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# EXTREME FIRE BEHAVIOURS: SURVEYING FIRE MANAGEMENT STAFF TO DETERMINE BEHAVIOUR FREQUENCIES AND IMPORTANCE

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# ABSTRACT

## EXTREME FIRE BEHAVIOURS: SURVEYING FIRE MANAGEMENT STAFF TO DETERMINE BEHAVIOUR FREQUENCIES AND IMPORTANCE

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An understanding how bushfires cause damage is important if they are to be effectively managed. Extreme fire behaviours (EFBs) are phenomena that occur within intense fires that have been shown to contribute greatly to their to impacts. However, there exists little understanding regarding how often particular EFBs occur, how these contribute to fire behaviour and what importance should be allocated to each in the development of models for decision support. To address this problem, we surveyed fire fighters from fire and land management agencies in Australia regarding their experiences with EFBs. All fires greater than 1000 ha in the period 2006-2016 were considered in the survey. Representatives were asked which, if any, EFBs they had observed and whether there was any documentation to support these observations. We found that EFBs are common in large fires. In more than 60 % of case studies, each bushfire had two and more EFBs simultaneously (or one after another). Our survey indicated that Spotting, Crown fires, Pyro-convective events, Eruptive fires and Conflagrations are the most commonly observed EFBs, and so should be a priority for research. The relative commonness of direct evidence available for EFBs is indicative that there should be the potential for further study of these phenomena.

# INTRODUCTION

Extreme bushfires create conditions that have disproportionate risk to environmental and human assets. These fires can have significant consequences, particularly relating to the loss of life. In 2017 alone, 11 people were killed in Chile (1); 64 people were killed in Portugal (2); and 42 people were killed in California, USA (3). The trend for extreme bushfires - fires that require more people, more equipment, and greater commitment of financial resources - appears to be increasing every year (4–7).

Extreme fire behaviours (EFBs) are localised phenomena that occur during bushfire that are greatly alter their behaviour. These can include mass spotting, pyro-convective events and conflagrations. EFBs can significantly influence the intensity, rate of growth and impact of bushfires (8–11). They are anecdotally common in large fires, however there has been limited research quantifying their nature, importance and occurrence. In part, this may be due to the challenges with observing rare complex phenomena that occur under dangerous conditions.

A lack of a clear understanding of the importance of EFBs in defining damaging fire behaviour has provided challenges in how to prioritise their research. To understand the importance of EFBs in fire behaviour, we initially need to understand how frequently they occur in order to prioritise future research effort. We use an expert elicitation approach to determine the frequency of occurrence of nine recognised extreme fire behaviours in Australian fires larger than 1000ha.

# METHODS

EFBs have been reported to be a feature of extreme fires. To collect data on these, we considered all fires greater than 1,000 ha in Australia that occurred between 2006 and 2016. We approached representatives from management agencies responsible for fire response in each state (in Australia forest and fire management is predominantly done at a state level) via email and telephone and asked them to complete a guided survey. For each fire, we asked which (if any) EFBs had been observed (Table 1) and what data there may be to support this. The EFBs we asked about were: Spotting, Crown fires, Pyro-convective events (PyroEvs), Eruptive fires, Conflagrations, Jump fires, Fire tornados/whirls, Fire channelling and Downbursts.

| EFB | Definition |
|---|---|
| Spotting | Spotting is a behaviour of a fire producing sparks firebrands or embers that are carried by the wind and which start new fires beyond the zone of direct ignition by the main fire (12). |
| Fire tornado/whirls | A fire tornado/whirl is a spinning vortex column of ascending hot air and gases rising from a fire and carrying aloft smoke, debris, and flame. Fire whirls range in size from less than one foot to over 500 feet in diameter. Large fire whirls have the intensity of a small tornado (12). |
| Fire channelling | Fire channelling is a rapid lateral fire spread across a steep leeward slope in a direction approximately transverse to the background winds, in addition to the usual downwind direction (13). |
| Jump fires | Jump fire/Junction zones are associated to the merging of the fire fronts making a small angle between them producing very high rates of spread and with the potential to generate fire whirls and tornadoes (Viegas 2012). |
| Eruptive fires | Eruptive fires is are a fires that occur usually in canyons or steep slopes and are characterised by a quick rapid acceleration of the head fire rate of spread (14). |
| Crown fires | Crown fire are fires that advances in the tree crowns (NWCG 2017). |
| Conflagrations | Conflagration are raging, destructive fire s. Often used to connote such a fire with a moving front as distinguished from a fire storm (NWCG 2017). |
| Downbursts | Downbursts are downdrafts associated with pyro- cumulus clouds that induces an outburst of damaging strong winds on or near the ground. These winds spread from the location of the downburns and may result in fire spread into the prevailing wind direction (15). |
| PyroEvs | A Pyro-convective event is an extreme manifestation of a pyrocumulus cloud, generated by the heat of a wildfire, that often rises to the upper troposphere or lower stratosphere (16). |

TABLE 1 EXTREME FIRE BEHAVIOURS FOCUSED ON IN THIS STUDY

Data were categorised into three types: direct measurements (linescans, images, video, etc.), indirect data (weather records, etc.) and the data based on anecdotal evidence (observations recorded in situation reports, etc.).

The survey was structured to include all fires >1000 ha that had occurred in the relevant state.

Obtained data were analysed regarding to frequency of EFBs, quantity of EFBs per fire and confidence level of data.

# RESULTS AND DISCUSSION

Responses were received from New South Wales (NSW), Victoria (VIC), South Australia (SA) and Tasmania (TAS). Information on EFBs was received for a total of 96 fires among 934 fires surveyed (~10 %) (Table 2). It should be noted, that it was impossible to accurately calculate the percentage of fires with EFBs, interviewees could only answer for fires that they were familiar with. Therefore, a 10 % is likely to be a conservative estimate.

| Data type | Spotting | Fire tornado/whirls | Fire channelling | Jump fires | Eruptive fires | Crown fires | Conflagrations | Downbursts | PyroEvs | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Direct | 32 | 3 | 2 | 4 | 13 | 22 | 14 | 2 | 27 | *119* |
| Indirect | 22 | 0 | 1 | 7 | 13 | 20 | 4 | 2 | 5 | *74* |
| Anecdotal | 18 | 2 | 1 | 1 | 4 | 18 | 6 | 1 | 4 | *55* |
| Total | *72* | *5* | *4* | *12* | *30* | *60* | *24* | *5* | *36* | *248* |

TABLE 2 EXTREME FIRE BEHAVIOURS. TALLY OF EXTREME FIRES IN DEPENDS ON THE DATA TYPE

All EFBs were recorded at least four times with spotting being observed most frequently (72 times). Table 1 shows that the Fire tornado/whirls (n=5), Fire channelling (n=4) and Downburst (n=5) were observed the fewest times.

Analysis of the relative frequency of various EFBs showed that the percentage of occurrence of each EFB per fire. Spotting and Crown fires were the most frequent EFBs, making up a total of 53 % of all EFB observations. PyroEvs, Eruptive fires and Conflagrations were observed to have similar frequencies of occurrence, accounting for 37 % of the remaining observations. Jump fires, Fire tornado/whirls, Fire channelling and Downbursts combined accounted for 11 % of EFBs in total.

Spotting, Crown fires, PyroEvs, Eruptive fires and Conflagrations were the most frequent EFBs observed. They can be more easily identified and detected and fire managers are more likely to be familiar with them in contrast to less frequently occurring EFBs. One third of fires in this study had at least one EFB observed. Two and more EFBs were recorded in 64 % of these fires. Therefore, their interactions could have complimentary effects on fire behaviour, e.g. PyroEvs can facilitate long distance Spotting and Fire tornados/whirls. Consequently, the potential interactions of these phenomena should be a focus of further investigation.

Roughly half of all observations were recorded as direct data; 48 %. Indirect and anecdotal data were less common but similar proportions (30 % and 22 % respectively). For each EFB, the percentage of direct data observations was higher in all cases than anecdotal data. Despite this, there have been few studies devoted to analysis of EFBs. The number of events where EFBs are supported by direct data indicate that there is great potential for future quantitative study.

## SUMMARY

More effort is required to understand, describe and utilize EFBs. We found that EFBs occur frequently in fires greater than 1000 ha and often with multiple EFBs per fire. Given their commonness, the recognition of EFBs in fire behaviour modelling may be important if we want to accurately estimate fire impacts. Our survey indicated that Spotting, Crown fires, PyroEvs, Eruptive fires and Conflagrations are the most commonly observed EFBs, and so these should be the highest priority in determining which EFBs to research. The relative commonness of direct evidence available for EFBs is indicative that there should be data available for the development of models.

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