The Santa Barbara "Paint" Fire: Data Collection for Urban-Wildland Interface Structure Loss Analysis

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Abstract

The Santa Barbara "Paint" fire destroyed 476 residential and business structures in June 1990. A recently developed survey instrument was employed to quickly gather information on over thirty factors previously identified as being associated with the loss or survival of structures in wildland fires. This effort yielded a data base suitable for rigorous statistical analysis of the interactions among these factors. Preliminary assessment with respect to one factor, type of roof covering, revealed a particularly clear pattern - structures with fire resistant roofs had a higher survival rate and lower rate of damage than structures with untreated wood roofing material.

Introduction

Santa Barbara experienced a devastating wildland fire which began on June 27th, 1990, popularly referred to as the Paint fire. One resident was killed, and over 800 buildings of many types were damaged or destroyed. The magnitude of this structure loss places the fire in the top three wildland fires in California state history (in terms of number of homes destroyed). Yet, many homes survived undamaged amid the destruction in both suburban neighborhoods and less dense rural areas. Despite the commonly held belief that little can be done to protect structures exposed to intense wildland fires, the surviving structures appeared to differ from those destroyed with respect to factors such as type of building construction and surroundings.

Statistical correlations are useful for objectively identifying which factors are associated with structure loss, especially in the absence of experimental trials to prove causal relationships. This paper reports on data collection methods employed in the aftermath of the Paint fire to support

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statistical analysis of structure loss in wildland fires. The usefulness of the approach employed is clearly demonstrated by preliminary results on the effect of roofing material in structure survival or loss. Roof type and degree of structure damage, two of over thirty factors for which data were collected, are used here to illustrate how data collection was implemented and the need for rigorous statistical analysis. It also highlights the importance of a multifactor analysis that evaluates the simultaneous impact of several variables on structure damage. The analysis reported on here will be extended from roofing material to all factors thought to be associated with structure damage for which data were collected on the Paint fire.

The structure losses on the Paint fire occurred in a community located at the base of a coastal mountain range five miles north of Santa Barbara, 100 miles north of Los Angeles (see *Figure 1*). The Paint fire was started by an arsonist on a mountain highway near Painted Cave State Park at approximately 6 pm. Winds gusting up to sixty miles-per-hour pushed the fire downhill. After spreading through twelve-foot tall brush, the fire reached areas of rural development in thirty minutes, and suburban neighborhoods at the base of the mountains within sixty minutes. This initial advance of the fire was accompanied by flame lengths of forty to seventy feet. Burning embers, or firebrands, were blown up to three quarters of a mile in advance of the main fire, igniting numerous spot fires. The fire progressed, spotting from house to house and spreading through landscaped vegetation and across open spaces, until it stopped at approximately 8 pm, 4.3 miles from its point of origin. The perimeter resulting from this initial two hours of burning contained over 90% of the structures exposed to the fire. As winds died that night, the fire burned back up into the hills, consuming about five hundred more acres and exposing additional structures. Wildland vegetation on the upper flanks of the fire continued to burn until containment two days later at a final size of 4,900 acres.

Data Collection

Structure loss information on 542 destroyed and damaged structures was collected in the two weeks following the fire by employees of local, state, and federal agencies assigned to an interagency fire effects survey team hosted by the Santa Barbara County Fire Department. Additional data collection trips were made one and two months after the fire to obtain information on the 343 undamaged structures that were exposed to the fire. Each structure site was visited in the process, and information was collected on over 30 factors thought to be associated with structure loss.

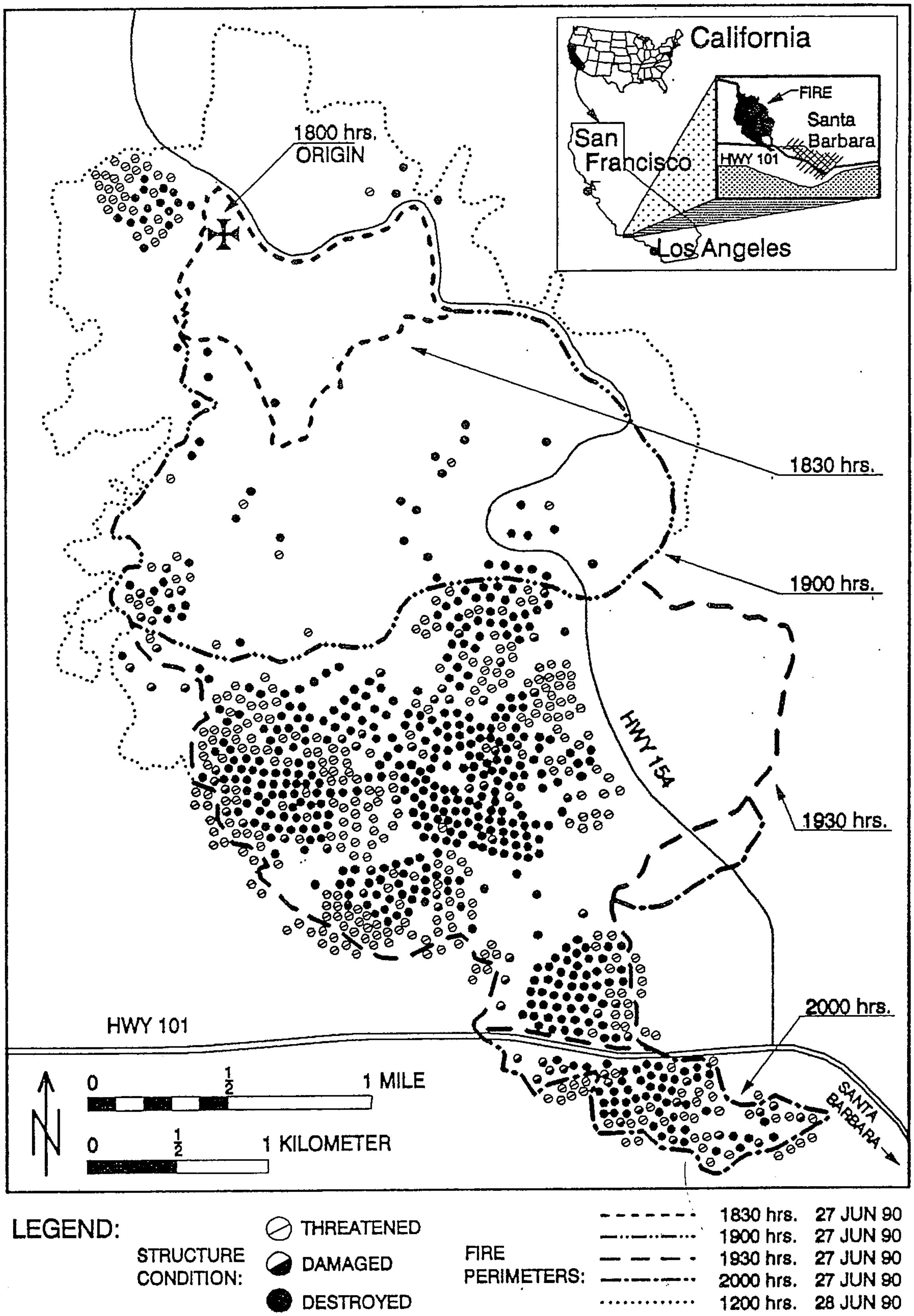

Figure 1. Distribution and extent of damage for all structures exposed to the Paint Fire and fire perimeter progression [1] *during the main advance of the fire.*

The information was gathered using a modified version [2] of the Defensible Space Factor Study, Data Collection Survey Form developed by the California Department of Forestry and Fire Protection [3] as part of an on-going effort to characterize structure loss and improve the defensibility of structures in wildland fires. The 96-question data collection form addresses building construction characteristics, structure site factors, and fire behavior observations, and was based on previous studies of the Florida Palm Coast Fire [4] and the Australian Ash Wednesday Fires.[5,6,7]

Members of the interagency fire effects survey team, going from structure to structure, questioned residents about the fire and their homes, and occasionally about neighboring structures. When residents or neighbors could not be located to provide information, team members completed the survey to the extent possible based on their own first hand observations. Rapid deployment of the team proved critical since demolition and site clearing work was well underway within a week of the fire. By the second month after the fire, most destroyed structures had been cleared.

The extent of damage to a structure was categorically classified as "destroyed", "damaged", or "threatened". The "destroyed" classification denoted extensive damage necessitating construction of a new structure, "damaged" structures had at least one hundred dollars of fire damage but could still be economically repaired, and structures that were undamaged but located within one hundred feet of any burned structure or vegetation were classified as "threatened". Only thermal damage to structural materials was considered for the purpose of damage classification. This includes scorched or blistered exteriors and windows broken by radiant heat, but excludes smoke damage and destroyed landscaping vegetation. The term exposed, used elsewhere in this paper, includes all three structure damage classifications and refers to any structure affected by the fire, inside or outside the perimeter.

Only residential dwellings, business structures and primary public buildings were classified as "structures", for the purpose of data collection. Where several separate structures existed at an address and each met the above definition of "structure" each structure was separately surveyed. Single structures containing multiple residential or business units, such as a duplex or commercial complex, were counted as one structure. Outbuildings, primarily various types of storage buildings, were not surveyed or counted as structures. A separate tabulation was made, however, of destroyed and damaged outbuildings over one hundred square feet in size.

The specific definitions and classifications used were necessary because of the variety and large number of structures involved, and reflect the study's focus on factors associated with structure ignition and damage. Surveys of the fire reflecting other information needs and classifications, such as number of business or living units lost, have reported somewhat different counts.

The roof covering material was classified following the *California Fire Incident Reporting System* coding [8] and is consistent with *NFPA 901- Uniform Coding for Fire Protection.*[9] Only the roof covering was noted and no attempt was made to determine the roof class.* The survey form identified six roof type classifications:

"tile" (clay, concrete, fiber-cement, etc. of any shape including flat and concave)
"composition shingle" (asbestos or glass felt coated with asphalt and granules)
"wood shake/shingle pressure-treated" (impregnation process fire retardant)
"wood shake/shingle untreated" (split shakes or sawn shingles)
"metal" (pressed steel tiles, corrugated sheets, etc.)
"built-up" (continuous layers of felt and tar or asphalt, some surfaced with gravel).

Roof type was easily identified by the survey team for structures with non-combustible roofing materials, abundant evidence of which remains at the sites of even the most intensely burned structures. Identification of combustible roof type for destroyed structures was contingent upon input from occupants, neighbors, or finding significant shingle samples near the structure (usually pieces that had been blown off and self-extinguished).

At the end of the initial data collection effort the authors were apprised of a chemical test, suitable for field use, to detect the presence of orthophosphate fire retardants in wood roofing material.[10] Accordingly, wood shake or shingle samples were taken for chemical analysis from twenty eight structures during the two additional data-collection trips.

Results and Discussion

Structure Damage:

The number of structures exposed to the fire and extent of damage to these structures is presented in *Table 1* along with the additional number of outbuildings lost and damaged. A relatively small number of surviving structures identified as threatened following the primary data collection have not been surveyed, leaving the possibility that they may eventually be classified as damaged. The tabulations are judged to be greater than 95%

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* Roof types are classified A, B, and C, based on the relative performance of roof assemblies (roof covering and roof deck) in standardized exterior fire exposure tests e.g., Underwriters Laboratories Inc. UL 790 *Test for Fire Resistance of Roof Coverings*, and American Society for Testing and Materials ASTM E-108 *Standard Test Methods for Fire Tests of Roof Coverings.*

	RESIDENTIAL DWELLING STRUCTURES, BUSINESS STRUCTURES & PUBLIC BUILDINGS				ADDITIONAL OUTBUILDINGS
	Destroyed	Damaged	Threatened	TOTAL Exposed	TOTAL Destroyed & Damaged
number	476	66	343	885	266
percent	53.79%	7.46%	38.76%	100.00%	

Table 1. Extent of damage to structures & outbuildings

ROOF TYPE	STRUCTURE DAMAGE Destroyed (number / row %)	Damaged	Threatened	TOTAL Exposed (# / col %)
Composition Shingle (asphalt & fiberglass)	41 26.62%	19 12.34%	94 61.04%	154 17.40%
Concrete / Clay Tile (all types, flat & convex)	64 31.53%	25 12.32%	114 56.16%	203 22.94%
Built-up (tar and gravel)	4 18.18%	7 31.82%	11 50.00%	22 2.49%
Wood Shake/Shingle (fire retardant treated)	4 40.00%	1 10.00%	5 50.00%	10 1.13%
Other	1 50.00%	0 0.00%	1 50.00%	2 0.23%
Metal	15 57.69%	0 0.00%	11 42.31%	26 2.94%
Wood Shake/Shingle (untreated or unknown)	233 81.47%	9 3.15%	44 15.38%	286 32.32%
No roof type data	114 62.64%	5 2.75%	63 34.62%	182 20.56%
TOTAL	476 53.79%	66 7.46%	343 38.76%	885 100.00%

Table 2. Cross tabulation of roof covering type and structure damage ranked by decreasing percentage of structures undamaged by fire.

accurate at this time with respect to the number and damage classification of structures. Inconsistent application of the "structure" definition criteria during data collection may also be a source of error.

The survey team's mission was to collect data during the first two weeks after the fire on the damaged and destroyed structures that were being demolished. Subsequent data collection on threatened structures identified a number of structures that suffered previously unnoticed damage including interior ignitions. These cases proved especially useful in documenting examples of structure ignition mechanisms.

A pattern noticeable throughout the fire area (and reflected in *Table 1*) was that the vast majority of structures was either completely destroyed or survived undamaged. In addition, those structures reported as "damaged" characteristically had very minor damage. Data collection for damage classification in this study combined damage resulting from structure ignition and non-ignition thermal damage into a single category. This complicates analysis if the focus is on structure ignition, where damaged structures are included with destroyed in one category. Structure ignition has been the focus in some previous studies.[11,12] An alternative is to focus on reducing damage.[13] There may be factors which enhance a structure's ability to survive a wildland fire with building ignition that results in slight damage instead of destruction. This paper presents the preliminary data as collected without category combinations that may be necessary in future analysis.

Roof Covering:

No single characteristic of a building or its surroundings is sufficient to predict survival or damage in a wildland fire. However, roof material is often cited as being of paramount importance. This was confirmed in California's only previous quantitative analysis of structure loss or survival in wildland fires.[14,15] Because of the sustained interest and controversy over roofing materials,[16,17] this factor was selected for preliminary analysis. The results of this examination clearly demonstrate the value of post-fire data collection. Conclusions drawn from this preliminary analysis must, of course, be tempered by consideration of possible interactions with other important factors such as fire intensity, defensive actions, and vegetation clearance.

Roof covering information was collected on 80% of the structures exposed to the fire. These data are presented in *Table 2*, cross-tabulated with degree of structure damage. Each cell of the cross tabulation contains the number and percentage of structures with a roof type that were "destroyed", "damaged", or "threatened". The total column shows the frequencies for different roof types as a percentage of all structures exposed to the fire.

Three quarters of the surveyed structures had one of three types of roof covering: untreated wood shake or shingle; composition shingle; or tile. Looking only at these classifications and combining composition shingle with tile into one fire resistant group, a clear pattern of structure loss or survival emerges with respect to roof type. Of the structures with fire resistant roofing, three out of ten were destroyed and six out of ten survived undamaged. In contrast, eight out of ten structures with untreated wood roofing were destroyed, with fewer than two out of ten surviving undamaged. The relationships among the roof types with small sample sizes, considering only roof covering as a factor, will likely change when the effects of other factors are taken into account. However, a multifactor analysis is unlikely to substantially modify the pattern described above for fire resistant and untreated wood roofing.

Wood Roofing Materials:

The data collection survey classified wood shake and shingle roofing into two fire retardant categories "untreated" and "pressure treated", neither of which produced clear results with respect to fire retardant treatments. The "untreated" category became a combination of structures where the occupant stated that the roof was not treated, where the occupant was unsure of any treatment, and where there was no occupant to provide information. In the absence of occupant information it was essentially impossible to distinguish between treated and untreated wood roofing materials. As a result the survey classification of "untreated" is reported in *Table 1* as "untreated or unknown". Thus, it is possible that this group contains some structures with pressure treated fire retardant roofs. However, this would appear unlikely due to the relatively recent use of pressure-impregnated fire retardant roofing materials and the observed age of the structures.

The second category of wood shake or shingle roofing, "pressure-treated", was similarly confounded due to occupant lack of knowledge and the indistinguishable nature of wood roofing materials. When queried by the survey team, homeowners were rarely able to state unequivocally that their roof had a pressure-impregnated fire retardant treatment as opposed to other types of fire retardant treatments. If they seemed reasonably sure and the roof was relatively new, the response was recorded as "pressure-treated". As a result this survey classification is reported as simply "fire retardant treated". The distinction here is important because only wood roofing materials that have been pressure-impregnated for fire retardance at the time of manufacture are being considered as potentially fire resistant for the life of the roof. The post-manufacture spray-on application of various substances has not been shown to retain effectiveness beyond a year after application.[18]

A chemical analysis to test for the presence of orthophosphates, fire retardants commonly used in the pressure-impregnation process, is available for easy field use. However, the results only indicate the presence of the fire retardant chemical and do not distinguish between the type or degree of treatment used. This colorimetric analysis was applied to the twenty eight wood shake or shingle samples collected, the results of which are presented in *Table 3*. There were no false negative test results using the survey data as a comparison base. Two samples from destroyed structures, identified by the survey as "untreated", tested positive and were included in the reported "fire retardant treated" classification for the tabulations. Due to the identification problems with wood roofing materials, it was not possible to evaluate the performance of pressure-treated fire retardant wood shake or shingles in this fire.

Tile and Metal Roof Covering:

The survey team received numerous comments in regard to the loss of structures with fire resistant roofing. While 69% of the exposed structures with tile roofs survived the fire, compared with an overall survival rate of 45%, the image of a new fire resistant roof resting on the foundation of a destroyed house was striking. Multifactor analysis of the data from this fire will, hopefully, reveal the other factors such as vegetation clearance that are associated with loss or survival of structures with fire resistant roofs.

One case of tile roof structure ignition was documented during the follow up data collection, providing an example of how such structures can be ignited during wildland fire exposure. A house, identified initially as undamaged, had a fire burn through two-inch tongue & groove sheathing* under a clay tile roof. The fire was seen through the living room window by a patrolling engine company and was extinguished before extensive damage occurred. The engine company officer, home owners, and roofing contractor who repaired the roof, all stated that the fire appeared to have originated at the hole, with the only possible source of ignition having been a firebrand blown up under the concave roofing tiles. The engine company officer indicated that there was no evidence of fire having travelled up under the tiles, along the roofing felt, from the base of the roof to the hole six feet from the base. He also found unburned vegetative debris under the tiles around the burned hole and burning debris at the base of the tile roof. The roofing contractor further stated that birds and rodents frequently bring in nesting

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* Roof deck lumber.

COLORIMETRIC TEST FOR ORTHOPHOSPHATE FIRE RETARDANT PRESENCE	STRUCTURE DAMAGE			TOTAL
	Destroyed	Damaged	Threatened	Exposed
Positive	2	1	3	6
Negative	8	5	9	22
TOTAL	10	6	12	28

Table 3. Test for chemical fire retardant presence in wood shake/shingle samples

material under these roofs, resulting in fuel accumulations for a potential firebrand ignition.

This type of potential structure ignition was witnessed by another home owner who stated that he extinguished two spot fires *under* his tile roof. In this case, the owner saw flames coming out from the eave openings of the concave roof tiles and extinguished them with a garden hose. A post-fire examination of the roof revealed no observable damage but accumulations of pine needles were found under the tiles in several places.

Barriers to prevent fuel build-up and firebrand entry under roofing tile are available in the form of "birdstops" or preformed filler strips that block the openings of the concave tiles at the eave end of the roof. A review of roofing product literature from five concave tile manufactures in California revealed that only one mentioned a connection between blocking these openings and fire safety.

The metal roof type category consisted primarily of granule coated pressed steel tiles. This class of roofing appeared to have faired worse than other types of fire resistant roofing (*see Table 2*). However, interpretation in this case is more difficult due to the small sample size. As has been the case with most reports on urban-wildland interface structure losses,[19,20,21,22,23,24] two key questions cannot be answered at this time: 1) Was it simply chance that three times as many structures with metal roofs were destroyed as structures with built-up roofs?; 2) Furthermore, is it possible that the fourteen structures with metal roofing happened to be located in areas of greater fire intensity or had less defensive actions? These questions become increasingly important the smaller the sample size is for the characteristic of interest and illustrate the need for statistical analysis.

Future Work:

Statistical methods are available to measure the degree of association between a factor and an outcome, in this case roof type and structure damage, and answer the question of chance occurrences. The combined simultaneous influence of several factors, such as roofing and defensive actions on structure damage, can also be estimated by statistical techniques. This will be the focus of continued analysis of the data collected on this fire.

The large number of structures destroyed and the characteristics of fire spread make the Paint fire well suited for this type of analysis. *Figure 1* illustrates that the majority of structures were exposed to the passage of the fire front over a very short period of time, which eases assumptions about temporal factors, such as general weather influences. Because the losses were so great and because data were collected on a similar number of threatened structures, it is thought that spatial factors, such as fire intensity differences, can be accounted for in a meaningful way.

This approach is, however, limited by the fact that the relationships produced are based on the complex environment of a single fire. Extrapolation of the findings from a particular fire to the generalized case is difficult. In recognition of this, one of the goals of the California Department of Forestry and Fire Protection (CDF) Defensible Space Factor Study is the collection and analysis of data from hundreds of fires throughout California. This process currently parallels information gathering for a standard fire incident reporting system, but the potential of merging the two data collection efforts needs to be explored.

Another approach is an improved understanding and application of the fundamental mechanisms of structure ignition at the urban-wildland interface. Such an effort is being carried out by U.S.D.A. Forest Service researchers with support form CDF.[25] Their goal is to develop a fire hazard assessment model based on the analytical relationships between a structure and the wildland fire environment.

Summary

In the midst of an urban-wildland interface conflagration that veteran fire service personnel described as a "fire storm", many structures survived with little or no damage. Structure loss and survival was observably not random with respect to defensible space factors.

Useful information can be collected from the remains of structures destroyed in wildland fires if survey instruments, trained personnel, and organizational frameworks are prepared well beforehand. Meaningful conclusions must be based on comparisons between structures damaged, and those which were exposed to the fire but survived undamaged. Collection of data on damaged structures alone precludes rigorous statistical analysis.

The data collected on the Paint fire indicates that the type of roofing appears to have played a major role in determining structure survival or loss. The complete Paint fire data base is now being analyzed to verify this, and to reveal the interactions between roof type and other factors that are thought to be associated with structure survival, such as defensive actions and vegetation clearance.

The results of the statistical analysis, as well as documented examples of weak points in structures' exterior fire defenses, will support fire loss prevention efforts. Data collection on fires and avenues of future research can both be guided by urban-wildland interface structure loss analysis.

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