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The association of Public Safety Power Shutoffs and motor vehicle crashes

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ABSTRACT

Introduction: Utility companies in California de-energize equipment during periods of high wildfire risk. These Public Safety Power Shutoffs (PSPS) are designed to prevent power lines from igniting wildfires. The loss of electricity and subsequent failure of traffic signals may increase the risk of motor-vehicle crashes. *Methods:* We determined the daily number of motor-vehicle crashes per county for all 58 California counties between September 15th and November 30th, 2019, a period of high wildfire risk. We obtained electrical circuit-level information from the California Public Utilities Commission and created two daily PSPS exposure metrics: the equivalent to (1) the number of utility customers and (2) the percent of households in the county without power for a full day. Exposure metrics were categorized into quartiles of households or population impacted by PSPS. We generated random effects negative binomial models to estimate the association between PSPS exposure quartile and motor-vehicle crashes at the county-day level. *Results*: We observed 522 county-days that experienced a PSPS event and 104,627 motor-vehicle crashes during our 77-day study period. Effect estimates from models using the two exposure metrics were similar. Higher levels of PSPS exposure were associated with slight decreases in the rate of motor-vehicle crashes. In the customer-day model, the highest level of PSPS exposure was associated with a 7% decrease in motor-vehicle crashes per 100,000 county residents (RR: 0.93, 95% CI: 0.88–0.98) compared to days without PSPS. *Conclusions:* Despite the failure of traffic signals, road lighting, and other traffic safety equipment during power outages, the fall 2019 PSPS events were not associated with an increase in motor-vehicle crashes, potentially due to changes in driving habits and behavior. *Practical Applications:* PSPS may have unintentional consequences. Motor-vehicle safety during PSPS should be a focus of future monitoring efforts.

1. Introduction

Catastrophic wildfires have increased globally in recent decades (Abatzoglou & Williams, 2016; Balch et al., 2017; Burke et al., 2021; Tyukavina et al., 2022). While anthropogenic climate change has contributed to this increase, (Abatzoglou and Williams, 2016; Barbero et al., 2015; Jolly et al., 2015; Zhuang et al., 2021; Goss et al., 2020; Balch et al., 2022) human-caused ignitions have also played a major role (Balch et al., 2017; Abatzoglou et al., 2018; Hantson et al., 2022). Electrical infrastructure, including power lines, ignited many recent deadly wildfires, including the 2009 Black Saturday bushfires in Victoria, Australia (2009 Victorian Bushfires Royal Commission (Ed.)., 2009) and the 2018 Camp Fire in California (CAL, 2019). When power lines contact another object, they arc or spark, releasing small particles of molten or burning metal (Mitchell, 2013). These sparks can ignite dry fuel and cause wildfire ignition. Since high winds can cause trees to break or power lines to swing and contact vegetation, wildfires started by power lines are more likely to occur during high winds than fires ignited by other causes. As a result, fires ignited by power lines are generally larger and spread faster than fires ignited by other causes (Mitchell, 2013; Miller et al., 2017; Collins et al., 2016). In California, power lines have ignited less than 10% of wildfires, but about half of the most destructive wildfires in California history, including many of the deadliest fires, are attributable to electric utility infrastructure (CAL, 2021).

To prevent electrical lines from sparking wildfires, the California

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Public Utilities Commission (CPUC), the regulatory agency that oversees privately owned public utilities in the state, developed policies to implement Public Safety Power Shutoffs (PSPS), which authorize utility companies to de-energize power lines to protect public safety (California Public Utilities Commission, 2021). CPUC first authorized one utility company to conduct PSPS in 2012. The Commission established guidelines, including requiring utility companies to notify customers in advance of the power shutoff and to submit reports to the CPUC justifying the decision to shut off power and the result of the event. The authority to conduct PSPS events, along with the established requirements, was extended to all investor-owned utility companies in 2018 (Reasonableness et al., 2018). The use of PSPS increased drastically after the ruling. In 2017, one utility company conducted five PSPS events, impacting nearly 21,000 utility customers for an average of 36 h. In 2019, three utility companies conducted 15 PSPS events, which impacted over 2.2 million customers for an average of 46 h (California Public Utilities Commission, 2021; Murphy, 2021).

As PSPS are a relatively new intervention, few peer-reviewed studies have been published about their use and impact. Most peer-reviewed publications about PSPS are based on surveys exploring experiences during PSPS events, (Brown et al., 2022; Wong et al., 2022) attitudes toward PSPS policies, (Wong-Parodi, 2020; Wong-Parodi, 2022; Zanocco et al., 2022) and how PSPS have influenced perceptions about climate change and energy, and preparedness behaviors (Zanocco et al., 2021; Mildenberger et al., 2022). For example, Wong and colleagues surveyed 210 California residents impacted by PSPS events about their experiences and travel behavior during the power outages. They found that between 61% and 74% of survey respondents conducted typical travel, or did not alter their travel behavior, on the day of PSPS events (Wong et al., 2022). To our knowledge, this is the only published study in the peer-reviewed literature about transportation and PSPS events.

Reports, law reviews, dissertations and theses, and blogs have attempted to investigate PSPS policies and events. A 2020 Manhattan Institute report conducted a cost-benefit analysis, concluding that, overall, the costs of PSPS exceed the benefits, except under the most extreme assumptions (Lesser & Feinstein, 2020). A risk analysis conducted by a wildfire science and technology company concluded that the PSPS events in the fall of 2019 prevented more than 600 fires from burning over four million acres across California, (Technosylva, 2021) but these findings have not been corroborated. Finally, official reports from the State of California, including the CPUC's Safety and Enforcement Division's report on the late 2019 PSPS events (Commission, 2020) and a 2022 report published by the California State Auditor, (California State, 2022) have criticized the use of PSPS and called for improvement.

While PSPS events have likely prevented wildfires, as de-energized electrical equipment cannot release sparks, the collateral health and safety consequences of these power outages have not yet been evaluated. As electricity is required for numerous transportation safety measures, one potential consequence of PSPS is increased motor-vehicle crashes. Traffic signals play a prominent role in transportation safety by managing traffic flow and controlling the right of way at intersections. When signals are not operational due to a power outage, drivers may fail to detect signals and not yield at intersections, or may not know who has the right of way, potentially increasing the number of crashes. Additionally, power outages may affect street lighting, roadway signage, electronic message boards, and other transportation safety measures. It is important to investigate this potential association, as motor-vehicle crashes are a major public health concern in the United States. In California, the number of severe injuries and fatalities due to motor-vehicle crashes increased between 2010 and 2018, with over 16,000 severe injuries and 3,700 fatalities due to motor-vehicle crashes in 2018 alone (California Department of Transportation, 2022) The objective of this study was to quantify the impact of PSPS events on motor-vehicle crashes in the state of California. We hypothesize that motor-vehicle crashes increased during PSPS events. To test this hypothesis, we posed the research question: What was the association between the late 2019 Public Safety Power Shutoffs in California and motor-vehicle crashes?

2. Methods

2.1. Design and setting

We conducted an ecological study at the county level to examine the association between PSPS and the daily, county-level rate of motor-vehicle crashes in California during the fall of 2019. The analysis included data across all 58 counties in California from September 15th to November 30th, 2019, resulting in 4,466 county-day observations. The time frame was selected to encompass large PSPS events that occurred in October of 2019 and impacted more than two million utility customers (Table 1) (Commission, 2020).

Because a motor-vehicle crash at any single location is a rare event, we aggregated crashes to a larger geographic area to examine potential differences between days with and without PSPS events. We chose to conduct this ecological study at the county level to have sufficient variation in the number of crashes per day to detect differences between days with and without PSPS events.

2.2. Data sources/measurements

2.2.1. Public Safety power Shutoffs impact metrics

We quantified the impact of PSPS at the county level by creating two exposure metrics: a metric combining the number of customers impacted and the duration of the outage (**customer-days**) and a metric accounting for the proportion of households in a county impacted and the duration of the outage (**percent household-days**). These metrics were derived from the CPUC PSPS dataset (California Public Utilities Commission, 2021). The PSPS dataset contains the time of de-energization, the time of power restoration, and information about the number and types of customers impacted, for each circuit de-energized in a PSPS (California Public Utilities Commission, 2021). "Customers" refers to all utility customers, including commercial and industrial customers, while "residents" refers specifically to residential customers.

We obtained electrical circuit maps (Pacific Gas & Electric, 2022; Edison, 2023; 35). containing the geographic locations of electrical circuits from the three utility companies that conducted PSPS events in the fall of 2019. Using GIS, we spatially overlaid utility company maps with California counties (Walker, 2022) to determine where each circuit

Table 1
PSPS events conducted in California between September 15th and November 30th, 2019.

Utility Company	Event Start Date (2019)	Event End Date (2019)	Number of counties affected	Number of customers affected
PG&E	9/23	9/25	8	70,826
PG&E	10/5	10/6	3	11,609
PG&E	10/9	10/12	35	735,440
PG&E	10/23	10/5	17	178,800
PG&E	10/26	10/29	30	967,700
PG&E	11/20	11/21	15	49,000
SCE	9/21	10/1	1	85
SCE	10/2	10/12	5	23,824
SCE	10/12	10/21	4	444
SCE	10/21	10/26	6	31,386
SCE	10/27	11/4	10	126,364
SCE	11/15	11/17	3	49
SCE	11/23	11/26	5	1,192
SDG&E	10/10	10/11	1	395
SDG&E	10/20	11/1	1	27,703
SDG&E	11/17	11/18	1	21

Adapted from: California Public Utilities Commission, Safety and Enforcement Division. Public Report on the Late 2019 Public Safety Power Shutoff Events; 2020:90 (Commission, 2020).

was located. For circuits that crossed county borders, we determined the proportion of the circuit in each county and multiplied it by the total number of customers and the total number of residential customers on the circuit to estimate the number of customers and residential customers on the circuit in each county. This step relied on the assumption that customers were evenly distributed across the circuit. If a circuit in the PSPS dataset could not be linked to a circuit from the utility company maps, we attempted to identify the county of the circuit by reviewing the post-event reports that utility companies provide CPUC after a PSPS event (California Public Utilities Commission, 2021).

We split each outage-level observation into days and created a customer-day metric by multiplying the estimated number of customers impacted by the outage duration for each circuit and day. To create a resident-day measure, we used a similar approach. We aggregated the circuit-level data to the county level, summing the customer-day metric and the resident-day metric for each county for each day. We divided the resident-day measure by the number of households in the county, based on the 2015–2019 American Community Survey estimates, (Census Bureau and (n.d.). U.S. 2021) to create the final percent household-day metric. A graphical representation of these data processing steps is provided in Supplemental Fig. S1.

Our analysis examined both the customer-day metric, which represents the equivalent of the number of customers in a county without power for a full day, as well as the percent-household-day metric, which represents the equivalent of the percent of households in a county without power for a full day. We determined quartiles for these metrics among days that experienced impacts of PSPS and used days with no PSPS impacts as the reference group.

2.2.2. Motor-vehicle crashes

We obtained motor-vehicle crash data from the Statewide Integrated Traffic Records System (SWITRS), (California Highway Patrol, 2021) a database containing data gathered from collision scenes and managed by the California Highway Patrol. SWITRS contains all fatal and injury crashes reported by the California Highway Patrol and its Allied Agencies (California Highway Patrol, 2021). Some property damage only crashes are included in SWIRTS, however, not all agencies report any or all of their property damage only crashes. We used SWITRS to determine the number of crashes that occurred in each county on each day during the study period.

2.2.3. Covariates

A variety of weather-related variables are associated with both PSPS and with motor-vehicle crashes, potentially confounding the association. The United States Federal Highway Administration reports that approximately 21% of motor-vehicle crashes are weather-related (U.S. Department of Transportation Federal Highway Administration., 2023) Studies have shown that precipitation and wet road conditions are associated with increases in motor-vehicle crashes,(Liu et al., 2017; Stevens et al., 2019) and that extreme temperatures are associated with an increased risk in motor-vehicle crashes and fatal motor-vehicle crashes (Wu et al., 2018; Hou et al., 2022).

To account for time-varying, environmental factors that could confound the association between PSPS events and motor-vehicle crashes, we acquired the average maximum daily temperature, wind velocity, and precipitation from gridMET, a collection of daily high-spatial resolution datasets (Abatzoglou, 2013). We used the climateR package (Johnson, 2023) to identify the average maximum temperature (°C), wind velocity (m/s), and precipitation (mm) for a five km region around the U.S. Census Bureau's 2020 population-weighted county centroid (Census Bureau, 2023) for each county and day. Because most county-day observations had no precipitation, we created a dichotomous variable for precipitation (none vs. any) and rescaled temperature by dividing it by 10 degrees for modeling.

2.3. Statistical methods

We modeled the number of daily crashes using negative binomial mixed effects models, using county as a random intercept to account for daily repeated measures and PSPS exposure quartiles as the primary exposure. We selected negative binomial regression because the outcome, number of daily crashes, was overdispersed. Models adjusted for temperature, wind speed, precipitation, holiday status, and day of the week with three levels (i.e., Monday through Thursday, Friday, and weekend days). The 2015–2019 American Community Survey estimate of county population (Census Bureau and (n.d.). U.S. 2021) was included as an offset variable to model rates of vehicle crashes per 100,000 county residents.

We created two models using the different exposure metrics: one using the exposure metric based on the quartile of the number of customers impacted (customer-day) and the other using the exposure metric based on the quartile of the percent of households impacted (percent household-day). We examined both exposure metrics because there is no predetermined definition of county-level exposure to power outages, and the two metrics classified county-days into different quartiles. As a general practice, the use of quartiles allowed for examining effects across the distribution of outage impacts, rather than selecting arbitrary thresholds as cut-points without prior knowledge. Analyses were conducted in R version 4.2.3 (R Core Team, 2023) using the lmerTest package (Kuznetsova et al., 2017).

2.4. Sensitivity analysis

To account for differences in the number of miles driven due to PSPS events, we obtained the daily vehicle miles traveled on freeways for the 41 counties in California that have traffic detector stations from the California Department of Transportation Performance Measurement System (California Department of Transportation., 2023). We conducted a sensitivity analysis for these 41 counties using freeway vehicle miles traveled as the offset variable instead of the county population.

3. Results

3.1. Public Safety power Shutoff impacts

Between September 15th and November 30th, 2019, the 58 counties in California experienced a combined 522 days with impacts from PSPS events, representing 11.6% of the county-day observations. On average, outages impacted the equivalent of 9,440.5 customers for the full day (range 0.02 to 119,801.1; median: 2,350.5) in a county, and the equivalent of 18.1% of households in a county were without power for the full day (range: 0 to 100%; median: 3.4%) (Fig. 1). While both exposure metrics measured the extent to which a county experienced a PSPS on a given day, using the absolute number of customers impacted and the percent of households impacted resulted in differences in the geographic distribution of the exposure quartiles (Fig. 2).

3.2. Motor-vehicle crashes

The average number of motor-vehicle crashes per county in California per day was 23.4 crashes (range: 0 to 536; median: 6) (Fig. 3). The daily number of crashes was highly dependent on county. The minimum daily number of motor-vehicle crashes in Los Angeles County during the study period was 321 crashes, while no other county had more than 123 motor-vehicle crashes in a day. The average rate of crashes per county was 3.8 crashes per 100,000 county residents (range: 0 to 177.8; median: 3.2). The average rates of motor-vehicle crashes per 100,000 people were similar across all quartiles of customer-day metric and across the first three quartiles of the percent household-day metric, before dropping slightly in the highest quartile (Table 2).

The association between the PSPS quartile and the rate of motor-

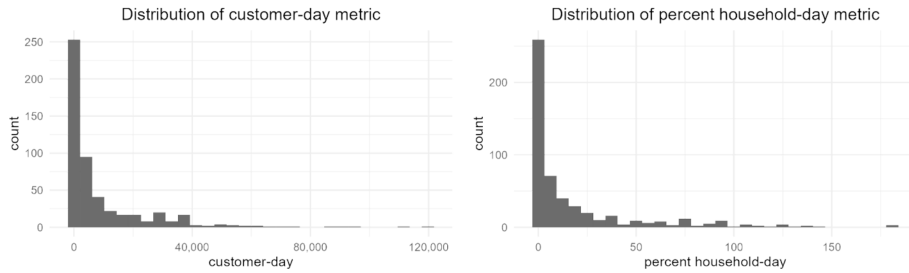

Fig. 1. Distribution of customer-day (left) and percent household-day (right) metrics among county-days with Public Safety Power Shutoff (PSPS) events.

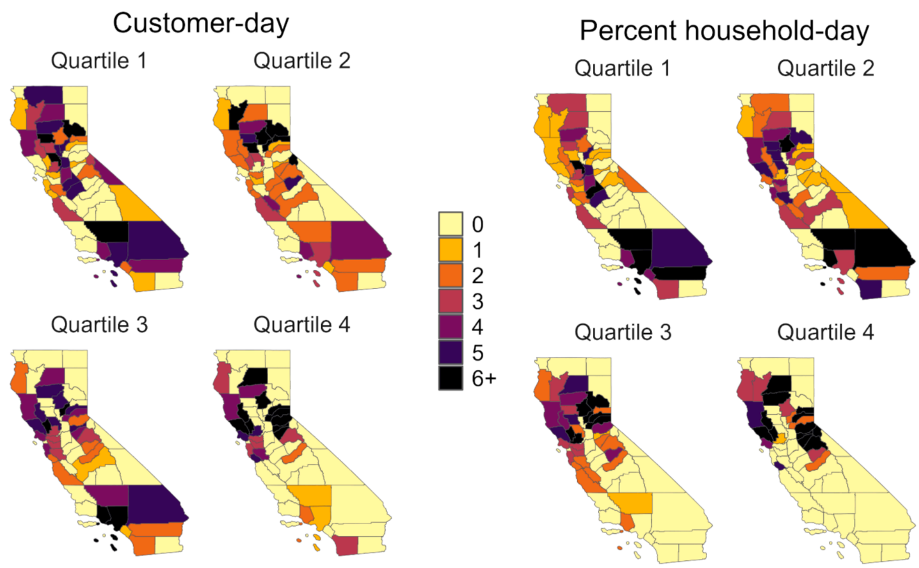

Fig. 2. Number of observations per county in each Public Safety Power Shutoff (PSPS) quartile, based on the customer-day metric (left) and the percent household-day metric (right).

vehicle crashes differed slightly between the models with different exposure metrics (Table 3; Fig. 4). In both models, the rate of motor-vehicle crashes for the first and second quartiles, representing the smallest PSPS impacts at the county level, did not differ from days with no PSPS impacts. In the customer-day model, the highest level of PSPS exposure, representing 10,563 or more customers without power for the full day, was associated with an 7% decrease in motor-vehicle crashes per 100,000 county residents (RR: 0.93, 95% CI: 0.88–0.98) compared to days without PSPS. In the model using percent household-day metric, the rate of motor-vehicle crashes decreased 10% (RR: 0.90, 95% CI: 0.84–0.97) in counties where the equivalent of between 2.6% and 19.7% of households were without power for the full day due to PSPS, relative to days with no PSPS exposure. The highest level of PSPS exposure, with 19.7% or more of households without power, was associated with a 5% decrease in motor-vehicle crashes per 100,000 county residents (RR: 0.95, 95% CI: 0.86–1.05) compared to days without PSPS exposure, however, this finding was not statistically significant.

3.3. Sensitivity analysis

We conducted a sensitivity test using freeway vehicle miles traveled as an offset variable instead of the county population to account for the potential reduction in driving due to PSPS events. Results showed minimal changes between effect estimates, however, none of the effect estimates yielded statistically significant results in these models (Supplemental Table S1).

4. Discussion

Interventions and policies must be evaluated for collateral consequences. While it is probable that PSPS events have prevented wildfires, the current burden of these power outages on public health is unknown.

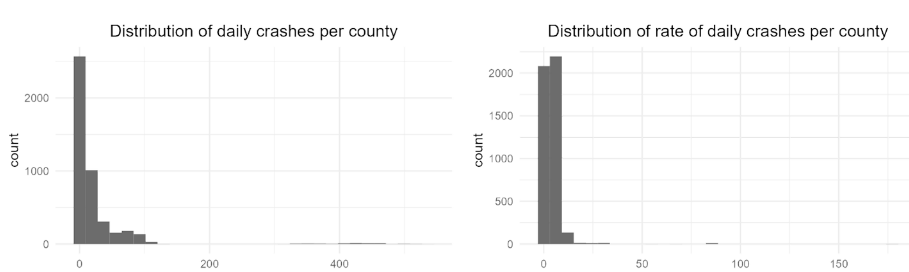

Fig. 3. Distribution of motor-vehicle crashes (left) and rate of motor-vehicle crashes per 100,000 county residents (right) for each county-day observation.

Table 2
Summary of quartile splits based on customer-day and percent household-day metrics and distribution of rates of motor-vehicle crashes per 100,000 county residents per quartile of Public Safety Power Shutoffs (PSPS).

PSPS Exposure Level	Motor-vehicle crashes per 100,000, Mean (SD)
Customer-day Quartiles	
No PSPS	3.2 (2.0, 4.5)
Quartile 1 (<201)	3.4 (2.5, 4.6)
Quartile 2 (201–2,350)	3.2 (0, 4.6)
Quartile 3 (2,350–10,563)	3.2 (2.3, 4.1)
Quartile 4 (>10,563)	3.0 (2.0, 4.0)
Percent household-day Quartiles	
No PSPS	3.2 (2.0, 4.5)
Quartile 1 (<0.2%)	3.4 (2.9, 4.3)
Quartile 2 (0.2%-3.4%)	3.3 (2.4, 4.5)
Quartile 3 (2.6%-19.7%)	3.1 (2.0, 4.3)
Quartile 4 (>19.7%)	2.3 (0, 4.4)

Table 3
Rate ratio (95% confidence interval) comparing the rate of motor-vehicle crashes per 100,000 people for each quartile of PSPS exposure, compared to days without PSPS exposure.

	Customer-day model	Percent-household-day model
PSPS		
No PSPS	Reference	Reference
1st quartile	0.98 (0.94, 1.03)	0.98 (0.95, 1.02)
2nd quartile	0.99 (0.94, 1.04)	0.99 (0.95, 1.03)
3rd quartile	0.98 (0.94, 1.02)	0.90 (0.84, 0.97)
4th quartile	0.93 (0.88, 0.98)	0.95 (0.86, 1.05)
Day of Week		
Mon-Thurs	Reference	Reference
Fri	1.09 (1.07, 1.12)	1.09 (1.07, 1.12)
Sat-Sun	0.82 (0.80, 0.83)	0.82 (0.80, 0.83)
Holiday	0.77 (0.74, 0.80)	0.77 (0.74, 0.80)
Any precipitation	1.01 (0.98, 1.04)	1.01 (0.98, 1.04)
Maximum temperature (10 °C)	0.99 (0.97, 1.01)	0.99 (0.97, 1.01)
Maximum wind speed (m/s)	1.01 (1.00, 1.01)	1.01 (1.00, 1.01)

To our knowledge, this is the first study to examine the impact of PSPS on motor-vehicle crashes. Using data from California's Statewide Integrated Traffic System from the fall of 2019, results suggest no increase in the rate of motor-vehicle crashes per 100,000 county residents during most PSPS events, but a possible decrease in crash rates during high levels of PSPS impacts. These findings were contrary to our hypothesis of PSPS events increasing rates of motor-vehicle crashes.

Research on the impact of power outages on motor-vehicle safety is lacking. A 1978 survey of over 2,500 traffic engineers across the United States concluded that most traffic engineers considered power failure at signalized intersections to be a minor problem and estimated that less than 0.1% of crashes were due to signal outages (Rankin & Rosenbaum, 1980). The Ohio Department of Transportation reviewed over 26,000 reports from crashes that occurred at signalized intersections between 1994 and 1997, and found just 17 crashes that involved a dark signal as a possible cause of the collision (Pant & Lenski, 1999). Despite these studies, reports of crashes due to power outages and the subsequent failure of traffic signals have been recorded in the literature (St. Bernard & Matthews, 2003; Kile et al., 2005) and anecdotally in the news (Curtis, 2021; Crawford, 2023).

PSPS events are fundamentally different from other power outages since utility companies are required to mitigate their impacts and notify customers in advance of the power shutoff. With advanced knowledge of the PSPS event, many residents may have chosen to not drive during these power outages. In addition, people may not commute to places of work or drive for personal reasons, such as to a retail store, gym, or restaurant, if the destination does not have electricity. As a result, there may be fewer vehicles on the roads and fewer crashes on days with PSPS events compared to days without PSPS events. A study on travel behavior during October 2019 found that between 17% and 32% of survey respondents changed their travel behavior on the day of a PSPS event, although the study was limited by low sample size and self-selection bias (Wong et al., 2022).

We were unable to account for the potential reduction of driving during PSPS events. Comprehensive county-level daily driving data were not available, as very few locations in California continuously count traffic (California Department of Transportation. (n.d.). Traffic Volumes. Caltrans. Retrieved July 11, 2024). We conducted a sensitivity analysis using freeway vehicle miles traveled. This was an imperfect measure, as it was not available for all counties and did not account for the potential reduction in driving on roads other than freeways, where there are intersections and traffic signals impacted by the power shutoffs. Our sensitivity analysis did not find an increase in the rate of motor-vehicle crashes per freeway mile driven when accounting for fluctuations in traffic volume due to PSPS events.

Beyond changes in travel patterns, changes in driver behavior may have been responsible for the decrease in motor-vehicle crashes on days with high levels of PSPS exposure in a county. Power outages may have prompted drivers to drive more cautiously than usual, resulting in a decrease in motor-vehicle crashes. During a major power outage in the Netherlands in 2015, traffic sensors detected a 40% decrease in traffic speed (Melnikov et al., 2015). Reduction in speed during power outages could have led to less severe crashes, which may not have been captured by the SWIRTS data.

Finally, many traffic signals contain emergency battery backup systems to provide power to the signal during power failures. Some backup systems provide full power to the signal, while other systems have all traffic signals flash red. These battery backup systems may have kept traffic signals functioning and prevented motor-vehicle crashes during PSPS events. The duration of battery backup systems can vary, but is often between four and eight hours, (California Department of Transportation., 2019) so these systems likely did not last for the duration of PSPS events. However, solar powered traffic signals and signs may

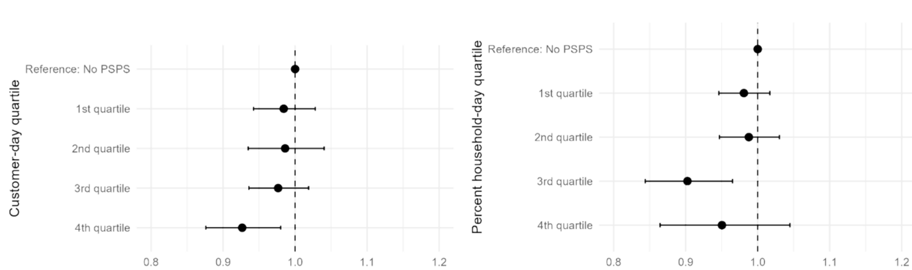

Fig. 4. Rate ratio (95% confidence interval) of motor-vehicle crashes per 100,000 county residents for each quartile of Public Safety Power Shutoff (PSPS) exposure compared to days without PSPS exposure using quartiles created from the customer-day metric (left) and the percent household-day metric (right) Estimates were adjusted for daily temperature, wind speed, precipitation, holiday status, and day of week.

continue to function throughout a PSPS event. Because most traffic signals are operated by a local government, statistics are not available about the prevalence of solar-powered equipment or battery backup systems at traffic signals across California.

We employed an ecological study design, with the geographic regions of counties as the unit of observation. Ecological studies are beneficial for hypothesis-generating and are particularly useful when individual-level data are unavailable (Morgenstern, 1995). To model the daily rate of crashes in a county, we needed to measure the exposure at the county-day level. Since there is no defined minimum threshold required to classify a county as experiencing a power outage or not, we created novel metrics based on both the number of utility customers impacted by the outage and the percent of households impacted by the PSPS event and split these metrics into quartiles.

4.1. Limitations

This study is not without limitations. First, as an ecological study, inferences are limited to the county level and extrapolations cannot be made to the individual level. To conduct this ecological study, we aggregated the exposure (PSPS events) and outcome (crashes) to the county-day level. This involved mapping electrical circuits impacted by PSPS events and matching each circuit to one or more counties. We assumed that customers were distributed evenly across the circuit, but deviations from this assumption may have contributed to misclassification of the exposure. However, misclassification is likely low, as more than 80% of circuits were contained within a single county. Nonetheless, county is a large unit of analysis, which may have obscured localized impacts.

Additionally, we were unable to account for the potential changes in driver behavior, including the potential decrease in driving or a reduction in speed while driving during PSPS. We could not account for backup systems that may have allowed electronic traffic control devices to function during PSPS events. As motor-vehicle crashes are relatively rare events, we were not able to examine a subset of crashes, such as crashes that occurred at intersections, or crashes involving injuries and fatalities. Finally, as this study was limited to PSPS events in California during the fall of 2019, generalizability is limited. Results may not be applicable to unexpected power outages or to other geographic areas.

4.2. Future directions

Power outages pose risks to health, safety, economic well-being, and other aspects of life. The current body of research regarding the collateral consequences of PSPS is inadequate. As electrical infrastructure continues to spark wildfires and more jurisdictions consider implementing PSPS, it is critical to understand the unintended impacts of these power shutoffs to better mitigate their effects. Additional research should be conducted to characterize the comprehensive impacts of PSPS events, particularly on vulnerable populations.

Future work should continue to assess the potential association between PSPS and motor-vehicle crashes using data at a finer spatial and temporal resolution to reduce the potential for exposure and outcome misclassification. Studies could consider crashes at intersections or crashes from dusk until dawn, which might be more likely to be impacted by power outages. Additionally, future studies should attempt to model the rate of crashes per daily vehicle miles traveled to account for the potential decrease in driving during PSPS events. Speed and crash severity could also be investigated, as power outages are likely to influence driver behavior. If studies indicate increases in motor-vehicle crashes or other negative consequences of PSPS, interventions should be developed and evaluated to reduce the burden of PSPS events.

5. Conclusion

This ecological study conducted at the county-day level found that most PSPS events impacted a small number of people and a small proportion of households within a county on a given day and did not affect the county's motor-vehicle crash rates. However, at high levels of PSPS exposure, rates of motor-vehicle crashes per 100,000 county residents decreased. As PSPS events are a new intervention, it is important to assess their potential unintended consequences.

CRediT authorship contribution statement

Alyson B. Harding: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation. **Gillian A.M. Tarr:** Writing – review & editing, Methodology. **Jesse D. Berman:** Writing – review & editing, Methodology. **Darin J. Erickson:** Writing – review & editing, Methodology. **Marizen R. Ramirez:** Writing – review & editing, Supervision, Funding acquisition.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsr.2025.02.001.

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