Fuel Dynamics and Fire Behaviour in Australian Mallee and Heath Vegetation

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***Abstract**—In southern Australia, shrubby heath vegetation together with woodlands dominated by multistemmed eucalypts (mallee) comprise areas of native vegetation with important biodiversity values. These vegetation types occur in semiarid and mediterranean climates and can experience large frequent fires. This study is investigating changes in the fuel complex with time, fuel moisture dynamics, vertical wind profile characteristics, fire propagation thresholds, rates of spread, and flame characteristics. The project is being conducted at Ngarkat Conservation Park in South Australia with data coming from experimental and prescribed burns conducted under a range of weather conditions. The final output of this project will be a prescribed burning guide to assist land management agencies to plan and safely conduct effective hazard reduction and ecological management burns in mallee and heath fuel types.*

Introduction

Low woodland and heath vegetation are fire prone environments in Australia and around the world. In mediterranean climates, typical shrub dominated vegetation such as chaparral (California) (Keeley and others 1999), kwongan (Western Australia) (Hassell and Dodson 2003; Keith and others 2002), fynbos (South Africa) (Schwilk and others 1997), and maquis and matorral (Mediterranean Basin) (Bilgili and Saglam 2003) are known for their flammability. In southern Australia, shrubby heath vegetation together with woodlands dominated by multistemmed eucalypts (mallee) represents significant areas of native vegetation that burns frequently (Bradstock and Cohn 2002; Keith and others 2002).

In the past, tracts of mallee woodlands covered much of the semiarid parts of southern Australia, including southern Western Australia (WA), southern South Australia (SA), northwestern Victoria, and western and central New South Wales (NSW) (Noble 1984). However, about 35 percent of this vegetation has been cleared (ANVA 2001) and relatively little of it remains in conservation reserves. One such reserve is the Ngarkat Conservation Park (CP), in eastern South Australia. This reserve comprises a mosaic of heath and mallee vegetation and experiences bushfires almost annually. This 270,000 ha (1,042 miles^2) reserve is part of an 800,000 ha (3,088 miles^2) section of contiguous native mallee and heath vegetation extending into the neighbouring state of Victoria.

Ngarkat CP is habitat for a number of threatened flora and fauna, contains floral resources for the apiary industry, and is used for recreation. These values are threatened by large bushfires. These bushfires usually occur in late spring and summer, can be of high intensity, and have on occasion burnt in excess of 100,000 ha (386 miles^2) in single events (Department for Environment and Heritage, South Australia, unpublished fire history database, 2007).

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The loss of large tracts of native vegetation in a single fire in this fragmented landscape is not a desirable management or conservation outcome. Most of the fires in the park result from lightning ignitions and may be exacerbated by extended drought periods and suppression difficulty. Therefore, the current focus of management is on the prevention of large fires across the reserve, managed through prescribed burning. For managers to use prescribed burns effectively in this landscape requires more robust information on both fuel dynamics and fire behaviour.

Studies of fire behaviour and fuels have been undertaken in the mallee heathlands of southwest Western Australia (McCaw 1997). McCaw (1997) found existing fire danger rating systems and fire behaviour models are not suitable in mallee heath fuel types. The rate of spread in these fuel types is consistently faster (up to 200 percent) than those predicted for other scrub fuel types. The exception to this is the South African fynbos scrub fuel, which tends to exhibit faster rates of spread under similar conditions (Van Wilgen and others 1985). A major problem encountered was that the current fire danger rating systems and spread models are not able to accurately predict conditions of fire spread. Inaccuracies in model output arise from the inability of these models to account for the threshold dead fuel moisture content, above which fires will not spread in mallee heath. This critical threshold for Western Australian mallee heathlands was found to be a dead fuel moisture content in the litter layer of no greater than 8 percent (McCaw and others 1995, 2003; McCaw 1997).

A number of other studies have been carried out in Australian heathlands, investigating fuel moisture relationships and prediction of fuel moisture content (Catchpole and others 2001; Pippen 1999), determining ignition thresholds related to fuel moisture and fire development (Plucinski and Catchpole 2002; Plucinski 2003).

The aim of this project is to develop a prescribed burning guide to assist land management agencies to plan and safely conduct prescribed burning for effective hazard reduction and ecological sensitive management in South Australian mallee and heath vegetation. The specific objectives are: (1) characterise changes in the fuel complex with time; (2) model the seasonal and diurnal fuel moisture dynamics of live and dead fuel components; (3) determine the vertical wind profile in these fuel types; (4) model the fire environment conditions that will sustain fire spread (propagation thresholds); and (5) model rate of fire spread and flame characteristics.

This study will be collecting data from controlled experimental and prescribed burns in Ngarkat CP. The models developed from this research in South Australia will be tested for their applicability in mallee and heath in other states of Australia. In this paper we describe a project in progress and highlight the context and experimental and modelling approaches proposed.

Outline of Experiments

Quantifying Fuels for Fire Behaviour

Mallee and heath in semiarid and mediterranean Australia are characterised by a highly discontinuous fuel complex (Bradstock and Cohn 2002). Mallee woodlands are made up of short (2 to 10 m; 7 to 33 ft tall) multistemmed eucalypts, often (but not always) with a shrubby understory.

In the mallee, the surface fuel and suspended bark fuel are the main fuel layers that carry the flame front and are concentrated around the base of individual multistemmed eucalypt clump. The heath fuel type is made up of scattered small-leafed shrubs, or clumps of shrubs (up to 1 m; 3 ft tall), the sparse litter of which is usually in a tightly packed litter bed and can be partially buried by sand (Bradstock and Gill 1993). In this fuel type, the fire spreads in the low shrub canopy. In both cases (mallee and heath), the fuel layer that carries the flame front is discontinuous, with little fuel in the gap between the clumps of fuel.

The fuels that provide the energy flux that enables a fire to spread have generally been assumed to be those that are consumed in the continuous flaming zone of a fire front. The load of fine fuels, such as dead leaf, bark and twig litter <6 mm (¼ inches) in diameter, has been used as the major fuel variable (in many studies the only fuel variable) to predict fire spread (McArthur 1967; Peet 1965). Although fine fuel load has been the basis of Australian fire spread models in the past, and may be useful in providing practical information for burning guides, it has not been a significant variable in a number of recent studies (Buckley 1992; Burrows 1994; Cheney and others 1992, 1993). In complex fuels, the simple measure of total fine fuel is inadequate to describe the fuels that contribute to the forward rate of spread.

It is important to get a good estimate of fuel quantity, structure, composition, continuity, and height in order to quantify the effect of low-intensity prescribed burning in modifying the behaviour of wildfires. Detailed fuel sampling techniques can quantify the fuel loads of the surface (ground litter fuel) and near-surface (suspended live and dead fine fuel above the ground surface, but not on it) fuel layers, but these methods are not suited to operational use for assessment of fuels.

The development of more sophisticated burning guidelines requires a sound understanding of fire behaviour and suppression difficulty in fuels of different structure and composition. Australian studies (Cheney and others 1992; Gould and others 2001; McCarthy and others 1999; McCaw and others 2003; Project Vesta unpublished reports) have identified the importance of fuel structure in determining fire behaviour and ease of suppression. They have also developed a system for quantifying fuel structure with a numerical index that can be used as a fuel predictor variable to replace fuel load.

Rating systems that assess the relative hazard of fuel factors that affect fire behaviour and suppression difficulty represent a new approach in fuel assessment (McCarthy and others 1999; Gould and others 2001; Project Vesta unpublished progress reports). The fuel hazard rating systems developed by Wilson (1992, 1993) and McCarthy and others (1998) for eucalypt bark, elevated fuel, and surface fuel into a combined overall fuel hazard rating provided a simple, easy-to-use method for operational assessment of the hazard presented by fuels. This assessment emphasises the whole fuel complex by combining a hazard rating for each of the different fuel layers—bark, elevated, and surface fuels—using visual fuel characteristics.

This project will examine what changes need to be made for the system to be applicable to mallee and heath vegetation. Fuels load will be quantified through a combination of destructive and nondestructive sampling and visual systems of scoring structure and hazard as described above. The fuel assessment will characterise the changes in the fuel complex with time and compare the mallee and heath fuel types.

Fire Behaviour

Models to better predict fire behaviour in mallee and heath fuels are an important tool for managing prescribed burns. Improved fire spread predictions will be invaluable for the management of wildfires, providing more timely warnings of threat, and aiding decisionmaking on suppression tactics.

In order to improve fire behaviour models, it is necessary to encompass a wide range of fuel moisture and weather conditions in experimental burns. To achieve this, experimental burnings are being carried out in three seasons: in mid autumn (May 2006), early autumn (April 2007), and late summer (Feb/March 2008). To capture the differences in fire behaviour between the mallee and heath fuel types, and between different fuel ages under identical atmospheric conditions, simultaneous ignitions between different fuel types and ages will be conducted wherever possible. The fire behaviour under these conditions can then be related to the fuel characteristics.

Fire propagation threshold—Of the range of fire behaviour information necessary for the planning and conducting of prescribed burning, the determination of the threshold conditions under which the fire will spread (the fire propagation threshold) is critical. This is because prescribed burnings are mostly conducted under marginal burning conditions.

Due to the discontinuous nature of mallee and heath fuel complexes (Bradstock and Gill 1993; Bruner and Klebenow 1979; McCaw 1997), fire spread requires conditions that will allow the development of a flame angle, depth, and length that will bridge the gaps between individual shrubs or clumps, and/or initiate short range spotting that allows the fire to bypass the small scale fuel discontinuities. Under the conditions sought for prescribed burning, this creates highly nonlinear fire behaviour, with an abrupt increase in rate of spread when the conditions for sustained fire propagation are met.

Modelling of the propagation threshold in these discontinuous fuel complexes can be approached through a mechanistic framework as initiated by Bradstock and Gill (1993) or through logistic regression analysis, which attempts to describe the likelihood of an event, in this case fire spread, occurring (Fernandes and others 2002; Marsden-Smedley and Catchpole 2001).

We will use the logistic regression approach to model the propagation threshold. Propagation will be defined as successful if the fire spreads 100 m without self-extinguishing. A series of smaller scale (1 ha; 2.5 acre) fire spread experiments will be conducted under a range of conditions in each fuel type and age class in order to determine the propagation threshold in each. To achieve sufficient replication, these data will be supplemented by data collected at operational prescribed burns in these fuel types.

Fire behaviour parameters—During experimental burns, fine fuel moisture and weather parameters will be measured, including wind measurements. The fire behaviour parameters being measured will include forward and lateral rates of spread, flame dimensions, intensity, head fire width, spotting distance, fuel consumption, and the fuel layers influencing fire spread.

The limited size of the experimental fire plots (3 ha; 7 acres) will mean that we need to test whether the predictions from our models can be confidently extrapolated to fires occurring on a larger scale (Marsden-Smedley and Catchpole 1995; McCaw 1997). The experimental design includes model validation against larger scale experimental fires and against reliable prescribed burn and wildfire data.

Contribution to Improved Bushfire Management

The results of this research will better quantify the effects of fuel structure, fuel moisture dynamics, and wind on fire behaviour in mallee and heath vegetation. This will provide fire spread models that have an application to a wider range of mallee, heath, and other shrubland fuel types for both wildfire and prescribed burn situations.

New functions describing the relationship between fire spread and wind will be designed so that they can be used to predict the behaviour of high-intensity wildfires. This could be useful for analysing zones of potential wildfire impact and providing timely public warning. Fire spread predictions can be applied to data on suppression effectiveness limits to develop better fire management strategies.

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