**Title**

Recent fire severity is unprecedented compared to the previous four centuries in the Jemez Mountains, New Mexico

**Running Title**

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**Authors**

Jens T. Stevens 1\*, Ellis Q. Margolis1, Jonathan D. Coop, Sean A. Parks, Calvin A. Farris, Craig D. Allen1

**Author Affiliations and Addresses**

1U.S. Geological Survey, New Mexico Landscapes Field Station, Santa Fe NM

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**Target Journal**: Landscape Ecology

**Abstract**

Abstract

**Introduction**

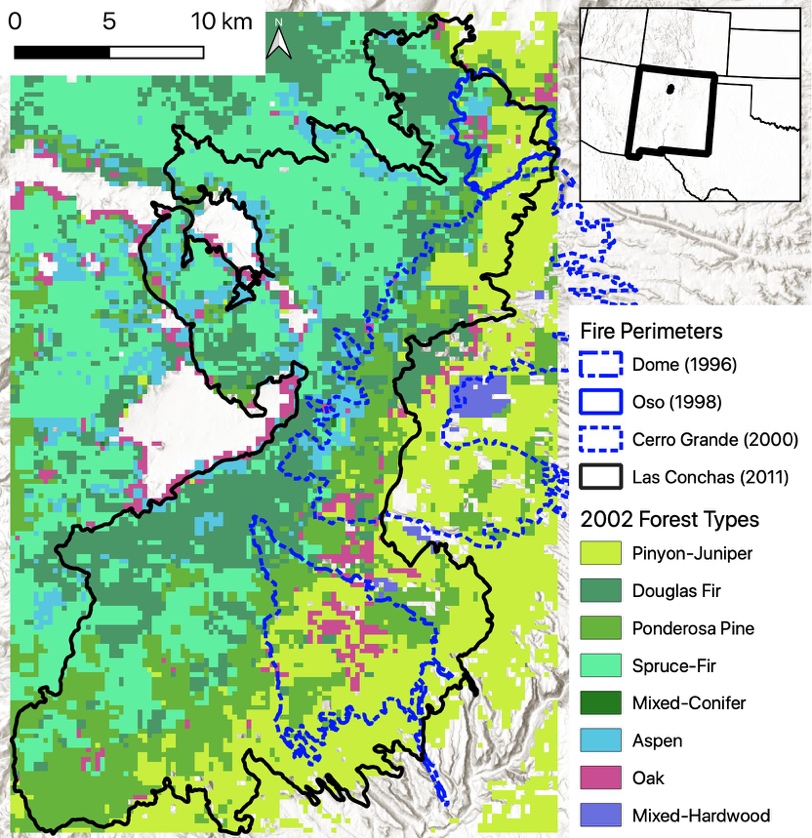
In North American forests where fire was frequent prior to the 20th century, contemporary fires are widely understood to have effects outside the range of historical variability (cite).

Here, we compared the observed pattern of **fire scar mortality** against a neutral landscape model of high-severity fire, simulated to reflect the observed distributions of stand-replacing patch sizes but not their observed locations on the landscape. We represented observed distributions of stand-replacing patch sizes using three **high-severity fire models**: A conservative **single-burn** estimate, an intermediate **multi-burn** estimate, and a cumulative **treeless** estimate, using different standardized remote sensing techniques. For a given high-severity fire model, we thus generated a null distribution of fire scar mortality by intersecting observed scar locations with simulated stand-replacing patches. We hypothesized that if the observed (nonrandom) collection of fire scars across the landscape represents **recurring fire refugia** compatible with observed contemporary fire severity, then the observed number of dead scarred trees (or dead tree clusters) should occur less than 5% of the time under a neutral landscape of high-severity fire, for a given true model of high-severity fire. If a neutral model failed to meet this criterion by killing fire scarred trees more than 5% of the time, then we adjusted the proportion of high-severity fire in the simulation downwards until the criterion was met. The proportion of high-severity fire that meets this criterion represents a putative upper boundary on historical high-severity fire, for the degree of patch aggregation represented by a given high-severity model. Finally, we simulated recurring fire at a range of fire return intervals to generate a putative upper bound for proportion of high-severity fire on a 15-year return interval.

**Methods**

*Study site*

We integrated contemporary burn severity data with historical fire scar records within the eastern Jemez Mountains of northern New Mexico, USA (Figure 1). The eastern Jemez Mountains range in elevation from approximately 1600 m on their eastern boundary with the Rio Grande, to over 3000 m on the mountain peaks that comprise the rim of the Valles Caldera, created by a series of volcanic eruptions over 1 million years ago. Much of the eastern flank of the mountains is comprised of banded volcanic tuff formations deposited by these eruptions, sitting on top of basalt. Erosion of the tuff has created a series of deeply incised canyons and mesa tops, with topography generally sloping gradually except for canyon walls and fault scarps.



**Figure 1**: Map of the study area, with Las Conchas and treeless perimeter shown. Forest vegetation classification by USDA Forest Service (Ruefenacht et al. 2008) based on 2002 data. Within the rectangular footprint of forest vegetation, areas shown in transparent white are not classified as forest. This includes montane meadows in the central and west portion of the study area and desert scrubland and grassland in the southeastern portion.

The Las Conchas fire started on June ##, 2011, burning 61057 ha in total. The fire burned through different forest types, ranging from pinyon-juniper at lower elevations, to ponderosa pine and mixed-conifer (including Douglas-fir) at mid-elevations, to spruce-fir at the highest elevations (Figure 1). The Las Conchas fire burned partially or completely over the footprints of at least nine previous fires since 1977: La Mesa (1977), Dome (1996), Lummis (1997), Oso (1998), Unit 29 prescribed burn (1998), Unit 38 prescribed burn (1999), Cerro Grande (2000), San Miguel (2009) and South Fork (2010). The deforested landscape following Las Conchas therefore reflected the cumulative high-severity effects of these previous fires, even if the fire effects from Las Conchas itself did not register as high severity (see below). For our burn severity assessments (below), we examined satellite-derived burn severity metrics for Las Conchas and three prior fires that had substantial (> 10 ha) high-severity area: Dome, Oso, and Cerro Grande (Table 1). The La Mesa fire burned prior to standardized satellite mapping technology, and a reliable assessment of burn severity following this fire is not available, so we did not include this fire in the above list, although it is accounted for in the treeless model (below).

**Table 1**: Area of fire effects in the East Jemez, 1984-2011. High-severity area calculated following the methods of Parks et al. 2019. Overlap refers to portions of three earlier fires that overlapped the Las Conchas fire perimeter.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| fire | year | area | high severity area | proportion high severity |
| Las Conchas | 2011 | 61057 | 21834 | 0.36 |
| Cerro Grande | 2000 | 17919 | 6155 | 0.34 |
| Cerro overlap |  | 7799 | 2789 | 0.36 |
| Oso | 1998 | 2144 | 615 | 0.29 |
| Oso overlap |  | 1952 | 605 | 0.31 |
| Dome | 1996 | 6385 | 1249 | 0.2 |
| Dome overlap |  | 6320 | 1253 | 0.2 |

*Burn severity assessment*

There are a wide range of methods available for deriving contemporary vegetation burn severity. Rather than choose one a priori as the most accurate, we used three alternative models to represent the actual occurrence of stand-replacing patches (“high-severity models” or HSM). First, we calculated the predicted Composite Burn Index (CBIp) using a composite model of Relative Burn Ratio (RBR) and other satellite and topoclimatic variables following the methods of Parks et al. (2019), for the Las Conchas fire only (HSM1: single burn). Second, we calculated CBIp for the Dome, Oso and Cerro Grande fires, and used the cumulative high severity effects from these fires plus Las Conchas (HSM2: multi burn). High-severity fire was defined as CBIp >= 2.25 (Appendix 1). Third, we defined treeless areas from high-resolution (1m) postfire imagery (HSM3: treeless) following the methods of Walker et al. (2019). Each subsequent HSM predicts greater collective area of high-severity fire.

Figure 2: Map of high-severity area from the three simulations, plus scar locations (option to code scars by live/dead)

To compare contemporary fire patterns against historical fire evidence, we compiled a record of 479 crossdated fire scars from within the footprint of the Las Conchas fire. A subset of scarred trees (n = 89) within the fire footprint occurred at the margin of large montane meadows within the Valles Caldera National Preserve (Dewar et al. 2021), which often formed containment lines for the western border of the fire (Figure 1). Because these lower-density forests at grassland ecotones are expected to constitute fire refugia (Chapman et al. 2020), we conducted our analyses both with (all trees) and without (interior trees) these scarred individuals.

START HERE To simulate a range of possible historical (pree-1900) stand-replacing patch size distributions, we…

We compared the observed number of dead scarred trees with the distribution of simulated number and proportion of dead scarred trees for each HSM. For each simulation, we counted every fire scar that intersected a simulated high-severity patch and considered it dead. Because the fire scar collections occurred in clusters around fire history sites, as is standard practice, the likelihood of multiple dead scars within a cluster increases once one scar is killed due to spatial autocorrelation. Thus we also assessed the number and proportion of impacted clusters, in addition to individual trees, by defining clusters of 1 or more trees based on proximity to each other using the dbscan algorithm in QGIS. We identified 63 clusters ranging from 1 to 37 scarred trees and 1 tree to 69 ha in size, and n clusters from 1 to n trees and 1 tree to n ha among interior trees only. For each simulation we counted a cluster as “impacted” if at least one tree in the cluster intersected a high-severity burn patch and “heavily impacted” if all trees in the cluster intersected a high-severity burn patch.

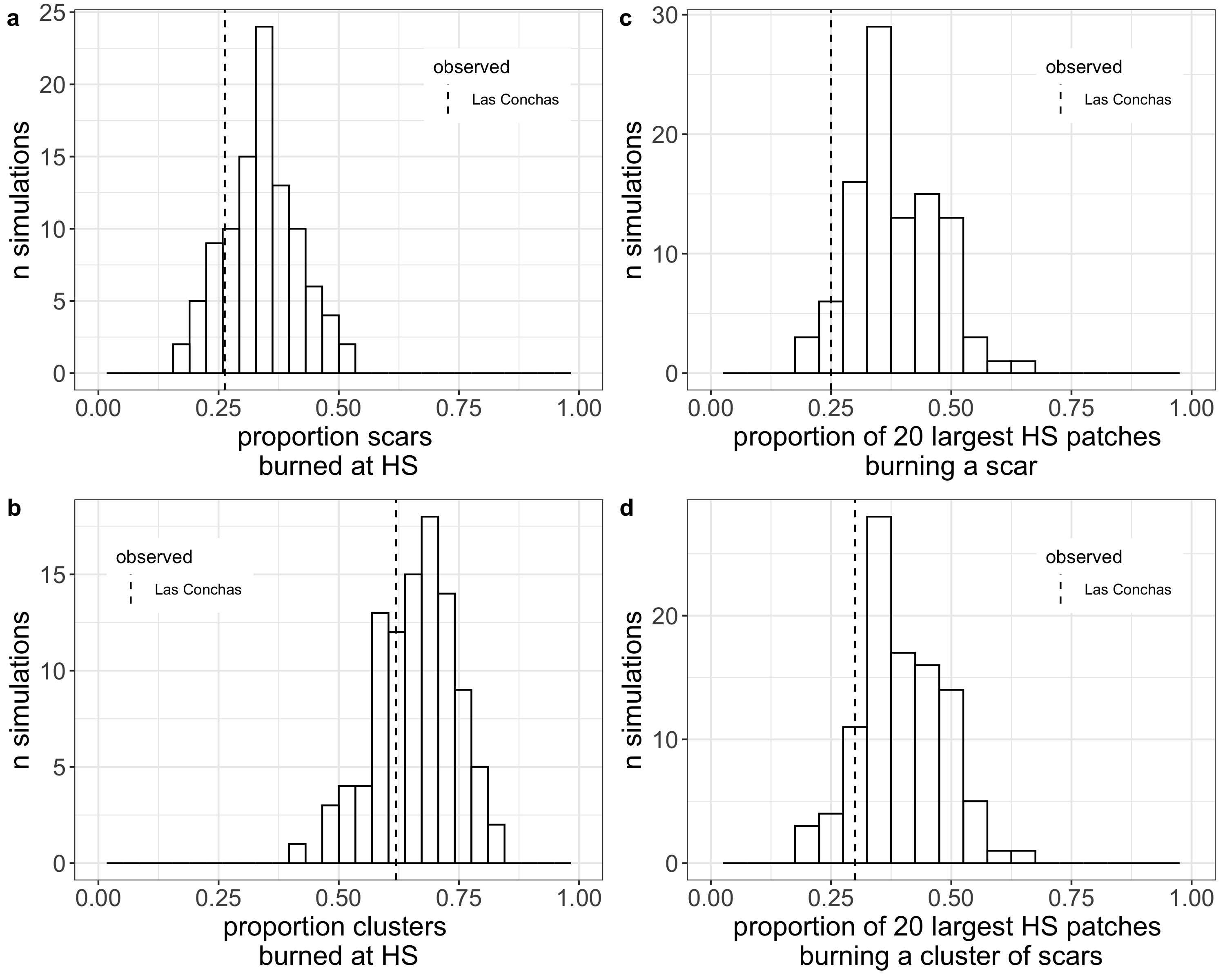
**Results**

Results

**Table 2**: High-severity model evaluation. Proportion high severity is out of a total fire area of 61057 ha (Table 1). Predicted number and proportion of dead scarred trees is based on point intersections with each high-severity model, out of a total of 479 points (or 390 points for interior scars only), representing fire scarred trees within the footprint of the Las Conchas fire. An independent validation of those points using high-resolution NAIP imagery was used to determine where a given model predicted “false” mortality events (where points fell in a predicted high-severity patch but had live conifers within 15 m) and “false” survival events (where points fell outside of a predicted high severity patch but had no live conifers within 15 m). Classification error is the sum of false mortality and survival events divided by the total number of points. The true number of dead fire scarred trees from the independent assessment is 241 (50.3%) for all trees and n (x%) for interior trees only. Option to add number of clusters with at least one scar.

|  |  |  |  |
| --- | --- | --- | --- |
|  | observed high-severity model (HSM) | | |
|  | single | multi | treeless |
| high-severity area (ha) | 21834 | 26265 | 45998 |
| proportion high severity | 0.358 | 0.43 | 0.753 |
| Dataset with all trees |  |  |  |
| predicted proportion dead scarred trees | 0.267 | 0.355 | 0.622 |
| predicted number dead scarred trees | 128 | 170 | 298 |
| false mortality events | 10 | 14 | 65 |
| false survival events | 123 | 85 | 8 |
| classification error | 0.278 | 0.207 | 0.152 |
| Dataset with interior trees only |  |  |  |
| predicted proportion dead scarred trees | 0.3 | 0.408 | 0.667 |
| predicted number dead scarred trees | 117 | 159 | 260 |
| false mortality events | 8 | 12 | 48 |
| false survival events | 109 | 71 | 6 |
| classification error | 0.3 | 0.213 | 0.138 |
| Selected parameters for simulation |  |  |  |
| pct | 0.6 | 0.6 | 7 |
| nugget | 0.6 | 0.6 | 0.3 |
| magvar | 10 | 10 | 10 |

Figure 3: Replace the histogram with a smoothed curve, and generate a smoothed curve for each of the three models. Shade the area that is to the left of the value associated with the bottom 0.5% of the simulated distribution, and say that is the “predicted number of dead scars under the refugia hypothesis”. Possibly 2 columns, L all scars, R core scars only



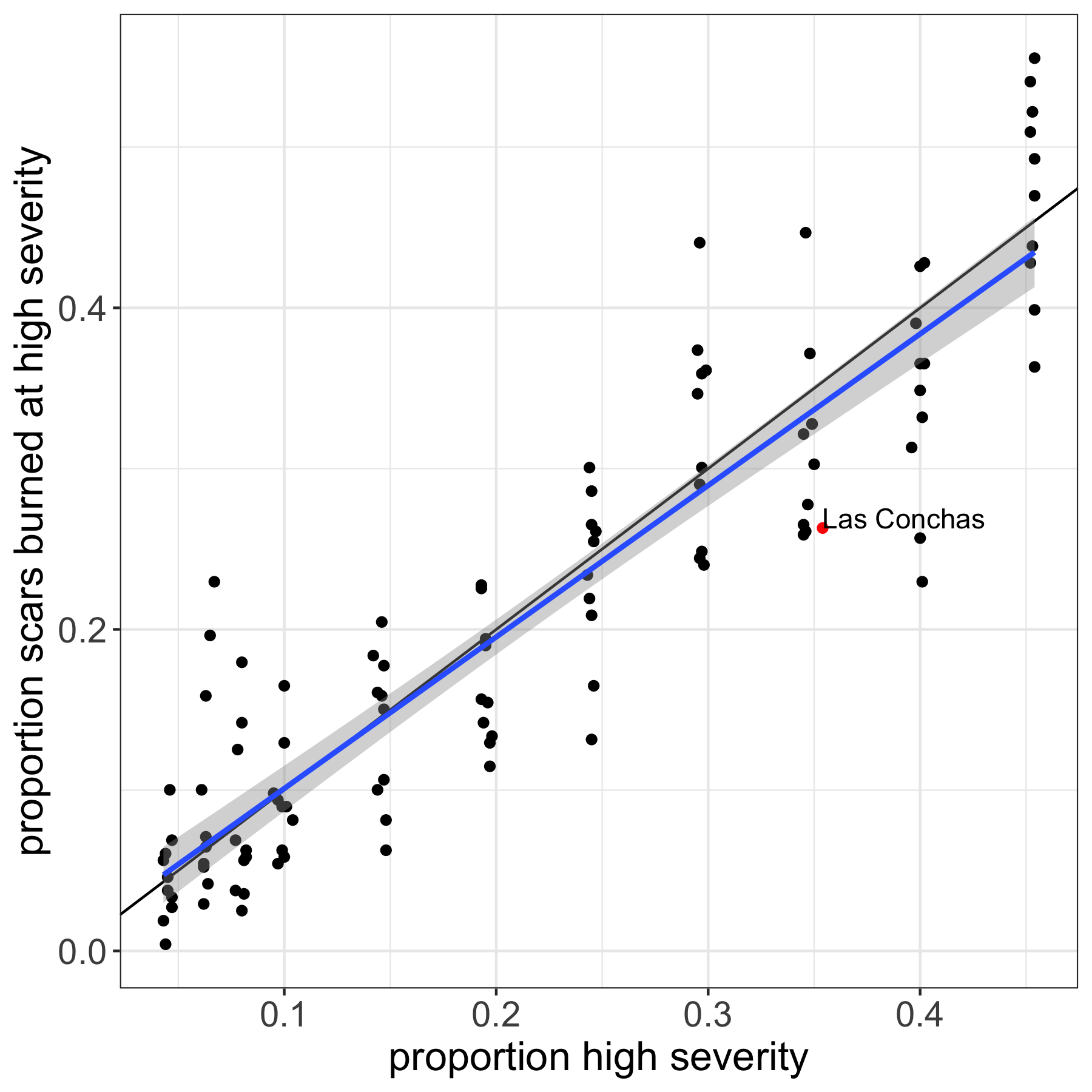
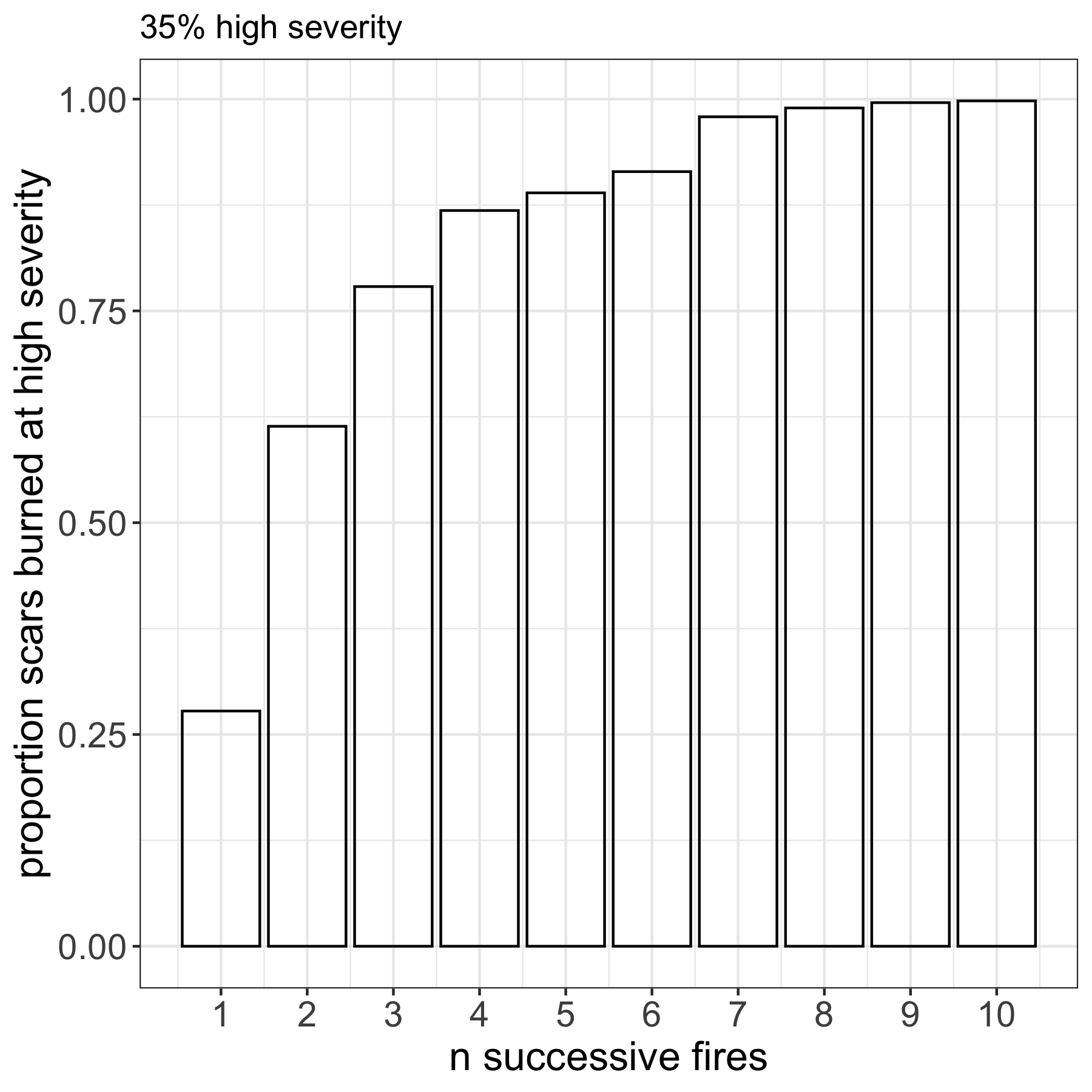


Figure 4:

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**Figure 5:**

**Discussion**

Discussion

**References**:

**References**

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