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

FIRE NOTE

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FIRE DEVELOPMENT, TRANSITIONS AND SUPPRESSION: AN OVERVIEW

▲ An experimental fire burning in the CSIRO Pyrotron in Canberra. The facility allows free-burning fires to be studied under repeatable conditions in safety.

SUMMARY

All bushfires start small. Understanding how they progress from ignition to conflagration, from surface fire to high intensity crown fire, is critical to planning appropriate suppression strategies and issuing public warnings. This project is investigating factors influencing the transport of firebrands, the initiation of spot fires from firebrands and the growth and development of these fires. It is studying the behaviour of a fire as it transitions into, and consumes different layers, of fuel during its development. The occurrence patterns of fires and the productivity of suppression resources is also being studied. From this knowledge, predictions about the number, size, shape, extent and intensity of fire can be used to construct models to determine the most effective allocation and deployment of suppression resources, on both a seasonal and incident basis.

ABOUT THIS PROJECT

Bushfire CRC Program: *Managing the Threat*.
Project: *Fire Development, Transitions and Suppression*.

AUTHORS

Dr Andrew Sullivan, Dr Miguel Cruz, Dr Peter Ellis, Mr Jim Gould, Dr Matt Plucinski, Bushfire Dynamics and Applications team, CSIRO Ecosystem Sciences and CSIRO Climate Adaption Flagship.

BACKGROUND

Understanding the rapidly changing demands for suppression and allocation of resources will provide fire managers with greater confidence in pre-season planning and incident management, particularly during multiple fire events.

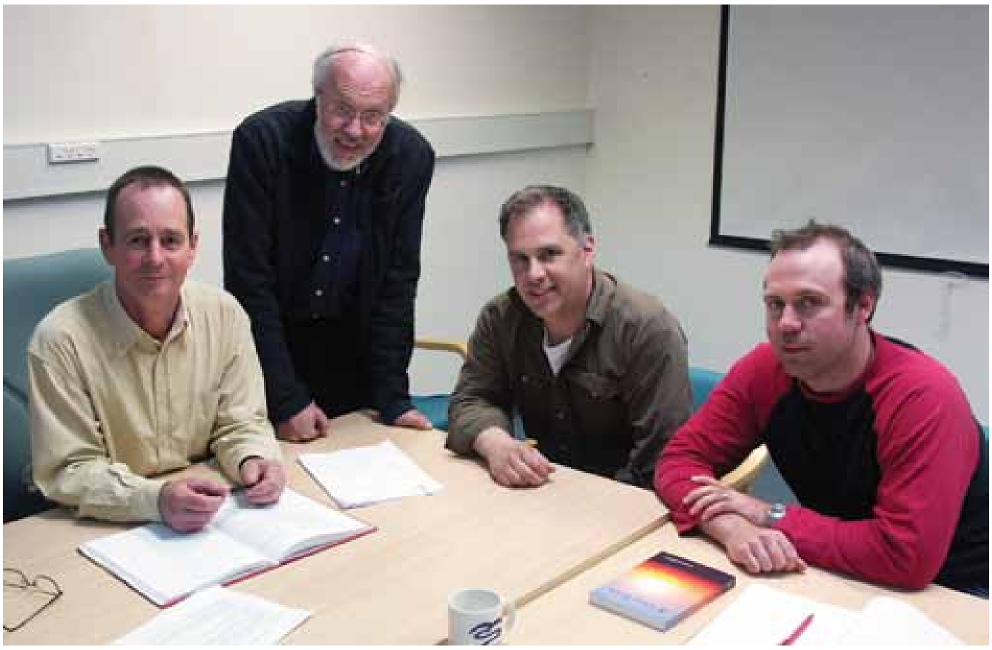
Determining the level of suppression resources required on any given day will depend on how soon the outbreak of a new fire, burning under given weather, fuel and topographic conditions, will be beyond successful first attack.

Our existing knowledge of fire behaviour and tools for prediction assumes steady-state spread for the environmental conditions. Understanding spot fires – their likelihood, development and behaviour – as well as how new fire outbreaks develop and propagate, is essential to understanding bushfire behaviour under the full range of possible fire weather conditions. This knowledge will then determine the window of opportunity for successful initial attack of new fires.

This project brings together fire behaviour and suppression specialists from CSIRO with the Bureau of Meteorology's atmospheric boundary layer meteorologists. The project will develop new tools for predicting the rate of development of new fires, identifying the spotting potential of these fires and develop frameworks to determine the level of suppression resources needed for given weather and fuel conditions.

BUSHFIRE CRC RESEARCH

High intensity fires burning under extreme weather conditions are typified by rapid development and high rates of spread. This behaviour makes them extremely dangerous and difficult to suppress and can result in large fires that often result in loss of lives, property and other assets. These fires can also threaten biodiversity and harm the environment. While the behaviour of a low intensity fire



▲ From left: Lachie McCaw (DEC), Jim Gould (CSIRO), Mike Wotton (Canadian Forestry Service) and Matt Plucinski (CSIRO) discuss fire occurrence and fire growth research at CSIRO.

CSIRO VISIT

In May 2011, the CSIRO Bushfire Dynamics and Applications team hosted a visit by national and international collaborators Dr Lachie McCaw (Western Australian Department of Environment and Conservation) and Dr Mike Wotton (Canadian Forestry Service). The aim of the visit was to progress the Fire Development, Transitions and Suppression project and to identify existing historical datasets that may be incorporated into a joint data analysis. Dr McCaw and Dr Wotton spent two weeks working on a number of aspects of the project, in particular fire occurrence and fire growth. Dr Wotton presented a seminar on 2 June 2011, which is on the Bushfire CRC website.

burning under mild weather conditions is predictable (within limits) in some fuel types there is limited understanding of the specific conditions under which it transitions to a fire of high intensity.

The development and propagation of high intensity fires is generally dependent on a number of interacting conditions and processes. The most important of these are: wide-spread drought and landscape dryness; a sufficient quantity and distribution of dry fuel; hot, dry winds; sharply dissected terrain; and unstable atmospheric conditions.

High intensity fires in most forest types in Australia are characterised by the combustion of all layers of fuel (including tree crowns) and the generation of large numbers of firebrands and embers. These can cause new ignitions (spot fires) downwind of the main fire, often breaching breaks in fuel and topography. This can lead to a failure of suppression efforts. The extreme weather conditions associated with Black Saturday, 7 February 2009, meant that fuels were extremely dry and could be readily ignited. Coupled with extensive tracts of long unburnt forest fuels and hot strong winds, this created conditions where any spark could start a fire that would quickly develop beyond control. The long unburnt forest fuels in which many of the fires burnt that day generated a storm of firebrands that travelled up to tens of kilometres ahead of the main fire. The density of firebrands, the distance they travelled, and the number of spot fires that formed downwind of the main fires were significant features of fire behaviour on that day. Often spot fires generated from earlier spotting led to mass conflagrations and disjunct fire perimeters. These thwarted suppression efforts and led to confusion as to where the fires were and the direction they were travelling. Such a fireground is challenging and dangerous, making suppression extremely difficult and the issuing of effective warnings to communities problematic.

END USER STATEMENT

"This project has the potential to fill one of the major gaps in fire behaviour predictions by more accurately understanding the fire spread during the initial development of a fire. The implications for our organisation and firefighting agencies in general are significant. A greater understanding of fire growth and development has the potential to substantially increase accuracy of fire spread predictions. This will help with protecting and warning communities as it will increase the accuracy of the predictions of the timing of fire impacts. It also has the potential to increase suppression efficiency. This could assist better resource allocation for first attack, which could enable fires to be contained faster, increasing the number of fires that can be contained on days of multiple ignitions. For agencies such as ours with a volunteer based workforce, greater efficiency in resource allocation is increasingly important due to the ever increasing demands on our workforce."

– Simon Heemstra, Manager Natural Environment Services, New South Wales Rural Fire Services

The traditional approach to modelling bushfire behaviour assumes that under most conditions fire spread is a continuous and contiguous phenomenon that presents a distinct front burning through the landscape according to reasonably well understood physical laws. Although firebrands and spot fires have long been identified as a primary source of new ignitions that allow a fire to overcome breaks in fuel and topography, it has been assumed that under fairly flat topography, most spot fires are quickly subsumed by the passage of the main front and do not increase rate of spread of the fire. All current operational models of fire behaviour are built on this foundation, and for short distance spotting under relatively mild burning conditions these models perform acceptably. However, it has not been determined to what extent spot fires, mass spot ignition and secondary spot fire generation influence the spread of bushfires across broken topography.

The potential for firebrand generation, the probability and rate of spot fire ignitions, the development of these fires (both singly and en masse), and the interaction of these fires with the main zone of fire, are significant factors that drive fires burning under all but the mildest fire weather. Improved knowledge of the complex interactions that influence the growth, acceleration and transitions of these fires will enable better planning for suppression.

During the past decade fire agencies have increasingly needed to share suppression resources during peak demand periods. This makes it even more important to be able to anticipate short-term fire danger, fire load, and suppression resource demands so that resources can be mobilised in time to be most effective. Fire propagation and development information can be used with models of fire occurrence to better understand the extent, behaviour and density of fires in the landscape (i.e. fire load). This information can assist decision making about resource requirements, allow fire authorities to better determine the transition between initial and extended attack, prioritise between fires, and generally improve planning for combating fires.

RESEARCH PLAN

This project consists of three components, each of which is linked through knowledge of the development and propagation of fire. These are:

A) Firebrand potential and spot fire initiation.

B) Fire development and transitions.

C) Fire load and suppression resourcing.

A) Firebrand potential and spot fire initiation

The nature and scale of the threat posed by spotting is a combination of: the availability and characteristics of firebrand material; the local atmospheric boundary layer meteorology (which dictates the potential height to which a firebrand can be lofted and the distance it can be carried downwind); the size and intensity of a fire; the interaction of a fire's convection column with the topography and the atmospheric boundary layer; and the likelihood of ignition of the firebrand.

The aerodynamic and combustion characteristics for one particularly notorious bark species (messmate stringybark) have been described previously by Ellis (2000, 2011). A postgraduate (PhD) project has been developed to extend this knowledge to other notorious species using the CSIRO Vertical Wind Tunnel. The study of ignition potential of firebrands under a range conditions will be carried out in the CSIRO Pyrotron.

The hypotheses to be tested in this project are (i) that bark is the agent of long distance (>10 km) spotting observed on high intensity fires; and (ii) that under extremely dry conditions (<5% fuel moisture content), even tiny glowing firebrands of less than 0.1 gram can ignite spot fires in forest litter fuels.

▲ A eucalypt bark firebrand (circled in red) being studied falling at its terminal velocity while it burns in the CSIRO Vertical Wind Tunnel. An ember (circled in yellow) has broken off the firebrand and is being accelerated away in the air stream.

B) Fire development and transitions

While there have been a number of empirical studies of fire acceleration, there is no robust and reliable method for predicting the growth of bushfires. Any such method must be based on a sound understanding of the fundamental processes by which fires grow. Growth occurs in two directions: horizontally over the ground, and vertically through fuel layers. A number of transitions will occur as the fire develops in these directions: the transition from ignition establishment to surface fire propagation; the transition from surface to higher fuel strata (culminating in crown fire); transitions involving convective interaction between the fire plume and the surrounding atmosphere; and ignitions of structures and other non-vegetative fuel in the flame zone. The hypothesis is that the rate of development or growth of a fire depends upon fluctuations in wind direction and the involvement of different fuel strata; more specifically, that ladder fuels contribute to the ignition of the canopy strata in eucalypt forests and that crown fire propagation in eucalypt forests depends on the energy released by the combustion of sub-canopy fuels.

This component of the project will collate and analyse historical datasets of point and line ignition field experiments (for example, Alan McArthur's original datasets). These will be augmented by carefully designed controlled experiments using a selected range of fuel, weather and atmospheric conditions. Factors contributing to the transition from moderate intensity fire in surface fuels to high intensity fires that may involve multiple layers of fuels, including tree canopies, will be identified and quantified.

From the data analysis a model will be developed of fire growth from ignition to steady-state behaviour for dry eucalypt forests. This model may provide a front-end to existing operational fire spread models. Pathways of research for other fuel types will be identified.

C) Fire load and suppression resourcing

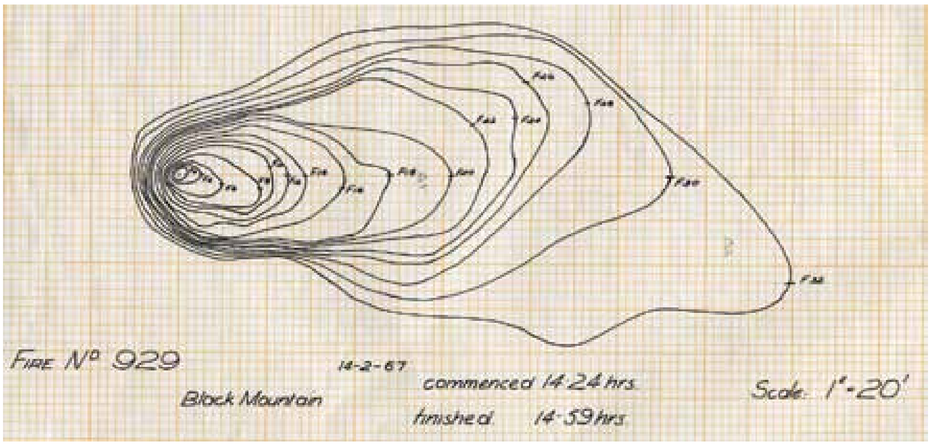
Fire load is the number, extent and behaviour of active fires in a landscape, and it varies

STUDY OPPORTUNITY

This project presents a unique opportunity for a PhD candidate to extend the knowledge of firebrand combustion and aerodynamics to the bark of a eucalypt species notorious for long distance spotting. Candidates should have a degree in physics, engineering or an environmental science; have sound skills in statistics; a flexible and innovative approach to problem-solving; strong communication skills and a commitment to research. Interested candidates should contact the Bushfire CRC for further information. This opportunity is still open. If no suitable student is engaged, this component cannot be undertaken.

STUDENTS NEEDED

This project relies significantly upon fire agency involvement, including access to fire history databases, selection of potential case study regions and agency staff participation as postgraduate students. The timely commencement of suitable experienced and/or agency-based Masters of Science student/s capable of undertaking research into agency resource response and productivity with minimal supervision is critical. We are pleased that a student has recently been engaged in this area, however further interest is welcome. Please contact the Bushfire CRC for more information.



▲ A fire spread map for experimental fire 929 in dry eucalypt forest at Black Mountain, ACT, conducted by Alan McArthur in 1967. The fire was started with a point ignition and the fire isochrones show the growth of the fire perimeter at two-minute intervals.

considerably in time and space. Suppression resourcing must be able to cope with a given load for most of the fire season, accepting that occasionally there will be times when the fire load will overwhelm resources. The optimal amount and type of suppression resources for a given region can be determined using a resource allocation tool.

This research activity will involve three key sub-elements:

(i) Investigation of fire occurrence patterns and development of ignition models for selected regions of Australia. Fire incident records from south west Western Australia are currently being analysed and used to develop models predicting the probability of a fire and the number of new fires in management regions, based on dynamic temporal and spatial variables. A model of potential fire load for a given set of environmental conditions will then be developed in conjunction with fire development knowledge from research components A and B.

(ii) Development of suppression productivity and response models. This is designed as a postgraduate project (Master of Science) and will involve the collection of data and elicitation of expert knowledge from agencies on the performance of specific resource types in rural and peri-urban study regions under a broad range of conditions. The intent of this postgraduate project is that agencies will provide candidates to work within their jurisdiction and develop models specific for their region.

(iii) Development of a prototype resource allocation framework suitable for Australian fire environments. This will combine the suppression productivity and response models and the fire load models. This resource allocation framework will enable the future development of tools to examine the effects of fire management policies and budgets, and compare the overall effectiveness and efficiency of different suppression resources. The hypothesis for this work is that fire load can be reliably predicted from forecast weather.

FUTURE DIRECTIONS

The rate of development of a fire determines whether it can be suppressed by initial attack or will escape to potentially develop into an uncontrolled fire. Under most fire weather conditions it is only during the early developmental period of a fire (from ignition to quasi-steady spread) in which direct suppression efforts will be effective.

The outcome of this research project will be new fire behaviour knowledge that can be incorporated into existing fire behaviour modelling systems or used to improve planning for prescribed burning operations. This knowledge, directly linked to suppression resourcing requirements through a resource allocation model based on a fire load predicted for any given day, month and season, will provide support for evolving fire management decision needs, including community warnings, planning, operations, monitoring and assessment.

REFERENCES /FURTHER READING

Ellis, PFM. (2000) The aerodynamic and combustion characteristics of eucalypt bark: A firebrand study. *The Australian National University School of Forestry PhD thesis.*

Cheney, NP & Gould, JS. (1997) Fire growth and acceleration. *International Journal of Wildland Fire* **7**, 1-5.

Ellis, PFM. (2011) Fuelbed ignition potential and bark morphology explain the notoriety of the eucalypt messmate `stringybark' for intense spotting. *International Journal of Wildland Fire* **20**, 897-907.

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Bushfire Cooperative Research Centre
Level 5/340 Albert Street
East Melbourne VIC 3002
Telephone: 03 9412 9600
www.bushfirecrc.com

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Australasian Fire and Emergency Service Authorities Council
Level 5/340 Albert Street
East Melbourne VIC 3002
Telephone: 03 9419 2388
www.afac.com.au

AFAC is the peak representative body for fire, emergency services and land management agencies in the Australasia region. It was established in 1993 and has 35 full and 10 affiliate member organisations.