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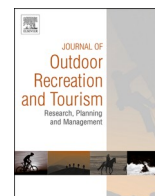
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Research Article

Wildfire-driven entry closures influence visitor displacement and spending to alternative park entrance corridors and gateway communities around Yosemite National Park

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ABSTRACT

Visitor attendance to national parks is affected by road closures from environmental hazards, particularly wildland fire in the American West. Visitors must often decide between displacing to other entrance stations to access sites within the park, and spending time in gateway communities and nearby locations during closures. We analyze variance of county sales tax revenue during fire-driven road closure extents to show whether visitors to Yosemite National Park are displacing, and how their movement is reflected in spending to further understanding of contemporaneous economic impacts to gateway communities. We find that visitors are choosing to displace to entry gates that remain open, rather than pursue activities in surrounding communities. Additionally, our findings indicate that contemporaneous economic impacts are largely dependent on categories of visitor spending, rather than presence/absence of visitors during entrance station closures. While visitors are spatially displacing to access other gates, their spending is not reflected in gateway communities where they are displaced across spending categories. Routine-based spending, such as at restaurants, does not increase with a through-flux of visitors. Need-based spending, particularly gasoline, increases contemporaneous to increases in gate attendance. When one gate closes, monthly attendance increases consistently at primary gates that remain open by approximately 50%, respective to their mean attendance. This is accompanied by an equivalent increase in need-based spending. Put simply, during fire-driven closures of park entrances and corresponding highway corridors substantially more visitors are passing through neighboring gateway communities, but not spending time there, and thereby not contributing significantly to these tourism-dependent economies.

Management implications:

- During corridor closures, visitors are displaced to the closest open gate. Increases in need-based spending (e.g., gasoline) indicate people are passing through gateway communities, but increases are not reflected in routine-based spending (e.g., restaurants).
- During displacement events, partner organizations may capitalize on the through-flux of visitors with marketing targeted at open corridors
- Agencies could co-locate informational kiosks or visitor centers in gateway communities, external to park boundaries to facilitate additional time in communities
- New approaches to marketing and visitor communications, particularly phone applications, may increase visitation and spending in gateway communities, and direct visitors to activities

1. Introduction

Detrimental wildfire impacts strongly influence visitation to public

lands, particularly national parks in the American West (Kim & Jakus, 2019). In recent decades, there has been an anthropogenically exacerbated increase in fire severity and duration in the west (Abatzoglou &

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Williams, 2016; Williams et al., 2019). In Mediterranean climates, peak visitation to western national parks collides with the historical late summer and early fall fire season (Swain, 2021). Increased visitation during fire season heightens visitor exposure to negative experiential impacts and health risks. Impacts range from obscured views to unhealthy air quality, traffic congestion, road closures, and even mandated evacuations. Visitors to public lands that feature access through limited corridors, particularly national parks, may be displaced totally-choosing to forego any visitation, spatially-choosing to go somewhere else, or temporally-visiting at a different time (Perry et al., 2021) (see Tables 1–4, Figs. 3–6).

During a corridor closure, visitors must decide between displacing to a different corridor (or return later) or dispersing to surrounding areas. Dispersal indicates distribution over a wider area and displacement refers to a collective shift to a new place or position. One strategy to reduce overcrowding effects in Yosemite has been to encourage dispersal of use among different communities through promoting the diverse regional network of historic, cultural, and recreational attractions beyond Yosemite’s boundaries (Gladfelter & Mason, 2012) However, this strategy may not fully account for displacement at park entrance stations due to climatic hazards such as fire.

Place attachment drives visitation, despite increased risks associated with hazardous events. Both recurring visitors and first timers may be strongly influenced to continue with visitation despite degrading conditions and decreased safety, but for divergent reasons. Repeat visitation and increased familiarity with navigating challenges in a park establishes strong place attachment for repeat visitors (Perry et al., 2021). Ideographic perspective (such as seeing places in popular culture and media) influences first timer attachment. Financial and temporal commitments due to inflexible policies, such as airline tickets and lodging reservations, are associated with out-of-state and international visitation (Ram et al., 2016).

Corridor closures negatively impact economies dependent on public spending and tourism impacts, traffic congestion, and increased commute times (Harp et al., 2008). Approximately three-quarters of a million fewer people visit national parks annually-directly resulting from wildfire-specific closures (Cai, 2021 preprint). Even when scenarios are sub-optimal for safety, visitors still desire to access popular locations (De Dominicis et al., 2015; Perry et al., 2021). Visitors must pass through gateway communities for resources (e.g., fuel) and to access destinations, including during hazardous events.

Diverse locational contexts and varied research needs lead to multiple gateway community definitions (Stoker et al., 2021). Our research question focuses on economic impacts to low population and economically homogenous communities, specifically incorporating State-regulated taxes in our analysis; therefore, we utilize gateway communities’ legal definition. Gateway communities are legally encoded in California documentation as those places that are ‘significantly affected economically, socially, or environmentally by planning and management decisions regarding Federal lands ...’ (H.R.1014—108th Congress (2003-2004), 2004). We further define gateway communities as “towns adjacent to and having economic ties to public lands ... most have a population below 15,000,” as our research question focuses on economic impacts to low population and economically homogenous communities (Kurtz, 2010). These communities exist within a checkerboard matrix of rural and agricultural land uses on both public and

private lands that pose challenges for contiguous landscape-scale management of hazards including wildland fire (Jenkins & Brown, 2020).

While recreational opportunities vary by climate and geography, the economic transformation for many tourism areas globally has been from extractive resource to recreation-based economies, and gateway communities, which serve as economic hubs to facilitate regional tourism are a notable trend manifestation (Fredman and Yuan., 2011; Mules, 2005; Walpole & Goodwin, 2000). Recent literature has explored the fire’s impacts on gateway communities’ economics. While literature relating to post-fire responses to recreation, economies, and other systems expands, researchers note a significant gap in the literature specific to understanding contemporaneous hazard impacts on gateway community economies (Duffield et al., 2013; Kim & Jakus, 2019; White et al., 2020). Serving initially as simplified to-and-from routes, trade, and “to-market” development, transportation corridors connect Yosemite to gateway communities and further downslope into the Central Valley (Weber, 2005). These corridors feature environments where ecological processes, human dynamics, and economies are inextricably intertwined – known as coupled-human natural systems and socio-ecological systems. (Walker et al., 2004; Liu et al., 2007; Ostrom, 2009; Miller et al., 2022).

Comparative opportunities exist in spatial and temporal aspects, addressed in Gladfelter and Mason (spatial) and Kim and Jakus (temporal). Therefore, we ask two key questions, utilizing Yosemite National Park and its surrounding region as a case study. First, during a wildland fire hazard event resulting in closures to some, but not all, of a park’s entrance corridors, do visitors displace to other open entrance stations? Furthermore, how is dispersal (or displacement) reflected in contemporaneous spending across adjacent counties and their corresponding entrance corridors? This article analyzes Yosemite’s entrance closures and resultant corresponding visitor displacement across entrance stations. We additionally analyze regional county tax revenues to understand shifts in visitor movement-driven spending patterns during hazard events to distill the contemporaneous fire impacts on local economies.

2. Background

Yosemite National Park stretches across four counties (Fig. 1), each with a singular corresponding entrance corridor. Vehicle counts (a proxy for visitor count) are tallied at each entrance station when accessing Yosemite. We can see how many vehicles are entering through each corridor, but not the corridor through which they depart. Over 90% of all visitation is centered in Yosemite Valley. Yosemite Valley can be directly accessed through the Arch Rock entrance from Highway 120 while the other three corridors descend into the valley from higher elevations (see Fig. 2).

In response to the Covid-19 pandemic, Park management implemented a day use reservation system to limit vehicular access and control crowd densities (Jenkins et al., 2021). The reservation system applied to access between 6am and 4pm. Though the reservation system was disengaged for Summer 2023, there is substantial likelihood that it will return in a similar form. Park management is actively engaging in a Visitor Access Management Plan to combat extended wait times and vehicle congestion that ultimately returned when the reservation system was lifted (National Park Service, 2023). Additionally, management has implemented recurring, short-term reservation requirements around

Table 1
Statistical results for ANOVA, comparing corridor status (Open/Closed) to Attendance fluctuations for Arch Rock corridor. Source: Authors.

Gate Impacted	Gate Influenced	Open Mean Attendance	Closed Mean Attendance	Relative % Change (±)	F Statistic	Pr(>F)
Arch Rock Mean Attendance: 32,455	Big Oak Flat	29513	49982	+69.36	8.89	0.00317**
	Hetch Hetchy	1796	2717	+51.28	3.174	0.0761
	South	36358	50603	+39.18	5.593	0.0188*
	Tioga Pass	16043	45611	+184.31	16.22	0.59e-05 ***

Source: Author.

Table 2

Statistical results for ANOVA, comparing corridor status (Open/Closed) to Attendance fluctuations for Big Oak Flat corridor. Source: Authors.

Gate Impacted	Gate Influenced	Open Mean Attendance	Closed Mean Attendance	Relative % Change (\pm)	F Statistic	Pr(>F)
Big Oak Flat (BOF- shared corridor) Mean Attendance: 30,281	Arch Rock	32043	46153	+44.03	6.687	0.0103 *
	Hetch Hetchy	1828	1918	+4.92	0.023	0.878
	South	36324	55817	+53.66	8.308	0.00431 **
	Tioga Pass	15932	57743	+262.43	26.47	5.6e-07 ***

Source: Author.

Table 3

Statistical results for ANOVA, comparing corridor status (Open/Closed) to Attendance fluctuations for South Gate corridor. Source: Authors.

Gate Impacted	Gate Influenced	Open Mean Attendance	Closed Mean Attendance	Relative % Change (\pm)	F Statistic	Pr(>F)
South Mean Attendance: 36,893	Arch Rock	32170	49294	+53.23	5.678	0.018 *
	Big Oak Flat	29850	55696	+86.59	6.37	0.0123 *
	Hetch Hetchy	1817	2645	+45.57	1.156	0.283
	Tioga Pass	16421	60294	+267.18	16.21	7.6e-05 ***

Source: Author.

Table 4

Statistical results for ANOVA, comparing corridor status (Open/Closed) to Attendance fluctuations for Tioga Pass corridor. Source: Authors.

Gate Impacted	Gate Influenced	Open Mean Attendance	Closed Mean Attendance	Relative % Change (\pm)	F Statistic	Pr(>F)
Tioga Pass Mean Attendance: 17,152	Arch Rock	32312	49487	+53.15	2.846	0.0929
	Big Oak Flat	30014	62009	+106.6	4.893	0.0279*
	Hetch Hetchy	1822	2908	+59.60	1.001	0.318
	South	36666	63868	+74.19	1.156	0.283

Source: Author.

popular events generating high access demand, such as “Firefall”, when lighting illuminates a particular waterfall such that it looks like it is on fire.

While applying the reservation system to an already limited transportation networks restricted access overall, it was not entrance station specific (National Park Service, 2022). During hazard events resulting in select entrance station closures, visitors must access this densely visited area through the remaining open corridors, thereby compounding entrance station wait times. As experienced during the 2013 Rim Fire, though individual corridors may be closed, the Valley may be beautiful, clear, and most operationally critical - safe-therefore still promoted for visitation by Park representatives.

‘Park officials said the fire has not impacted the park itself, which can still be accessed via State Routes 140 and 41 from the west, as well as State Route 120 from the east side. Yosemite Valley is clear of smoke, all accommodations and attractions are open, and campgrounds are full, said park spokesman Scott Gediman’ - Visalia Times-Delta, August 23, 2013

So long as Yosemite Valley remains open (and promoted for visitation), visitors remain drawn to the region, along with their spending money for lodging, fuel, food, and other goods and services.

Large wildland fires within and near Yosemite National Park have led to disruptions in the visitor flows in recent decades given the entrance station and road corridor closures that were necessary to maintain safety and allow for emergency response. While closures are usually limited to one entrance station, in some cases high-severity fires and associated smoke impacts have led to park-wide closures that have displaced would-be visitors later into the season, or entirely (Jenkins, 2022). Despite Yosemite remaining open, entrance station closures due to fires within or proximate to park boundaries physically prevent park visitors from accessing intended entrances. Park visitors must reroute through another ingress or egress point, at a minimum 1-h drive time from ‘gate to gate.’

Independent of hazardous events, Yosemite National Park is heavily impacted by visitation and usage-induced degradation, known as

‘hotspots.’ Implemented in the early 2000s, the Yosemite National Park Geotourism Initiative, in collaboration with National Geographic was designed to disperse visitors across gateway communities to reduce congestion and hotspot degradation within Yosemite’s boundaries. Since Beyond Boundaries: An Assessment of the Yosemite National Park Geotourism Initiative was published in 2012, nearly a decade after the Geotourism Initiative’s implementation, visitation has increased by 10%, at an average of 2% per year over the previous decade-ultimately the desired dispersal to reduce negative wear-and-tear within Yosemite was not achieved (National Park Service, 2022).

The greater Yosemite region and the Sierra Nevada have undergone an ecotransformation of ecologies and economies from resource extraction to recreation-based economic development (Duane, 2000). The Mariposa community experienced extensive economic disturbance during the complete multiday evacuation during the 2017 Detwiler Fire, along with Highway 140 corridor closures (Arch Rock Entrance) (Associated Press, 2017). For extended corridor interruptions, such as the Ferguson Rockslide, economic impacts to local communities totaled nearly five million USD (Harp et al., 2008).

Emotional connection to Yosemite may be driven by powerful visuals recognizable in popular culture and media, such as well-known recreational gear branding and documentaries. This connection utilizes the concept of place attachment, defined as ‘a space that has been given meaning through personal, group, or cultural processes’ (Altman & Low, 2012). Nearly 50% of summertime visitors (corresponding temporally with fire season) are first time visitors to Yosemite, compared to wintertime visitors, where approximately one-quarter of visitors are first timers (Le et al., 2008). Iconic ‘pull factors,’ such as El Capitan and Half Dome, draw visitors to Yosemite through ideographic or physical features of a place (Brown, 2003; Ram et al., 2016). Visual pull factors strongly influence visitor motivations, and thereby spatial behavior (Smith et al., 2021).

People rarely deviate from established, individualized daily routines, as expounded through the Theory of Planned Behavior (Ajzen, 1985), even when on vacation. Within the Valley itself, visitor navigational decision making is further influenced by collectivized car-culture and

corresponding ease of access to pull factors and motivating constructs. First time visitors largely access Yosemite through personal vehicles. Repeat visitors and those who have experience in other National Parks with robust public transit systems tend to utilize public transit option in the Valley (Youngs et al., 2008). The power of habit has been recently reinforced in sustainability studies, detailing how habit drives recreators' behavior and decision-making (MacInnes et al., 2022).

2.1. Regional hazardscape

The physical landscape, human activity, and development around Yosemite National Park interact dynamically to create a unique landscape of hazards (Corson, 1999; Cutter, 2001). This hazardscape is constructed via the interconnectedness between contemporary hazards with emphasis on global connectivity, technological, and societal influences (Mustafa, 2005).

Prior to European arrival in the Ahwahnee (now called Yosemite Valley) region, indigenous Ahwahneechee utilized managed fire on the landscape for harvesting resources and maintaining desirable conditions (Spence, 1996; Thornton & Bhagwat, 2020). Deliberate and controlled seasonal burning facilitated the proliferation of desirable plant species while simultaneously decreasing potential fuels. Later shifts in economic and transportation priorities – particularly logging and wooden rail infrastructure-led to paradigm and practice shifts towards burning and fire suppression, leading to overly dense forests, particularly susceptible to drought, insect infestations, and wildfire. Land management and legislation decisions further constrain corridors by preventing route expansion, reinforcing limited redundancies, and heightening risk. The Wild and Scenic Rivers Act restricts development along the Merced and Tuolumne Rivers, co-located with two of the four transportation corridors in Yosemite National Park (Cathcart-Rake, 2009).

Granitic geology largely dictates Yosemite's physical hazardscape.

Steep drainages, such as the Merced River Canyon (Arch Rock Corridor), constrain transportation infrastructure, which significantly increases visitor vulnerability to environmental hazards (Fraser et al., 2020). Biophysical processes impacting the region include wildland fire, flood, rockfalls and rockslides, and cyclical drought. These phenomena have become socially constructed hazards through historical-dependent development patterns and anthropogenically exacerbated and inter-connected landscape-scale environmental disturbances which literally place communities and visitors in harm's way of otherwise naturally-occurring phenomena (Bramwell, 2015; Jenkins, 2022).

Climate change has led to landscape-scale ecological disturbance throughout the region. In addition, extensive drought and subsequent bark beetle infestation compounded by years of fire suppression policy exacerbate conditions for megafires experienced in Mediterranean climates in recent decades (Korshidi, 2018; Crockett & Westerling, 2018). California receives most of its annual precipitation through atmospheric rivers – intense, punctuated rainfall events (Dettinger et al., 2011). Heavy precipitation events can initiate landslides in previously burned areas due to ground cover loss and decreased slope stability (Agha-Kouchak et al., 2018; Van Asch et al., 1999). Consecutive fires, floods, and landslides created compound hazard scenarios, experienced seasonally through the region.

Social vulnerability to hazards increases with increasing population density – in our case, both permanent and transient (temporary, travel-based) occupation (Cutter & Finch, 2008). Within Yosemite's boundaries, permanent and seasonal employees live in several key sites, while thousands of visitors also enter and exit each day. Externally, there are approximately one dozen small hamlets and growing gateway communities in foothill and mountainous regions. Radial and grid style connected transportation networks, typifying urban areas, are limited in the region due to topography. Path dependency on limited hierarchical corridors heightens risk for travelers using the minimal corridor options (Litman, 2013).

The California Department of Transportation (CalTrans) oversees Yosemite National Park access corridors, external to Park boundaries; Highway 120 East and West, Highway 41, and Highway 120. CalTrans categorizes closures as planned and unplanned (CalTrans, 2020). The unplanned classification describes emergency conditions as 'damage to the state highway system that are recent, unexpected, and event-driven.' Events like rockslides experienced in Mariposa County's Highway 140 corridor, which occurred in 2006 are considered unplanned (Harp, 2008). Bridges constructed across the Merced River and back to circumvent the slide-covered highway segment are still deemed temporary, despite being utilized for nearly two decades due to ongoing land movement and constraints associated with the Wild and Scenic Rivers Act.

Dynamic closure events such as wildfires have more plasticity and



Fig. 1. Map overview of Yosemite National Park with entrance corridors and corresponding gates. Map by Author. Sources: Authors, CalTrans, Esri Living Atlas, National Park Service. Basemap: Esri, DeLorme, HERE, MapmyIndia.

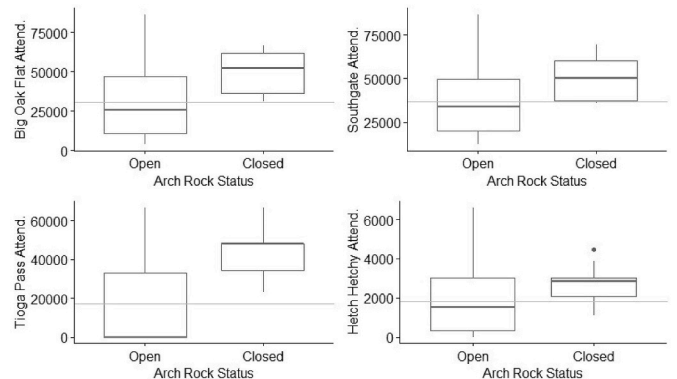


Fig. 2. Box plots representing shifts in attendance across gates when Arch Rock corridor is Open and Closed (fire), along with mean annual attendance indicated via the gray abline. Source: Authors.

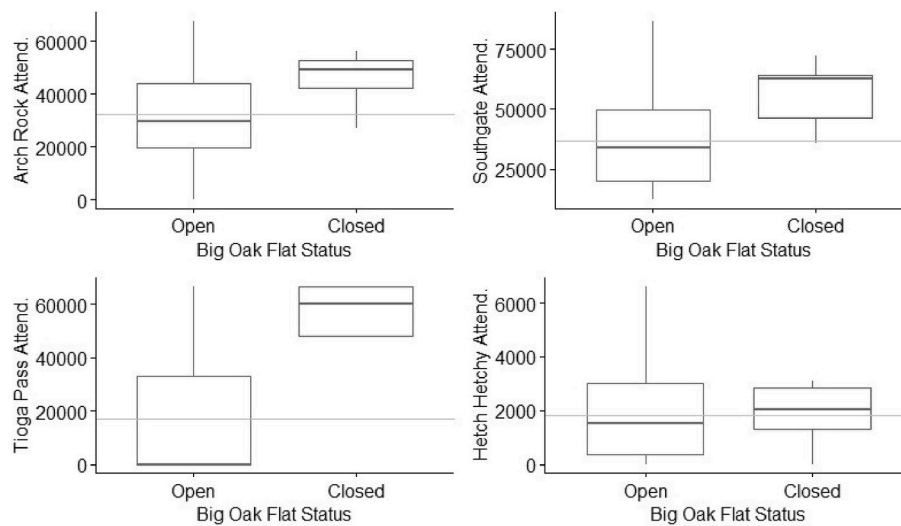


Fig. 3. Box plots representing shifts in attendance across gates when Big Oak Flat corridor is Open and Closed (fire), along with mean annual attendance indicated via the gray abline. Source: Authors.

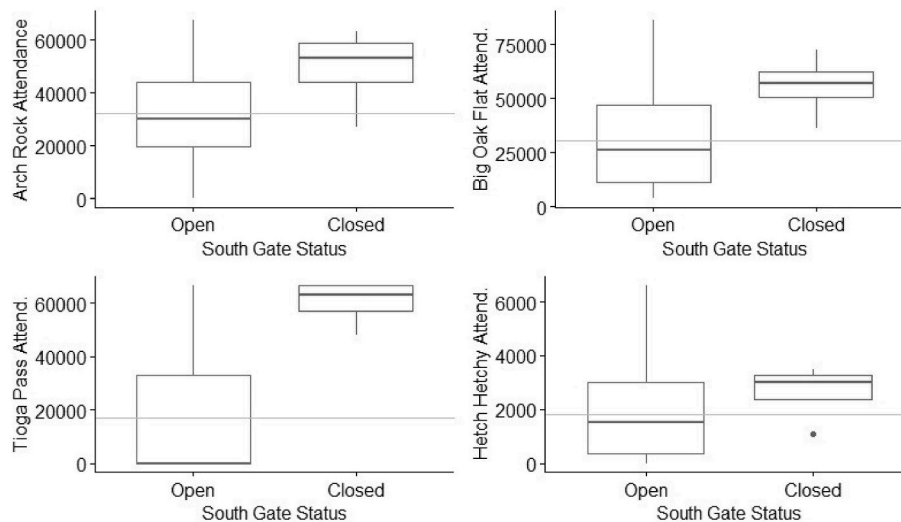


Fig. 4. Box plots representing shifts in attendance across gates when South Gate corridor is Open and Closed (fire), along with mean annual attendance indicated via the gray abline. Source: Authors.

complexity than a punctuated event like a rockslide. For example, following wildfire (and the predictable fire-atmospheric river-landslide cycle), roads can be preemptively closed to ensure driver safety. While we can heed red flag warnings during critical fire weather, it is impossible to pinpoint specific locations and fire movement due to multiple variables from ignition source and location to day-to-day weather patterns. Fires, therefore, fall under the unplanned emergency classification.

2.2. Yosemite gateway community economic trends

Global climate change impacts affect gateway communities earlier than non-gateway communities due to connectivity to, and dependence on, associated parks and public lands. The Sierra region containing Yosemite National Park accounts for one-third of the entire State of California’s federal-lands based contributions (Winter et al., 2021). When hazardous events physically disconnect gateway communities from their parent park, communities are directly impacted by associated financial losses (Gabe, 2016). Conventional outdoor recreation activities such as hiking and camping and ‘other’ outdoor recreational events and

festivals inject between \$350 and \$400 billion of value into the national economy in the 2010s (Highfill & Franks, 2019). Between 1998 and 2019, recreational-based roles increased by 82.8%, and food service and accommodations-based roles increased by 16.6% (Headwaters Economics, 2022).

When visitors are physically prevented from entering Yosemite National Park in accordance with their primary route during a road closure, they may spatially displace themselves through other gateway communities to gain access. As visitors continue to access Yosemite, they contribute to neighboring communities’ economies. In 2009, groups spent a median amount of \$490 (\$584 adjusted for inflation to 2019 buying power) and stayed overnight in the vicinity for 3.5 days (Blotkamp et al., 2009). Gateway communities often provide supplementary goods and services unavailable within their associated park (Joyner et al., 2019). For example, within Yosemite National Park the only two gas stations are located in the Crane Flat and Wawona regions. There is no gas available in Yosemite Valley.

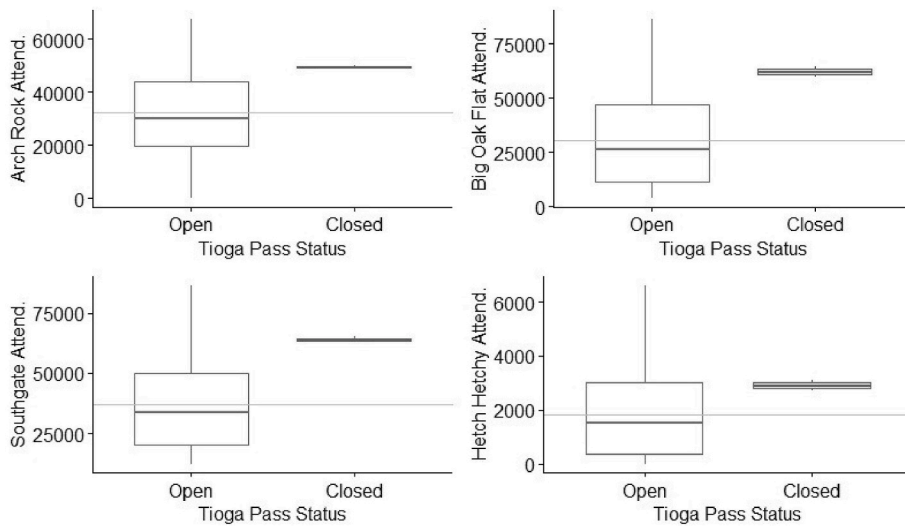


Fig. 5. Box plots representing shifts in attendance across gates when Tioga Pass corridor is Open and Closed (fire), along with mean annual attendance indicated via the gray abline. Source: Authors.

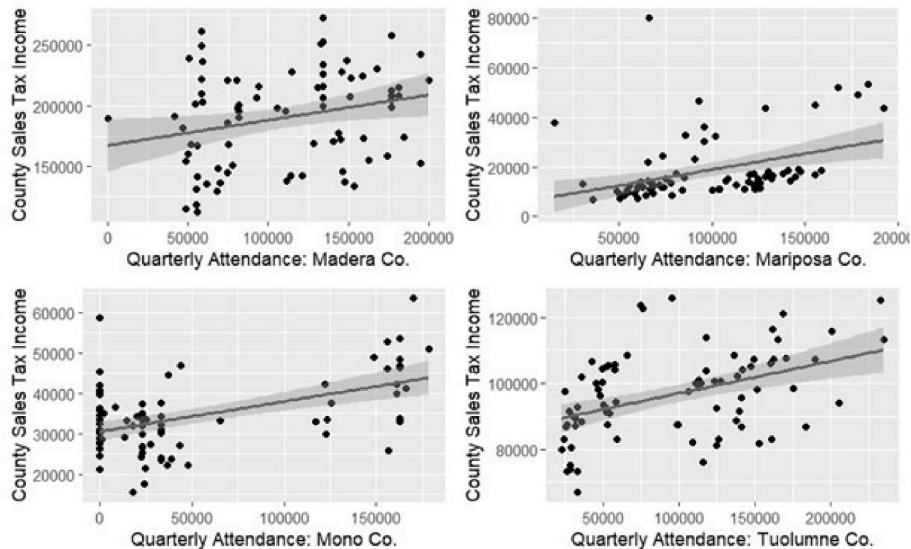


Fig. 6. Plots for each county indicate positive relationships between quarterly attendance and quarterly sales tax revenue by county and corresponding corridor. Source: Authors.

3. Materials and methods

Data for this study were constrained to the 2000–2020 timeframe. Ultimately, 2020 was removed from all utilized datasets due to Covid-associated full park closures and implemented reservation systems reflecting dynamic federal policy interventions (Curtis et al., 2021; Jenkins et al., 2021).

3.1. Data collection and refinement

Attendance Data: We utilized visitor attendance in the form of vehicles accessing Yosemite at each primary entrance gate, collected from the National Park Service’s Integrated Resource Management Applications website (IRMA) at the necessary monthly scale for each access point. There is no publicly available data for exit counts, but previous survey-based studies indicate that many visitors exit through a different corridor than which they entered (Le et al., 2008).

Economic Data: Regional economic data in the form of quarterly sales tax by county were collected through the California Department of Tax and Fee Administration’s Open Data Portal from 2009 through 2020. To obtain years 2000 through 2008, we submitted a public records request and fulfilled it via email pursuant to the California Public Records Act (Gov. Code, § 6250 et seq.). Quarterly sales taxes were tabulated in Excel files as transactions in thousands of dollars for the following categories within Retail Stores: Apparel stores, general merchandise stores, food stores, eating and drinking places, home furnishings and appliances, building materials and farm implements, service stations, and other retail stores. Quarterly sales tax spending was used as a proxy to undergird visitor counts as movement indicators impacting local economies. For this study, the following three categories were ultimately utilized for analysis given their connection to tourism-dependent spending: Food and Drink Stores, Eating and Drinking Places, and Gasoline Stations.

Though other indicators may seem more indicative of visitor

presence in a gateway community, shortcomings lead to their deliberate omission. Overnight hotel stay counts are not appropriate due to confounding factors such as strict no-cancellation policies, inconsistencies in reporting, and data privatization. Each county has a Transient Occupancy Tax (TOT), surcharges for motel and hotel guests, and paid overnight stay locations. TOTs may not adequately represent visitor movement due to cancellation policies. Taxable sales were normalized to account for inflation in alignment with purchasing power in 2019 through utilizing the US Bureau of Labor Statistics CPI Inflation Calculator and entering sales tax per category in dollars, given the middle month of Quarter 3 (August of July through September). Values were rounded to the nearest whole dollar.

Fire Data: We collected historic fire perimeters from California Fire Perimeters hosted feature layer in ArcGIS Pro, via egis.CALFIRE. Data were then refined to 2000 to 2020 within 1 mile of each key corridors using Select by Attribute and Select by Location. All unnamed fires and fires less than 1 acre were eliminated from the dataset. The process resulted in 61 named fires within 1 mile of the four key corridors. Upon initial report to the response agency, all fires receive an alphanumeric unique identifier for internal tracking. This is common across varying agencies. Certain agencies name the fire at the time of reporting (CalFire), while other agencies may wait for the fire to cross a minimum acreage or resource-use threshold (USFS). We deliberately excluded unnamed fires, as fire names are critical for media communications. US-based media uses fire names rather than agency unique codes in reporting (e.g., the 2018 Ferguson Fire was Incident # 00000745 for CalFire, but is referred to in media as the Ferguson Fire). Given the utilization of newspaper-based media to identify road closures based on wildfires, we specifically required a fire name to search.

Road Closure Dates: Road closure dates were collected via extensive news media searches online, mainly through the newspaper repository www.newspapers.com. Search criteria were refined by combining 'fire name', Yosemite, and road clos%, open and related terms. Textual criteria were paired with the fire year and locational criteria set to California. Each of the 61 fires was searched using the criteria, along with supplemental searches for highway numbers and abbreviations, such as 'Hwy.' We maintained a database documenting each fire with any associated closure and reopening date and articles which documented the dates.

Resident-only reopening dates were omitted from the dataset. It is important to note that hard closures are not necessarily at the exact named entrance station. Closures may be outside the associated entrance station or within park bounds. To correctly attribute a road closure to an associated impacted gate-the assignment was based on which entrance station the driver would be accessing Yosemite Valley. The road closure dates were used to assign a categorical variable to the full month of Open or Closed for the following analysis.

3.2. Methods

All statistical analyses were completed using the R programming language and R Studio graphical user interface Version 2021.09.1 build 372.

3.2.1. Movement analysis—fire closures

Preliminary data exploration and analysis using analysis of variance (ANOVA) and post hoc Tukey HSD indicated statistical significance ($p_{adj} = 0.00052$, 95% CI) in the relationship between the variables across select entrance station pairings. First, we analyzed connectivity between all entrance stations using analysis of variance (ANOVA), comparing the categorical open/closed status variables for closures at any corridor (25 closures across the dataset) to the continuous attendance variable. Q-Q Plots indicated normal distribution with slight left skew and fat tails, reflecting seasonal variation attendance fluctuations at Tioga Pass and Big Oak Flat corridors.

HO. (null): When entrance station A closes, there is no change to attendance at the other entrance station[visitors are not displacing to remaining entrances]

HA1. (alt): When entrance station A closes, there is an increase in attendance at the other entrance station[visitors are displacing to remaining entrances]

HA2. (alt): When entrance station A closes, there is a decrease in attendance at the other entrance station[fewer visitors at all gates typically are not accessing the park]

Upon validation, further ANOVA tests were completed for closure for each of the four corridors, with accompanying fluctuations at other entrance stations to identify any statistically significant visitation shifts. For statistical results, $Pr(>F)$ indicates the statistical significance associated with the F statistic (a variance ratio between two mean squares), where if $Pr(>F)$ is less than 0.05, we can reject the null hypothesis. Per RStudio, significance codes for ANOVA results are; 0 '****' 0.001 '***' 0.01 '**' 0.05 '.' 0.1 '.' 1.

3.2.2. Economic analysis

Attendance data were aggregated from monthly to quarterly sums to work on the same temporal scale as each county's quarterly taxable sales data. Open and closed statuses were also aggregated to the quarterly level, where any three-month period with a closed attribute was ascribed to the full quarter. Simple linear regression models for each entrance station and their corresponding county were used to identify any relationships between tallied quarterly attendance and quarterly taxable sales records. Analysis of variance was then used to compare the categorical open/closed status and numeric quarterly taxable sales.

4. Results

4.1. Part 1: entrance station displacement results

Preliminary iterations of analysis of variance (ANOVA) with a Tukey test completed on the results between our continuous variable attendance and categorical variables of fire (open/closed) indicate statistically significant connectivity in attendance fluctuation between gates. The statistical significance thereby validates additional analysis to distill contemporaneous inter-gate influence further.

Data were subset by Open and Closed to find the fluctuations in attendance means during closure and non-closure scenarios. Then basic summary statistics were run. Median values were not used due to seasonal closures at Tioga Pass, leading to medians of 0. Upon completing the secondary ANOVA, we rejected the null hypothesis for select gates with a statistically significant increase in attendance contemporaneous with fire-driven closure events.

4.1.1. Arch Rock closures

There were 6 instances of fire-driven closures to the Arch Rock corridor between 2000 and 2019. Arch Rock is approximately mid-way between Big Oak Flat and South Gate corridors. Arch Rock corridor passes through the Merced River canyon and is regularly subject to fire-flood-landslide cycles. Significant increases in Tioga Pass attendance are representative of seasonality, as Arch Rock entrance is open year-round, and Tioga Pass closes in the winter.

4.1.2. Big Oak Flat closures

There were 4 instances of fire-driven closures to the Big Oak Flat corridor between 2000 and 2019. Big Oak Flat offers the most direct access (driving) from California's Bay Area, featuring major international airports in San Francisco, Oakland, and San Jose. Significant increases in Tioga Pass attendance are representative of seasonality, as Big Oak Flat entrance is open year-round, and Tioga Pass closes in the winter. We may infer significant shifts to the southernmost entrance

station – South Gate - in deference to the most direct transportation corridors (Highway 99) as well as gateway community amenities and available resources (Oakhurst). Private vehicle corridors between Big Oak Flat and Arch Rock are via the narrow winding Highway 49- known for scenic views, but not travel efficiency.

4.1.3. South Gate closures

There were 4 instances of fire-driven closures to the South Gate corridor between 2000 and 2019. This corridor offers the first point of access to Yosemite National Park for visitors travelling from the Interstate 5 and Highway 99 corridors in California's Central Valley. Additionally, this would be the first point of access for visitors 'doing the loop,' by visiting other popular destinations across California, including not just other public lands and National Parks such as Sequoia-Kings Canyon, but also major attractions stretching from Disneyland to San Francisco. South Gate consistently has the highest mean attendance month to month.

4.1.4. Tioga pass closures

Tioga Pass is the furthest removed entrance station and corridor from Yosemite Valley, located on the eastern slope of the Sierra Nevada mountains, as well as the only eastern access to Yosemite National Park. There are only two noted fire-caused road closures along the Tioga Pass corridor during the 2000–2019 window. Limitations associated with low sample size are further discussed in the latter section on Confounding Factors and Challenges. In both closure instances, all other gates experienced an increase in visitation. Notably, the increase in visitation at Big Oak Flat (Tuolumne County) is statistically significant (within consideration of constraints). Big Oak Flat is the next closest entrance station to Tioga Pass.

4.2. Part 2: economic fluctuation results

After understanding where visitors displace to during closure events, we can compare this to see if there is a correlation between spending and shifts in visitation counts. To identify preliminary correlation between attendance and county sales tax incomes, we plotted the dependent variable (attendance) against county sales tax income to verify positive correlation.

Before and after conversion based on inflation, we still see consistent trends in increasing spending overall, corresponding to upward trends in National Park attendance, excluding Covid years (National Park Service, 2022). For the statistical analysis for each category, values were limited to Quarter 3 (July, August September), as it is peak fire season. All but one closure in the sample occurred in Quarter 3. By limiting analysis to Quarter 3, this ensured we were analyzing comparable months.

However, this positive correlation did not directly translate into statistically significant fluctuations in taxable spending during regular open periods and closures due to fire hazards during the analysis of variance (ANOVA) analyses, as demonstrated in supplemental Tables A-C. Therefore, we then subdivided analyses into three subcategories of tax data from the parent dataset to further distill the potential influence of partial closures on displacement 'gate to gate,'; Food and Drink Stores, Eating and Drinking Places, and Gasoline Stations, where $Pr(>F)$ is less than 0.10.

ANOVA analysis of categorically subset data indicates several statistically significant relationships between entrance station status and gas spending in other counties. For example, when South Gate (Madera County) experiences closures, there is a statistically significant increase in gas spending in Tuolumne County. In addition, all analyses of 'gate to gate' gas spending shifts return increases in mean gasoline sales tax earnings, ranging from minor increases of just over 1% to over 35%. All closures resulted in increases to mean Gasoline Station sales tax, though only three locations' increases were statistically significant. Results for spending in Food and Drink Stores and Eating and Drinking Places were inconsistent, with only two of 24 analyses resulting in a statistically

significant fluctuation – results for these latter categories did not have any consistent trends like that of wholly positive increases in Gasoline Station sales tax. All but two results were between ± 10 percent in fluctuation.

4.3. Confounding factors and challenges

There are several challenges and confounding factors to recognize in this study on contemporaneous visitor displacement and spending around Yosemite National Park. First, while wildfire occurrence and intensity are increasing in the American West, fire occurrences ($N = 61$) within the context of this study fall short statistically significant population sizes for applied statistics in managerial contexts of $N > 100$ (Singh and Masuku, 2014). Due to the lower sample size of fires, it is difficult to distill economic influence of displacement on the three analyzed sales tax categories. While there are few notable statistically significant fluctuations in sales tax income, it is critical to note that the fluctuations in means, though comparatively minor, still represent large values in real dollars for rural, tourism-based economies. Headwaters Economics reports that three of the four key corridor counties depend significantly on private-sector jobs based on travel and tourism: Mono County (68%), Mariposa County (43%), Tuolumne County (29%), and Madera County, with its strong connection to Central Valley agriculture at a 15% (Headwaters Economics, 2022). Therefore, this study approach should be repeated longitudinally as additional events and data become available. Despite low statistical sample sizes available for analysis, results are supplemented and ground-truthed through anecdotal evidence.

Second, this study utilizes two data aggregations at two temporal scales. Closure data were aggregated from days per fire to days per month to align with monthly Yosemite attendance. This may introduce bias in grouping, as one fire could burn through the end of one month into the beginning of another. The second aggregation for analyses of movement with spending as a proxy is the aggregation of monthly attendance up to quarterly. This is required, as tax data are not available at any granularity smaller than the three-month quarter. This aggregation may result in obscuring outliers. In both instances of aggregation, we lose the specificity of data at their initial collection granularity. Analyses may be rerun should increasingly granular data become publicly available.

A third challenge in analysis of contemporaneous visitor displacement and spending is being unable to determine visitor sources – where people are travelling to Yosemite from. Points of trip initiation may impact where visitors divert to should their initial access point close resulting from management strategy decisions to close routes due to environmental threats. For example, when South Gate closes, we see a statistically significant increase at the Big Oak Flat and Tioga Pass Gates – which would be the most direct access points for visitors from the Bay Area and Southern California, respectively. Given that we do not have point of origin information, we cannot draw conclusions about why specific gates are chosen during displacement.

5. Discussion and conclusions

Our results indicate that Yosemite National Park visitors' displacement actions depend mainly on the primary corridor choice's proximity to other gates-they are displacing spatially, not temporally, represented through statistically significant increases in mean attendance. Most notably, during Tioga Pass fire-generated corridor closures, the singular statistically significant increase in attendance occurred at the Big Oak Flat corridor, the closest drive-time for visitors who still want to access Yosemite. When accessing Yosemite with Tioga Pass closed, the nearest pass is Highway 178 (Sonora Pass) to the north, offering access to the Big Oak Flat Corridor. The closest southerly route to cross the Sierra Nevada and access Yosemite if diverted from Tioga Pass would be State Route 178 (Walker Pass), hours out of the way to the south.

Previous studies emphasize incorporating deliberate and strategic

visitor dispersal to decrease negative impacts to degradation hotspots in Yosemite National Park (Gladfelter & Mason, 2012; Walden-Schreiner & Leung, 2013). Our attendance results at various gates during closure events indicate visitors are choosing to *not* disperse, as visitation rises at entrances remaining open during closure events. Visitors opting to utilize the next-closest ingress corridor reinforces negative impacts of condensed visitation and degradation instead of the goals of dispersed visitation across the greater region to reduce overuse, such as the goals of Yosemite National Park Geotourism Initiative (Gladfelter & Mason, 2012).

In non-emergency instances, limited corridors may prove beneficial as limited infrastructure can be a mitigating factor for demand, with improved accessibility increasing demand (Tverijonaite et al., 2018). In a region already overburdened by demand, yet limited in infrastructure capacity, Yosemite has repeatedly undergone reconfigurations of existing corridors (Federal Highway Administration, 2016). However, within the context of closure events and limited options for ingress corridors, there are additional risks to visitors displacing to the next nearest corridor during a closure event. As the number of routes further decreases, visitor density along open routes increases, contributing to increased wait times to access Yosemite. Shifted access patterns may then disrupt first responders and emergency services. Within these rural communities, geography can be a major contributor to increased (slowed) response times, increased distance to medical services, and increased fatalities during emergencies (Gonzalez et al., 2006). While corridors pass through rural regions, within the immediate vicinity of Park boundaries and within Yosemite itself, traffic experiences are recognizably urban – with backlogs, limited parking, and even roundabouts.

Within the context of fire, traffic congestion due to displacement to limited corridors may delay first responders. Navigating through and waiting in traffic congestion increases fuel utilization and extends burn durations, as fire burns exponentially quicker over time (Brent & Beland, 2020). Daily summer arrivals to entrance stations peak between 3 p.m. and 4 p.m., leading to wait times upwards of a half hour (Yosemite Gateway Partners, 2022). Extended wait times of a half hour exist when all gates are open. With varied gates closed and visitors displaced, condensing access through fewer entrance stations dramatically increases entrance wait times.

The risk potential for new fire ignitions is exacerbated through the increased presence of people and vehicles displaced to limited routes, further compounded by the day's lowest relative humidity and atmospheric turbulence (Taylor, 2020). With fire behavior shifting due to anthropogenic climate change, visitors attempting to access Yosemite before 6 a.m. and after 4 p.m. correspond with warmer, dryer conditions. In contrast, night and early mornings were previously associated with decreased fire activity (Balch et al., 2022). In regions with wider roads, response can adapt to increased traffic volumes – this is not possible in the Greater Yosemite region due to legislative and geologic constraints, such as the steep Merced River Canyon corridor, regularly impacted by rock falls, and restricted from expansion by the Wild and Scenic Rivers Act.

Response to route disruptions at additional National Parks in the Sierra Nevada were recently demonstrated in Lassen Volcanic National Park. Lassen was closed entirely to visitors to facilitate uninterrupted firefighting equipment movement during the Dixie Fire in Summer 2021 – forcing dispersal, rather than allowing for, visitor-choice displacement of select corridors. Additionally, the KNP Complex (a complex being a collection of contemporaneous regional fires managed as one) in Sequoia-Kings Canyon National Parks began with closures of the highly visited Generals Highway corridor in mid-September 2021. Closures expanded throughout the fire's duration to include intra-park corridors and additional entrance stations, then the entire park by the month's end (InciWeb, 2021). Two recent fires demonstrate challenges with both responders and public regional movement (Amaro, 2022). The Washburn Fire ignited within Yosemite boundaries and burned outward

from park, impacting park communities (Wawona), whereas the Oak Fire began external to Yosemite's boundaries, impacting a gateway community (Mariposa/Midpines), and impacted ingress and egress routes. Similar to Yosemite, Lassen Volcanic and Sequoia-Kings Canyon National Parks have a limited number of ingress and egress corridors, impacting visitor movement, park personnel, and emergency resources during hazard events. Additionally, tourism-dependent gateway communities near these parks have close economic ties to seasonal visitor flows, like the gateway communities surrounding Yosemite and other parks.

Our results further existing conversation on contemporaneous economic impacts, as preceded by Kim and Jakus (2019) and Duffield et al. (2013), of large, catastrophic wildfires. While the data verify that visitors choose to displace spatially to another ingress route, we find few significant fluctuations in economic inputs to local economies, despite spatial displacement – potentially reflecting people being 'creatures of habit' who do not deviate from their regular routines. Increases in need-based spending (e.g., gasoline) indicate people are passing through gateway communities – and stopping to fill their gas tanks at least. However, increases are not reflected in routine-based spending (e.g., eating lunch at a restaurant). This is supported by three statistically significant gasoline station sales tax income increases. Gasoline station sales tax consistently increases contemporaneous to fire events. Entrance station closures may not significantly impact meal routines and habits. Due to limited ingress options from physical path dependency, visitors must fuel up along their new route. Moving forward, fluctuations to economic inputs on local economies may shift due to post-Covid day use reservation systems updates forcing stability in, and temporal distribution of, visitors.

By expanding systems thinking in relation to transportation networks as comparatively simple binary inputs – open/closed, in/out, moving/stationary-managers and gateway communities can better manage visitor access and gateway engagement (McCool, 2022). Thereby, circular, causal relationships of closures can be disrupted intentionally to improve dispersion. During displacement events, partner organizations and communities may capitalize on visitor through flux with marketing targeted at open corridors through novel methods. Specifically, agencies and localized visitor bureaus – designed to positively influence visitor dispersion into communities – could co-locate informational kiosks or visitor centers in gateway communities.

Increased promotion of neighboring communities' resources and recreational opportunities may result in increased dispersion. New marketing and visitor communications approaches, particularly phone applications, may increase visitation and spending in gateway communities and direct visitors to activities (Oppegaard & Shine, 2014). Public land management agencies, Yosemite included, across multiple scales from local through federal, are increasingly utilizing mobile apps to supplement web and paper-based information. Management recommendations for positively influencing dispersion should have clearly stated goals and objectives (Riley et al., 2015). Managerially subjective promotion of alternative dispersion activities is temporally relevant considering the extended Covid-19 pandemic, where visitors may desire reduced interpersonal contact (Miller-Rushing et al., 2021). Tailoring communication to specific motivating factors and similar opportunities may influence spatial behavior, and thereby dispersion into gateway communities-whether visitors are hoping to feel a sense of isolation from other humans (wilderness experience), learning (museum locations), or achievement (hiking or scenic opportunities) (Smith et al., 2021). Dispersion into gateway communities supplemented by mobile devices benefits local economics, provides recreationists with increased control over routine, and promotes self-guided and smart (technology) tourism for activities with analogous motivations (Shen et al., 2020).

Visitation displacement findings across gates during partial closure events at Yosemite National Park supplement previous studies by Gladfelter and Mason (2012), Duffield et al. (2013), and Kim and Jakus (2019), specifically within parks and public lands management context.

We demonstrate that visitors are displacing amongst entry gates contemporaneous to fire hazard events. We show that visitors still access their destination through spatial displacement despite disturbances to initial ingress points. Our results demonstrate statistically significant shifts in spending in non-habit-based, trip-specific gasoline spending and mixed fluctuations in spending in habit-based categories associated with meal spending. Policymakers and emergency response agencies may utilize the information for decision making, such as proactively utilizing forced dispersal by closing all corridors as seen in Lassen Volcanic National Park, supported by statistical insights that visitation is displacing, thereby concentrating, in increasingly limited available corridors. Additionally, land management agencies may utilize displacement findings to implement or update reservation system policies to further entrance station efficiency, visitor experience, and staff and visitor safety. Future research would benefit from carrying out this study longitudinally to better understand potential changes in contemporaneous attendance displacement trends and hazard’s economic impacts in the National Park and surrounding gateway communities.

Disclosure statement

The authors declare there are no competing interests and no financial

Analysis of Variance Results by Category

Source: Authors

A: Sales Tax Income Category: Gasoline Stations						
Gate Impacted	County Influenced	Open Mean Gas Tax Rev (Q3)/1000	Closed Mean Gas Tax Rev (Q3)/1000	% Change in Gas Tax Revenue (±)	F	Pr(>F)
Arch Rock (Mariposa) 6 closures	Madera County	61254	62220	+1.55	0.009	0.925
	Mono County	12800	13083	+2.20	0.071	0.794
	Tuolumne County	19507	21683	+11.15	0.746	0.399
Big Oak Flat (Tuolumne) 4 closures	Mariposa County	3706	4309	+16.27	2.519	0.13
	Madera County	57214	78865	+37.84	4.353	0.0514*
	Mono County	12492	14458	+15.74	3.012	0.0998*
Hetch Hetchy (Tuolumne)	No Hetch Hetchy Rd closures were identified during data collection					
South (Madera) 4 closures	Mariposa County	3158	4150	+31.41	1.832	0.193
	Mono County	12659	13788	+8.92	0.893	0.357
	Tuolumne County	19134	24262	+26.80	3.647	0.0723*
Tioga Pass (Mono)2 closures	Madera County	61167	64940	+6.17	0.06	0.809
	Mariposa County	3822	3864	+1.10	0.006	0.94
	Tuolumne County	19968	21879	+9.57	0.24	0.63
B: Sales Tax Income Category: Eating and Drinking Locations						
Gate Impacted	County Influenced	Open Mean Eating and Drinking Tax Rev (Q3)/1000	Closed Mean Eating and Drinking Tax Rev (Q3)/1000	% Change in Eating and Drinking Tax Revenue (±)	F	Pr(>F)
Arch Rock (Mariposa) 6 closures	Madera County	29,899	30,125	+0.75	0.011	0.917
	Mono County	17,157	17,106	- 0.30	0.003	0.958
	Tuolumne County	18,679	19,177	+2.70	0.311	0.584
Big Oak Flat (Tuolumne) 4 closures	Mariposa County	5726	5691	- 0.61	0.004	0.948
	Madera County	29475	31936	+8.35	1.083	0.312
	Mono County	17233	16774	- 2.66	0.181	0.676
Hetch Hetchy (Tuolumne)	No Hetch Hetchy Rd closures were identified during data collection					
South (Madera) 4 closures	Mariposa County	5696	5810	+2.00	0.046	0.833

(continued on next page)

sources to disclose.

CRedit authorship contribution statement

Madeline Brown: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Jeffrey S. Jenkins:** Conceptualization, Resources, Writing – original draft, Writing – review & editing, Supervision.

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.

Data availability

Data are in an open Mendeley Data Repository, as identified on page 24 of anonymized manuscript

(continued)

A: Sales Tax Income Category: Gasoline Stations						
Gate Impacted	County Influenced	Open Mean Gas Tax Rev (Q3)/1000	Closed Mean Gas Tax Rev (Q3)/1000	% Change in Gas Tax Revenue (±)	F	Pr(>F)
Tioga Pass (Mono) 2 closures	Mono County	17,262	16,660	- 3.49	0.313	0.583
	Tuolumne County	19,060	17,903	- 6.07	1.355	0.26
	Madera County	29943	30186	+0.81	0.00	0.941
	Mariposa County	5693	5947	+4.46	0.13	0.723
	Tuolumne County	18974	17513	- 7.70	1.207	0.286
C: Sales Tax Income Category: Food and Drink Stores						
Gate Impacted	County Influenced	Open Mean Shop Tax Rev (Q3)/1000	Closed Mean Shop Tax Rev (Q3)/1000	% Change in Shop Tax Revenue (±)	F	Pr(>F)
Arch Rock (Mariposa) 6 closures	Madera County	32305	32325	+0.06	0	0.993
	Mono County	6494	6519	+0.38	0.009	0.926
Big Oak Flat (Tuolumne) 4 closures	Tuolumne County	13704	13114	- 4.31	0.219	0.645
	Mariposa County	4275	4626	+8.21	1.227	0.283
	Madera County	32966	29693	- 9.93	1.786	0.198
Hetch Hetchy (Tuolumne)	Mono County	6528	6356	- 2.63	0.298	0.592
	No Hetch Hetchy Rd closures were identified during data collection					
South (Madera) 4 closures	Mariposa County	4229	4810	+13.74	3.812	0.0666*
	Mono County	6561	6274	- 4.37	1.083	0.313
	Tuolumne County	14054	11420	- 18.74	4.025	0.0601*
Tioga Pass (Mono) 2 closures	Mariposa County	32554	30123	- 7.47	0.519	0.481
	Mariposa County	4308	4686	+8.77	0.783	0.388
	Tuolumne County	13711	11876	- 13.38	0.945	0.344

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