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A Tale of Two Fires: Retreat and Rebound a Decade After Wildfires in California and South Carolina

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ABSTRACT

In recent decades, wildfires have destroyed growing numbers of homes in the United States. Wildfire recovery has emerged as a critical time to reduce future vulnerability, yet we lack knowledge of how rebuilding efforts unfold over time, and are shaped by resident and housing characteristics, land use planning, and government regulations. We used a case study approach to document housing recovery a decade post-event for the Highway 31 fire in suburban South Carolina, and the Station fire in exurban California (both in 2009). We found divergent rebuilding and mitigation outcomes; rebuilding was rapid after the Highway 31 fire (all but one house rebuilt) but minimal (11.7% houses rebuilt) after the Station fire where a complex setting and regulation regime effected an 'unmanaged retreat.' We discuss implications for post-fire recovery programming and the need for longitudinal research as the world faces increasing wildfire losses.

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Introduction

Over the past several decades, wildfire losses have increased in the United States, due to a changing climate, altered wildfire regimes, and a growing wildland-urban interface (WUI) where housing is located in proximity to wildland vegetation (Schoennagel et al. 2017, Radeloff et al. 2018). As losses increase, there a growing need to understand the social, health, and economic effects of wildfire on communities, as well as subsequent recovery (Paveglio et al. 2015; Edgeley and Paveglio 2017; Schumann III et al. 2020). Housing is a critical component of disaster recovery, as an essential human need that is also relatively straightforward to track (Peacock et al. 2018). For homeowners, their house is a critical financial investment while local economies and government also depend on housing recovery (Hamideh, Peacock, and Zandt 2018; Krueger, Winkler, and Schumann 2019). Tracking rebuilding and documenting characteristics of housing and/or residents rebuilding can provide additional insight into vulnerability and the

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need for recovery programming (Zhang and Peacock 2009; Hamideh, Peacock, and Zandt 2018; Krueger, Winkler, and Schumann 2019).

In the case of wildfire, the spatial arrangement of rebuilt homes, size, and materials all contribute to future vulnerability (Schumann III et al. 2020). Building larger homes increases total exposure, or resources at risk. If homes are closer together the chances of house-to-house fire spread increases (Simon 2014). Conversely, using fire-resistant materials and establishing defensible space around homes will reduce future risk (Schumann III et al. 2020). Understanding who rebuilds—original owners, new residents, developers—can provide additional insight into changes in community composition, and target audiences/need for hazard outreach. However, systematic longitudinal studies that track housing recovery, sales, and mitigation of rebuilt homes are still rare, especially for wildfire (Peacock et al. 2018; Schumann III et al. 2020).

We examine housing recovery a decade after two destructive wildfires in 2009, using two case studies: The Highway 31 fire, which destroyed homes in a suburban golf development in North Myrtle Beach, SC and the Station fire, which destroyed homes in an exurban area of Los Angeles County, CA, near the Angeles National Forest (ANF) (Figure 1). This study emerged opportunistically from a larger investigation of post-wildfire adaptation and mitigation at the community level in eight locations (Mockrin, Fishler, and Stewart 2018, 2020), because these two sites had data on housing lost, enabling us to study rebuilding. These fires are appropriate for a comparative case study as they burned 60 modestly-priced single-family residences on small parcels during the same year and recovery was locally managed (neither received federal individual assistance for those rebuilding), but had critical differences in settings and recovery outcomes.

Given the lack of knowledge about housing recovery over time after wildfire, *our first goal was to use government records to document critical aspects of housing recovery*, including (1) Rebuilding rates and timing, (2) Identity of those rebuilding and resident turnover, and (3) Housing attributes, focusing on fire-resistant materials and size. We then used qualitative data from interviews of local government officials and community leaders for *our second goal, to determine community-level perspectives on why rebuilding outcomes emerged.* These community-level perspectives provided additional insight into factors community leaders deemed instrumental in determining rebuilding outcomes, e.g., resident and housing characteristics, government regulations, and local government assistance to rebuilding efforts. We draw upon housing outcomes to consider future wildfire vulnerability, discuss broader prospects for changing land use, and need for assistance and outreach when rebuilding. To our knowledge, this is the first study to utilize parcel data to study post-wildfire housing recovery in detail, a critical endeavor during an era when losses have increased throughout the United States.

Literature Review

We overview the existing literature on housing recovery, for wildfire and other hazards, below. In general, housing recovery is little-studied after wildfire (Peacock et al. 2018; Schumann III et al. 2020).

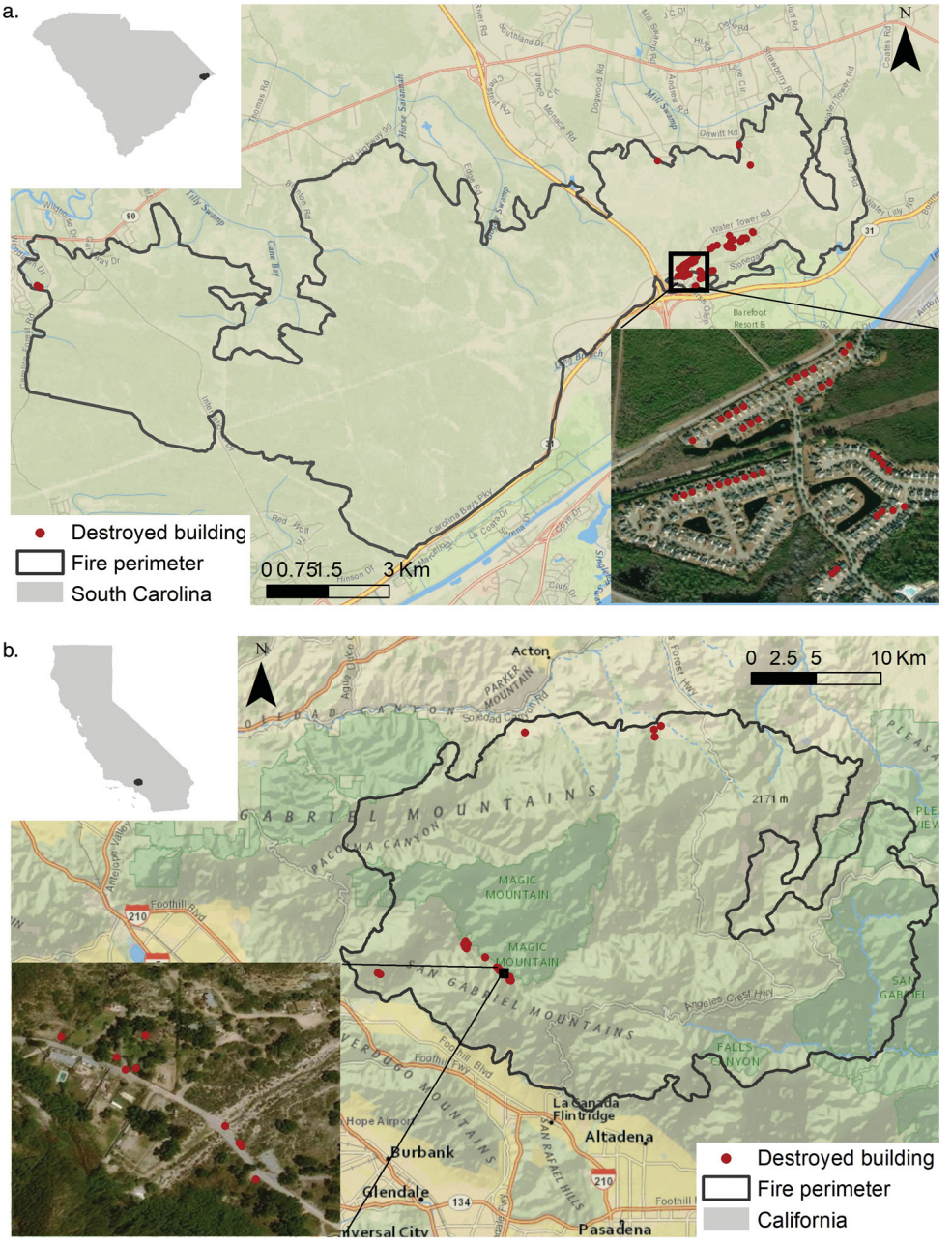

Figure 1. Wildfire perimeters and burned buildings from 2009 for (a) Highway 31 fire, South Carolina and (b) Station fire, California, with 2020 topographic map and aerial imagery courtesy of ESRI.

Rebuilding and Development Post-Disaster

Short-term, rebuilding rates per wildfire are highly variable: from 2000 to 2005, 106 fires destroyed buildings nationally, after which rebuilding occurred for 39 (8–100% rebuilding per fire, up to 5 years post-fire (Alexandre et al. 2015). This and other

studies typically track only completely destroyed buildings, which make up the vast majority of damages (Syphard and Keeley 2019).

As with other disasters, homeowner resources and insurance play a critical role in rebuilding—only over the past 5 years has federal individual aid typically been available (for larger wildfires), but such grants are small in comparison to costs of rebuilding (Edgeley and Paveglio 2017; Greer and Trainor 2021). Case studies suggest resident resources and neighborhood characteristics, especially logistics of construction determine rebuilding rates. In suburban Colorado Springs, CO, 75% of destroyed homes had a building permit within 2 years, promoted by multiple factors: most were insured; these were primary homes and thus a substantial financial asset and shelter; homeowner's associations (HOAs) required rebuilding; and plans, builders, infrastructure, and supplies were available (Mockrin et al. 2016). In contrast, rebuilding was slower in exurban Colorado: permits were issued for 30% of homes in Larimer County and 34% in Boulder County within 2 years. Recovery here was more challenging and costly: each house was a custom build, many on steep slopes and a distance from commercial centers; more were uninsured, or underinsured in relation to high costs of building; and some houses lost were second homes (Mockrin et al. 2016). Additional factors were uncovered in rural Montana; here, residents cited a lack of social cohesion or supportive networks, and the degradation of vegetation as reasons for not rebuilding (Carroll and Paveglio 2019).

While rebuilding after wildfire can be challenging, existing land use plans and zoning do not prohibit it, or new development (regulations may require mitigation) (Kocher and Butsic 2017; Mockrin, Fishler, and Stewart 2018, 2020). In fact, new construction outpaced rebuilding after 75 of 106 fires investigated by Alexandre et al. (2015). Long-term, rebuilding was nearly 100% by 10–23 years post-fire in California (11 fires from 1970s to 1990s) (Kramer et al. 2021). In addition, new development was common, often higher than rebuilding. The robust rebuilding, new development, and lack of consistent changes in exposure of locations rebuilt (based on topography, land cover, elevation, etc.) meant vulnerability of the built environment rarely changed post-fire (Kramer et al. 2021).

Other hazards are typically larger, damaging tens of thousands of homes, leading to a complex web of government assistance to those rebuilding, including federal individual assistance (Schumann III et al. 2020; Greer and Trainor 2021). Housing recovery is usually characterized at the event-level as being complete within 2–3 years, supported by homeowner resources including insurance settlements (Peacock et al. 2018). For example, 3 years after Hurricane Andrew, most single-family homes were recovered (Zhang and Peacock 2009). However, rebuilding is not uniform: rebuilding is slower when damage is higher, social capacity and community ties are weaker, in low-income and minority areas, and in rental, multi-family, and seasonal homes (Zhang and Peacock 2009; Hamideh, Peacock, and Zandt 2018; Krueger, Winkler, and Schumann 2019; Greer and Trainor 2021). Even when individual federal assistance is authorized, it is difficult to obtain, and intended for those who lack other resources (Greer and Trainor 2021).

Over time, however, the expectation is that housing recovers or even expands (Pais and Elliott 2008; Lazarus et al. 2018). Housing recovery can be robust even when

residents lack resources, driven by developers (Wyczalkowski et al. 2019). Only rarely have disasters resulted in long-term housing decline; if for example, preexisting socioeconomic challenges are amplified and lead to abandonment (Zhang 2012). In some cases, federally funded buyout programs purchase houses from willing sellers and preserve land as open space. However, thus far such 'managed retreat' in the US has been limited (Greer and Brokopp Binder 2017; Mach et al. 2019).

Identity of Those Rebuilding and Turnover

Aerial imagery or repeat photography does not provide information about identity of those rebuilding. However, understanding who rebuilds after disaster and ongoing turnover contributes to knowledge of community composition and well-being post-disaster (Zhang and Peacock 2009; Hamideh, Peacock, and Zandt 2018; Krueger, Winkler, and Schumann 2019). Few studies have directly addressed this question. Hendricks and Meyer (2021) found that 82% of homeowners rebuilt after the West, TX fertilizer plant explosion. Home sales after Hurricane Andrew nearly tripled, suggesting that rebuilding was attracting real estate speculators (Zhang and Peacock 2009). In contrast, Rathfon et al. (2013) found sales slowed after a hurricane, with similar rates for damaged and undamaged homes (but only $< 8\%$ of buildings destroyed). In the case of wildfire, original homeowners may be highly motivated to rebuild because of attachment to place and landscape (Nawrotzki et al. 2014; Mockrin et al. 2015), or disinclined to rebuild after disrupted community ties and damage to cherished landscapes (Eisenman et al. 2015, Carroll and Paveglio 2019).

Housing Attributes-Mitigation and Size

When rebuilding after wildfire, using fire-resistant materials and establishing defensible space can reduce future risk (Schumann III et al. 2020; Kramer et al. 2021). Such efforts may be mandated at the state or local level (Community Wildfire Planning Center 2021). Without such regulation, it is unclear if those rebuilding will mitigate given financial limitations, fatalism, or lack of knowledge (McGee, McFarlane, and Varghese 2009; Mockrin et al. 2016). Similarly, building permit processes can be used to limit size of rebuilt homes (Mockrin et al. 2016). Without constraints, rebuilt homes may be larger (Simon 2014; Mockrin et al. 2016; Eriksen and Simon 2017). Voluntary mitigation when rebuilding after other disasters is rarely studied, in part because mitigation is often required (notably, in federally-designated floodplains). Building permits revealed installation of hurricane shutters increased notably after Hurricane Charley (Rathfon et al. 2013), but barring regulations or incentives, people typically rebuild with similar materials (Greer and Brokopp Binder 2017), and rebuild larger, if assets allow (Pais and Elliott 2008; Lazarus et al. 2018).

Methods

We used a sequential strategy, with a first phase of qualitative data collection on community-level recovery and adaptation as part of a broader study, approximately 5 years

post-fire (please see Mockrin, Fishler, and Stewart 2020). We selected these two fires for this study because local government provided data on housing loss during interviews. We then used publicly available information to track rebuilding 10 years post-fire, and revisited interviews for community perspectives on rebuilding outcomes. Below, we describe each study site, housing data and analysis, interview data collection and analysis, and consider implications of combining data sources and time periods.

Study Sites

The Hwy 31 fire occurred in April 2009, started by residential debris burning in more rural Horry County before advancing into the city of North Myrtle Beach. Over 19,000 acres of forest and 76 homes were destroyed (13 in Horry County, 63 in the Barefoot housing development in North Myrtle Beach) (South Carolina Forestry Commission 2010) (Figure 1). Data on housing loss came from the city of North Myrtle Beach. A total of 57 homes on individual parcels were destroyed, as were six additional houses under construction at the time of the fire (the 57 form the focus of our analyses).

North Myrtle Beach and surrounding Horry County have grown rapidly in population over the past 20 years, with many new residents arriving with retirement, attracted by access to the beach. Much of the housing growth has been in large, planned subdivisions. There were no state or local requirements for defensible space or fire-resistant materials, before or after this fire (Mockrin, Fishler, and Stewart 2018). Development of the Barefoot development started in the early 2000s, so homes lost were less than 10 years old. The development contains nearly 1,000 single family homes, a mix of modest primary residences and vacation homes, on small parcel surrounding golf courses and wetlands/forest. Houses were worth on average $266,000 (2009 USD; derived from sales 2008 to 2009, for 11 houses lost in fire). The area had a long history of wildfires before housing had expanded into wildlands, but this fire was notable given the number of homes destroyed and overall fire size and speed of progression.

The Station fire began in the ANF, deliberately set by arsonists in August 2009, ultimately destroying 115 commercial and residential structures (LAC Fire Department 2009). We used damage inspection data to focus on residential parcels that were no longer habitable post-fire: 63 single family residences lost on 60 parcels, including 27 recreation residences (on long-term lease from Forest Service; more detail below) and 36 houses on 34 privately owned parcels. The majority of homes lost were in an inholding near the ANF's southern border called Stonyvale/Vogel Flats (LAC Fire Department 2009) (Figure 1).

Homes in Stonyvale were older, modest primary residences clustered on small parcels, including 20 homes that were privately-owned homes and 27 recreation residences, owned by the Forest Service but on 20-year leases as part of a national program. Although recreation cabins are intended for seasonal use, these were inhabited full-time. Residents in Stonyvale commuted within the greater Los Angeles area for work, but considered themselves typical WUI residents, valuing privacy, natural amenities, and the unconventional nature of their community. Housing values were moderate for the area: median home price within areas threatened by the fire was $398,000 (2009 USD; LAC

Fire Department 2009). There were no HOAs in Stonyvale, although privately-owned parcels communally managed their water.

California first began requiring building materials be fire-resistant and have defensible space after the 1991 Oakland Hills Tunnel Fire, and LA County has a long history of land use planning and extensive fire requirements (Plevel 1997). Homes within the Station fire area were older homes, some dating back to the 1940s, but anyone rebuilding had to comply with current codes. Recreation cabin residents and homeowners on privately-owned parcels were both responsible for paying for rebuilding, even though in the case of recreation cabins, residents did not own homes but leased them. WUI fires are common in LA County and the ANF, but the Station fire was notable for its size (at more than 160,000 acres, it remains the largest fire on record in the County).

Housing Data

We obtained data on losses (described above) and used government records and online real estate records (Zillow.com) in 2020 to collect data on rebuilding. For each house we created a spreadsheet entry to note if and when a house had been rebuilt, number and timing of sales, developer involvement in rebuilding (see more below), if parcels were consolidated when rebuilding, size of rebuilt homes, and use of fire-resistant materials (see more below).

We used data to calculate rebuilding rates and determine the identity of those rebuilding (original vs. new owners). When homes were rebuilt by new owners we examined data for signs of developer involvement—if parcels were purchased as vacant, rebuilt, and then quickly sold it could suggest the rebuilding was done for profit (Zhang and Peacock 2009). For the Hwy 31 fire we noted any transactions that involved commercial developers, as indicated by LLC or INC in the name (we did not have equivalent information for the Station fire). For both fires we determined overall turnover, i.e., how many of the owners in 2020 had owned the homes in 2009. For the Hwy 31 fire, interviews revealed some homes were seasonal homes. We examined addresses listed on records in 2020 to note if the address was the same as the home (likely a primary residence) or a different address (out of state, PO Box), and thus more likely a seasonal residence. We were unable to determine how addresses had changed over time, so we lack similar information before the fire.

We examined two attributes of rebuilt homes, materials and size. In LA County all houses had to be rebuilt to current code, and thus we did not collect additional information about materials. For the Hwy 31 fire there were no such requirements, so we used county records to track the siding materials used. We first collated all materials, and then used expert consultation to group materials into two categories: noncombustible (brick) or combustible (siding was at least in part vinyl or wood) (no houses were rebuilt solely with ignition-resistant siding) (Steve Quarles, pers. comm.). For this analysis, we used a larger data set of 63 houses (includes six that were still under construction when fire occurred as developer-owned). We compared the siding materials used by original owners rebuilding vs. new owners/developers with a Pearson's Chi-squared test with Yates' continuity correction. We then considered the size of houses rebuilt in comparison to those destroyed. For the Station fire, damage inspection report provided

size of houses destroyed (LAC Fire Department 2009). For the Hwy 31 fire, we did not have information on size before the wildfire, so we visually inspected housing footprints before and after the wildfire using aerial photographs available on Google Earth.

Interviews and Analysis

We conducted interviews in 2015 for our study of community-level post-wildfire outcomes in eight sites across the U.S. (Mockrin, Fishler, and Stewart 2018). We identified key community informants from reports, web searches, news articles, and other respondent recommendations. Respondents included community leaders active in recovery and mitigation (e.g., head of a civic association), county and city staff (e.g., fire department staff, planners, emergency managers), and land managers. We used a consistent set of open-ended questions in semi-structured interviews to cover multiple topics, including wildfire history, wildfire risk awareness in the community, community-level adaptation post-fire, and rebuilding outcomes. For this paper we focus only on the two study sites where we had data on housing loss, a total of 19 respondents—seven in Station and 12 in Hwy 31. We conducted all but one interview in person (one via phone due to scheduling issues). Each interview was 60–90 min, typically individually or in pairs, but in a small group in one case (e.g., multiple members of a government department).

All interviews were professionally transcribed and then analyzed through open coding, where we first grouped concepts into initial categories, and then used focused coding to further assign interview text into emergent themes (Corbin and Strauss 2015) in QSR Nvivo 11 software (QSR 2014). Mockrin, Stewart, and Fishler collaborated on code development and Mockrin conducted the final coding for emergent themes. For our broader study we grouped codes into aspects of each setting (wildfire history, vegetation/fire regimes, history of development and characteristics of housing), wildfire risk reduction (including fuel treatments and vegetation management, education and outreach to homeowners, land use planning and regulations, suppression and emergency response, and post-fire outcomes and recovery) (Mockrin, Fishler, and Stewart 2018). For this paper, we revisited these coded interviews in tandem with our housing data analysis. We examined all text coded as post-fire outcomes, and then focused only on the portions that pertained to rebuilding. We re-read these quotes and examined all additional coding, including aspects of each setting and wildfire risk reduction efforts, to determine which factors local government and community leaders considered critical in influencing rebuilding outcomes.

Throughout our analysis we also considered the timing of rebuilding and our interviews. Interviews were conducted at the midpoint of the post-fire period for which we obtained housing data. As dominant trends in rebuilding had already emerged by then, we considered interviews appropriate to characterize factors that local government and community leaders saw as important in determining rebuilding outcomes. Waiting until a decade post-fire to conduct interviews would have risked losing some of these perspectives as memories faded and staff turnover occurred, and extending the rebuilding record out to 2020 was valuable, particularly when rebuilding was slower (i.e., Station fire).

Results

We first provide information on three aspects of housing recovery and then present the community perspectives garnered through interviews.

Rebuilding Rates and Timing

After the Hwy 31 fire, rebuilding was rapid: 88% of homes rebuilt within 2 years (Table 1, Figure 2). By 2020, all but one of 57 homes were rebuilt (98.2%). In contrast, rebuilding was limited after the Station fire. No recreation residences were rebuilt. Seven houses on privately-owned parcels (one per parcel) were rebuilt by 2020, a rate of 11.7% for all parcels, and 20.6% for privately-owned parcels (Table 1). Rebuilding was slow, with the first house rebuilt 5 years after fire (Table 1, Figure 2).

Identity of Those Rebuilding and Turnover

After the Hwy 31 fire, 74% of those who rebuilt ($n = 42/57$) owned homes at the time of the fire (Table 1). The remaining 26% ($n = 15$) were sold as vacant, sometimes more than once. Of these 15 parcels, 12 were rebuilt by developers (10 parcels rebuilt by owners with LLC or INC in the name, two by individuals who then quickly sold). Rebuilding was slower when parcels were sold as vacant than when original owners rebuilt, but still relatively quick, with 86.7% (13/15) of those parcels sold as vacant rebuilt by 2013 (4 years post-fire) (Figure 2). Over time, turnover continued so that 10 years post-fire, 56% of the houses rebuilt were owned by people who lost houses in the fire[1] (Table 1). There was no consolidation of parcels post-fire. As of 2020, 75% of houses were occupied by primary residents ($n = 63$).

After the Station fire, four of the seven houses rebuilt were built by those who owned them at the time of the fire. We saw no evidence of development involvement in rebuilding. Only one rebuilt house was later sold. By 2020, three of the seven rebuilt homes were owned by people who had lost a house in the fire originally (Table 1). Vacant parcel sales have continued: of the 27 privately-owned parcels that remained vacant in 2020, nine had been sold to new owners (in some cases, more than once) (Table 1). Two of the parcels on which houses were rebuilt after the Station fire were consolidated with adjacent parcels (in total, five parcels, four undeveloped and one that lost a house in the fire).

Housing Attributes—Fire-Resistant Materials and Size

For the Hwy 31 fire, houses were evenly divided between noncombustible ($n = 34$) and combustible siding ($n = 33$). Siding varied with identity of those rebuilding, however: those who owned the house at the time of the fire were more likely to select brick (62%), rather than siding that was combustible (38%) (Supplementary Figure). In contrast, for houses rebuilt

[1]For homes that were rebuilt by owner after the Hwy 31 fire, we examined timing of rebuilding to see if owners remained following rebuilding. We found the quickest sale was three years post-rebuilding (on average 4.8 years after being rebuilt, $n = 10$ sales), suggesting that homeowners who rebuilt intended to own the house afterwards.

Table 1. Rebuilding outcomes after Hwy 31 and Station fires.

Fire (State)	Housing Type	Parcels lost	Rebuilding rate by 2020	Rebuilding timing	Consolidation after fire	Developers rebuilding	Improved materials when rebuilt	Enhanced defensible space when rebuilt	Larger houses when rebuilt
Hwy 31 (SC)	Suburban PUD	57*	98.2% rebuilt	Rapid—87.7% rebuilt 2 years after fire	No	Yes, 17.9%	50% (more common if owners)	Unclear	No
Station (CA)	Exurban, Nat'l Forest inholding	60; (34 privately-owned, 26 recreation cabins)	11.7% rebuilt (21% for privately owned; 0% recreation cabins)	Slow—no rebuilding until 5 years after fire	Two parcels consolidated with other parcels when rebuilding	No	Yes	Yes	No

*Another 6 parcels under construction at the time of fire.

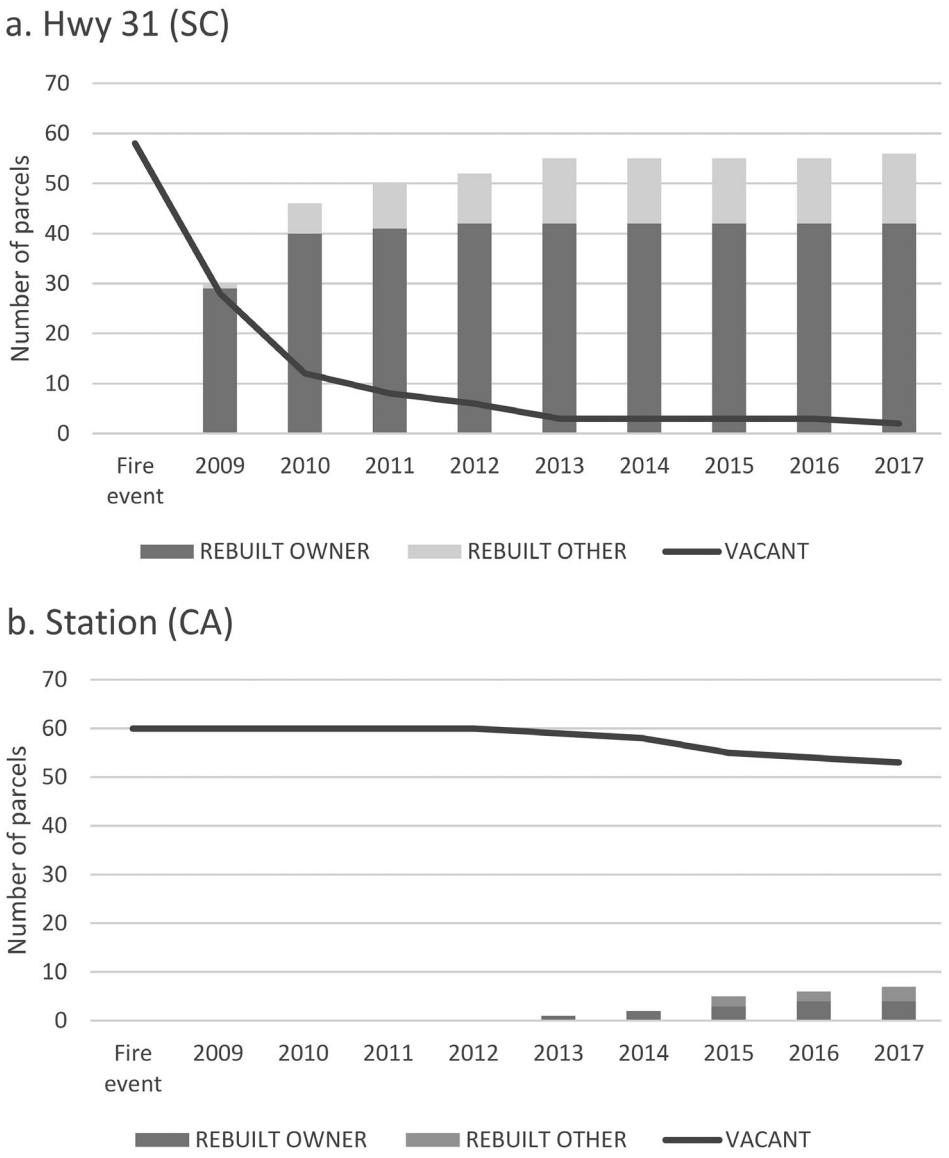

Figure 2. Number of vacant and rebuilt parcels over time, rebuilding by original owners and others, 2009–2017, for (a) Hwy 31 fire and (b) Station fire (for both fires, no change after 2017).

by new owners and developers, brick siding was rare (25%) and combustible materials were most popular (75%) (differences were statistically significant, Pearson's Chi-squared test with Yates' continuity correction, $df = 1$, $X^2 = 6.16$, $p = 0.013$). Visual inspection of footprints showed only minor changes in size (Figure 1).

After the Station fire, state and county regulations required fire-resistant materials, enhanced access to water supplies, and defensible space (see more on community perspectives, below). The seven houses rebuilt were on average slightly smaller than the houses destroyed (four rebuilt smaller and three larger; average change −97 sq. ft; min −1,361 sq. ft, max 1,211 sq. ft.).

Local Factors That Influenced Rebuilding

Interviews revealed a combination of factors that resulted in rapid rebuilding after the Hwy 31 fire, but hindered rebuilding post-Station fire, including characteristics of the setting (housing age, infrastructure, hazard concerns, real estate conditions), government regulations and assistance, and homeowner resources.

For those who lost homes in the Hwy 31 fire, insurance settlements were described as adequate to rebuild. These were modest homes and uncomplicated rebuilds, in a subdivision that was still under construction. The HOA required owners to rebuild, in order to discourage vacant parcels and maintain property values. The city created a mobile permitting office and waived fees. Contractors were readily available because the 2008 recession had slowed development. All of these factors combined to result in rapid rebuilding.

> Shortly after it'd been mopped up, we've controlled the [fire], the build back was like that [snaps fingers] … That particular area, there were nice houses, people had homeowners insurance, so they had the ability to build back, that community is back stronger—Hwy 31 fire

After rebuilding, residents were still able to get home insurance and, given the flat terrain, there were no concerns about secondary hazards post-fire (e.g., flooding or mudflows). After this event and another fire nearby in 2013, the area saw a noticeable expansion in the number of Firewise communities, a voluntary certification program that encourages residents to work together to reduce wildfire risk, often through an HOA and/or with the support of government or fire departments (Mockrin, Fishler, and Stewart 2018). However, the Barefoot development did not pursue this program. There were no requirements for fire-resistant materials or defensible space when rebuilding. Respondents noted uneven voluntary mitigation over time.

> A lot of people made the decision to go with either the cement board siding or brick, and they got away from vinyl. Not everybody, but a lot. A lot of people got away from the pine straw mulch, but memories are short. Or, if they built a new house and three years later sold it, the new homeowner had no experience of the fires at all, well … —Hwy 31 fire

In contrast, following the Station fire, respondents indicated that many were underinsured for the costs of rebuilding a custom home, removed from the city center. These homes had been built on small parcels before modern requirements for setbacks and infrastructure (roads, septic) which further complicated rebuilding.

> This community had been in existence way before our zoning code. Our zoning code came online in the early '30s, but the enforcement of it really didn't start until after World War II, even into the 1950s, early '60s. People would just build things willy-nilly, without building permits, no zoning or planning approval—Station fire

In response to these challenges, residents on privately owned parcels worked with the county to create a Community Standards District (CSD) that was subject to modified zoning codes (LA County Department of Regional Planning 2011). Without these changes through the CSD homeowners would have been unable to rebuild because of requirements for setbacks from roads and for distancing septic systems from riparian areas (CSD allowed for smaller setbacks and higher walls for privacy). LA County also assisted residents through "one-stop shops" for permits, facilitated permits to remove

damaged trees, and repaved the main access road. There were no regulations that specifically constrained size of rebuilt homes, although parcel size and requirements for septic and setbacks constrained buildable area (e.g., the largest house rebuilt, at just over 3,000 sq. ft was built on a parcel created by consolidating four parcels, three of which had been undeveloped). Among requirements, those for water and access proved particularly challenging. Residents successfully negotiated with the county fire department to approve private water storage tanks as opposed to additional pipes or hydrants, but some faced requirements for access that were cost-prohibitive (e.g., improved roads or bridges).

> Then fire gets involved, and they don't mess around. If they're saying you need to have this much water, this much PSI, this many tanks, you've got to do it. And if it costs you $10,000, $20,000, $50,000, you've got to do it. 'You can rebuild, but you need to meet these requirements.'—Station fire

The low rates of rebuilding after the Station fire did not result from lack of social capacity, given that residents were able to work collaboratively with county government on a number of aspects of rebuilding. Although county planning staff emphasized in interviews that residents have the right to rebuild, in reality, only a small minority has been able to do so, even 10 years post-fire. The fire department has been using such experiences to encourage wildfire mitigation in other areas.

> People have said, 'Well, you know if it burns, there's insurance. They just rebuild'. But we try to tell them if your home was built in 1930s or '40s, the current laws may not allow it … what was built 50-60 years ago, you may not be able to rebuild to today's standards – Station fire

Recreation cabin residents were required to comply with codes, and pay for all rebuilding and infrastructure upgrades, even though those were homes that they did not own, but were leasing from the Forest Service. In addition, leases would have been subject to review to ensure that rebuilding and road improvements were consistent with National Forest management (i.e., botany, archeology, recreation access, riparian protection). Ultimately, none of those who lost recreation residences were able to rebuild. Similarly, respondents indicated that recreation residences lost to other wildfires in the 2000s in the ANF were not rebuilt. In 2015, National Forest staff were anticipating the challenges of debris clean-up and restoration, which came out of their limited local budget if not completed by lessees.

Finally, those who were able to rebuild were facing a number of challenges with hazard exposure. Homeowners insurance was difficult to obtain before the Station fire, and remained so afterwards, leaving some dependent on state-run California Fair Plan, which is relatively expensive and provides minimal coverage. Post-fire, mudslides and flooding were threats.

Discussion

Despite rising wildfire losses in the U.S., much about recovery and rebuilding after fires is still unknown (Schumann III et al. 2020; Kramer et al. 2021). The Station and Hwy 31 fires were contemporaneous, and homeowners affected by each fire received some local government assistance intended to facilitate recovery and rebuilding. Despite these

similarities, outcomes differed, with a rapid 'rebound' after the Hwy 31 fire and limited and slow rebuilding after the Station fire.

The rapid rebound we observed after the Hwy 31 fire is similar to the post-fire rebuilding observed after the Waldo Canyon fire in Colorado Springs and rebuilding after many other disasters, where homeowner resources in combination with suburban/urban settings facilitate rebuilding (Zhang and Peacock 2009; Mockrin et al. 2016). In contrast, the Station fire's aftermath could be characterized as an 'unmanaged retreat' (Mach and Siders 2021) with 27 privately-owned parcels adjacent to public forest land now vacant. To our knowledge, this is the first study to document and examine low rebuilding rates a decade following fire, associated with the high costs and complexity of rebuilding in this exurban area of LA County. It is noteworthy that the regulations identified as most onerous and expensive were not requirements for defensible space or fire-resistant materials, but rather emergency response and access requirements. Such regulations on water supply and access are among the more common mitigation regulations and are typically seen as more palatable than requirements for materials or defensible space, as they do not dictate individual management on private property (Muller and Schulte 2011).

That the fire department did not waive or reduce these requirements speaks to their centrality to fire protection. In contrast, local governments in other hazard prone areas have waived or unevenly applied land use regulations designed to reduce hazard exposure, even after disaster (Platt, Salvesen, and Ii 2002; Cutter et al. 2018; Neal et al. 2018). This outcome is also notable in light of the emphasis on housing supply and availability in state and local policy (State of California 2018)—perhaps because this was a relatively small number of homes, unlike recent wildfires, the county faced less political pressure for exceptions. However, after repeated devastating wildfire seasons, the state issued emergency regulations in 2020 that allowed local jurisdictions to facilitate rebuilding and expansion of housing through accessory dwelling units without road upgrades (Board of Forestry and Fire Protection 2020). CAL FIRE is also now revising road standards statewide in response to 2018 state legislation, in one of the largest overhauls since enacted in the 1990s (Dodd 2018). These standards will have implications for wildfire rebuilding, new construction, and future evacuation, and have generated intense interest from local governments, wildfire victims, and stakeholder groups (Silva 2021).

To our knowledge, this is also the first study to document who rebuilds post-fire, with most of our data coming from the Hwy 31 fire, where nearly 75% of original residents rebuilt. This was a new housing development, demonstrating that commitment to rebuilding does not require long tenure or rural settings, and suggests that logistical and financial considerations might have been more crucial than lived experience or attachment to the setting. Such ties, often termed 'place attachment' are still poorly understood in the context of hazards, including rebuilding and mitigation (Bonaiuto et al. 2016). Over time, however, turnover continued, demonstrating the importance of ongoing education and outreach about wildfire hazards and homeowner mitigation.

In addition, the majority of those original homeowners rebuilding after Hwy 31 fire (62%) elected to use noncombustible siding, significantly more than when developers or new owners were rebuilding, suggesting that hazard experience was contributing to voluntary improvement in building materials, as has been observed in other hazards

(Rathfon et al. 2013; McRae et al. 2018). However, relationships between past experience with hazards, risk perception, and mitigation actions are complex: experience does not always result in heightened risk perception, nor does risk perception lead to mitigation, for many potential reasons including costs, fatalism, and denial (as reviewed in Bubeck, Botzen, and Aerts 2012). Ultimately, in our study as well, 38% of homeowners who lost a house to wildfire chose to rebuild with siding that was combustible, as did the majority of new owners and developers, suggesting there are limits on relying upon voluntary mitigation (McGee, McFarlane, and Varghese 2009; McRae et al. 2018).

The rebuilding rates and mitigation outcomes we observed in both settings have implications for future wildfire vulnerability, when considered as a combination of exposure (number of buildings, size of homes) and sensitivity (mitigation). We note that numerous other factors also influence the vulnerability, including the position of homes on the landscape, access for suppression, community-level suppression resources, landscape-level vegetation management, emergency response/preparedness, and on many of these factors our study sites improved during recovery (Mockrin et al. 2018). However, given the critical role housing characteristics play in wildfire losses (Syphard and Keeley 2019) the changes we saw in the built environment in these two locations are essential to understanding future vulnerability.

After Hwy 31 fire, exposure (total number of homes, size of homes) quickly returned to pre-fire conditions, while improvements in sensitivity (building materials, defensible space) were modest—half the houses were rebuilt with siding that was combustible, respondents thought defensible space was limited, and the HOA declined to pursue Firewise certification, even as the program became more prevalent in the area. In contrast, those rebuilding ($n = 7$) after the Station fire were required to make changes in materials and access as described above, as well as create defensible space, while the majority of homes were not replaced, reducing exposure and lessening vulnerability. We note that in both study sites, we did not see larger homes rebuilt as has been noted after hazards (Lazarus et al. 2018); perhaps because both study sites had small parcels and Hwy 31 had an HOA. Over time, it is unclear how exposure may continue to change in the Station fire footprint. Kramer et al. (2021) found wildfires typically led to enhanced exposure via rebuilding and new development over the long-term in California (10–23 years post fire). There are no land use regulations that prevent rebuilding here, and nine of the 27 vacant privately-owned parcels had been sold to new owners – in some cases, multiple times—indicating continued interest in development.

Considerations for Recovery and Mitigation Programming

Both of the recovery outcomes we observed—rebound and retreat—offer some considerations for recovery. For the Station fire, where the difficulty and expense of rebuilding discouraged many homeowners, could a purposeful buyout program have compensated homeowners, facilitated ecological restoration, and allowed coordinated responses within county government, and with federal government? Nonprofit environmental organizations have experience in vegetation management, which would be critical to maintain ecological functioning and constraining wildfire risk for homes that remain amidst vacant lots. The nonprofit sector has been a leader in post-disaster buyouts (e.g., The Nature Conservancy

has collaborated on buyouts after floods, and is studying buyouts to create wildfire buffers around Paradise, CA) (The Nature Conservancy 2020a, 2020b).

However, we acknowledge that voluntary buyouts are challenging to fund and implement (Mach and Siders 2021). Ideally, such efforts are conducted en masse to confer the greatest environmental and mitigation benefits, and to avoid unevenly depopulating neighborhoods, which creates a new set of social challenges (Zavar and Hagelman III 2016; Binder and Greer 2016). With infrastructure access and rebuilding requirements that can vary by individual parcels, the design of an effective buyout program in a setting like the Station fire would require careful consideration to yield a cohesive outcome. Thus far, we are aware of only one post-fire buyout, in Australia, which had uneven participation (Hersher and Rizzo 2020).

The rapid rebound we observed after the Hwy 31 fire, in combination with uneven mitigation choices, continued turnover, and seasonal use raise questions about how mitigation can be improved when rebuilding, and education and outreach about risk and mitigation maintained over time. Given the reliance on voluntary mitigation, how could local stakeholders further encouraged improvements in materials and defensible space, particularly for developers and new residents who may lack the experience and motivation to invest in mitigation? In other fire-affected communities, nonprofit organizations have arisen to promote sustainable rebuilding (Mockrin et al. 2016). Land use regulations such building codes or defensible space standards could require mitigation, but similar to other hazard affected communities, local government and the HOA in the Hwy 31 study site declined to pursue such requirements, emphasizing the importance of rebuilding and unpopularity of land use regulations. Research about public approval of and governmental processes of pursuing such wildfire-related regulations is only now emerging, but remains critical to better understand the conditions and processes by which they are supported by local residents and governments alike (Edgeley, Paveglio, and Williams 2020; Mockrin, Fishler, and Stewart 2020; Paveglio, Stasiewicz, and Edgeley 2021).

Study Limitations and Considerations for Future Research

Despite the wealth of detailed information about rebuilding over time we were able to gather in two locales, many questions about wildfire recovery remain. For this study we concentrated on housing data and perspectives of local community leaders and government officials but lack the perspective of homeowners. For example, rebuilding decisions after the Hwy 31 may have varied with homeowner use (primary vs. seasonal). It is unclear how or why homeowners selected building materials. In addition, many aspects of wildfire recovery remained outside the scope of our interviews and beyond the data we could gather from housing records, including the financial cost of recovery, outcomes for renters, and broader human psychological and health outcomes (including for those who relocated post-disaster). In the future, merging data on rebuilding with resident surveys and information about community-level initiatives and regulations, across disciplines, will be a powerful way to more fully understand post-fire recovery and vulnerability at household- and community-levels (Nofal and van de Lindt 2020; van de Lindt et al. 2020). Ideally, a longitudinal study would assess post-fire recovery

and vulnerability for the individual, the built environment, and the community. However, funding and carrying out longitudinal research on disaster recovery is an ambitious goal.

Our findings also reflect the modest size of the two wildfires we studied: recovery was managed at the local level; federal individual disaster assistance was not granted for either fire; and losses were small relative to the remaining housing stock. It is unclear what additional opportunities or constraints on rebuilding and adaptation emerge after large wildfires where more assistance is available for recovery but losses are greater. For example in Northern California, years of destructive wildfires, most notably the 2018 Camp Fire, have destroyed substantial housing at town and county-scales, as well as infrastructure (drinking water, schools, stores), with regional economic and social impacts (Schulze et al. 2020; Chase and Hansen 2021).

In addition, in both of our study communities residents were primarily homeowners, with resources to invest in rebuilding. There is much yet to learn from communities where residents have fewer financial resources (Chase and Hansen 2021). Over the past decade, large wildfire losses have occurred in settings with a range of socioeconomic conditions. Such larger events could also allow for a deeper understanding of variation within community recovery outcomes, e.g., if recovery differs with or exacerbates housing disparities for minorities, renters, elderly, or otherwise socially vulnerable residents, as has been found in other post-hazard studies (Finch, Emrich, and Cutter 2010; Cutter, Schumann, and Emrich 2014). Such community-level perspectives will be particularly critical in supporting sustainable and equitable recovery without recreating risk-prone development, goals that are locally and nationally proclaimed, but remain challenging to carry out (Pearce 2003; Ingram et al. 2006; Olshansky and Johnson 2014).

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