Background briefings on emerging issues for fire managers from AFAC and Bushfire CRC.

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FIRE NOTE

TOPICS IN THIS EDITION
- SMOKE
- TECHNOLOGY
- INFORMATION AND WARNINGS

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ASSESSING SMOKE EXPOSURE FROM BUSHFIRES AND PRESCRIBED BURNS

This study provides a better understanding of smoke exposure risks from both bushfires and prescribed fires.

Photo: CFA Communities and Communication

SUMMARY

Across Australia, prescribed burning is a management tool to mitigate the risk from bushfires. However the health impacts of the smoke it generates is a major public issue. Balancing the health risks from smoke against the risk to life and property from bushfire, and minimising the risk from prescribed burning, are challenges for the agencies charged with meeting large prescribed burning targets. But how significant are smoke risks from bushfires and how do they compare with those from prescribed fires?

As part of the Fire Impact and Risk Evaluation Decision Support Tool (Fire DST) project, a health risk exposure framework for bushfire smoke has been developed to answer this question. The framework was applied to three contrasting fire events of the past decade: the 2006/2007 Victorian Alpine fire, the Kilmore East fire on Black Saturday (7 February 2009), and a series of high-intensity, prescribed burns in the Huon Valley, Tasmania, in April 2010.

The study demonstrated that the impact on regional populations from particulate matter (PM) in the smoke could be severe; in the extreme it could be a much greater public health hazard than the direct risks at the fire front. Bushfire emissions of PM can be enormous and fire is often the dominant source of particulate pollution, occasionally outstripping industrial sources by orders of magnitude.

However, the key issue is not the total emission of PM, but the extent to which it mixes back into the atmosphere's surface layer and the length of time that PM concentrations remain high around population centres. These are determined by fire duration and the patterns of smoke dispersion. The greatest health impact was from the 2006/2007 Alpine fire, which burned 1.1 million hectares over a period of 60 days. Most of the Victorian population, including Melbourne, was impacted. The model indicates that 84 additional deaths may have occurred due to the health impacts from this fire.

ABOUT THIS PROJECT

This *Fire Note* reports in more detail on the smoke dispersion modelling work undertaken as part of the Fire Impact and Risk Evaluation Decision Support Tool (Fire DST) project. An overview of Fire DST is provided in *Fire Note 109*.

AUTHOR

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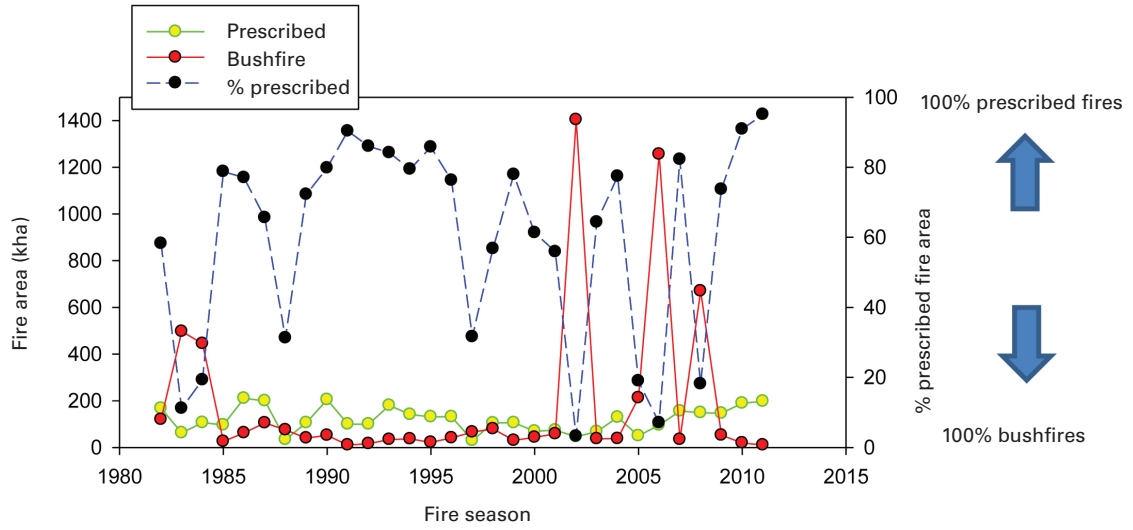
FIGURE 1: TOTAL AREA BURNT BY BOTH PRESCRIBED FIRE AND BUSHFIRE IN VICTORIA IN THE LAST 30 YEARS



Annual area of prescribed fire and bushfire in Victoria, and the fraction of total annual fire area that is prescribed.

CONTEXT

Bushfires emit large quantities of smoke, consisting of particles and gases, to the atmosphere. This smoke reduces visibility, influences atmospheric photochemistry (chemical changes caused by light) and can be inhaled into the deepest parts of the lungs. This can be hazardous to human health.

BACKGROUND

The potential negative health impacts from smoke particles are well known.

Particles are measured in micrometres, denoted by µm; one µm is one thousandth of a millimetre. Particle mass is commonly defined by two size classes: PM10 (particulate matter with a particle diameter less than 10 µm) and PM2.5 (PM with a particle diameter less than 2.5µm). Because fine particles can penetrate deeply into the lungs, the health impact per unit of PM2.5 concentration is generally greater than the impact from PM10, which includes larger particles that are captured in the nose and upper respiratory tract. More than 90% of smoke PM is in the PM2.5 size class.

The relationship between particle mass and negative health outcomes is well established. Decreased lung function, along with increases in respiratory symptoms, chronic obstructive pulmonary disease, cardiovascular and cardiopulmonary disease, and mortality are among the well-known impacts. Those most at risk are the elderly, the young, those with existing illnesses and people who are exposed to smoke for extended periods. If the smoke is widespread, the population health risk may be considerable.

The economic, health and social costs of these impacts can be substantial and, consequently, smoke management is now a major issue for fire agencies. The exposure risks vary widely with the type of fire event and its location, and range from extensive fumigation of populations in south eastern Australia from fires that persist for weeks, through to localised impacts from small fires.

END USER STATEMENT

As any responsible land manager is aware, knowing the impact of your management decisions is a critical need. Smoke from planned burning is a major public concern for health and social values, so our decisions on where and when to burn need to be robust and transparent. We cannot just rely on issuing warnings to the public 'that they may experience smoke'; we need to know what the possible impacts from smoke are, informing us to what mitigation measures can be taken.

The window for conducting planned burning is largely weather dependent, with spring and autumn providing the best opportunities. This means an increasing amount of burning needs to occur over a relatively short period of time. Smoke management is a major consideration in scheduling our burning operations as we attempt to balance health and social impacts, with the anticipated risk reduction from planned burning to communities from damaging bushfires.

This practical research by Mick and the team will allow land managers and planners to model the likely impact of smoke from planned burning operations. Adding this knowledge to our 'tool box' will significantly inform decision making and our approach to mitigation of the negative impacts to the health of our communities.

– Andrew Bennet, Planned Burning Community Engagement Manager, Department of Environment and Primary Industries, Victoria

BUSHFIRE CRC RESEARCH

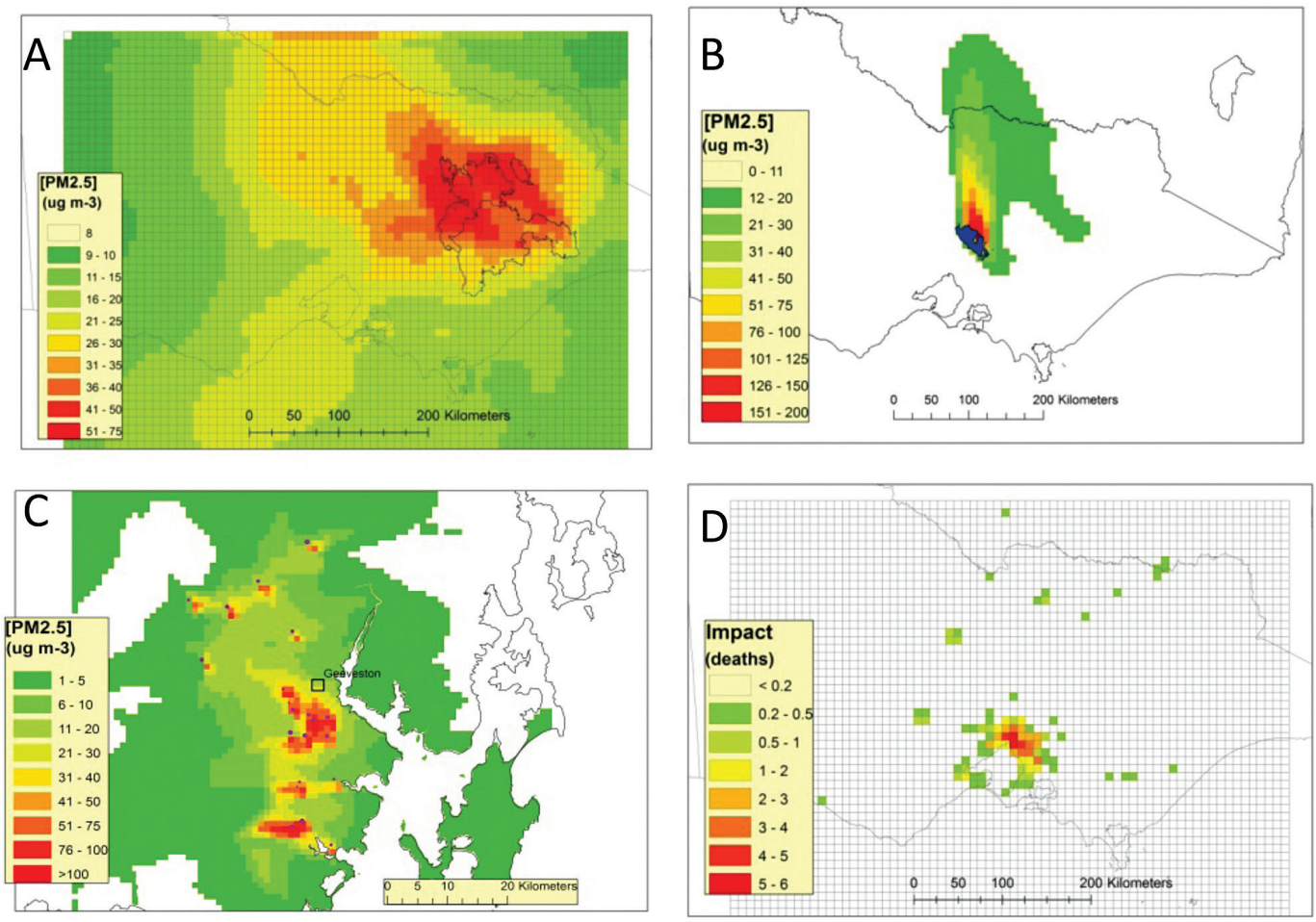
Statistics from annual reports of Victorian fire agencies show that from 1982-2012, the area of the state annually burned by prescribed fire and bushfire has averaged 120,000 hectares and 186,000 hectares respectively. This equates to 1.5% and 2.4% respectively of the 7.8 million hectares of public land. Note the figures for bushfire are skewed dramatically by four large bushfires. On average, the median amount of land burnt by prescribed burning each year is approximately 70% of the total land burnt. For 22 of the years in the date range, the area of prescribed burning has exceeded the area of bushfire, on average by a factor of 3.5 (see figure 1, above).

Therefore, for most of the time, the smoke impact was mostly from planned burns. On rare occasions (four events in 33 years), there were extreme bushfires. While low intensity fires dispersed smoke into the lower atmosphere, creating the likelihood of local surface impact, high intensity fires developed convection columns that distributed smoke through the daytime convective boundary layer and into the troposphere. These plumes were likely to have been widely dispersed.

Three case studies were undertaken to determine the likely health impacts. They were:

1. The Victorian Alpine fires of 2006/2007, which burned 1.2 million hectares and 58 million tonnes of fuel between 8 December 2006 and early February 2007.
2. The Victorian Kilmore East fire on Black Saturday, 7 February 2009. This

FIGURE 2 – MEAN SURFACE CONCENTRATIONS OF PM2.5



▲ Mean surface concentrations of PM2.5 during the bushfires at A: Alpine fires (case study one); B: Kilmore East (case study two); and C: Huon Valley (case study three); D: Health impacts (additional deaths due to smoke) from Alpine fires.

fire burned 93,000 hectares of forest and urban interface and approximately three million tonnes of fuel.

3. A series of high-intensity regeneration burns were ignited in the Huon Valley, Tasmania, between 16 and 19 April 2010. Fifty-six logging coupes totalling 500 hectares and 50,000 tonnes of fuel were burnt. Details are given in Meyer *et al.* (2011) and Reisen *et al.* (2013).

The impacts have been calculated using a health risk exposure framework. This framework combines emissions from the fires, chemical transport modelling (to see where the smoke goes) and information on where people are located (to calculate the impact of smoke). Emissions from the fires are used to drive the chemical transport model and from this, the spatial distribution of surface PM2.5 is calculated. When combined with population density, exposure can be calculated and a risk determined.

RESEARCH OUTCOMES

The populations of both rural Victoria and the Huon Valley are sparse, with widely spaced regional cities and towns. The exception is Melbourne, which houses most of Victoria's population. The Kilmore East fire (case study two) was slightly beyond the northern rural/urban interface of Melbourne; the Alpine fire (case study one) was 200 kilometres to the north east. The fires in the Huon Valley (case study three) were south of Geeveston, and in the upper reaches of the Huon River, north east of Geeveston and isolated from it by the main ridge. The closest logging coupes were six kilometres from Geeveston (see Figure 2, above).

Each plume was modelled, with the average PM2.5 concentrations for the full duration of each of the case studies presented in Figure 2. In all cases the PM2.5 concentrations were highest near the fire source, but extended at lower concentrations over large areas of all domains.

The Alpine bushfire impacted the whole of Victoria to some degree; 30% of the total state had average PM2.5 concentrations that breached the national air quality limit of 25 µg m^{-3} (i.e. 25 micrograms of particles per cubic metre of air). The modelled plume mostly impacted an area north west of the source but with a spur extending south over Melbourne, potentially exposing a large population to the hazard. The smoke impact from the Kilmore East bushfire was similarly widespread, affecting 750,000 hectares north of the fire. However, the extreme impacts persisted for only a day in the model, and significantly affected only one regional city (Shepparton). The modelled plume in the Huon Valley prescribed burns were also extensive, but dispersed to the south, away from the populated areas, and there was no indication that smoke persisted or was trapped in the valley.

Table 1 (page 4) shows the health risks resulting from the impact of dispersed PM2.5 on the populations of the three case studies. The long duration and widespread dispersion of PM2.5 in case study one (Alpine fire) posed a major risk to health. Assuming the validity of the risk factor applied here, the model estimated that 84 additional deaths could have resulted from the event, mostly associated with the plume impacting on Melbourne (Figure 2D). However, more recent studies suggest that morbidity and mortality risks were probably several times greater. Even with this conservative estimate, the estimated health impacts were greater than all other risks to people during the 2006/2007 Alpine fire, and the number is

TABLE 1: RELATIVE HEALTH IMPACTS OF THE CASE STUDY FIRES

Fire	Start date	Duration of smoke impact (days)	Area (km^2)	Emission (k t C)	Smoke impact zone			
					Area (km^2)	Population (1000s)	Baseline (deaths y^{-1})	Impact (deaths)
Alpine	8/12/2006	60	11,400	28,700	212,600	5,370	34,611	84
Kilmore East	8/02/2009	1	925	1,340	50,200	270	1,745	0.10
Huon Valley	16/04/2010	6	5.5	25	1,275	4.36	30	0.015

significant even in comparison to the Black Saturday fires, which caused 173 deaths. Therefore the concerns about risks from smoke are fully justified. How universal is the risk?

Case studies two (Kilmore East) and three (Huon Valley) show that the risks are event specific. In both these cases the impacts were minor. This was not because the emissions were small, but because the duration of the smoke plumes were short. The health risks do not scale with total carbon emission, but depend on the details of the dispersion pattern. The health risk per unit PM2.5 emission from the 2006/2007 fires was five times the Huon Valley burns and 40 times the Kilmore East fire. Much of the public perception of health risks from smoke is based on emission rate but, clearly, emission rate alone is a poor indicator of health impact. The critical factor is the dispersion pattern. With persistent events, dispersion and impact patterns reflect the monthly climate, but for short events the patterns are determined by the weather on the day. Fortunately, for both of these fires, the smoke was dispersed across regions with low populations.

HOW COULD THE RESEARCH BE USED?

The imperative to increase the area burned annually in Victoria to 400,000 hectares per year, coupled with the short prescribed burning season, presents complex scenarios. It means that for some jurisdictions, prescribed burning could emulate the scale of large bushfire events with respect to smoke production and its regional impact. Managing these fires to avoid significant health impact will be a growing challenge for managers, who will increasingly rely on smoke dispersion modelling.

REFERENCES /FURTHER READING

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Meyer CP, Reisen F, Keywood M and Crumeyrolle S, 2011, Impacts of smoke from regeneration burning on air quality in the Huon Valley, Tasmania, final report to Forestry Tasmania, CSIRO Marine and Atmospheric Research.

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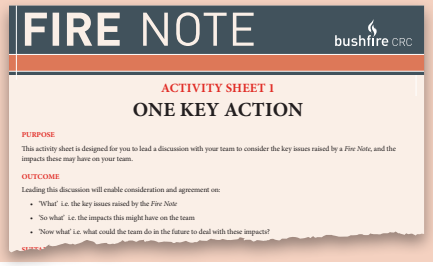
NOW WHAT?

What three things stand out for you about the research covered in this *Fire Note*? What information can you actively use, and how? Tools are available at www.bushfirecrc.com/firenotes to help, along with activities you can run within your team.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ACTIVITY SHEET 1

ONE KEY ACTION

PURPOSE

This activity sheet is designed for you to lead a discussion with your team to consider the key issues raised by a *Fire Note*, and the impacts these may have on your team.

OUTCOME

Leading this discussion will enable consideration and agreement on:

- 'What' i.e. the key issues raised by the *Fire Note*
- 'So what' i.e. the impacts this might have on the team
- 'Now what' i.e. what could the team do in the future to deal with these impacts?

FUTURE DIRECTIONS

The study has demonstrated that smoke impact on regional populations can, on occasions, be the greatest risk from a fire event, far outweighing the direct risks at the fire front. However, new modelling approaches and applications of extant modelling systems have been developed to assist fire managers and planners to limit these risks. The authors will continue their work in this area.

Smoke dispersion models are computationally intensive, and are not currently in a form that can be incorporated directly in the Fire DST proof of concept simulation system for tactical applications. However, a current project developed in part from the Fire DST experience may within the next three years deliver a modelling framework suitable for operational planning. It involves adapting the United States modelling framework, BlueSky, to southern Australia. Contact Mick Meyer for more information.

Fire Notes were published jointly by the Bushfire Cooperative Research Centre (Bushfire CRC) and the Australasian Fire and Emergency Service Authorities Council (AFAC). This Fire Note was prepared from available research at the time of publication to encourage discussion and debate. The contents of the Fire Note do not necessarily represent the views, policies, practices or positions of any of the individual agencies or organisations who were stakeholders of the Bushfire CRC.

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AFAC is the peak body for Australasian fire, land management and emergency services, creating synergy across the industry. AFAC was established in 1993.