AGU ADVANCING EARTH AND SPACE SCIENCES

Earth's Future

RESEARCH ARTICLE
10.1029/2024EF005744

COVID-19 Fueled an Elevated Number of Human-Caused Ignitions in the Western United States During the 2020 Wildfire Season

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Key Points:

- The 2020 fire season in the western United States experienced one of the highest number of human-caused ignitions in nearly 3 decades
- Climate variability was weakly correlated with ignitions; non-climatic factors drove the near record number of human-caused ignitions
- Increased human presence in wildlands due to COVID-19 behavioral changes contributed to increased in human-caused fires

Supporting Information:

Supporting Information may be found in the online version of this article.

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Citation:

Jorge, A. L., Abatzoglou, J. T., Fleishman, E., Williams, E. L., Rupp, D. E., Jenkins, J. S., et al. (2025). COVID-19 fueled an elevated number of human-caused ignitions in the western United States during the 2020 wildfire season. *Earth's Future*, *13*, e2024EF005744. https://doi.org/10.1029/2024EF005744

Received 10 DEC 2024
Accepted 28 FEB 2025

Abstract

The area burned in the western United States during the 2020 fire season was the greatest in the modern era. Here we show that the number of human-caused fires in 2020 also was elevated, nearly 20% higher than the 1992–2019 average. Although anomalously dry conditions enabled ignitions to spread and contributed to record area burned, these conditions alone do not explain the surge in the number of human-caused ignitions. We argue that behavioral shifts aimed at curtailing the spread of COVID-19 altered human-environment interactions to favor increased ignitions. For example, the number of recreation-caused wildfires during summer was 36% greater than the 1992–2019 average; this increase was likely a function of increased outdoor recreational activity in response to social distancing measures. We hypothesize that the combination of anomalously dry conditions and COVID-19 social disruptions contributed to widespread increases in human-caused ignitions, adding complexity to fire management efforts during the 2020 western US fire season. Knowledge of how social behavior changes indirectly contributed to the increased number of ignitions in the 2020 wildfire season can help inform resource management in an increasingly flammable world.

Plain Language Summary

Aggregated fire records show that the 2020 wildfire season in the western United States resulted in both the greatest burned area in recent decades and one of the greatest numbers of human-caused fires since 1992, despite a 30-year low in the number of lightning-caused fires. While the record area burned has largely been attributed to climate and weather conditions favorable to wildfire, we show that climate alone is unlikely to be responsible for the spike in human-caused fires. Instead, we suggest that changes in human behavior and mobility during the COVID-19 pandemic facilitated increases in the number of human-caused fires in 2020 against a backdrop of longer-term declines in human-caused fires. We show that ways in which people responded to the pandemic, such as by sheltering in place and social distancing, potentially contributed to increases in the number of ignitions caused by debris burning, recreation, and use of fireworks. For example, increased outdoor recreation—a social distancing measure—during summer 2020 contributed to a 36% increase in the number of recreation-caused fires. Although we focus on the 2020 fire season, our results inform understanding of complex human-natural system interactions in places with escalating fire danger.

1. Introduction

Fire was widespread across the western United States (US) during the 2020 wildfire season, setting modern records for area burned in a single year (Abatzoglou et al., 2021; Higuera & Abatzoglou, 2021; Safford et al., 2022). Synchronous fires compounded by anomalously dry fuels degraded regional air quality (Kalashnikov, Schnell, et al., 2022; Li et al., 2021) and exacerbated the human-health toll from the COVID-19 pandemic (Zhou et al., 2021). The influence of climate and the legacy of fire suppression over the last century influenced the 2020 wildfire season across the western US (Abatzoglou et al., 2021; Higuera & Abatzoglou, 2021; Safford et al., 2022), but limited attention has been given to the indirect impacts of COVID-19 on fire. Here, we examine links between COVID-19 and the number of human-caused wildfire ignitions.

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The COVID-19 pandemic introduced a series of complex shifts in human behavior aimed at curtailing the spread of the virus, including stay-at-home orders, service closures, and social distancing measures (Mateer et al., 2021). These changes required social, political, and institutional adaptation (Edgeley & Burnett, 2020; Rice et al., 2020). Pandemic-induced changes in human behavior altered subsequent human-environment interactions, including decreases in industrial activity and transportation that temporarily decreased carbon emissions and improved overall air quality across the world (Abu-Rayash & Dincer, 2020; Diffenbaugh et al., 2020; Edgeley & Burnett, 2020; Muhammad et al., 2020; Rice et al., 2020).

Previous studies highlighted how COVID-19 impacted both fire suppression resources and regional fire activity. The COVID-19 pandemic decreased the availability of fire management resources, thereby reducing capacity for fire suppression (Belval et al., 2022; Metz et al., 2022). For example, a significant decrease in the number of fires in spring 2020 across the southeastern US resulted from federal and state agencies halting the implementation of prescribed fires (Poulter et al., 2021). By contrast, in western Madagascar, the number of land-clearing fires in protected areas increased while enforcement patrols and management activities were reduced during lockdowns (Eklund et al., 2022).

Although interannual correlations between climate and burned area in the western US are strong (Abatzoglou & Kolden, 2013), the relationship between climate and the number of ignitions is typically weak (Keeley & Syphard, 2015). Lightning-caused fires tend to occur in mountainous and sparsely populated regions of the West and account for the majority of burned area (Balch et al., 2017), whereas human-caused fires have a variety of sources (Balch et al., 2017; Costafreda-Aumedes et al., 2017), each with distinct spatial and temporal attributes. The geography of human-caused fires is strongly linked to factors such as population density, land use, road density, and vegetation type (Parisien et al., 2016). Certain human causes of fire (e.g., debris burning, recreation, fireworks) are sensitive to changes in management, policies, and human presence in flammable lands (Eklund et al., 2022; North et al., 2015). This suggests that changes to policies shaping human behavior in such environments are likely to affect the number and type of ignitions (Eklund et al., 2022; North et al., 2015; Syphard et al., 2015). Policies, technologies, and fire prevention efforts have generally reduced the incidence of human-caused fires in parts of the West (Balch et al., 2017; Keeley & Syphard, 2018; Syphard et al., 2015).

Here, we focus on the potential effects of climate and COVID-19 on human-caused ignitions that occurred during the 2020 wildfire season in the western US. We use a fire-occurrence database to examine spatial and temporal anomalies in 2020 relative to the number of wildfires attributed to various causes over the previous 28 years (Short, 2022). We hypothesize that changes in personal mobility and behavior resulting from pandemic restrictions contributed to an unusually high number of human-caused fires during 2020.

2. Materials and Methods

The sixth edition of the Fire Program Analysis Fire-Occurrence Database (FPA FOD) provided georeferenced data characterizing ignition causes and area burned for 2.3 million wildfires reported by federal, state, and local agencies from 1992 to 2020 (Short, 2022). From the FPA FOD, we extracted unique identifiers for each fire, discovery dates, latitude and longitude, final fire sizes, land ownership at the point of ignition, reporting agency, and cause as identified by the reporting agency. Our domain included the 11 western states of the contiguous US: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. The FPA FOD classifies ignition cause as human, natural (lightning), or missing data/not specified/undetermined (Short, 2022). Known human causes are further classified as arson or incendiarism; debris and open burning; equipment and vehicle use; firearms and explosives use; fireworks; misuse of fire by a minor; power generation, transmission, or distribution; railroad operations and maintenance; recreation and ceremony; smoking; and other causes (Short & Finney, 2022).

We recognize that the FPA FOD data set, like all fire data sets, is associated with uncertainties. We opted to use the FPA FOD rather than other independently assembled data on large fires ($\geq$1 km^2, Juang et al., 2022) or data from individual state agencies given our focus on fire counts. We chose to not use a minimum size threshold for exclusion of fires from our analysis given that all fires in the FPA FOD elicited an agency response. Fires smaller than 0.4 ha represent approximately 50% of the human-caused fires in the database, and because small fires require suppression resources, they are not trivial. While most studies have used the FPA FOD pro forma, we screened the data to limit the influence of potential artifacts and data irregularities resulting from changes in how fires were reported over the 29-year timeline of this study. Although metrics such as annual area burned or the

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number of large fires may not be substantially impacted by changes in reporting practices, the number of ignitions may be more heavily affected (Short, 2014). Changes in reporting practices by state and local agencies are not always well documented and hence not easily rectified. We included all fires reported by federal agencies in our analyses and adopted measures to exclude non-federal incidents that might be associated with more reporting uncertainties. About half of the human-caused ignitions in the region were reported by non-federal agencies.

We excluded ignitions reported by non-federal agencies that met any of three criteria: (a) municipal or local land ownership, (b) a majority of the area within 500 m of the ignition was classified as high or medium density development by the National Land Cover Database, and (c) fires with final sizes <4 ha categorized as human-ignited that had an undefined or missing general cause (Pourmohamad et al., 2025). Our screening removed several apparent data artifacts, such as 3,000 human-caused ignitions during 2020 in Arizona on lands with local or municipal ownership that were exactly 0.04 ha (0.1 acre) (Figure S1 in Supporting Information S1). Additional details of this screening are provided in Supporting Information S1.

To identify temporal and spatial anomalies in the number of fires in 2020 relative to the 1992–2019 reference period, we calculated the 7-day rolling average of the daily number of ignitions. We used the 7-day rolling average to better account for potential increases in the number of weekend ignitions with certain human causes (Prestemon et al., 2012). We also summed and ranked the annual number of fires ignited by each human cause by state.

We used gridded surface meteorological data from gridMET (Abatzoglou, 2013) to assess the degree to which climate anomalies during 2020 explained the number of wildfire ignitions. We used daily ignition component (IC), calculated using the US National Fire Danger Rating System (Cohen & Deeming, 1985). IC is a function of 1-hr fuel moisture and spread component, and encompasses the influences of temperature, humidity, radiation, and wind. IC operates as a proxy for the likelihood of a firebrand igniting fine fuels and becoming a fire that requires suppression (Schlobohm & Brain, 2002). Other metrics from the US National Fire Danger Rating System, including 10 and 100-hr dead fuel moisture and vapor pressure deficit, yielded results similar to those of IC, as shown in Supporting Information S1.

We used a two-step process to estimate the effect of IC anomalies on the number of ignitions across the western US during the 2020 fire season. First, we examined Pearson's correlations between the number of ignitions by cause and IC, averaged across the western US, from 1992 to 2019. We calculated correlations at the level of climatological seasons (March–May, June–August, and September–November) and the fire season (March–November). We removed linear trends in each time series before calculating correlations to avoid bias from trends due to exogenous factors (e.g., decline in the number of fires ignited by smoking) (Keeley & Syphard, 2018). Second, we built a linear regression model of the detrended number of human-caused fires from 1992 to 2019 as a function of detrended IC. We then applied this regression to IC data for 2020 to develop a null model that estimated the effect of IC during 2020 on the number of human-caused fires. This null model served as a reference scenario to compare against the observed number of fires.

We conducted additional analyses of the number of wildfires ignited in 2020 by debris and open burning, recreation and ceremony, and fireworks, which were the highest (debris and open burning, recreation and ceremony) and fourth highest (fireworks) annual numbers on record. Although the greatest number of power system-related ignitions was also observed in 2020, the lack of publicly accessible utility-centric data that could be linked to COVID-19 disruptions limited subsequent analysis herein. For each cause, we identified a seasonal window corresponding to the historical peak in ignitions. For fires ignited by debris and open burning, we chose 25 March–30 April. This period began approximately 10 days after issuance of COVID-19 emergency declarations in most states. Most of these declarations in western states were extended through the end of April. For recreation and ceremony, we chose the window from Memorial Day to Labor Day (25 May–8 September in 2020). This period followed the relaxation of the most stringent COVID restrictions but coincided with continued social distancing. For fireworks, we chose the week encompassing US Independence Day (1–7 July) given the well-known peak in fire ignitions from human-causes, especially fireworks, during this period (Balch et al., 2017). For each of these three periods we calculated state-level anomalies in the number of fires and IC as the percentage difference from their 1992–2019 mean values. We also used the previously described approach to build a linear regression of the number of fires ignited by each cause as a function of IC from 1992 to 2019. We applied this model to IC during 2020 to serve as a null model for estimating the effect of interannual climate variability on the total number of fires.

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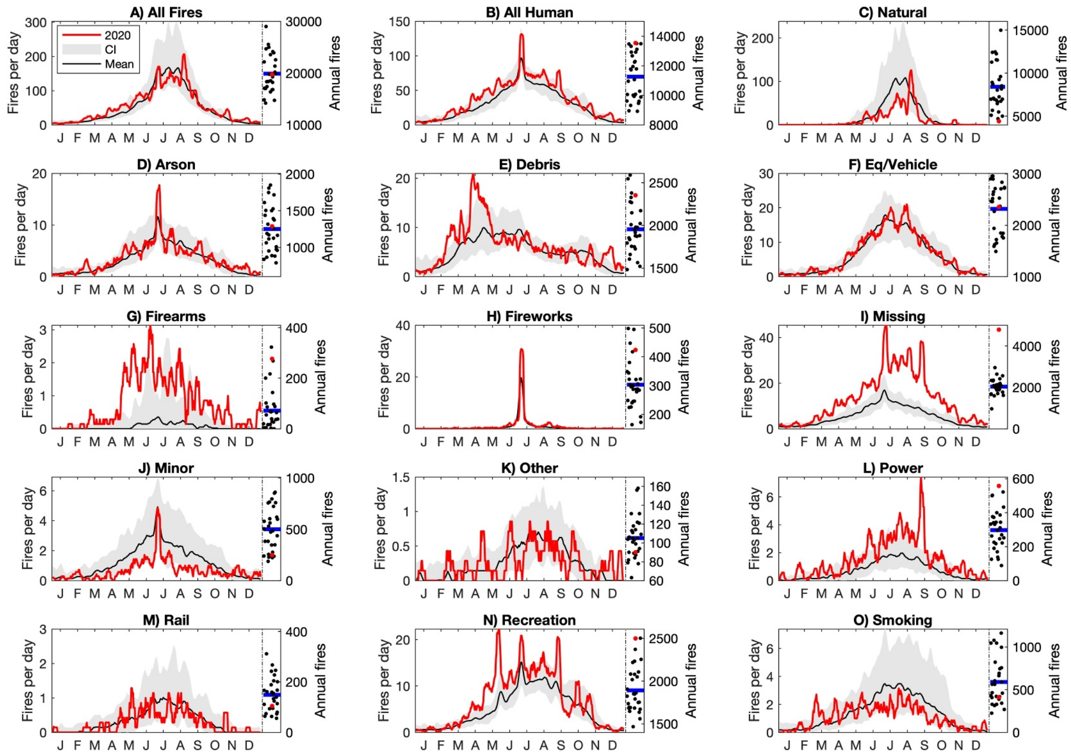

Figure 1. Rolling 7-day average number of fires in the 11 western US states during 2020 (red line) compared with the 1992–2019 average (black line) and 10th–90th percentile from 1992 to 2019 (gray shading) for each of the 13 general ignition causes in Fire Program Analysis Fire-Occurrence Database. All Fires is the total across all causes, and All Human reflects fires attributed to human-caused ignitions. The inset to the right of each plot shows the total number of fires during 2020 (red dots) and all other years (black dots) and the 1992–2019 mean (blue horizontal line). (a) All wildfire ignitions, (b) all human-caused wildfires, (c) natural (lightning) wildfires, (d) arson and incendiarism, (e) debris and open burning, (f) equipment and vehicle use, (g) firearms and explosives, (h) fireworks, (i) missing, data not specified or undetermined cause, (j) misuse of fire by minors, (k) other causes, (l) power generation, transmission, and distribution, (m) railroad operations and maintenance, (n) recreation and ceremony, and (o) smoking.

We used ancillary data to examine the potential effects of mobility and outdoor recreation on anomalies in the number of cause-specific ignitions. We acquired mobility data at the state level from Google Community Mobility Reports (Google Surveys, 2022), which evaluate changes in mobility from one's residence. Google Community Mobility data are expressed as a percentage difference from the median pre-COVID baseline (3 January–6 February 2020). We used these data to examine anomalies in the number of ignitions from debris and open burning. We obtained data on the weekly number of reservations and percentage of campsites that were closed at 1,688 US Forest Service campgrounds in the western US during 2019 and 2020 from Shartaj et al. (2022). We considered differences in the number of reservations and campground closures between 2020 and 2019 as a proxy for COVID-19 related changes, acknowledging that other factors, such as weather and hazard-related (e.g., wildfire) forest closures, impacted overall use. Many federal campgrounds did not open in late spring 2020 because of COVID-19 restrictions. We used these data to examine anomalies in the number of fires ignited by recreation and ceremony. We acquired data on aggregated annual fireworks sales (millions of US dollars) from 2000 to 2022 and total aggregated consumption from 2000 to 2021 from the American Pyrotechnics Association. We further classified sales as consumer (sold to private consumers) or display (sold to licensed professionals). We used these data to investigate anomalies in the number of fires ignited by fireworks.

3. Results

The number of human-caused fires across the western US during the 2020 fire season was one of the highest in the 1992–2020 study period (Figure 1, Figure S2 in Supporting Information S1). The number of human-caused fires was consistently high from March to November 2020. In particular, the number of fires ignited by recreation and ceremony; power generation, distribution, and transmission; and unknown causes were greatest during 2020. The numbers of ignitions from firearms and explosives, debris and open burning, and fireworks in 2020 were within the top four in the 29 years of our study. By contrast, the number of lightning-caused fires during 2020 was the lowest within the study period, despite a spike in mid-August associated with an extensive dry lightning outbreak in California (Kalashnikov, Abatzoglou, et al., 2022). The lowest observed number of lightning-caused fires is consistent with a failure of the North American monsoon in the southwestern US and the subsequent, substantial reductions in convective activity across the region in 2020 (Hoell et al., 2022).

The number of human-caused fires in 2020 was greater than in other years across most states and ignition causes (Figure 2). The number of fires ignited by all human causes during 2020 was the highest on record in Montana, Wyoming, and Utah, and in the top tercile in all other states except California and Washington. Moreover, the number of wildfires ignited by most human causes was higher in 2020 than in other years, with the exception of fires ignited by railroads, misuse of fire by minors, and smoking; the number of fires ignited by each of these causes substantially declined from 1992 to 2020. Although the overall number of human-caused fires in the western US in 2020 was anomalously high, the number of fires ignited by lightning during 2020 was lower than the historic median in all states except Wyoming.

We found weak, albeit statistically significant ($p < 0.05$), interannual correlations between seasonal IC and the seasonal number of wildfires across the western US ignited by most causes (Figure 3). The number of lightning-caused fires during summer and IC were moderately correlated ($r \sim 0.5$). Yet during summer, most cause-specific correlations between IC and the number of human-ignited fires were not significant, suggesting weak climatic control on the number of human-caused fires relative to other factors in summer. By contrast, correlations between IC and the number of human-caused fires in both spring (March–May) and autumn (September–November) generally were statistically significant, indicating that warmer and drier conditions enabled more ignitions. Correlations between numbers of fires and other fire danger metrics were similar (Figure S3 in Supporting Information S1).

We applied a linear regression built with data on all human-caused fires and IC from 1992 to 2019 to the IC observed in 2020 (Table 1). The number of human-caused fires in the western US has declined over the long term, which makes the surge in the number of ignitions during 2020 more anomalous (Figure S2 in Supporting Information S1). Our null model suggested approximately 126 (+1.2%) more human-caused fires compared to the trend due to the higher IC across the region. However, climate variability as characterized by IC explained a small portion of the additional number of human-caused fires observed in 2020 compared to the 1992–2019 average. Our null model applied to other years shows not only that climate variability alone is a weak predictor of the interannual variability in the number of human-caused ignitions, but also that the difference in 2020 between the number of ignitions observed and estimated on the basis of IC was an outlier in the context of the declining number of human-caused fires (Figure S4 in Supporting Information S1).

3.1. Debris and Open Burning

Historically, the number of fires ignited by debris and open burning across the western US was greatest from March to June, but the number of wildfires caused by debris burning from 25 March to 30 April 2020 was 70% greater than the 1992–2019 average (Figure 4a, Table 1). Across spring 2020, the number of debris burning-ignited fires was 47% greater than the average from 1992 to 2019 (Figure 1). The number of debris burning-caused fires during this period was elevated in all states (Figure 4b) except California and New Mexico (near median) and Arizona (slightly below median). During the same period, IC was below normal across portions of southern California and southern Nevada and above normal in the Pacific Northwest and Front Range (Figure 4c). The correlation between spring IC and the number of debris burning-caused fires across the western US was moderate and positive (Figure 3, Table 1). While average IC across the domain from 25 March to 30 April 2020 exceeded the 1992–2019 average, IC remained near the long-term trend, which was not significant in our null model (Table 1, Figure S5 in Supporting Information S1). By contrast, the anomalously high number of debris burning-caused fires during February and early March before the onset of stay-at-home orders was primarily associated with an exceptional number of fires in California during an unusually warm and dry February (Figure S6 in Supporting Information S1).

The distinct increase in the number of debris burning ignitions occurred in late March 2020, about 10 days after state stay-at-home orders were issued. Time spent at one's residence increased during March (increased

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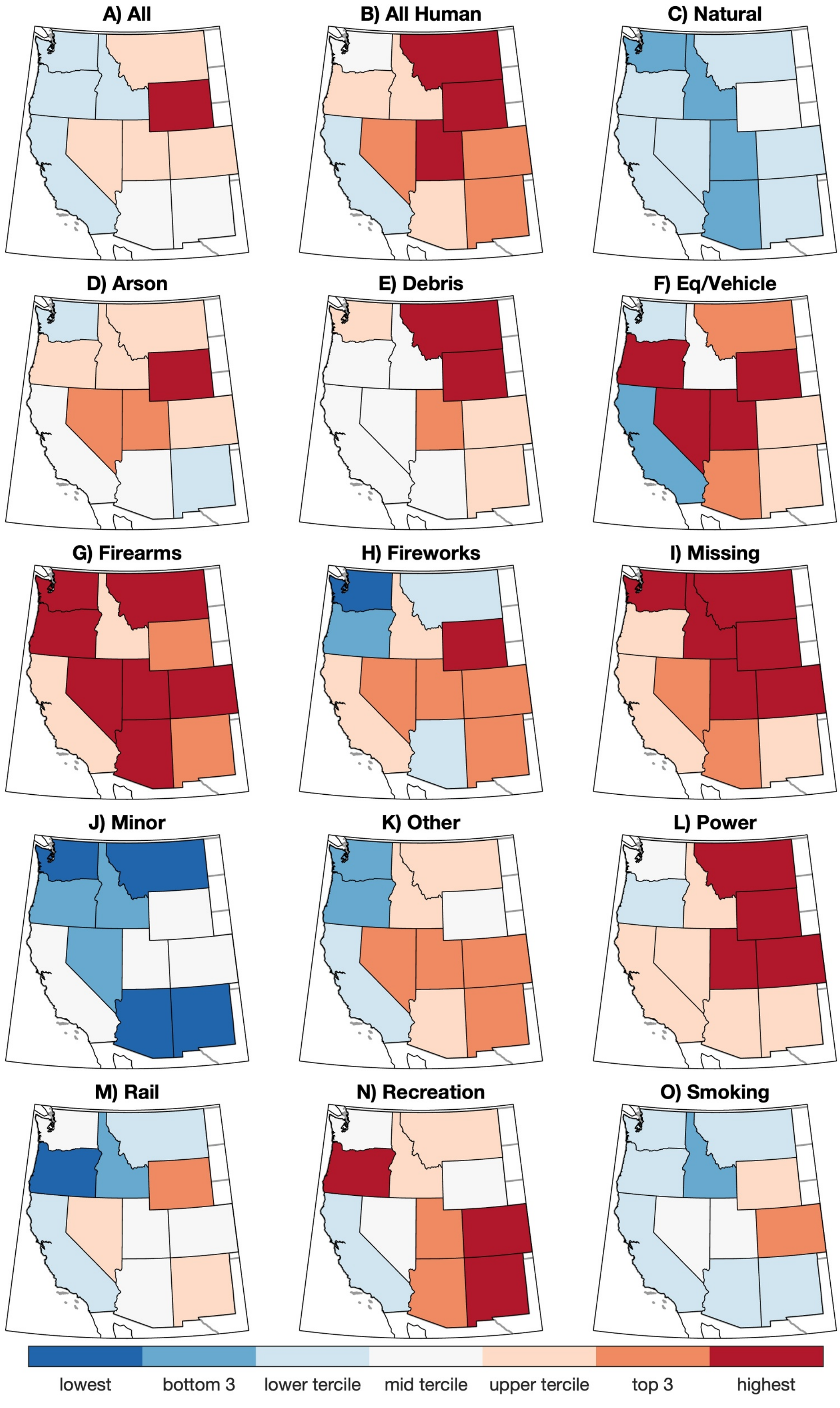

Figure 2. Rank of the total number of fires during 2020 compared to 1992–2019 by state and by cause. (a) All wildfire ignitions, (b) all human-caused wildfires, (c) natural (lightning) wildfires, and fires caused by (d) arson and incendiarism, (e) debris and open burning, (f) equipment and vehicle use, (g) firearms and explosives, (h) fireworks, (i) missing, data not specified or undetermined cause, (j) misuse of fire by minors, (k) other causes, (l) power generation, transmission, and distribution, (m) railroad operations and maintenance, (n) recreation and ceremony, and (o) smoking.

Figure 3. Interannual Pearson's correlation coefficients between the number of ignitions across the western United States in the Fire Program Analysis Fire-Occurrence Database database and the average ignition component (IC) from 1992 to 2019 by ignition cause and season (March-November, March-May [MAM], June-August [JJA], and September-November [SON]). We removed linear trends in both the number of ignitions and IC before calculating correlations. Statistically significant ($p < 0.05$) correlations are denoted by "x."

"Residential" presence in Google Community Mobility), coinciding with stay-at-home orders, before slowly tapering by mid-June to levels well above the pre-COVID baseline (Figure 4a). The volume of household solid waste increased during this period by 20%–30% as a byproduct of constrained mobility (Singh et al., 2022).

3.2. Recreation and Ceremony

The number and timing of fires ignited by recreation and ceremony shifted during the 2020 fire season (Figure 5a). From Memorial Day to Labor Day (25 May–8 September), the number of recreation-caused wildfires was over 36% greater than the 1992–2019 average, and the highest in the period of record. An anomalously high number of recreation-caused fires during this window was evident across the Southwest and Oregon (Figure 5b). IC was also considerably higher than the 1992–2019 average across much of the western US (Figure 5c). Although the locations of anomalies in IC and recreation-caused fires overlapped, our null model indicated a minor influence of IC on the number of recreation-caused fires in 2020 (+4.5%) given the weak historical relationships with summer mean IC (Table 1).

Prolonged periods of social distancing and isolation during spring and summer 2020 catalyzed an increase in outdoor recreation by novices and experienced people alike (Mateer et al., 2021; Rice et al., 2020; Shartaj et al., 2022). Many US Forest Service campgrounds remained closed in May and June due to COVID restrictions (Shartaj et al., 2022). As these campgrounds reopened, the number of summer reservations and visits to public recreation areas spiked (Figure 5a). The number of campground reservations from July to Labor Day 2020 was greater than the number during the same period in 2019 (Figure 5a). The number of recreation-caused fires dropped below the long-term average following widespread fires in the Northwest that ignited or expanded during the Labor Day weekend in conjunction with ongoing large fires in both California and Colorado. Additionally, National Forests throughout the West, including all 18 in California, were closed during much of September given the potential for wildfire ignitions, while some other federal lands, such as Yosemite National Park, were closed due to active fires during much of the same month (Jenkins et al., 2021).

3.3. Fireworks

The Independence Day holiday has historically been associated with a considerable increase in human-caused fires in the US (Balch et al., 2017), especially those caused by fireworks. Even so, the number of fireworks-

Table 1
Number of Fires During 2020 Ignited by All Human Causes (March–November), Debris and Open Burning (25 March–30 April), Recreation and Ceremony (25 May–8 September), and Fireworks (1–7 July)

	2020 observed	1992–2019 mean	2020 extrapolated trend	Null model	Pearson's r
All human-caused ignitions (March–November)	12,802 (+20%)	10,695	8,851	+126	0.09
Debris and open burning (25 March–30 April)	543 (+70%)	319	329	−3	0.62*
Recreation and ceremony (Memorial Day—Labor Day)	1529 (+35%)	1130	962	+51	0.41*
Fireworks (1–7 July)	221 (+40%)	158	195	+13	0.40*

Note. The average number of ignitions from 1992 to 2019, and extrapolation of linear trends from 1992 to 2019 applied to 2020, are shown in the third and fourth columns. The null model shows the departure from the trendline based on a linear regression of the detrended number of fires from 1992 to 2019 on the detrended ignition component and applied to the detrended ignition component during 2020. The right column shows the interannual Pearson's correlation coefficient between the detrended ignition component and detrended fire counts over the 11 western states from 1992 to 2019, with asterisks denoting statistical significance ($p < 0.05$).

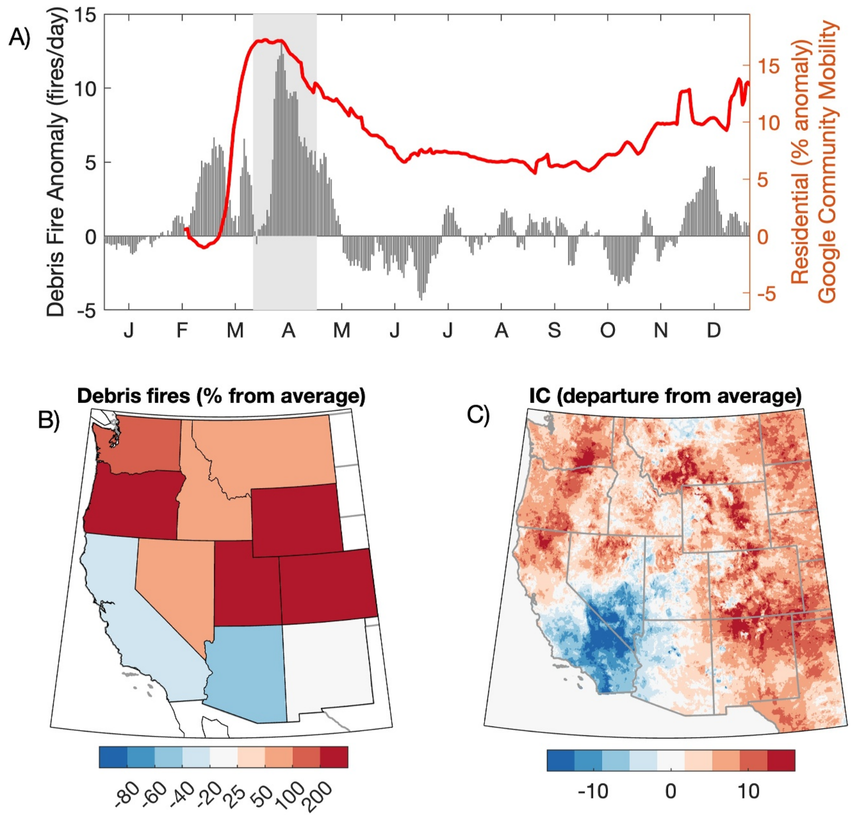

Figure 4. (a) Seven-day running average anomaly in the number of debris and open burning-caused fires (black bars) during 2020 compared with 1992–2019. The red line shows the 11-state average "Residential" data (presence at one's residence) from Google Community Mobility Reports expressed as departure from the January 2020 baseline. The light gray shading highlights the 25 March–30 April period. (b) Percentage difference in number of debris burning-caused fires from 25 March to 30 April 2020 compared to the average during the same period from 1992 to 2019. (c) Anomaly in ignition component from 25 March to 30 April 2020 compared to 1992–2019.

caused wildfires from 1 to 7 July 2020 was 40% greater than the 1992–2019 average, and the fourth highest in the period of record. In several states, the number of fireworks-caused wildfires during 2020 was more than double the long-term average (Figure 6a). Conversely, the number of fireworks-caused ignitions was below normal in Washington, Oregon, Idaho, and Montana. IC also was below normal across the northern states and above normal in states with an anomalously high number of fireworks-caused fires (Figure 6b), suggesting that weather conditions likely were wet enough to substantially limit the number of fireworks ignitions in the northern states. The null model yielded a minor increase in the number of fires during 2020 that partially explains the increase in firework-caused ignitions (Table 1).

The American Pyrotechnics Association reported a 55% increase in consumer firework sales during 2020 compared to 2019 as well as a 23% decrease in sales of display fireworks associated with cancellations of public fireworks displays (Fireworks Consumption Figures, 2022). Excessive use of fireworks by individuals is also indicated by the 160% increase in fireworks-related injuries in 2020 compared to 2018–2019 (Maassel et al., 2021). The cancellation of public fireworks displays during COVID-19 likely prompted some individuals, including those with limited prior experience with pyrotechnics, to acquire and detonate large quantities of fireworks and led to the increase in fireworks-ignited fires during the Independence Day period.

4. Discussion and Conclusions

Our results suggest that the number of human-caused fires across the western US during the 2020 fire season was one of the highest since 1992, at 20% above the 1992–2019 average. The increase during 2020 is notable given the long-term decline (26% drop from 1992 to 2019) in the number of human-caused fires across the West (Figure S1

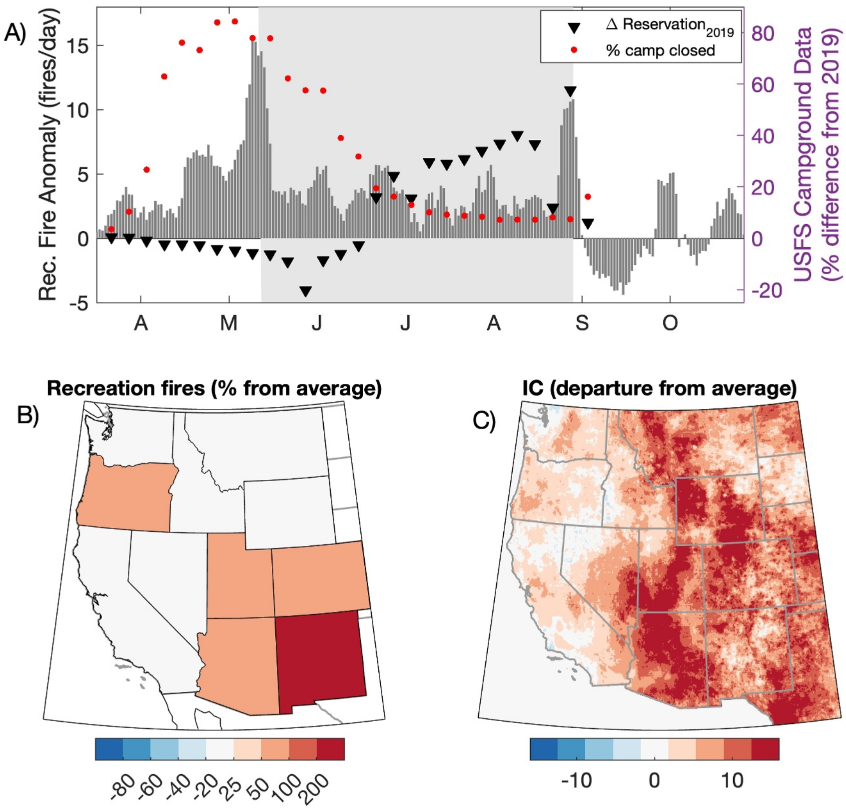

Figure 5. (a) Seven-day running average anomaly in the number of wildfires ignited by recreation and ceremony (black bars) during 2020 compared with the 1992–2019 average. Black triangles show differences in the weekly number of US Forest Service campground reservations during 2020 compared with 2019 (units are thousands of reservations), and red dots show the percentage of campgrounds that were closed in 2020. The light gray shading highlights the 25 May–8 September period. (b) Percentage difference in the number of fires caused by recreation and ceremony from 25 May to 8 September 2020, compared to the average during the same period from 1992 to 2019. (c) Anomaly in ignition component from 25 May to 8 September 2020, compared to 1992–2019.

in Supporting Information S1), similar to the decline reported in other regions (Coogan et al., 2020; Keeley & Syphard, 2018). The number of wildfires ignited by numerous human causes, including debris burning and recreation, set many records in 2020, while the number of lightning-caused fires was the lowest in the 29-year record. Widespread human-caused fires in 2020 co-occurred with anomalously warm and dry conditions that have been linked to the record area burned that year. The extent of burned area in 2020 is reasonably explained by extreme fuel aridity across the West (Higuera & Abatzoglou, 2021). Yet unlike the strong links between climate variability and either burned area or the number of large fires in forests (Juang et al., 2022; Williams et al., 2019), the weak links between interannual climate variability and the number of human-caused ignitions shown here (Figure 3) and in other studies (Keeley & Syphard, 2018) suggest that climatic and weather conditions alone do not explain the exceptional number of human-caused fire ignitions in 2020.

COVID-19 introduced diverse, novel protocols that affected social, psychological, political, and economic function, shifting typical activities for prolonged periods (Edgeley & Burnett, 2020; Mateer et al., 2021; Rice et al., 2020; Taff et al., 2021). These mitigation measures likely contributed to additional ignitions by altering mobility, behavior, and social interactions and led to increased human activity in fire-prone landscapes. We did not account for the added burden of the excess number of human-caused fires on fire management during 2020, but additional ignitions that require agency response and suppression reduce the ability to manage other fire events (Calkin et al., 2015; Cochrane & Bowman, 2021; Plucinski, 2019; Schweizer et al., 2020).

COVID-19 restrictions may have contributed to the record number of debris burning-caused fires in spring 2020 through at least two mechanisms. First, waste accumulation coinciding with increased time at home (Singh et al., 2022) may have engendered a need for more at-home waste disposal in communities without refuse service

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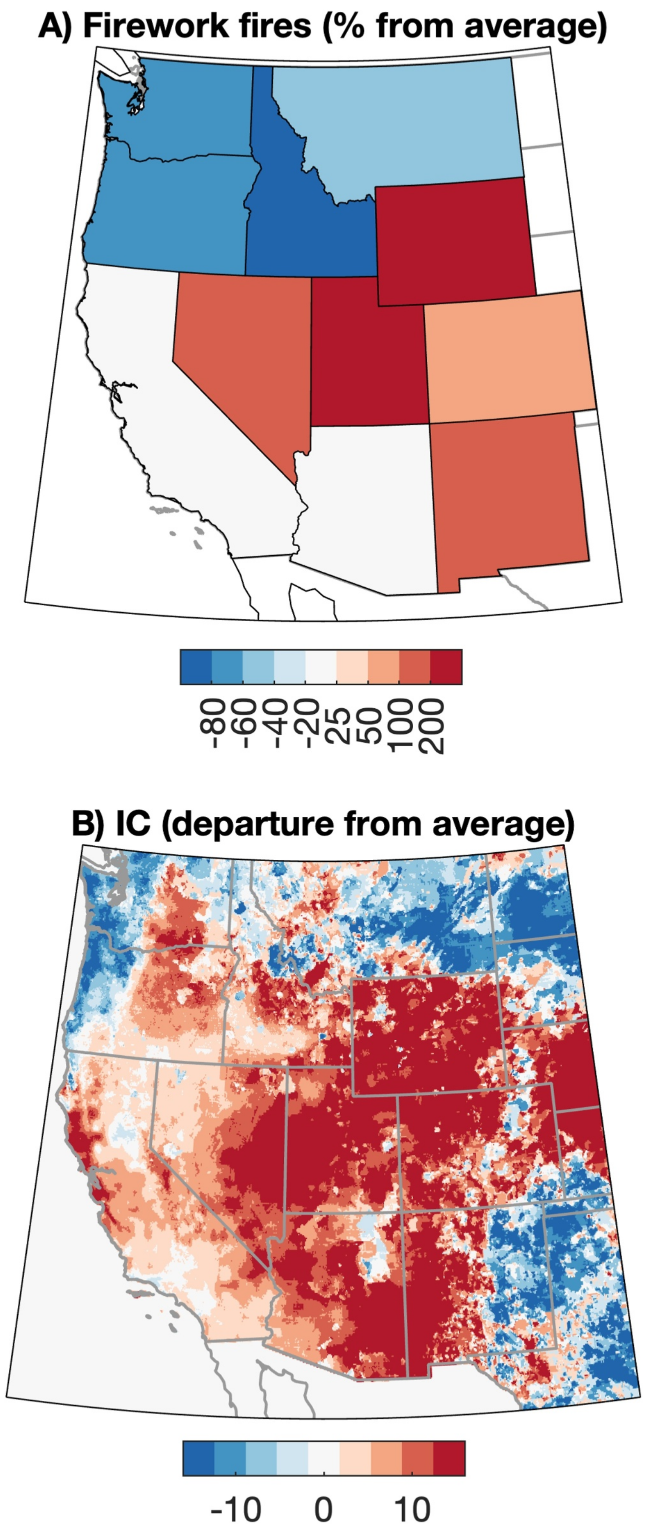

Figure 6. (a) Percentage difference in number of fireworks-caused fires from 1 to 7 July 2020, compared to the average during those dates from 1992 to 2019. (b) Anomaly in ignition component from 1 to 7 July 2020, compared to 1992–2019.

or where refuse services were temporarily unavailable. Second, an increase in the proportion of time spent at one's residence may have led property owners to remove vegetation during the spring burning period.

Social distancing measures from late spring to early September 2020 led to well-documented increases in outdoor recreation (Mateer et al., 2021; Rice et al., 2020; Shartaj et al., 2022). Our results suggest that sustained, elevated numbers of recreation-caused fires were in part a result of increased recreational use (Jenkins et al., 2023). High levels of campground use and sustained campground closures also may have displaced some visitors from campgrounds to dispersed camping locations, incurring a higher likelihood of ignitions, particularly ignitions that became larger fires (Jenkins et al., 2023). Widespread closures of federal offices (e.g., ranger stations) also may have reduced the number of opportunities to conduct fire prevention outreach and education programs and the efficacy of such programs.

While not explicitly examined here, the number of fires caused by power generation, transmission, and distribution was elevated from May to September 2020. Weak correlations between the number of ignitions from such causes and fire indices examined herein (Figure 3, Figure S3 in Supporting Information S1) are suggestive of non-climatic contributors to the elevated number of power ignitions during 2020. Industry reports indicate that the aggregate impacts of the pandemic on the energy sector included a reduced workforce, supply chain disruptions, and limitations to availability and delivery of support services, such as maintenance of rights of way (North American Electric Reliability Corporation, 2020) and transmission and distribution infrastructure (Kim et al., 2022). The highest number of fires of undetermined cause also occurred in 2020. We suspect that fire cause investigations were deprioritized during ongoing COVID-19-related restrictions and changes in public health protection protocols. Additionally, the increased number of firearms sold during the COVID-19 pandemic and period of social unrest (Crifasi et al., 2021), in conjunction with increased use of wildlands, might partially explain the elevated number of firearm-caused ignitions throughout the western US in 2020.

Our screening methods place 2020 within the highest-ranking years for total human-caused fire ignition count (Figure S2 in Supporting Information S1). Although we used the most comprehensive fire ignitions database in the US, applied replicable quality assurance measures to remove inhomogeneities, and our core results were robust to such decisions, additional efforts to better harmonize fire ignition data sets would be valuable in future research. And while the number of human-caused ignitions in 2020 was the highest nearly three decades, the number of fires in several of the first few years of that period was comparable to that of 2020, leading to uncertainty in codifying 2020 as the record year.

The 2020 fire season offers novel insights into human-environment interactions. Human-caused fires are a major contributor to the total number of ignitions and area burned (Abatzoglou & Williams, 2016; Balch et al., 2017; Bowman et al., 2011; Fusco et al., 2016; Mann et al., 2016). The ignitions are driven by people's engagement with land, recreation, transportation, and large sectors of the economy, which in turn is affected by complex social, economic, behavior, and policy factors (Bowman et al., 2011; Fusco et al., 2016). The results of our analysis suggest that COVID-19 impacts substantially increased the number of fires ignited by several human causes in 2020. Our findings complement previous studies that have shown potential links between COVID-19 and fire activity in other regions that were mediated through alterations in human-environment interactions (Eklund et al., 2022; Poulter et al., 2021).

Although another global pandemic on the scale of COVID-19 may not materialize in the short term, changes in longer-term human dynamics catalyzed by COVID-19 may induce longer-term changes in the number and cause of human-ignited wildfires, including persistently high demand for outdoor recreational opportunities (Humagain & Singleton, 2021; Mateer et al., 2021; Rice et al., 2020; Taff et al., 2021) and increases in population density in fire-prone areas (González-Leonardo et al., 2022; Haslag & Weagley, 2022; Lei & Liu, 2022; Ng et al., 2022). Further understanding the role that unanticipated human behavioral shifts play in wildfire outcomes may lead to a deeper understanding of coupled human-natural fire systems. Understanding how social disruptions indirectly influence fire occurrence becomes increasingly important as climate change introduces ever-higher temperatures, drier conditions, and increased climate variability in wildfire-prone regions (Balch et al., 2017; Bowman et al., 2020; Higuera & Abatzoglou, 2021; Keeley & Syphard, 2015).

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

All data used herein are publicly accessible at the following repositories: (a) FPA-FOD data was obtained from Short (2022), (b) gridMET geospatial climate data was obtained from Northwest Knowledge Network (2017), (c) Firework consumption figures were obtained from the American Pyrotechnics Association (2023), (d) The *COVID-19 Community Mobility Reports* data set was obtained from Google Surveys (2022), (e) USFS Reservation Data was obtained from Shartaj et al. (2022), and (f) Wildfire ignition data from the National Interagency Fire Center (2024) was used in Supporting Information S1.

Acknowledgments

The work was supported through Grants from the Department of the Interior's Joint Fire Science Program (L21AC10247 and L21AC10244) and the National Science Foundation (OAI-2019762).

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