W

Wildfires and WUI Fire Fatalities

Katharine Haynes[1,2], Karen Short[3], Gavriil Xanthopoulos[4], Domingos Viegas[5], Luis Mário Ribeiro[5], and Raphaele Blanchi[6]
[1]Centre for Environmental Risk Management of Bushfires, University of Wollongong, Wollongong, NSW, Australia
[2]Bushfire and Natural Hazards Cooperative Research Centre, Melbourne, VIC, Australia
[3]USDA Forest Service, Rocky Mountain Research Station, Missoula, MT, USA
[4]Institute of Mediterranean Forest Ecosystems, Hellenic Agricultural Organization "Demeter", Athens, Greece
[5]Forest Fire Research Centre of ADAI, University of Coimbra. Rua Pedro Hispano, Coimbra, Portugal
[6]CSIRO Land & Water, Melbourne, VIC, Australia

Synonyms

Casualty; Civilian fatalities; Death; Firefighter fatalities; Life loss; Victim

Definition

Information collected on fatalities including civilian and firefighters during wildfire and Wildland-Urban Interface (WUI) fire. This information is used to better understand the context surrounding fatalities and to support emergency management policies.

Introduction

Understanding the detailed physical and social context surrounding wildfire and WUI fire fatalities is crucial in terms of ensuring effective emergency management policy and practice. Studies of fatalities over prolonged periods ensure changing trends in vulnerabilities and exposure are identified (e.g., Haynes et al. 2010; Molina-Terrén et al. 2019). There have been a number of catastrophic fires leading to high numbers of fatalities in recent years, including the 2009 Victorian bushfires in Australia, with 173 fatalities (Teague et al. 2010); the 2017 Portugal forest fires, with 66 fatalities in Pedrógão Grande (Viegas et al. 2017; Molina-Terrén et al. 2019) and 51 fatalities in the Central Region (Viegas et al. 2019); the 2018 Camp Fire in California, with 85 fatalities (Cal Fire 2019); and the 2018 Mati forest fire in Greece, with 102 fatalities (Xanthopoulos and Athanasiou 2019). However, detailed studies of wildfire fatalities are not common and remain country specific. In this contribution, the authors use the word bushfire in Australia, wildfire in the United States, and forest fire in Europe.

A number of studies have been conducted on fatalities resulting from bushfires in Aus-

S. L. Manzello (ed.), *Encyclopedia of Wildfires and Wildland-Urban Interface (WUI) Fires*,
https://doi.org/10.1007/978-3-319-51727-8_92-1

tralia (Blanchi et al. 2014; Cheney et al. 2001; Haynes et al. 2010; Krusel and Petris 1999). Two detailed studies have explored civilian fatalities longitudinally, the first investigated the activities and decision-making carried out at the time of death of those killed in bushfires between 1901 and 2008 (Haynes et al. 2010). The research emphasized the dangers of being caught outside and revealed a distinct gender bias in behavior. The second study explored the spatial and environmental circumstances of bushfire fatalities, determining the exact locations the fatalities occurred, their distance from the forest, and the fire conditions at the time of death (Blanchi et al. 2014).

In Europe a recent analysis of forest fire and WUI fire fatalities was carried out in Spain, Portugal, Greece, and Sardinia, where an increase of fatalities has occurred since the late 1970s (Molina-Terrén et al. 2019). Research exploring fatalities in Greece between 1977 and 2013 identified that approximately 75% of those killed in forest fire and WUI fire were civilians. The trends seen in the data were similar to the Australian studies, with a high proportion of male fatalities killed while engaged in firefighting or late evacuation on foot or in a vehicle (Diakakis et al. 2016). The 2017 fires in Portugal involved mostly civilian victims, including entire families, with a high proportion engaged in late evacuation by vehicle (Viegas et al. 2019).

In the United States (US), data tracking wildland firefighter fatalities have been collected since the early twentieth century and periodically analyzed to inform programs and policies intended to increase firefighter safety and minimize injuries and fatalities (e.g., NWCG 1997, 2017; Mangan 2007). While historically the focus has been on firefighter fatalities, there is growing concern about increasingly prevalent high-loss events, including recent WUI fires in California and elsewhere that claimed the lives of dozens of civilians (Cal Fire 2019; Calkin et al. 2019).

Research on firefighter safety has also been conducted following a number of incidents where firefighters perished during wildfire entrapment or burnovers (Cheney et al. 2001; Page and Butler 2018; Viegas et al. 2013; Xanthopoulos et al. 2009). The aim was to investigate the factors that led to the incident and to develop improved protective measures and training for firefighters.

This contribution presents a summary of wildfire- and WUI fire-related civilian and firefighter fatalities from Australia, the United States, and Europe.

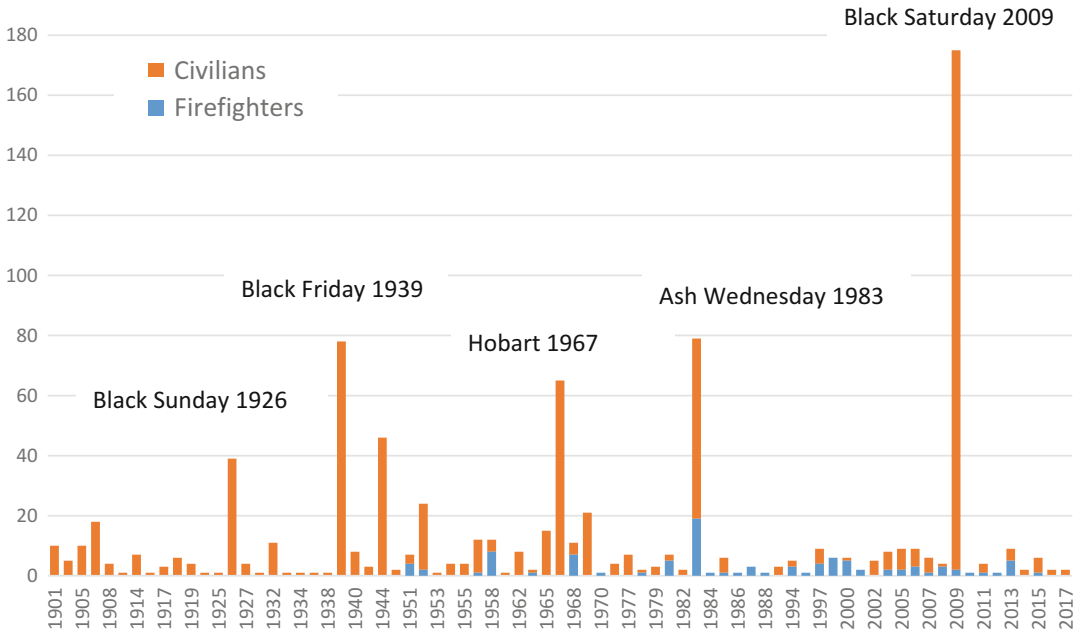
Australian Fatalities

In this section the term bushfire includes the fires that have also affected the WUI (WUI fires) as the data presented did not make the distinction between bushfire and WUI fire. No centralized data collection system for bushfire fatalities exists in Australia. Information on civilian and firefighter deaths was sourced from the Attorney Generals Department (AGD) bushfire life loss dataset (Blanchi et al. 2012). This dataset was developed by collating previous datasets and adding further information on bushfire related fatalities between 1901 and 2011 from reports in the print media and coronial inquest archives (Haynes et al. 2010; Blanchi et al. 2012, 2014). Recent fatalities from 2012 to 2017 have been added to update the data (from fire services and media sources). There is no distinction between bushfire and WUI fire in the data collected.

Distribution

The data presented covers fatalities between 1901 and 2017, with an average rate of 7.3 civilian deaths per year. There are a total of 846 fatalities, including 748 civilians and 99 firefighters. The number of fatalities and the trends seen in the data are dominated by a handful of iconic catastrophic events (Fig. 1), including bushfires in 1926 (Black Sunday), 1939 (Black Friday), 1967 (Hobart), 1983 (Ash Wednesday), and 2009 (Black Saturday). These events are strongly influenced by fire weather severity (Blanchi et al. 2010).

The deadliest bushfire in Australian history was the 2009 Black Saturday bushfires complex. On February 7 several bushfires burned under extreme weather conditions in the State of Vic-



Wildfires and WUI Fire Fatalities, Fig. 1 Distribution of civilian and firefighter fatalities between 1900 and 2017

toria. The fires caused 173 deaths and injured over 100 people; more than 2000 houses were destroyed (Teague et al. 2010). A large proportion, 113 people, died inside a property while sheltering from the fire. At the time of death, 29% of people were sheltering, 24% were defending and sheltering, 15% were defending, and 20% were evacuating late (Blanchi et al. 2012).

Number of Fatalities per State 1900–2017

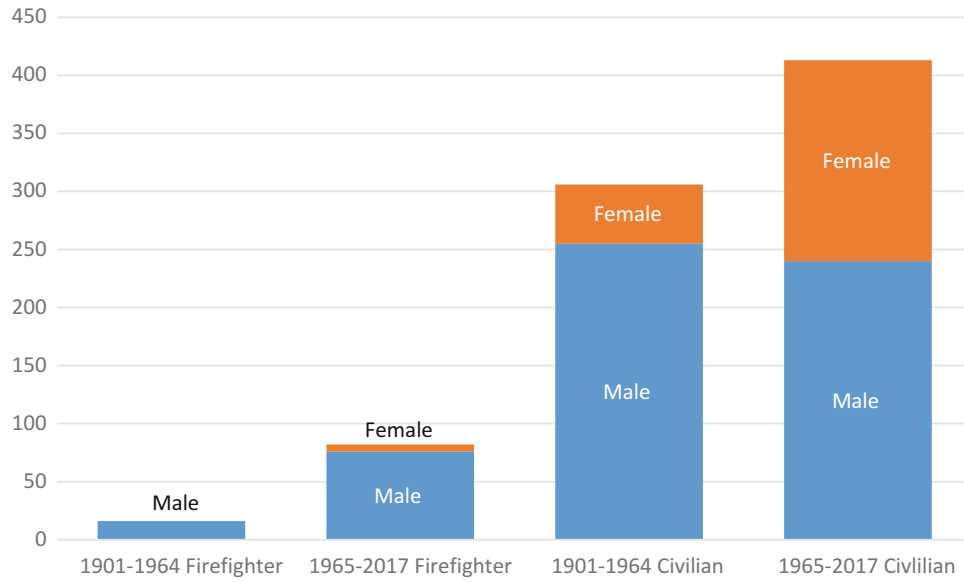
South Eastern Australia, including the State of Victoria and New South Wales, have experienced the largest number of losses (Table 1). The number of fatalities varies in each state depending on the States unique weather conditions, policies, building stock, population distribution, and vegetation characteristics.

Demographics

There has been an increase in female fatalities in recent years, with the proportion of females dying in recent fires significantly greater than the proportion in earlier fires (Fig. 2). The 2009 Black Saturday bushfire marks a change in fatalities from previous fires where most deaths occurred outside while defending and protecting asset (Haynes et al. 2010; Whittaker et al. 2017). Slightly more females died as a result of the fire compared to previous fires, with 58% male and 42% female. The age profile was similar to other fires (see Table 2).

Wildfires and WUI Fire Fatalities, Table 1 Number of fatalities by State – Firefighters and Civilians (between 1900 and 2017)

State	Firefighter	Civilian	Total
ACT		5	5 (1%)
NSW	41	101	141 (17%)
NT	2	3	5 (1%)
QLD	2	24	26 (3%)
SA	15	44	59 (7%)
TAS	2	67	69 (8%)
VIC	33	478	511 (60%)
WA	4	26	30 (4%)
Total	99	748	846 (1000%)



Wildfires and WUI Fire Fatalities, Fig. 2 Number of fatalities by gender between the period 1901–1964 and the period 1965–2017 (distinction between civilian and firefighters)

Wildfires and WUI Fire Fatalities, Table 2 Age and gender for the three time periods (all fatalities – civilians, firefighters, and non-directly related fatalities). (From Blanchi et al. 2012)

	1901–1964	1965–2011	1901–2011 (total)	Black Saturday fires
Total number killed	343	482	825	173
Male	272 (79%)	300 (62.3%)	572 (69.3%)	101 (58%)
Female	51 (14.9%)	173 (35.8%)	224 (27.2%)	72 (42%)
Unknown	20 (5.8%)	9 (1.9%)	29 (3.5%)	
Age				
0–9	32 (9.4%)	29 (6%)	61 (7.4%)	13 (8%)
10–19	31 (9.1%)	36 (7.5%)	67 (8.1%)	14 (8%)
20–29	33 (9.6%)	50 (10.4%)	83 (10.1%)	13 (8%)
30–39	29 (8.5%)	54 (11.2%)	83 (10.1%)	21 (12%)
40–49	34 (9.9%)	54 (11.2%)	88 (10.7%)	23 (13%)
50–59	24 (7.0%)	74 (15.3%)	98 (11.9%)	38 (22%)
60–69	27 (7.9%)	68 (14.1%)	95 (11.5%)	24 (14%)
70–79	20 (5.8%)	34 (7.0%)	54 (6.5%)	9 (5%)
80 and above	6 (1.8%)	31 (6.4%)	37 (4.5%)	18 (10%)
Unknown	107 (31%)	52 (11%)	159 (19.3%)	

Locations and Activities at the Time of Death

Information on the locations of fatalities, activities at the time of death, and weather conditions were also collated and analyzed by Haynes et al. (2010) and Blanchi et al. (2012). An overview is provided below and concerns fatalities from 1901 to 2011. The authors used a separation of the data to distinguish between the first and second half of the last century, providing an opportunity to compare demographic context, social behavior, and the prevalence of technologies (Blanchi et al. 2012).

Wildfires and WUI Fire Fatalities, Table 3 The location of fatalities over the three time periods. (From Blanchi et al. 2012)

Civilian	1901–1964	1965–2011	1901–2011 (total)
Inside structure	21 (7.1%)	167 (44.4%)	188 (27.9%)
Inside vehicle	11 (3.7%)	45 (12.0%)	56 (8.3%)
Open air	232 (77.8%)	158 (42.0%)	390 (57.8%)
Unknown	34 (11.4%)	6 (1.6%)	40 (5.9%)
Total	298 (100%)	376 (100%)	674 (100%)
Firefighters			
Inside structure	None recorded	None recorded	None recorded
Inside vehicle	None recorded	28 (51.9%)	28 (41.8%)
Open air	13 (100%)	25 (46.3%)	38 (56.7%)
Unknown	None recorded	1 (1.6%)	1 (1.5%)
Total	13 (100%)	54 (100%)	67 (100%)

The location of death was coded into four categories including inside structure, inside vehicle, open air, and unknown (Table 3). Table 3 shows that while most fatalities occurred outside in earlier fires, a greater proportion of fatalities occurred inside a structure or vehicle in recent fires.

Table 4 presents the activities of civilians prior to death. The majority of fatalities over the whole time period have occurred during late evacuation (30.4%), followed by sheltering inside a structure (24.8%), and defending a property outside (22.4%). This corroborates previous findings highlighting the danger of late evacuation (Krusel and Petris 1999; McArthur and Cheney 1967; McLennan et al. 2013; Whittaker et al. 2013). The main activities for the first half of the last century are late evacuation and defending a property outside which correlates well with the dominant location at the time of death for this time period (open air, see Table 3). In comparison, the most common activity over the more recent time period is sheltering inside (40.2%).

North American Fatalities

As in Australia, there is no single system of record for wildfire and WUI fire-related deaths in the United States, not even for wildland firefighter (WFF) fatalities. Data on US WFF fatalities are captured in several different systems of record (Table 5). Fatality data archived by the National Interagency Fire Center (NIFC) extend back to 1910, when there were at least 84 WFF fatalities from burnover/entrapment, including 78 deaths in a 1.2 million ha western wildfire episode known as the Big Blowup (Pyne 1982; NIFC 2019). The current NIFC archive is an updated, although less detailed, version of the National Wildfire Coordinating Group's historical wildland firefighter fatality dataset (NWCG 1997). Since 1987, those data have been sourced from the NWCG Safety Grams (NWCG SG), which track only line-of-duty deaths (LODD, i.e., during wildland fire response or work-capacity testing). Two other systems, the National Fire Protection Association Fire Incident Data Organization (NFPA FIDO) and the US Fire Administration Firefighter Fatality Incident Database (USFA FFID), currently track all on-duty WFF fatalities, including all LODD but also deaths occurring during other non-emergency work activities. Also included in the USFA FFID and increasingly accounted for in other systems are WFF fatalities that occur as the result of a heart attack or stroke within 24 h of arduous work-related activity.

Butler et al. (2017) compiled WFF fatality data for 2001–2012 from all of the sources listed in Table 5, except for the Incident Command System (ICS) 209 archive. An ostensibly complete accounting of all on-duty WFF fatalities for that period could only be obtained by com-

Wildfires and WUI Fire Fatalities, Table 4 Activities at the time of death for civilian fatalities. (From Blanchi et al. 2012)

	1901–1964	1965–2011	1901–2011 (total)
Late evacuation	111 (37.2%)	93 (24.8%)	204 (30.4%)
Defending property outside	90 (30.2%)	61 (16.3%)	151 (22.4%)
Inside property	18 (6.0%)	152 (40.2%)	168 (24.8%)
Travelling through the area unaware	22 (7.4%)	44 (11.8%)	66 (9.8%)
Waiting rescue	1 (0.3%)	6 (1.6%)	7 (1%)
Assisting firefighting operations	6 (2%)	2 (0.5%)	8 (1.2%)
Returned into burning building	2 (0.7%)	6 (1.6%)	8 (1.2%)
In an undefendable shelter (dugout, shed)	8 (2.7%)	3 (0.8%)	11 (1.6%)
Activity unknown at time of fatality	42 (14.1%)	9 (0.8%)	51 (7.6%)
Total	**298 (100%)**	**376 (100%)**	**674 (100%)**

Wildfires and WUI Fire Fatalities, Table 5 Sources of wildfire related fatality data for the US and scope of relevant information content

Source	Scope
Bureau of Labor Statistics Census of Fatal Occupational injuries (BLS CFOI)	All fatalities due to work-related injury. Does not account for medical—/illness-related deaths
Incident command system incident status summary, form 209 (ICS 209)	Responder and civilian fatality estimates made during active incidents, including large or otherwise significant wildfires
National Fire Protection Association Fire Incident Data Organization (NFPA FIDO)	All on-duty firefighter fatalities
National Institute for Occupational Safety and Health Fire Fighter Fatality Investigation and Prevention Program (NIOSH FFFIPP)	Subset of on-duty firefighter fatalities selected for thorough investigation
National Wildfire Coordinating Group Safety Grams (NWCG SG)	Line-of-duty WFF fatalities
US Fire Administration Firefighter Fatality Incident Database (USFA FFID)	All on-duty[a] firefighter fatalities

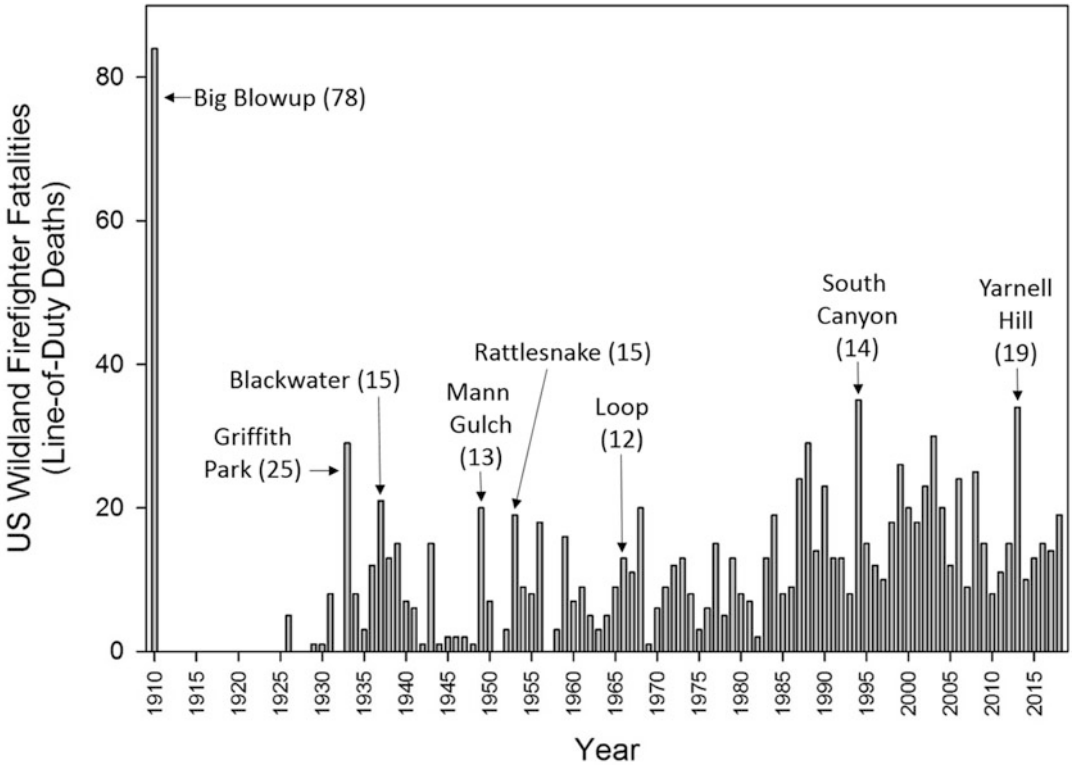
[a]Broadens the "on-duty" criterion to include fatalities that occur as the result of a heart attack or stroke within 24 h of arduous work-related activity

bining information from the NWCG SG, NFPA FIDO, and USFA FFID reporting systems. In doing so, Butler et al. (2017) identified 247 WFF fatalities over the 12-year period, or an average of ~20.6/year. The USFA, NWCG, and NFPA captured 223, 210, and 207 of those incidents, respectively (Butler et al. 2017). Counts from each of the three systems typically differed by 1–2 fatalities per year (Butler et al. 2017). However, fatality distributions by age, gender, cause, and type of worker were very similar across systems (Butler et al. 2017).

There is no single source of data on civilian fatalities attributable to wildland fires in the United States. Since 2014, the ICS 209 archive (FAMWEB 2019) has included estimates of civilian wildfire and WUI fire fatalities made during active incidents, but it is far from a complete record.

Distribution

Although the NIFC (2019) are purported to account just for LODD, the number of years in that archive is the greatest of the various sources of WFF fatality data. After adding in the latest year's NWCG SG fatality estimate (NWCG 2018) and aligning estimates for 1990–2006 with those published by Mangan (2007), there are a

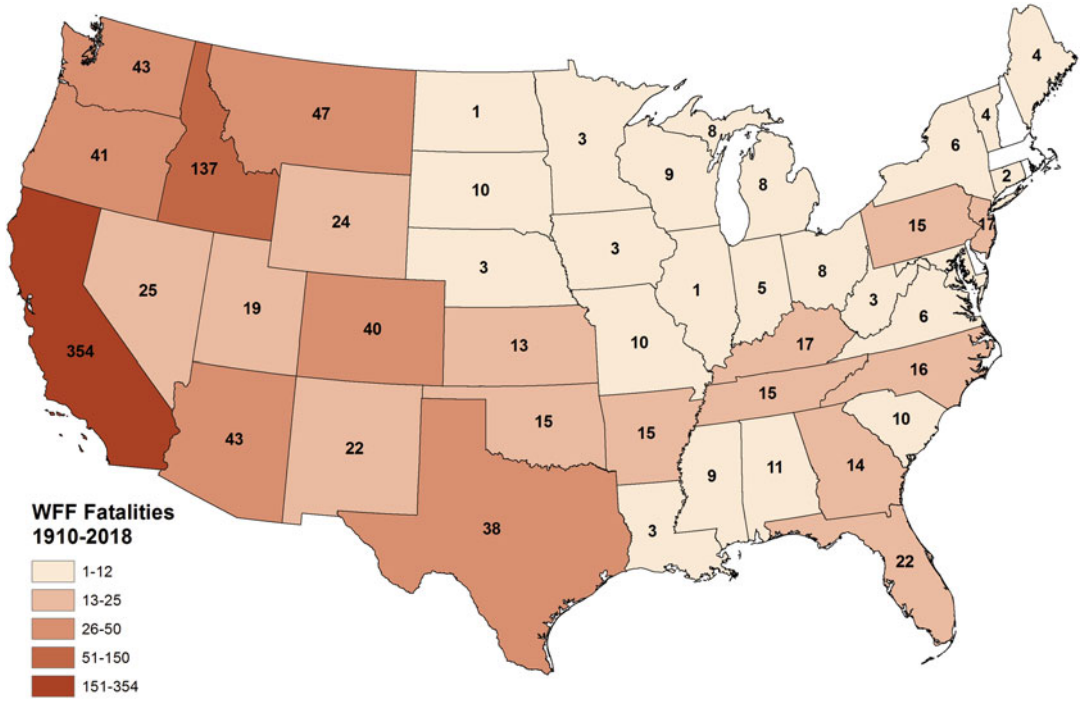


Wildfires and WUI Fire Fatalities, Fig. 3 Wildland firefighter fatalities (line-of-duty deaths) in the US, 1910–2018 (NWCG 1997, 2018; Mangan 2007; NIFC 2019). Fires with 12 or more deaths (due to burnover/entrapment) are listed with fatality numbers in parentheses

total of 1154 WFF LODD reported over the 109-year period 1910–2018 (Fig. 3). Of those, 1136 had specific locality (state) information reported, with 76% LODD occurring in the 14 western and south central states of the conterminous United States and over 30% in California alone (Fig. 4). The second largest number of LODD occurred in Idaho, which was the location associated with the 78 WFF fatalities from the Big Blowup of 1910 (Figs. 3 and 4). Since the Big Blowup, there have been 7 other US wildfires that killed 12 or more WFF, all due to entrapment/burnover (Fig. 3). The most recent was the 2013 Yarnell Hill Fire that claimed the lives of 19 WFF.

The ICS 209 archive includes reports of 57 wildland fires during the period 2014–2018 with civilian casualties. Of those 57 fires, 41 (72%) were reported as single-fatality events. Thirteen (81%) of the 16 multi-fatality fires occurred in California. While a complete accounting of all civilian casualties attributable to wildfires and WUI fires over even the most recent decade is not available, Thomas and Butry (2012) estimated that for the period 2002–2006, wildland fires within municipal jurisdictions resulted in 15 civilian fatalities and 88 civilian injuries per year.

The highest civilian casualty fire in that dataset is the Camp Fire of 2018, which burned through the town of Paradise, California, killing 85 people (Cal Fire 2019). The 2018 Camp Fire also tops California's list of deadliest fires on record, considering WFF and civilian fatalities combined (Cal Fire 2019, Table 6). Multi-fatality incidents in California and elsewhere in the United States are generally the result of fires that spread rapidly into WUI or otherwise developed areas under extreme (i.e., windy and dry) burning conditions that defy most suppression efforts (Keeley et al. 2004; Tedim et al. 2018; Nauslar et al. 2018). The wind-driven Camp fire grew to 40,000 ha



Wildfires and WUI Fire Fatalities, Fig. 4 Reported number of wildland firefighter fatalities (line-of-duty deaths, LODD) in the conterminous United States, by state, 1910–2018 (NIFC 2019; NWCG 2018). In addition, there were 18, 2, and 1 LODD in Alaska, Hawaii, and Puerto Rico, respectively, plus 8 LODD with the state-level locality unreported during this 109-year period

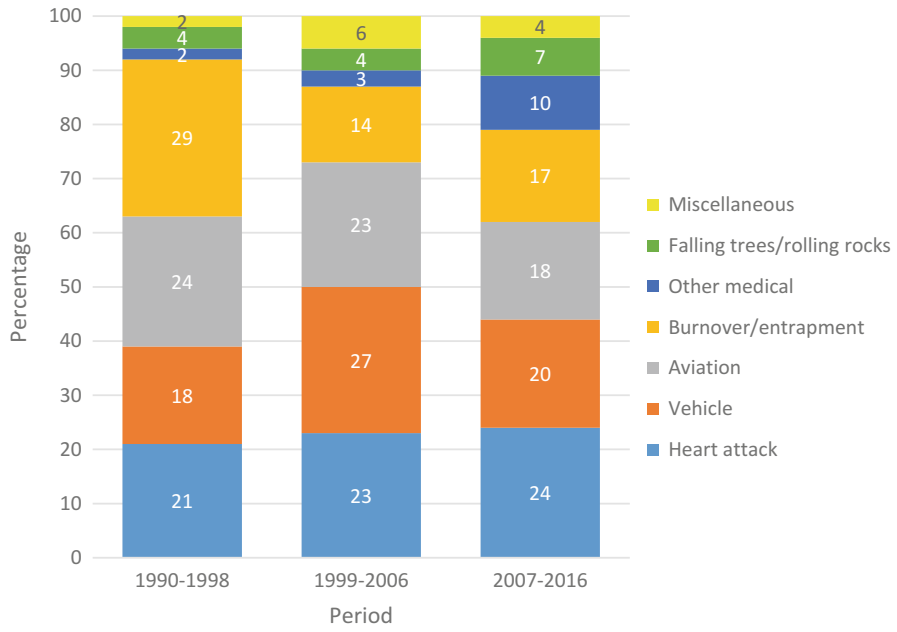
Wildfires and WUI Fire Fatalities, Table 6 Top 10 deadliest California wildfires and WUI fires (Cal Fire 2019). "Structures" include homes, outbuildings, and commercial properties destroyed. Fatality estimates include wildland firefighters and civilians

Fire name	Date	County	Hectares	Structures	Fatalities
Camp	November 2018	Butte	62,053	18,804	85
Griffith Park	October 1933	Los Angeles	19	0	29
Tunnel/Oakland Hills	October 1991	Alameda	647	2900	25
Tubbs	October 2017	Napa, Sonoma	14,895	5643	22
Cedar	October 2003	San Diego	110,579	2820	15
Rattlesnake	July 1953	Glenn	542	0	15
Loop	November 1966	Los Angeles	821	0	12
Inaja	November 1956	San Diego	17,767	0	11
Hauser creek	October 1943	San Diego	5320	0	11
Iron & alps complex	August 2008	Trinity	42,838	10	10

in its first 2 days, engulfing the forested town of Paradise (Inciweb 2018), destroying 80% of the town's buildings and trapping people in vehicles as they tried to evacuate with limited points of egress from the ridgetop community (Folkman 2018; St. John and Phillips 2018).

Causes

Aviation or vehicle use, medical events, and entrapment/burnover account for the majority (89%) of the WFF fatalities in the historical archive, 1910–2018 (NWCG 1997, 2018; Mangan 2007; NIFC 2019) and in the most recent



Wildfires and WUI Fire Fatalities, Fig. 5 Wildland firefighter fatalities by cause of death in the United States, 1990–2016 (NWCG 2017)

period of published analysis 2007–2016 (NWCG 2017). Using the broader on-duty WFF fatality criteria and data compiled from the NWCG SG, NFPA FIDO, and NIOSH FFFIPP, NWCG (2017) found that heart attacks were the most common cause of WFF fatalities between 2007 and 2016 (Fig. 5). The apparent uptick in heart attacks in 2007–2016 as compared to previous decades (Fig. 5) is due to a change in reporting criteria to capture all on-duty deaths, including fatalities that occur as the result of a heart attack or stroke within 24 h of arduous work-related activity. During the period 2007–2016, 22% of heart attack deaths among WFFs occurred after returning from the wildland fire incident.

During the period 2007–2016, heart attacks were the most common cause of fatalities among volunteer firefighters, WFF from the state fire service, and ground contractors, while vehicle accidents were the most common cause of death among federal WFFs (NWCG 2017). Most vehicle accidents were single-fatality events that involved rollovers or WFFs struck by vehicles (NWCG 2017).

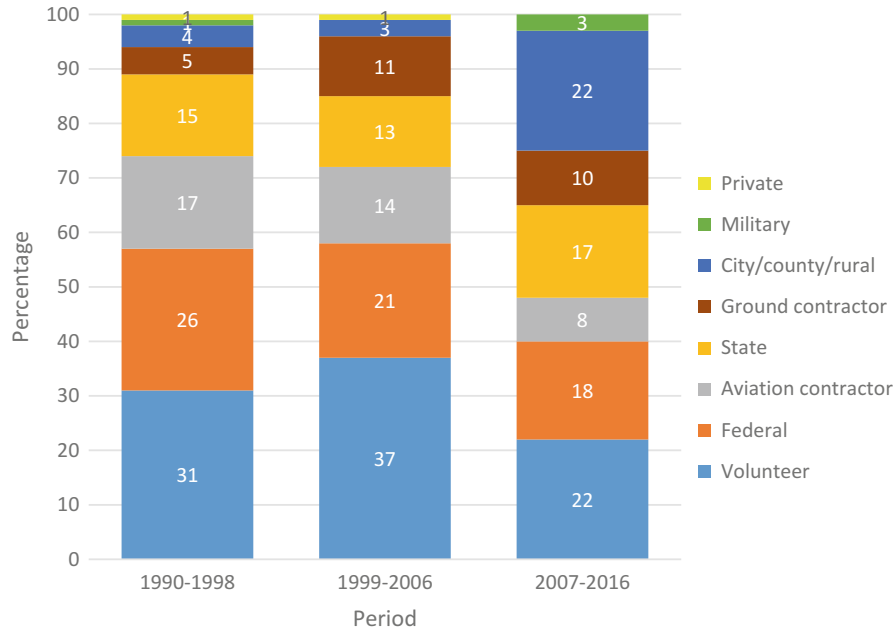
Demographics

During the period 1990–2016, there were more fatalities among volunteer WFFs than any other class of WFF (Fig. 6, NWCG 2017). There was an increase in city/county/rural WFF deaths during the period 2007–2016 as compared to previous decades largely due to a burnover/entrapment event on the 2013 Yarnell Hill wildfire that killed 19 WFF from a municipal (city) fire crew.

In their analysis of WFF fatality data from several systems of record for 2001–2012, Butler et al. (2017) found that most (94%) of WFF deaths occurred among males and 55–56% occurred in the >40- year age classes.

South European Fatalities

The systematic gathering of data regarding forest fire and WUI fire fatalities is not a common practice in Europe, and no official databases on civilian or firefighter's fatalities exist. Molina-Terrén et al. (2019) recently performed a detailed analysis of historical forest fire-related fatal incidents in Southern Europe, namely, Portugal,



Wildfires and WUI Fire Fatalities, Fig. 6 Wildland firefighter fatalities in the United States, by organization, 1990–2016 (NWCG 2017)

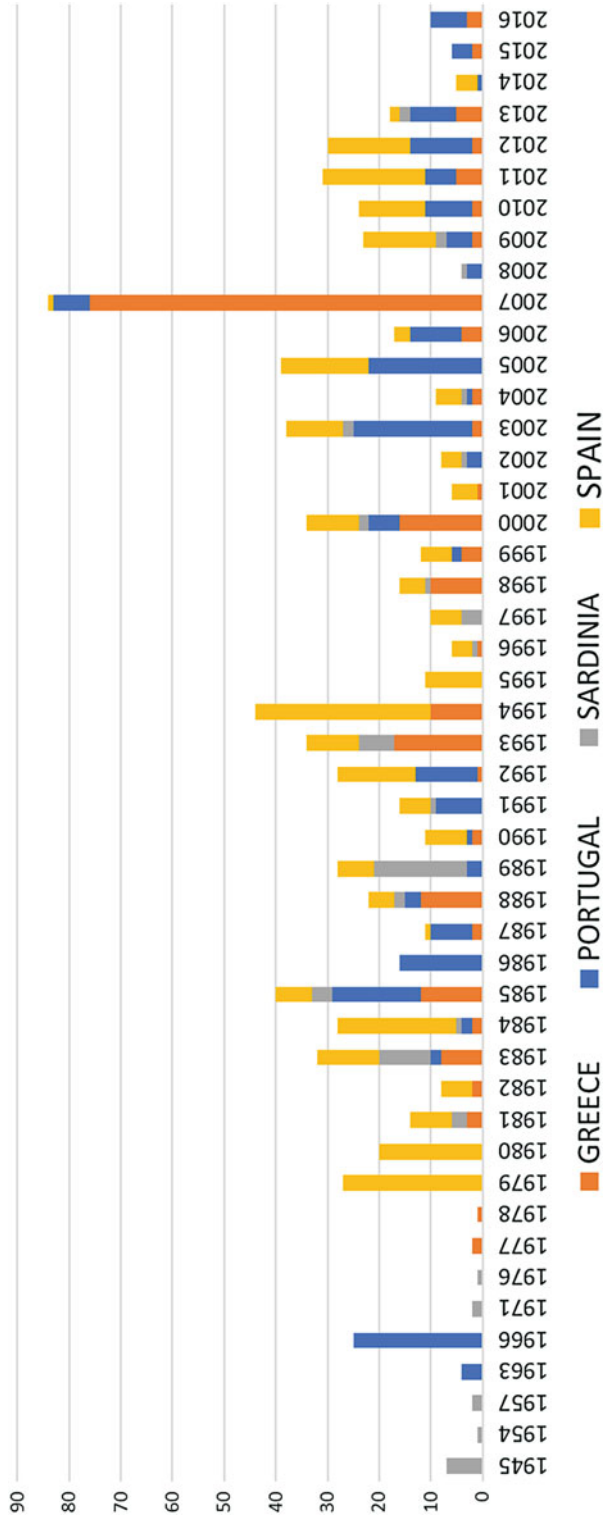
Spain, Greece, and the Italian Island of Sardinia, proposing what could be the basis for an official database covering European Union countries. The 2019 study did not include the most recent and most devastating forest fire episodes in Europe: the fires of 2017 in Portugal and 2018 in Greece with more than 200 fatalities. The authors summarize here the previous analysis of Southern Europe and present an overview of the fires in Portugal and in Greece.

Southern Europe Forest Fire and WUI Fire Fatalities

The full dataset used in Molina-Terrén et al. (2019) refers to different periods due to the absence of records or of incidents: 1977–2016 in Greece, 1945–2016 in Sardinia (Italy), 1979–2016 in Spain, and 1963–2016 in Portugal. The dataset contains a total of 865 deaths. The data used by the authors was collected from different sources, namely, national databases, where they existed (e.g., Spain), media (e.g., newspapers, TV), fieldwork (e.g., Portugal), and official or unofficial accidents reports. Figure 7 shows the distribution of fatalities per year and country. Since the late 1970s, there has been at least one fatality a year, contrary to the beginning of the analyzed period, where fatalities were less frequent, either because there were no accidents or because they were not recorded systematically.

There is no obvious pattern in the distribution of fatalities per country or year and, in many cases, particular episodes contribute to the majority of the fatalities in the region. Molina-Terrén et al. (2019) list a series of events with more than 20 fatalities:

- 2018, Mati (Greece, 102 fatalities)
- 2017, Central Region (Portugal, 53 fatalities)
- 2017, Pedrógão Grande (Portugal, 66 fatalities)
- 2007, Makistos–Artemida, Peloponnese (Greece, 30 fatalities), that fire season 78 fatalities were reported in separate incidents
- 1984, La Gomera, Canary Islands (Spain, 20 fatalities)
- 1979, Lloret de Mar, Girona (Spain, 21 fatalities)
- 1966, Sintra Mountains (Portugal, 25 fatalities)



Wildfires and WUI Fire Fatalities, Fig. 7 Forest fire- and WUI fire-related fatalities in Southern Europe, between 1945 and 2016, year with fires only from 1945 to 1976, then every year until 1976. (Adapted from Molina-Terrén et al. 2019)

France was not included in the south European analysis (Molina-Terrén et al. 2019), as little detailed data was currently available. The most devastating forest fire occurred in 1949, in the Landes region, and killed 82 people, between firefighters, volunteers, and soldiers. This remains one of the deadliest singular incidents in Europe (Deville 2009).

For simplicity, statistics on fatal incidents are presented here grouped in three periods: 1945–1975, 1976–2000, and 2000–2016. In Table 7, the authors present the distribution of the 865 registered deaths per country and per time period.

Greece and Portugal have similar figures overall, and Spain has the highest number of fatalities. As for Italy, this study only refers to the Sardinia Region, but from (outdated) official reports (Corpo Forestale dello Stato 2011), the authors observed 215 fatalities in the period 1978–2011, which seems to be similar to Portugal and Greece.

In terms of gender (Table 8), male victims make up five times the number of females in the entire period. In all countries there is a high number of civilians killed by forest fire and WUI fire (366 civilians, representing 42% of the total), with civilian fatalities outnumbering firefighters (280 firefighters, representing 32%). There are other deaths not included in either of the previous categories, mostly related to military personnel, or civil protection agents that do not belong to the firefighter category (219 fatalities, representing 25%).

The number of fatalities in WUI areas can be a good indicator of the absence of fuel management practices or rural abandonment. From the cases in which the previously referred study identified the environment of the accidents, 22.3% occurred in WUI areas and 41.3% in the wildland (36.4% could not be identified). The three recent European forest fire events not included in the Molina-Terrén et al. (2019) study are described below.

Wildfires and WUI Fire Fatalities, Table 7 Forest fire- and WUI fire-related deaths per country and time period

Country					
Period	Greece	Portugal	Sardinia (IT)	Spain	Total
1945–1975	0	29	12	0	41
1976–2000	105	81	55	231	472
2001–2016	106	122	9	115	352
Total	211	232	76	346	865

The Fires of June and October 2017 in Portugal

The Pedrógão Grande complex of fire events (Viegas et al. 2017), started on June 17, 2017, and lasted for almost a week, burning 45,000 ha. Almost 98% of that area was burnt during the first 2 days. Between 19 h00 and 22 h00 of June 17, 8700 ha of shrub, pine, and eucalyptus were consumed at an impressive rate of approximately 3000 ha per hour. During this period a firestorm developed when two of the main fire fronts joined producing several episodes of extreme fire behavior resulting in fatal accidents when most of the deceased tried to escape from the fire. In total 66 people lost their lives, 65 civilians and 1 firefighter. Only four people died at home, all of whom had mobility difficulties. On a short stretch of 400 m of road, 30 people died in a confusion of trapped or crashed cars, some inside their vehicles, others outside, after the cars crashed. In total, 31 persons lost their lives inside their cars, while trying to escape. Overall the victims were aged between 1 and 88 years old and were almost equally divided

Wildfires and WUI Fire Fatalities, Table 8 Forest fire- and WUI fire-related deaths per gender and activity

	Gender			Activity			
Period	Female	Male	N/A	Civilian	Firefighter	Other	Total
1945–1975	0	41	0	5	7	29	41
1976–2000	57	299	116	163	163	146	472
2001–2016	54	218	80	198	110	44	352
Total	111	558	196	366	280	219	865

Wildfires and WUI Fire Fatalities, Table 9 Victims gender and type of accident in Pedrógão fire complex from (Viegas et al. 2017)

	Type of accident				
Gender	Escaping from fire on foot	In vehicle	Indoors	Accidental entrapment	Total
Female	12	17	2		31
Male	18	14	2	1	35
Total	**30**	**31**	**4**	**1**	**66**

between females and males (Table 9). As Viegas et al. (2017) point out, the Portuguese Civil Protection warning system failed to inform citizens of the gravity of the developing fire. Also, the population were unprepared to reduce their risks and respond effectively.

This event remains the worst forest fire-related incident in terms of fatalities on record in Portugal.

On October 15, 2017, and late in the forest fire season, a series of very large fires burned more than 200,000 ha through the Central Region of Portugal. These fires were associated with abnormal severe meteorological conditions for the season due to the passage of Hurricane Ophelia off the Portuguese Coast, with temperatures above 30 °C and very strong winds. Viegas et al. (2019) describe in detail the fires and their impacts leading to 51 civilian fatalities: the fires of Lousã (15 fatalities), Oliveira do Hospital (23 fatalities), Seia (1 fatality), Sertã (2 fatalities), and Vouzela (10 fatalities). The number of fires that began on October 15 was above the response capacity of the Portuguese Civil Protection Agencies, with more than 500 registered fire events (Viegas et al. 2019).

As in Pedrógão Grande, many of the casualties occurred while people where running from the fire, either on foot or in a vehicle (Table 10), as they did not consider the houses a safe place to shelter (Viegas et al. 2019). Most of their houses remained unaffected. However, 17 of the fatalities occurred within the home, with most of the deceased sleeping at the time of their death as the fires reached their homes late at night.

In terms of area burned, the October fire events broke all records in Portugal, including the earlier June fires, doubling the average annual burned area in just 1 day. Multiple episodes of extreme fire behavior were observed, with intense spotting carrying the fire long distances (Viegas et al. 2019).

The Fires of July 2018 in Greece

On July 23, 2018 in Northeast Attica, Greece, a forest fire became the second deadliest worldwide forest fire event this century (Xanthopoulos and Athanasiou 2019). One hundred two people were killed and 150 injured. More than 1650 homes burned along with 1431 hectares of agro-forestry vegetation and urbanized land. A forest fire erupted on Mount Penteli at 16:41 in the northeastern part of the Attica region, 5 km west of the coast. It quickly picked up speed pushed by the strong wind from the mountain of Penteli toward the sea. Initial attack was delayed due to another fire in the region. The fire spread in light fuels, and it soon entered the settlement of Neos Voutzas and then the settlement of Mati, near the sea.

The area of Mati was characterized by thick Aleppo pine (*Pinus halepensis*) vegetation that surrounded numerous homes. People tried to evacuate toward the sea; however the high rate of fire spread and traffic jams that quickly formed in the narrow streets resulted in numerous fire entrapments. More than 20 people were trapped and died on a steep cliff above the sea. Others managed to find their way into the sea but suffered from the heat, smoke, and rough sea conditions. More than ten people drowned, while others were rescued by boats at a distance of kilometers from the coast (Xanthopoulos and Athanasiou 2019).

Wildfires and WUI Fire Fatalities, Table 10 Victims' gender and type of accident in the October 15 forest fire from Viegas et al. (2019)

Gender	Type of accident				Total
	Escaping from fire on foot	In vehicle	Indoors	Car accident (outside vehicle)	
Female	2	3	8	4	17
Male	13	7	9	5	34
Total	14	10	17	9	51

Conclusion

All countries described in this contribution have experienced recent catastrophic fires leading to high numbers of fatalities. The numbers of casualties in these fires are record breaking, and while climate change is a key driver, increasing development and populations in high fire prone environments is also an important factor (Moritz et al. 2014).

Recent civilian fatalities in the United States and Europe have been dominated by those trapped by fire as they tried to evacuate, and in Europe many homes that were evacuated survived. This mirrors trends seen in past large fires in Australia, hence the long-term Australian policy position to encourage people to prepare their homes and then either evacuate early or stay to defend (Tibbits et al. 2008). Following Black Saturday in 2009, which saw for the first time large numbers of Australians die in homes, there has been a shift in the messaging emphasis toward leaving early, rather than staying to defend, alongside improvements in education, forecasting, and warning provision (Whittaker 2019; Penman et al. 2013; Blanchi et al. 2014). In comparison with Australia, the advice in the United States and Europe remains dominated by evacuation measures. In the United States, there is an ongoing challenge with public safety in the expanding wildland-urban interface, increasingly resulting in large-scale evacuations in the face of wildfire (Cova 2005; Ronchi et al. 2019). In Europe, the 2017 fires in Portugal highlighted the need to prepare and better inform the general population about wildfire preparedness and response (Viegas et al. 2019). Similar measures are planned in Greece following the tragic experience of the 2018 fire fatalities in Eastern Attica.

No single system exists in any country worldwide to systematically record wildfire and WUI fatalities. In Australia and Europe, the datasets utilized to date have been compiled by researchers, and many are incomplete or incompatible for comparative analysis (Blanchi et al. 2012; Molina-Terrén et al. 2019). In the United States although detailed information on WFF fatalities exists, little detailed data on civilian fatalities has been captured, and the focus remains on firefighter fatalities. In order to develop evidence-based policy and practice, a dedicated and systematic approach to data collection on wildfires and WUI fire fatalities (civilian and WFF) is required globally.

Cross-References

- Computational Evacuation Modelling in Wildfires
- Defensive Actions and People Preparedness
- Evacuation
- Fire Data
- Public Education
- Stay and Defend

References

Blanchi R, Lucas C, Leonard J, Finkele K (2010) Meteorological conditions and wildfire-related house-loss in Australia. Int J Wildland Fire 19(7):914–926. https://doi.org/10.1071/WF08175

Blanchi R, Leonard J, Haynes K, Opie K, James M, Kilinc M, Dimer de Oliveira F, Van den Honert R (2012) Life and house loss database description and analysis Final

report. CSIRO, Bushfire CRC report to the Attorney-General's Department. CSIRO EP-129645
Butler C, Marsh S, Domitrovich JW, Helmkamp J (2017) Wildland firefighter deaths in the United States: a comparison of existing surveillance systems. J Occup Environ Hyg 14:258–270
Blanchi R, Leonard J, Haynes K, Opie K, James M, Oliveira FD (2014) Environmental circumstances surrounding bushfire fatalities in Australia 1901-2011. Environ Sci Policy 37:192–203
Cal Fire (2019) Top 20 deadliest California wildfires. Fact sheet https://calfire.ca.gov/communications/downloads/fact_sheets/Top20_Deadliest.pdf
Calkin DE, Short KC, Traci M (2019) California wildfires. In: Rubin CB, Cutter SL (eds) From disaster to catastrophe: U.S. Emergency Management in the 21st Century. CRC Press, Boca Raton
Cheney P, Gould J, McCaw L (2001) The dead-man zone – a neglected area of firefighter safety. Aust For 64(1):45–50
Corpo Forestale dello Stato (2011) Incendi Boschivi. Ministerio Politiche Agricole Alimentari e Forestali, Italy
Cova TJ (2005) Public safety in the urban-wildland interface: should fire-prone communities have a maximum occupancy? Nat Hazard Rev 6(3):99–108. https://doi.org/10.1061/(ASCE)1527-6988
Deville J (2009) L'incendie meurtrier – dans la forêt des Landes en août 1949, les Éditions des Pompiers de France, Paris
Diakakis M, Xanthopoulos G, Gregos L (2016) Analysis of forest fire fatalities in Greece: 1977–2013. Int J Wildland Fire 25:797–809
FAMWEB (2019) National fire and aviation management web application. https://fam.nwcg.gov/fam-web. Accessed May 2019
Folkman C (2018) California wildfires: the new abnormal. In: Risk management solutions, catastrophe review 2018. Newark, pp 3–5. https://www.rms.com/
Haynes K, Handmer J, McAneney J, Tibbits A, Coates L (2010) Australian bushfire fatalities 1900–2008: exploring trends in relation to the "prepare, stay and defend or leave early" policy. Environ Sci Pol 13(3):185–194. Retrieved from http://www.sciencedirect.com/science/article/B6VP6-4YNT93S-2/2/1345112f4c3c3a1815fffac6277a739e
Inciweb (2018) Final posting of inciweb for the camp fire. https://inciweb.nwcg.gov/incident/6250
Keeley JE, Fotheringham CJ, Moritz MA (2004) Lessons from the October 2003 wildfires in Southern California. J For 102:26–31
Krusel N, Petris SN (1999) A study of civilian deaths in the 1983 ash wednesday bushfire Victoria. CFA Occasional Paper No 1. Contry Fire Authority, Mt Waverley
Mangan R (2007) Wildland firefighter fatalities in the United States: 1990–2006. Publication PMS-841 of the National Wildfire Coordinating Group, Safety and Health Working Team, Boise, 28p
McArthur AG, Cheney NP (1967) Report on the southern Tasmanian bushfires of 7 February 1967. Forestry Commission Tasmania, Hobart
McLennan J, Elliott G, Omodei M, Whittaker J (2013) Householders' safety-related decisions, plans, actions and outcomes during the 7 February 2009 Victorian (Australia) wildfires. Fire Saf J 61:175–184
Molina-Terrén DM, Xanthopoulos G, Diakakis M, Ribeiro L, Caballero D, Delogu GM, Viegas DX, Silva CA, Cardil A (2019) Analysis of forest fire fatalities in Southern Europe: Spain, Portugal, Greece and Sardinia (Italy). Int J Wildland Fire 28(2):85. Retrieved from http://www.publish.csiro.au/?paper=WF18004
Moritz MA, Batllori E, Bradstock RA, Gill AM, Handmer J, Hessburg PF, Leonard J, Mccaffrey S, Odion DC, Schoennagel T, Syphard AD (2014) Learning to coexist with wildfire. Nature 515(7525):58–66.. Retrieved from. https://doi.org/10.1038/nature13946
National Interagency Fire Center [NIFC] (2019) Wildland fire fatalities by year. https://www.nifc.gov/safety/safety_documents/Fatalities-by-Year.pdf
National Wildfire Coordinating Group [NWCG] (1997) Historical wildland firefighter fatalities 1910–1996. Publication PMS-822 the National Wildfire Coordinating Group, Safety and Health Working Team, Boise, 45p
National Wildfire Coordinating Group (2017) NWCG report on wildland firefighter fatalities in the United States: 2007–2016. National Wildfire Coordinating Group PMS 841, Boise. https://www.nwcg.gov/sites/default/files/publications/pms841.pdf
National Wildfire Coordinating Group [NWCG] (2018) Safety Gram 2018, final. https://www.nwcg.gov/sites/default/files/committee/docs/rmc-sg-2018.pdf
Nauslar N, Abatzoglou J, Marsh P (2018) The 2017 North Bay and Southern California fires: a case study. Fire 1:18
Page WG, Butler BW (2018) Fuel and topographic influences on wildland firefighter burnover fatalities in Southern California. Int J Wildland Fire 27(3):141. Retrieved from http://www.publish.csiro.au/?paper=WF17147
Penman T, Eriksen C, Blanchi R, Chladil M, Gill A, Haynes K, Leonard J, McLennan J, Bradstock RA, (2013) Defining adequate means of residents to prepare property for protection from wildfire. Int J Disaster Risk Reduct 6:67–77
Pyne SJ (1982) Fire in America: a cultural history of wildland and rural fire. University of Washington Press, Seattle
Ronchi E, Gwynne SMV, Rein G, Intini P, Wadhwani R (2019) An open multi-physics framework for modelling wildland-urban interface fire evacuations. Saf Sci 118:868–880. https://doi.org/10.1016/j.ssci.2019.06.0
St. John P, Phillips AM (2018) Despite fire after fire, Paradise continued to boom – until California's worst wildfire hit. Los Angeles Times 13 November 2018. http://www.latimes.com/local/lanow/la-me-paradise-fire-development-warnings-20181113-story.html

Teague B, McLeod R, Pascoe S (2010) 2009 Victorian Bushfires Royal Commission final report: summary. Melbourne, State Government of Victoria

Tedim F, Leone V, Amraoui M, Bouillon C, Coughlan MR, Delogu GM, Fernandes PM, Ferreira C, McCaffrey S, McGee TK, Parente J, Paton D, Pereira MG, Ribeiro LM, Viegas DX, Xanthopoulos G (2018) Defining extreme wildfire events: difficulties, challenges, and impacts. Fire 1:9

Thomas DS, Butry DT (2012) Wildland fires within municipal jurisdictions. J For 110:34–41

Tibbits A, Handmer J, Haynes K, Lowe T, Whittaker J (2008) Prepare, stay and defend or leave early: evidence for the Australian approach. In: Handmer Haynes K (ed) In Community bushfire safety. CSIRO Publishing, Melbourne, pp 59–71. Retrieved from https://books.google.com.au/books?id=SbQr1pB3sQAC&printsec=frontcover&source=gbs_ViewAPI&redir_esc=y#v=onepage&q&f=false

Viegas DX, Ribeiro LM, Almeida MA, Oliveira R, Viegas MTP, Raposo JR, Reva V, Figueiredo AR, Lopes S (2013) Os grandes incêndios florestais e os acidentes mortais ocorridos em 2013. Centro de Estudos sobre Incêndios Florestais (CEIF/ADAI/LAETA)

Viegas DX, Almeida MF, Ribeiro LM, Raposo J, Viegas MT, Oliveira R, Alves D, Pinto C, Jorge H, Rodrigues A, Lucas D, Lopes S, Silva LF (2017) O complexo de incêndios de Pedrógão Grande e concelhos limítrofes, iniciado a 17 de junho de 2017. Centro de Estudos sobre Incêndios Florestais (CEIF/ADAI/LAETA)

Viegas DX, Almeida MA, Ribeiro LM, Raposo J, Viegas MT, Oliveira R, Alves D, Pinto C, Rodrigues A, Ribeiro C, Lopes S, Jorge H, Viegas CX (2019) Análise dos Incêndios Florestais Ocorridos a 15 de outubro de 2017. Centro de Estudos sobre Incêndios Florestais (CEIF/ADAI/LAETA)

Whittaker J, Haynes K, Handmer J, McLennan J (2013) Community safety during the 2009 Australian 'Black Saturday' bushfires: an analysis of household preparedness and response. Int J Wildland Fire 22(6):841–849. Retrieved from http://www.publish.csiro.au/paper/WF12010

Whittaker J, Blanchi R, Haynes K, Leonard J, Opie K (2017) Experiences of sheltering during the Black Saturday bushfires: implications for policy and research. Int J Disaster Risk Reduct 23:119–127

Whittaker J (2019) Ten years after the black saturday fires, what have we learnt from post-fire research? Aust J Emerg Manag 34:32–37

Xanthopoulos G, Athanasiou M (2019) Attica region Greece, July 2018. Wildfire 28(2):18–21

Xanthopoulos G, Viegas DX, Caballero D (2009) Recent forest fire related accidents in Europe. In: Viegas (ed) Recent forest fire related accidents in Europe (European C). European Commission Joint Research Centre Institute for Environment and Sustainability. Retrieved from http://forest.jrc.ec.europa.eu/media/cms_page_media/82/recent-forest-fire-related-accidents-in-europe.pdf