention, inhibiting their ability to bolster local prevention efforts through funds generated by this strategy.

Members of the public described a deficiency in law enforcement officers on local public lands and saw increasing enforcement presence as an effective avenue to reduce human-caused

ignition risk, even voicing a willingness to pay increased local taxes to strengthen enforcement programs. Public participants supported this approach because they described law enforcement personnel as capable of quickly detecting illegal and irresponsible fire behaviors from recreationalists and issuing disciplinary actions to disincentivize these behaviors, holding public land users accountable. Members of the public presented two limitations to increasing public lands law enforcement, including the large size of the Coconino National Forest that overextends the small number of enforcement personnel, and difficulty sourcing funding to strengthen agency enforcement budgets.

Like the public, managers perceived local law enforcement resources on public lands to be inadequate, frequently describing local factors like the large size of Coconino County that make enforcement challenging, as summarized by one local manager:

> *We've got so many acres in the county… There's just not enough people to be everywhere. It's not that they're not doing their jobs, it's that there's not enough people to do the job.*

Managers also described an overabundance of public land users and high concentration of roads that compound enforcement difficulties. In addition to local factors, managers identified systemic barriers within federal land management agencies to increasing public lands law enforcement that hindered their ability to make changes at the local level. Participants articulated that most funding for wildfire management is allocated towards suppression which severely limits prevention and enforcement budgets, a barrier that would require structural change within agencies to overcome. Because of these limitations, managers viewed increasing law enforcement resources as a complex avenue for human-ignition prevention and expressed a preference to pursue strategies they have more local control over.

5. Discussion

This study addresses the limited scientific understanding of user groups contributing to human-caused ignition risk and the effectiveness of wildfire prevention strategies by assessing: (1) community perceptions of human-caused ignition risk across diverse public land user groups, and (2) opportunities and challenges for human ignition prevention. We conducted focus groups with members of the public and managers in Flagstaff, AZ – a Southwestern U.S. community with a history of impactful human-caused wildfires from various causes – to extend social science and management guidance on human ignition and prevention. Through this research we developed typologies to characterize diverse public land users that interact variably with fire-prone landscapes, highlighting significant divergence from groups presented in the current literature and advancing place-based conceptualizations of ignition risk. We also connected perceptions of user groups to social factors such as wildfire experience, risk attribution, and place identity to provide insights into how risk perceptions are shaped in this community. Finally, we identified national-level limitations that inhibit the local feasibility of employing a range of effective prevention approaches. Below, we discuss how these findings build the foundation for critical knowledge advancements and highlight an urgent need for innovation in human-caused ignition prevention.

5.1 Reconceptualizing Public Land Users and Ignition Risks

Focus group participants identified five distinct user groups in the Flagstaff area that each exhibit unique behavioral patterns on public lands which are summarized here as 'landscape relationships.' Descriptions of involuntary unhoused persons indicate this group holds a 'utilitarian' landscape relationship, practicing fire-related behaviors motivated by survival, not risk mitigation, that increases their ignition risk. While a limited number of recent studies have

documented unhoused persons living on public lands as a source of unwanted ignitions, our results provide insights into the perceived underlying factors behind these behaviors (Cerveny & Baur, 2020; Derrien et al., 2023). Voluntary unhoused persons were perceived to introduce lower ignition risk and hold a 'lifestyle-based' landscape relationship, choosing to reside on public lands and valuing a nature-centered experience while seeking comforts and amenities. Characterizations of this group date back to the 1990's – first termed 'voluntary nomads' by Southard (1997) – but scarce attention has been given to this group's contribution to human-caused ignition risk before this study. Descriptions of transplants indicate a 'transitional' landscape relationship as this group's fire-related knowledge, behaviors, and cultural customs adapt to Flagstaff's public lands. This finding aligns with previous research documenting higher wildfire risk awareness among longtime residents than new residents, indicating developed risk awareness occurs over extended temporal scales (Gordon et al., 2010; Collins, 2008; Ryan & Hamin, 2008). Tourists were perceived as introducing high ignition risk based on their non-negotiable recreational expectations; as a result, their landscape relationship can be described as 'consumptive'. Finally, locals' landscape relationship is best framed as 'invested' due to their perceived low ignition risk as a product of public lands stewardship and developed local ecological knowledge, the latter being recognized as an important factor in wildfire risk adaptation (Uyttewaal et al., 2024). Ultimately, these results suggest that ignition risk posed by various user groups is a product of their valuation of public lands – whether as a means of survival, a temporary home, a recreational escape, a transitional space, or a local asset – offering insight into the layered complexities of place-based human-caused ignition risk.

While literature that explores land users and associated ignition risk has predominantly focused on recreationalists, children, and arsonists, participants in this study characterized

unhoused populations, transplants, tourists, and locals. This divergence from the literature demonstrates that recent fire history is a key determinant of user group characterization and risk perceptions, adding nuance to previous studies that have connected wildfire experience and risk perceptions more broadly (Larsen et al., 2021; Spano et al., 2021; Champ et al., 2013). Our results also suggest that while recreation-related ignitions are highly concerning to Flagstaff residents, the group described as 'recreationists' by scientific literature is far too vague to capture the granularity of ignition risk at the local level. Instead, participants used local knowledge to characterize recreational subgroups that pose varying levels of recreational ignition risk including tourists, locals, voluntary unhoused persons, and transplants. The strong divergence between user groups characterized by this study and those described in scientific literature emphasizes the importance of collecting primary social science data to capture ignition-related social nuance to paint a more comprehensive picture of place-based human-caused ignition risk (Edgeley, 2023).

Our results uncovered attitudes of high risk from tourists and low risk from locals which may be interrelated through the concepts of risk attribution and place identity. Attribution theory details a human need to assign responsibility for impactful events in a manner that minimizes personal responsibility (Weiner, 1982). In Flagstaff, the high volume and visibility of tourists during peak fire season make this group an easy target for assigning human-caused ignition risk, allowing locals to justify future wildfire events without accepting responsibility. Participants also described locals to hold a deep knowledge of and connection with public lands that decreases their ignition risk, aligning with research that identifies strong place identity as positively influencing environmental stewardship and responsible behaviors (Vaske & Corbin, 2001; Kyle et al., 2003). Conversely, tourists were perceived as negligent towards restrictions and practicing

irresponsible fire-related behaviors, indicative of weak place identity that has been found to reduce both responsibility for environmental stewardship and engagement in environmentally responsible behaviors (Tuan, 1980; Kyle et al., 2004; Halpenny, 2010). These findings highlight that perceptions and reality of public land user groups may differ; while attribution theory explains how ignition risk is assigned based on perceptions, it does not determine the accuracy of these beliefs. Future research should explore the validity of these risk attributions through detailed quantitative analysis of ignition source data to better understand the actual drivers of human-caused ignitions.

Our findings construct a more comprehensive understanding of place-based human-caused ignition risk by developing user group typologies. While these typologies were built on perceptions and only formulated in a single locale, they provide valuable insight into how different public land users may contribute to human-caused ignition risk. However, it is important to recognize that these typologies are not exhaustive and may not capture all sources of ignition risk from all public land users. Previous research demonstrates that human actors and communities across the U.S. share patterns of wildfire knowledge, engagement in mitigation actions, wildfire adaptation, and related behaviors, indicating that the typologies uncovered in this study may be similar in other communities (Paveglio et al., 2015; Carroll & Paveglio, 2016). For example, many Western U.S. communities are located near recreational destinations and receive high visitation during peak fire season, indicating that the 'tourist' typology described here likely exists in other locales. Therefore, our formulation of user group typologies serves as a foundation to be employed in additional communities to identify regional and national trends in public land users. This would allow managers and scientists alike to move past generalizations of human actors and understand specific behavioral patterns, answering calls in the scientific

literature to overcome ‘one-size-fits-all’ prevention (Davenport & Edgeley 2025; Edgeley, 2023; Reilley et al., 2023).

5.2 Capacity and Support for Local Prevention

Increasing roadway signage and implementing a geofence, both considered educational interventions, were perceived as low complexity prevention strategies because they offer promising avenues for human ignition prevention in the Flagstaff area. Several commonalities among low complexity prevention strategies arose through analysis; most importantly, managers perceived these strategies to be effectively administered and troubleshooted at the local level and both approaches were already under development. Additionally, educational interventions such as roadway signage and a geofence are designed to communicate fire-related knowledge and restrictions to large and diverse audiences; these results suggest that managers favor approaches that offer the greatest impact relative to effort, and those in which implementation pathways already exist. Conversely, frequent forest closures, increased enforcement, and campfire permits, all classified as enforcement interventions, were described as high complexity prevention strategies because their effectiveness is likely inhibited by local conditions. While both the public and managers acknowledged the effectiveness of these approaches, managers routinely cited inadequate capacity to fund, create, implement, and enforce these measures as major inhibitors to implementation. These capacity limitations are more broadly recognized at the national level as significant constraints to effective public lands management, challenging agencies’ ability to balance a range of values including recreation, forest health, and – most critically in the context of this study – wildfire prevention (Schultz et al., 2019; Davidson et al., 2016; Walls, 2022). Despite a growing recognition of wildfire prevention’s critical role in reducing human-caused ignitions and increasing calls for investment in this space, wildfire

prevention staff comprise only 4% of all wildland fire management personnel in the U.S. Forest Service (Kolher & Evans, 2021). This striking statistic in conjunction with our results underscores how limited capacity remains a major barrier to effective prevention, not only in Flagstaff but nationwide.

Our results indicate a misalignment in the types of wildfire prevention measures supported by managers and the public. While managerial support was limited to education interventions less constrained by systemic funding and staffing challenges, public support extended across all approaches, including enforcement interventions that restrict activities and access on public lands. People living in fire-prone environments hold varying attitudes, beliefs, and values of wildfire risk (Eriksen & Prior, 2011); in Flagstaff, members of the public demonstrate an acute awareness of the human-caused wildfire problem arising locally and a common sentiment that a lack of action is being taken to address the issue. These attitudes appear to be part of the shared identity of Flagstaff residents that promote support for nearly any human ignition prevention approach. While supportive, the public was largely unaware of the broader agency constraints local managers face in implementing more effective wildfire prevention but maintained high expectations nonetheless, suggesting that public support for prevention has outpaced agencies' operational capacities in Flagstaff. Fostering public engagement in decision making – recognized as a key component of effective public lands management (Shindler, 2002; Thomas, 1996) – may help bridge this gap between public expectations and agencies' capacity and lead to more feasible and impactful prevention.

This study highlights two major complexities necessitating further investigation to achieve effective wildfire prevention: (1) there is a diversity of public land users interacting variably with fire-prone environments yet previous efforts to characterize these users

overgeneralize the variety present at the local level, and (2) management agencies are hindered not by lack of public support, but by capacity limitations that inhibit their ability to employ a range of well-informed prevention approaches. The work presented here provides a first step towards understanding behaviors of public land users by developing typologies, and we suggest further research evaluates these typologies in other locales to characterize the nuance of ignition risk presented by diverse human actors on larger scales. This research also reveals challenges and opportunities for prevention at the local level that underscore an urgent need for innovation in wildfire prevention. Scientific literature provides scarce managerial guidance regarding the effectiveness of prevention strategies, and nationwide funding and staffing constraints already restrict the feasibility of implementing complex prevention approaches. These limitations highlight a broader shortfall in U.S. land management coined by scholars as 'analysis paralysis', or an 'elusiveness of change,' in which agency structural divisions, short-term risk aversion, and administrative frameworks prevent adaptation to complexities in land management that severely inhibit progressive on-the-ground wildfire adaptation (Steelman & Burke, 2007; Schultz et al., 2019). In the context of prevention, we suggest that increasing resource allocation and advancing scientific understanding are critical steps to ensure wildfire prevention receives the attention and investment needed to address the urgent human-caused wildfire problem.

6. Conclusions

Current wildfire social science research lacks examination of various user groups that contribute to human-caused ignition risk and factors that enhance or inhibit the success of wildfire prevention strategies. In response, we conducted focus groups with members of the public and land managers in Flagstaff, AZ, to extend social science and management guidance on

human ignition and prevention. Recommendations for public land managers and the scientific community resulting from this study include:

Recommendations for Public Land Managers:

1. Improve Ignition Source Documentation - Prioritize documentation of human-caused ignition sources to enhance understanding of local ignition risk, particularly as an outstanding number of human-caused ignitions are not attributed to a specific cause. This can be achieved through standardizing ignition source investigations, identifying user groups responsible, and expanding current wildfire cause classifications to capture a greater diversity of human-caused ignitions.
2. Enhance Capacity for Prevention - Advocate for increased funding and staffing for wildfire prevention in land management agencies. Improved capacity should include increasing the number of permanent and seasonal positions dedicated to prevention, creating actionable prevention plans informed through local social context, investing in prevention training for land managers, and initiating community outreach programs that promote responsible public land use.
3. Tailor Prevention Approaches - Develop and implement prevention strategies tailored to local land use patterns, biophysical conditions, and social dynamics that shape ignition risk across diverse locations. In practice, prevention strategies should specifically target high-risk public land users using insights through typologies developed in this study.
4. Advance Public Engagement - Foster greater public involvement in prevention decision making to bridge the gap between community support and operational capacity of local agencies. This may be achieved by developing avenues for public input such as

prevention workshops and meetings and utilizing volunteers when appropriate for efforts including ignition reporting and educational outreach.

Recommendations for the Scientific Community:

1. Research Prevention Effectiveness - Examine the effectiveness of various wildfire prevention strategies in reducing human-caused ignitions to improve managerial guidance. Initial efforts should focus on engineering interventions, as this area of research is particularly underexplored, and assess prevention effectiveness towards specific public land user groups identified through typologies.
2. Expand User Group Typologies - Explore fire-related behaviors of public land users across various regions and locales to refine and expand upon the typologies developed in this research. These efforts can inform regional and national trends in human-caused ignition risk on public lands to enhance prevention initiatives that target high-risk groups, such as tailored education campaigns and enforcement priorities.
3. Assess Validity of Risk Perceptions - Integrate spatial ignition source data with qualitative social science research to evaluate the accuracy of perceived ignition risks. These efforts will help identify discrepancies between perceived and actual risks, enabling public land managers to develop prevention efforts that target the actual drivers of human-caused ignitions.
4. Promote Collaborative Efforts - Encourage greater collaboration between researchers and land management agencies to produce insights applicable to real-world prevention challenges. This should include improving accessibility of ignition-related data, sharing findings in accessible formats, and conducting studies specifically designed to address local prevention barriers and inform place-based interventions.

These recommendations provide actionable insights to address the growing challenges posed by human-caused wildfire ignitions. While systemic funding and staffing challenges faced by land management agencies often limit their ability to implement and sustain effective prevention, these recommendations serve as a valuable starting point under current resource constraints. By prioritizing prevention, advancing scientific knowledge, and fostering collaborative involvement among managers, scientists, and the public, we can develop effective ignition prevention that reflects the complexities of human-caused ignition risk across diverse communities and landscapes.

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Appendix A: Perceptions of Low Complexity Prevention Strategies

Table 1: Perceived strengths and limitations of increasing roadway signage in the Flagstaff area

Prevention strategy	Perceived strengths	Perceived limitations
Increasing roadway signage	Public: • Current signage is effective • Prevents ignition risk from tourists along travel corridors • Participants had personally acquired knowledge from signs • Personal incentive is not required to obtain knowledge Managers: • Current signage is effective • High level of control locally • Many participants had experience implementing signage • Several agencies can administer • Implementation pathways exist	Public: • Visitors may ignore signage • Lack of enforcement capacity to hold public land users accountable Managers: • Limited funding for signage • Short temporal access to signs • Many staff positions that administer signs are seasonal instead of permanent

Table 2: Perceived strengths and limitations of implementing a geofence in the Flagstaff area

Prevention strategy	Perceived strengths	Perceived limitations
Geofence	Public: • Disseminates real-time fire restriction information • Communicates to all users in the area • Reaches tourists before they visit local public lands Managers: • Prevents ignition risks from tourists because they would receive alerts as they travel into the Flagstaff area • Targets phones originating outside the Flagstaff area which may prevent risk from high concern groups • Geofence was currently under development • Effort led by City officials; therefore, federal managers can take a hands-off approach in implementation	Public: • Locals may not want or need to receive regular alerts Managers: • No limitations discussed

Appendix B: Perceptions of High Complexity Prevention Strategies

Table 3: Perceived strengths and limitations of frequent forest closures in the Flagstaff area

Prevention strategy	Perceived strengths	Perceived limitations
Frequent forest closures	Public: • Forest closures are effective because they drastically reduce the number of public land users, therefore also reduce potential ignitions • Would mobilize to assist in closing the forest	Public: • Closing the forest is an arduous effort for local staff • Forest closures conflict with economic stimulus driven by tourism • Decision to close the forest is not only made by local managers, but also managers at the federal level • Lack of enforcement capacity to hold public land users accountable
	Managers: • Forest closures are effective because they drastically reduce the number of public land users, therefore also reduce potential ignitions	Managers: • Decision to close the forest often takes weeks to execute as it requires consensus at the local, regional, and federal level • Closing the forest is an exceptionally rigorous effort that is highly demanding on local staff • Closing the forest requires advanced coordination • Public land users commonly disobey forest closures • Public land users redirect their access to state-owned lands during forest closures • High volume displacement of unhoused persons during forest closures that places pressure on social services and local businesses

Table 4: Perceived strengths and limitations of a campfire permit system in the Flagstaff area

Prevention strategy	Perceived strengths	Perceived limitations
Campfire permit system	Public: • Because this strategy is used in California, it could be easily replicated locally • Would limit the number of campfires on local public lands • Permitted campfires would be spatially and temporally accounted for • Permitting system could be accompanied by useful fire-related education • Funds generated through the campfire permit system could be channeled into the fire prevention budget Managers: • Permitting system could be accompanied by useful fire-related education	Public: • This approach may fail to garner widespread public support • Lack of enforcement capacity to hold public land users accountable Managers: • Inadequate local capacity to create, implement, and enforce this approach • Current structure in federal agencies did not allow for recreation-related funds to be transferred into prevention budgets

Table 5: Perceived strengths and limitations of increased law enforcement on public lands in the Flagstaff area

Prevention strategy	Perceived strengths	Perceived limitations
Increased law enforcement on public lands	Public: • Law enforcement personnel could quickly detect illegal and irresponsible fire behaviors from recreationists • Disciplinary actions are useful at reducing potential ignitions • Willingness to pay increased local taxes to bolster law enforcement budgets Managers: • While current enforcement is lacking, this strategy is effective at reducing ignitions because it holds public land users accountable for their actions	Public: • Coconino National Forest is very large; enforcement personnel may be overextended • Federal agencies face difficulties sourcing funds to strengthen enforcement resources Managers: • Large size of Coconino National Forest challenges enforcement personnel • This strategy requires systemic changes in land management agencies which is out of local managers' control • There is an overabundance of public land users and roads on local public lands that challenges enforcement staff • Prevention and enforcement budgets are limited because most funding is allocated to wildfire suppression